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Rapid fuel switching from coal to natural gas through effective carbon pricing

Grant Wilson and Iain Staffell

Abstract

Britain's carbon emissions fell by an extraordinary 6% in 2016 due to cleaner electricity production. This was not due to a surge in low-carbon nuclear or renewable sources; instead it was the much-overlooked impact of fuel switching from coal to natural gas generation. This Perspective considers the enabling conditions in Britain and the potential for rapid fuel switching in other coal-reliant countries. Spare generation and fuel supply-chain capacity must already exist for fuel switching to deliver rapid carbon savings, and to avoid further high-carbon infrastructure lock-in. More important is the political will to alter the marketplace and incentivise this switch, for example through a strong and stable carbon price. With the right incentives, fuel switching in the power sector could rapidly achieve in the order of 1 GtCO₂ saving per year (3% of global emissions), buying precious time to slow the growth in cumulative carbon.

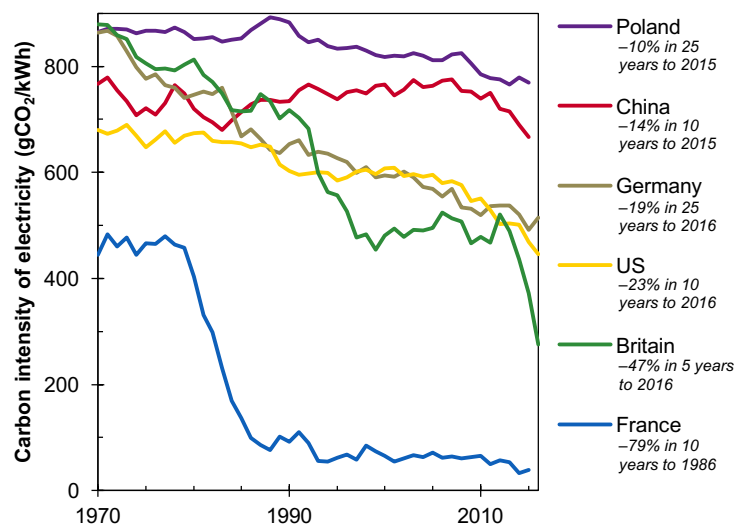
Introduction

Global carbon emissions from fossil fuels stand at almost 37 GtCO₂ and have grown by an average 2.4% per year so far this century¹. While emissions had stabilised between 2014 and 2016 they appear to be increasing once again, intensifying the need to reduce global fossil fuel consumption. Switching away from fossil fuels is recognised as a 'key mitigation strategy'² of 'crucial importance'³ in the transport sector, but switching between fossil fuels in the power sector lacks such recognition⁴ as it is incompatible with longer-term deep decarbonisation.

Power sector decarbonisation has received most attention with the rollout of renewables, especially wind and solar, which have grown twenty-fold in the last 15 years to reach 5% of global electricity generation⁵. Carbon capture and storage (CCS) is often considered an essential component of least-cost decarbonisation^{6,7}; however, it may take another three decades to achieve a 10% share of electricity generation⁸, and "expectations for CCS are very low in the current environment"⁹ after continued delays and cancellations¹⁰. With cumulative carbon emissions being a major determinant of climate change¹¹, any early opportunities to reduce emissions within months rather than decades deserve attention. Fuel switching between fossil fuels cannot be a long-term option as electrical

32 generation from unabated natural gas still emits around four tenths that of coal¹²; and if shale gas is
 33 used, upstream methane emissions may add a further 25% to its carbon intensity¹³.

34 However, Britain has recently demonstrated the short-term impact of fuel switching. Displacing coal
 35 with natural gas reduced per-capita annual emissions by 400 kgCO₂ between 2015 and 2016. Given
 36 the long-lived nature of energy systems and their endemic inertia, this rate of change is remarkable
 37 in the absence of any major accident or disaster. Figure 1 puts these changes in context; against
 38 market-led fuel switching in China and the US, renewables deployment in Germany, and incremental
 39 efficiency improvements in Poland. The unprecedented deployment of nuclear power lowered
 40 French carbon intensity by 40 g/kWh each year for a decade (1977–1986)^{14,15}. Fuel switching can
 41 proceed faster, but not so far: Britain’s carbon intensity fell by 85 g/kWh in 2016, but its potential is
 42 close to exhaustion as coal is almost eliminated.

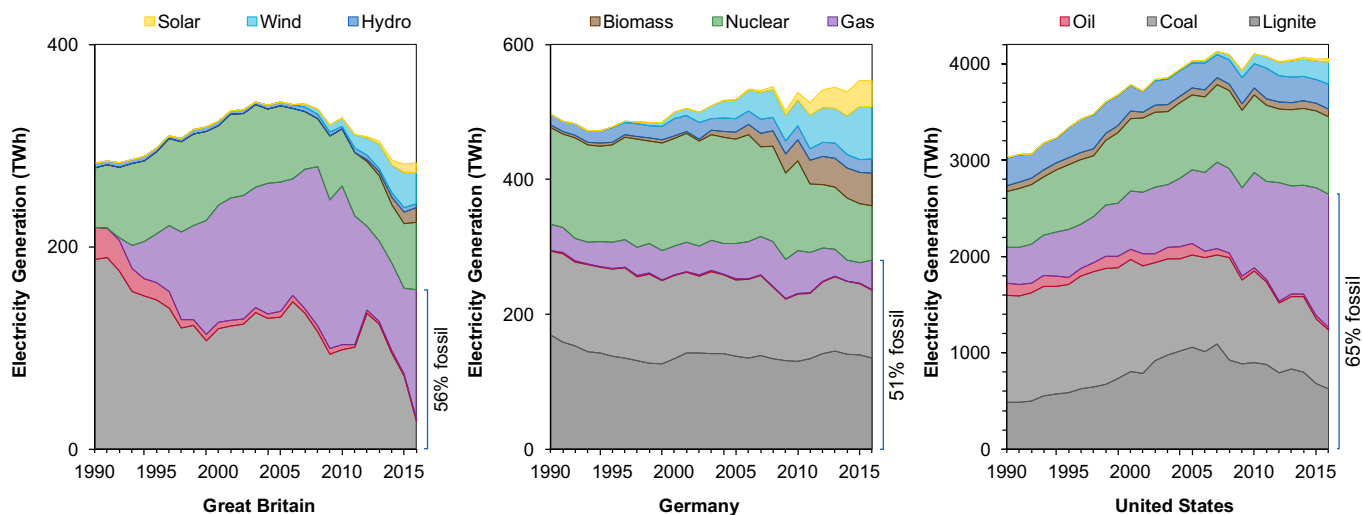


43
 44 **Figure 1: The carbon intensity of electricity generation in six countries over the last half-century.** Carbon intensity for
 45 gross electricity output (not accounting for losses in transmission and distribution). The legend indicates the depth and
 46 duration of sustained reductions in emissions intensity within each country. Data from refs. 14,15.

47 This Perspective argues that with the right conditions, both in terms of pre-existing infrastructure
 48 and political will, switching away from coal has an important role to play in the rapid early
 49 decarbonisation of power systems. This provides immediate benefits to other sectors, which will
 50 decarbonise faster through electrification due to lower associated emissions.

51 Britain’s power generation

52 Coal was the largest source of electricity generation for the first hundred years of Britain’s power
 53 system. This changed in the early-1990s (Figure 2) when the newly-liberalised market invested in
 54 combined cycle gas turbines (CCGTs), for reasons unrelated to carbon mitigation¹⁶.



55 **Figure 2: Electricity generation by fuel type in three countries over the last 25 years.** Imports are not included, waste is
 56 included with biomass. Between 2014 and 2016 coal + lignite generation fell by 5% in Germany, 22% in the US and 70% in
 57 Britain. Data from refs. 17–20.

58 This ‘dash-for-gas’ in Britain was not replicated in Germany or elsewhere in Europe, and although
 59 termed a ‘dash’ it took eight years (1991–99) for new gas capacity to be built and halve coal’s share
 60 of generation from 66% to 34%. Over the last decade, the US has shifted away from coal and lignite
 61 as shale gas production significantly reduced the price of natural gas. More recently, the
 62 combination of fuel switching and coal plant retirements in Britain has seen coal’s generation share
 63 fall three-quarters to 9% in just four years (2012–16); helping to halve power sector emissions from
 64 158 MtCO₂ in 2012 to 78 MtCO₂ in 2016. This fuel switch drove the largest ever annual reduction in
 65 British power sector CO₂ emissions²¹ of 25 MtCO₂ in 2016.

66 Figure 2 shows that renewable generation expanded rapidly over the last decade to supply nearly a
 67 fifth of Britain’s electricity. However, the fall in coal generation between 2015 and 2016 was filled
 68 entirely by natural gas: coal output fell 46 TWh and gas output increased 43 TWh, while zero-carbon
 69 renewables changed by less than 1 TWh due to underlying weather conditions²². For context,
 70 Britain’s switch from coal to gas in 2016 was greater than all other European countries combined²³.

71 If sustained, this rapid reduction arguably puts Britain well ahead of its near-term carbon reduction
 72 trajectory, as it could now beat its carbon targets for 2018-22 within the timeframe of the 2013-
 73 2017 carbon budget²⁴. However, as power sector emissions are part of the EU Emissions Trading
 74 Scheme (referred to as the traded sector), the net UK carbon accounting²⁵ means that these
 75 reductions can be ‘exported’ from the power sector as a surplus to other parts of the traded sector
 76 (e.g. heavy industry) potentially in other countries in Europe. Under agreed carbon accounting rules,
 77 they cannot be allocated to, or purchased by the non-traded sectors in Britain (e.g. domestic
 78 transport or heat) to provide additional carbon headroom²⁶. Nevertheless, the significant reduction
 79 in electricity carbon intensity provides a direct benefit for decarbonising these sectors through
 80 electric vehicles and heat.

Britain's commitment to reduce coal power

During the run up to COP21 in Paris, the British government began consulting on the phase-out of unabated coal by 2025^{27,28}, marking the world's first commitment to abandoning coal power²⁹. Although this deadline helps frame the Government's commitment to decarbonisation, there is concern that early power station closures pose an unacceptable security of supply risk. From another perspective, it is felt increasingly important to remove unabated coal as soon as is practical to free up its market share for new, cleaner generation³⁰.

Scheduling the demise of Britain's coal generation has been eased by the fleet's age (80% are over 30 years old), and tightening air pollution controls such as the Industrial Emissions Directive³¹. Half of Britain's coal capacity (14.3 GW) closed in the 5 years to 2017, and those that remain have historically low utilisation. Coal provided less than 10% (28 TWh) of electrical generation in 2016; a smaller contribution than wind (30.5 TWh) and less than solar generated in Germany (37.5 TWh)³² over the same year.

Britain is therefore on track to become the first major economy to transition away from coal after centuries of production and consumption (Figure 3). The latter fell to 12 Mt in 2016³³, levels not seen since 1935³⁴. The rate of this change is unprecedented; it took 14 years for power sector coal demand to increase from 12 to 28 million tonnes per annum (1936 to 1950), but only 1 year to make the reverse transition (2015 to 2016). Britain could be the first country to leave its coal reserves unburnt in the ground³⁵, and in November 2017 it set out a global alliance to end coal power generation³⁶. This would have been inconceivable to policymakers even a generation ago, when coal, nuclear and oil generation powered the country¹⁶.

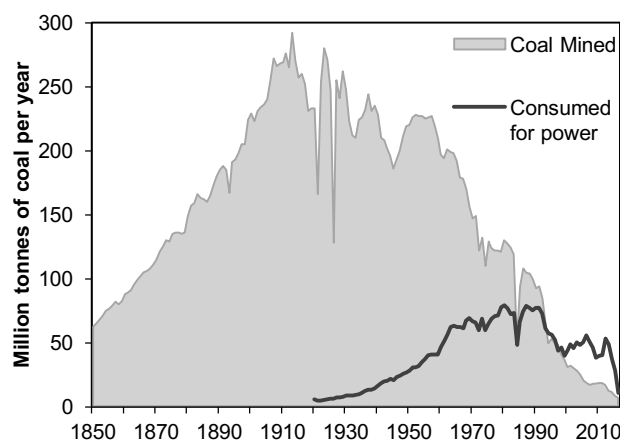


Figure 3: Quantity of coal mined and consumed for power generation in Britain. Power sector data from ref. ¹⁷ and coal production data from refs. 33 and 34.

[BOX 1 starts] Factors that enabled Britain's *rapid* fuel switch

Britain's experience of fuel switching can be viewed as a policy success, albeit at a rate that was better than anticipated. We suggest four factors were necessary to achieve this *rapid* fuel switch:

- Gas generation plants were already built and had spare underutilised capacity;
- Existing fuel supply infrastructure could cope with the increased power sector gas demand;
- The political will was available to intervene in markets to incentivise the switch, penalising coal vs. gas generation via an effective carbon price.
- Coal and gas prices were sufficiently close so that switching did not inflict large price rises on electricity consumers (a carbon price of £50/t was needed to incentivise fuel switching in 2013, vs. £16/t in 2016)¹².

Renewable generation has also rapidly increased in Britain, lowering emissions over the last decade, but contrasting Figure 2 and Figure 5, significant reductions only occurred since the 2013 increase in carbon prices, due to falling coal emissions.

While putting a price on carbon enabled the fuel switch in 2015 to be rapid, the development of this policy and the enabling conditions and the investment in generation and infrastructure for the switch to take place were decades in the making. The EU Large Combustion Plant Directive (2001)³⁷ and Industrial Emissions Directive (2010)³¹ aided in closing half of Britain's coal capacity; while the Climate Change Act (2008)³⁸ and Electricity Market Reform (2013)³⁹ laid the foundations for the Carbon Price Support scheme.

[BOX 1 ends]

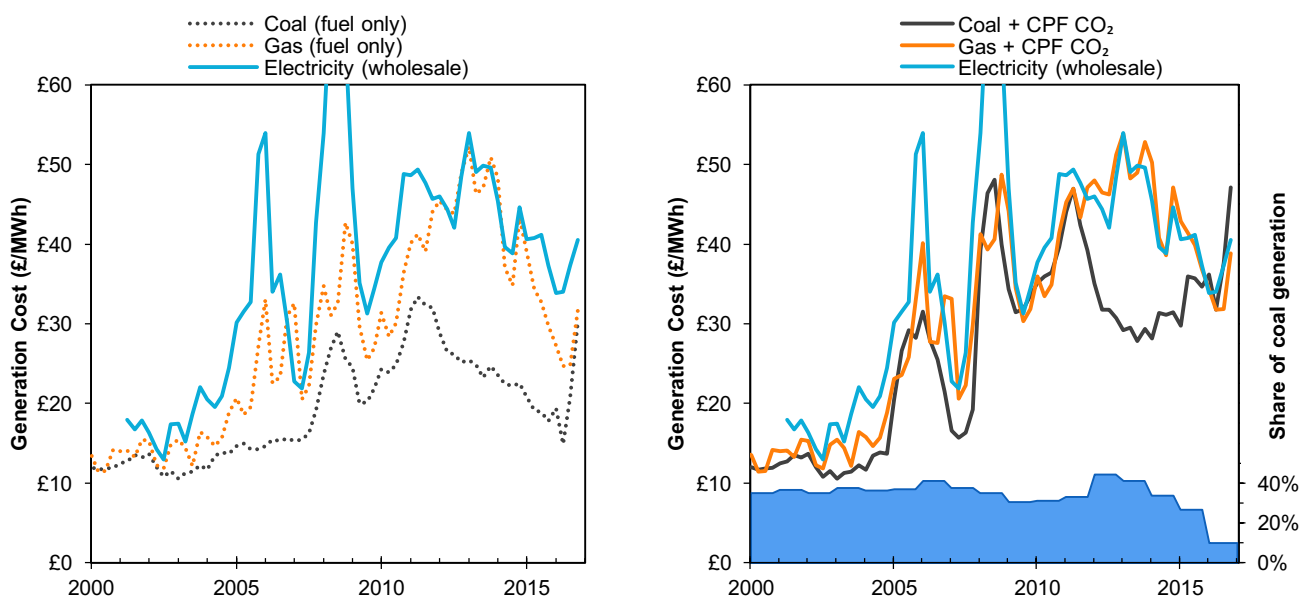
Putting a price on carbon

Our view is that the primary driver for coal's substitution in 2015–16 was the higher price placed on carbon emissions. Since 2005 British power stations were subject to the EU Emissions Trading Scheme (ETS) but it delivered carbon prices that were too weak to drive sustained lower-carbon investment^{40–43}. To address this, Britain introduced the Carbon Price Support (CPS) policy in 2013 which required power-sector emitters to pay a top-up price to a Carbon Price Floor (CPF) determined by policymakers⁴⁴. This aims to provide generators with the certainty of a more stable (but higher) price of CO₂ than delivered by the EU-wide market alone.

This CPS policy is still subject to regulatory risk as the floor price can be changed. Its initial trajectory was rising towards £70/tCO₂ in 2030; however, successive announcements have frozen the CPF at its 2017 level of £18/tCO₂ at least until 2021. While this suggests diminished ambition in the face of

136 cost sensitivities, it should be compared to an EU-ETS price of approximately €5/tCO₂ throughout
137 2016.

138 Debate continues about the floor price⁴⁵⁻⁴⁷. Whilst it has been effective in promoting the switch
139 from coal to existing natural gas generation, it has failed to incentivise construction of new low-
140 carbon generation, which continue to require other forms of financial support. The cost to
141 consumers can be approximated from the left panel of Figure 4 as the gap between the actual
142 electricity price, and the estimated cost of the marginal fuel (whichever is more expensive, gas and
143 coal). We estimate the carbon price floor has added in the region of 0.7 p/kWh to retail prices (~5%)
144 during 2016, which is comparable government analysis⁴⁸ and estimates for UK industry⁴⁹. This price
145 rise is very modest considering the ~25% reduction in power sector emissions it facilitated in just
146 one year.



147 **Figure 4: The wholesale price of electricity in Britain with the competitive benchmark based on fuel and carbon prices. a**
148 **electricity prices are compared with the estimated cost of generation from coal and gas with no carbon price. b shows the**
149 **comparison including the prevailing carbon price in Britain, along with the share of total electricity generation from coal.**
150 **Electricity prices are from the day-ahead spot market. Generation cost consists of fuel combusted (divided by conversion**
151 **efficiency) and carbon emitted (multiplied by carbon price), neglecting other aspects such as maintenance and network**
152 **charges. Prices and costs have quarterly resolution, the coal generation share has annual resolution. Carbon price data**
153 **from refs. 44 and 50, fuel price data from ref. 51, electricity price and coal share data from ref. 12.**

154 The costs of electricity generation are shown in Figure 4, highlighting the falling cost of gas relative
155 to coal since 2014. However, coal would still be the cheapest form of generation with the European
156 ETS carbon price, despite the sharp rise in international coal prices through 2016 (due to China
157 cutting production by 10%)⁵². Instead, the CPF allowed gas generation to become equivalent or
158 cheaper since the beginning 2016 and displace coal's share of generation. In terms of historical
159 precedence, the carbon price in Britain has been raised back to its level in 2008. In the rest of
160 Europe, it remains at just one-third of its peak.

161 Fuel switching is not unidirectional, and could equally be reversed while coal generation capacity
162 remains available over the coming years, helped by capacity market payments. All this would take is
163 another shift in relative fuel prices or a weakening of the carbon price to increase coal's annual
164 market share.

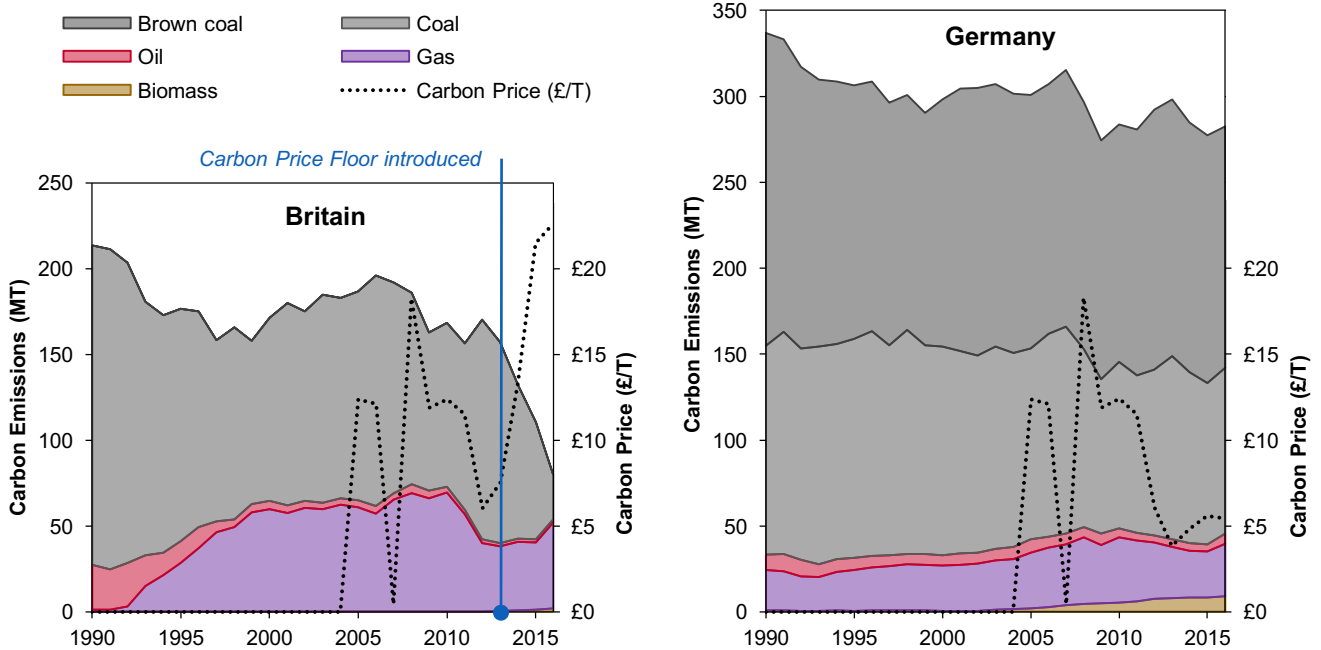
165 Leaving the markets to it

166 Britain's experience shows that liberal markets can rapidly adjust to well-timed well-aimed policy
167 signals. Policy is not an essential ingredient though, as America demonstrates that a confluence of
168 market factors can drive fuel switching alone, albeit at a slower pace.⁵³⁻⁵⁵ Since 2005 natural gas
169 prices have fallen 70% compared to 25% for coal due to increased production and the inability to
170 export shale gas⁵ (due to insufficient infrastructure). This has lowered the US average carbon
171 intensity of electricity by a quarter (see Figure 1), with a 7% swing from coal to gas occurring in 2015,
172 reducing power sector emissions by around 133 Mt⁵⁶.

173 The political landscape changed with the election of President Trump in November 2016, suggesting
174 ongoing tensions between Federal efforts to revive an ailing coal sector, and many State policies that
175 focus on decarbonisation. Carbon pricing at a federal level which would accelerate fuel switching
176 from coal to natural gas is therefore improbable under the Trump administration. The US has a
177 complex range of political drivers from federal environmental regulations impacted by sector
178 lobbying, layered with further political drivers at state level. Within this melange of political and
179 market forces, it is difficult to suggest future levels of fuel switching with any degree of certainty.
180 Federal regulations have switched back and forth to favour different technologies, which suggests
181 the benefit of having legal multi-decadal targets to aim for. Britain is not immune from lobbying and
182 switching regulations back and forth to suit different technologies, but it has pioneered the use of
183 long-term legal targets in the 2008 Climate Change Act³⁸. This has kept the long-term ambition on
184 track regardless of the change of policy makers and the political pressure to rescind policies that
185 become unpopular with core voters.

186 Potential for fuel switching in Germany

187 Germany is regarded as a champion of renewable energy for its extensive investment in wind and
188 solar power. However, it has had limited success in decarbonising its power sector, with emissions
189 down 15% since 1990, compared to Britain's reduction of 61%. Figure 5 shows that Germany's lack
190 of progress is due to continued reliance on lignite and hard coal for >40% of electricity supply.



191 *Figure 5: Power sector CO₂ emissions in Germany and Britain, broken down by fuel source. The carbon price in each*
 192 *country is overlaid, showing the marked difference since the introduction of the UK's Carbon Price Floor in 2013. It is our*
 193 *view that this was the major additional factor that caused the rapid shift from coal to natural gas generation after 2013.*
 194 *data from refs. 17 and 18, emissions intensities from refs. 32 and 12, and carbon prices from refs. 44 and 50.*

195 Germany is self-sufficient for lignite but imports 89% of its hard coal⁵⁷, as its geology makes local
 196 production internationally uncompetitive. Import dependency for natural gas is similarly 90%,
 197 although only one-sixth of demand is from the power sector as gas is primarily used for heating¹⁸.
 198 Around 15bcm/year (~150 TWh/year) of spare capacity exists in the Nordstream pipeline for
 199 increased gas supplies⁵⁸, with an additional 55bcm/year (540 TWh/year) if Nordstream 2 is
 200 constructed. At a national level, it seems the fuel supply infrastructure has the potential to
 201 accommodate significant levels of fuel switching.

202 However, several reasons temper Germany's desire to take this route, not least the security
 203 implications of swapping indigenous lignite to imported natural gas. Germany's decision to remove
 204 nuclear generation provides an additional challenge: installing 60 GW of wind and solar power in the
 205 last decade has done little more than offset the lost output from the 10 GW of retired nuclear
 206 power³². Both considerations were not applicable to Britain, which has no lignite mines, and in
 207 contrast to Germany, is embracing new nuclear build. Germany is a fascinating interaction of
 208 political economy interests, with a lignite lobby that capitalises on security of supply and cost
 209 arguments for Germany's energy transition. However, without the development of Carbon Capture
 210 and Storage in Germany (which currently seems highly challenging) at some point lignite generation
 211 will be impossible to reconcile with decarbonisation targets, and Britain's experience shows this
 212 could be rapidly reduced given Germany's pre-built but underutilised gas generation capacity.

213 Germany has 24 GW of gas-fired power stations, compared to 28 GW of hard coal and 21 GW of
214 lignite³². In recent years, nearly-new gas power stations have been mothballed after proving
215 unprofitable, and eventually exported to the Middle East⁵⁹. This is because gas capacity lies mostly
216 unused, with 18% utilisation vs. 40% for hard coal and 74% for lignite in 2016¹⁸. An additional 155
217 TWh of electricity could be produced if this gas generation capacity were utilised at 80%, sufficient
218 to completely eliminate hard coal plus four-tenths of lignite production, which would cut Germany's
219 power sector emissions by around a quarter, or 62 MtCO₂ per year.

220 Greater emissions savings would result from displacing lignite. However, this would increase
221 primary energy import dependency; whereas switching from hard coal to natural gas would simply
222 switch one type of energy imports for another, introducing a different set of risks.

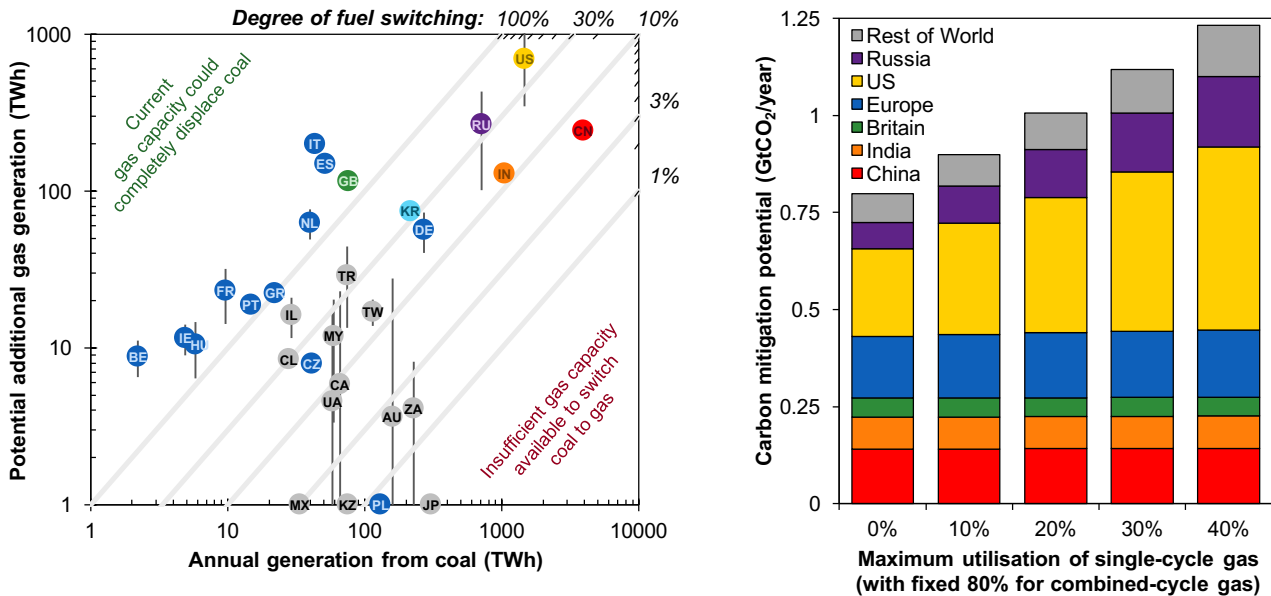
223 Potential for fuel switching globally

224 Quantifying an accurate global potential for fuel switching requires a detailed country-by-country
225 analysis of infrastructure, generation and demand, prices and policies. Nonetheless, the broad
226 order-of-magnitude can be estimated using statistics for annual generation and installed generating
227 capacity. We estimate the potential for fuel switching in the 30 largest coal consuming nations
228 (covering 97% of global coal capacity) by compiling the amount of coal and lignite generation in
229 2015, and comparing this to the additional generation that could come from gas in each country.
230 This is based on existing, underutilised gas generation; disregarding the option of building new
231 capacity. The maximum gas generation potential assumes that combined-cycle gas turbines (CCGTs)
232 could run up to 80% utilisation (limited by availability and downtime), while open-cycle (OCGTs) and
233 steam boiler stations would be limited to 0–40% utilisation (due to economic rationale). Displacing
234 coal with single-cycle (rather than combined-cycle) gas stations would yield half the carbon savings
235 due to their lower efficiency and thus higher carbon intensity. We assume CO₂ emissions of 405
236 g/kWh for CCGTs and 710 g/kWh for OCGTs, relative to 1025±55 g/kWh for national coal fleets¹⁴.
237 Sources, details and justification are given as supplementary information.

238 Figure 6a shows the potential for fuel switching across the OECD and coal-reliant developing
239 countries. Many European countries (including Britain) have over-built power systems with
240 sufficient idle gas capacity to completely eliminate coal, at least at the annual aggregate level. Of
241 the largest coal consumers, Russia and the US could convert 40–50% of their coal generation to gas,
242 but China and India could only displace 6–12% due to the vast scale of their coal fleets.

243 Poland depends on solid fuels for over 90% of its electricity, and lacks the pre-existing gas plants to
244 take over market share⁶⁰. Japan is still gripped by a capacity shortage in the wake of the Fukushima
245 disaster and shutdown of its nuclear fleet, thus its gas stations are running close to capacity already.

246 Figure 6b shows that if fuel switching was fully realised in these 30 countries, annual emissions could
 247 fall by 0.8–1.2 GtCO₂, around 3% of global emissions. Reductions in China, India and Europe amount
 248 to 440 MtCO₂ per year, and are insensitive to the utilisation of single-cycle plants as these make up
 249 only a fifth of their gas fleet. The mitigation potential in the US and Russia is more sensitive to the
 250 assumed utilisation, as OCGTs and steam boilers form half their gas capacity.



251 **Figure 6: Estimation of the carbon mitigation potential from fuel switching in 30 countries.** **a** Comparison of output from
 252 coal power stations in 2015 with the potential for additional gas generation, if existing combined-cycle gas plants operated
 253 at 80% utilisation and single-cycle plants at 20% (with bars showing 0% to 40%). **b** The annual greenhouse-gas emission
 254 savings if the identified potential for fuel switching was realised across these countries, showing the sensitivity to the
 255 utilisation of single-cycle plants. In panel **a**, countries are identified using their two-letter ISO codes, and diagonal lines
 256 highlight the share of coal that could be displaced by gas. Colours are used to group countries into the geographic regions
 257 listed in the legend of panel **b**. The four countries with zero potential for additional gas output are shown below the axis.
 258 Data from sources listed in the supplementary information.

259 No Silver Bullet

260 While this analysis is only a first-order approximation, it suggests that fuel switching in the power
 261 sector could provide a significant boost to global decarbonisation. However, fuel switching is no
 262 silver bullet, and many barriers can explain why only a small percentage of the estimated potential
 263 has been realised thus far.

264 Fuel switching will change supply-chain and energy security risks, and in many countries would
 265 create political tensions by increasing import dependency for primary energy. Although
 266 employment in the coal sector has fallen dramatically in many western countries, policies which are
 267 seen to further decimate domestic mining industries will face opposition, as seen in America. Over
 268 the longer term, politicians must grapple with the consequences of transitioning away from solid
 269 fuels; notably how to engage and retrain affected mining communities where coal production is
 270 culturally significant, as well as a source of employment.

271 There are also risks with carbon leakage in highly interconnected markets such as Germany^{61,62}. A
272 strong carbon price to promote fuel switching can reduce within-country emissions, but may also
273 shift electricity production (and thus carbon emissions) to areas subject to a lower carbon price.
274 Britain now imports high-carbon electricity from the Netherlands, where coal usage increased 40%
275 and generators pay one-fifth the carbon price. Supranational harmonisation of carbon pricing is
276 needed to avoid the 'offshoring' of power sector emissions. Other considerations, such as the level
277 of methane leakage in the natural gas supply chain must also be carefully assessed^{63,64}.

278 Carbon pricing however is not a blanket policy that will work everywhere. In countries which lack
279 the gas infrastructure such as Poland or Japan, raising a carbon price would in the short term be no
280 less blunt than a blanket tax on electricity. In the longer term, a careful balance is needed to
281 redirect how existing infrastructure could be used without going so far as to incentivise building new
282 gas infrastructure and avoidable carbon lock-in. If no more carbon emitting electricity generation
283 can be built for a 2°C temperature rise to remain likely⁶⁵, the distinction between utilising existing
284 gas generation versus investing in additional capacity is of critical importance^{66,67}.

285 Conclusions

286 Switching between fossil fuels can only ever be a temporary stepping stone. Its potential is bounded
287 by the scale of existing coal and gas infrastructure, and natural gas is incompatible with deep
288 decarbonisation^{68,69} unless carbon capture and storage emerges from its 'valley of death'¹⁰. If spare
289 capacity already exists, then fuel switching does not require several years to wind up to material
290 emissions savings, unlike other key options (renewables, nuclear, efficiency improvements). The
291 'quick win' is provided simply by using pre-existing infrastructure more effectively.

292 Britain's example highlights the effectiveness under certain key circumstances of placing a modest,
293 but stable, £18/tCO₂ on carbon, and the speed with which the power sector generation changed in
294 response to such a signal; it switched 15% of its generation mix (45 TWh) in a single year, saving 25
295 MtCO₂. Fuel switching can demonstrably achieve very rapid carbon reductions. In comparison
296 renewables took six years to grow from 4% to 19% of Britain's generation (a 45 TWh/yr increase),
297 saving approximately¹² 22 MtCO₂. It will be at least 10 years before new nuclear capacity will be
298 built in Britain⁵⁹, which would require three projects the size of Hinkley Point C to save 27 MtCO₂ per
299 year⁷⁰ to fuel switch from natural gas (as coal will no longer be on the system).

300 Fuel switching can also be a cost-effective and convenient form of decarbonisation. If driven solely
301 by market forces it will lower bills; if policy support alters the balance between closely-priced fuels, it
302 can have minimal impact on consumers, as seen in Britain. Natural gas retains the energy system
303 benefits of being a fuel: controllable and dispatchable generation, and extensive storage

304 infrastructure with days to weeks of capacity, rather than minutes to hours for electrochemical and
305 thermal storage^{71,72}. Controllable flexibility is increasingly desirable to accommodate greater levels
306 of variable renewable energy generation, especially so if coal generation is simultaneously being
307 retired.

308 Anthropogenic carbon emissions had almost plateaued⁷³. The next, momentous step, for emissions
309 to decrease, could be catalysed by a concerted global effort to switch away from coal to natural gas.
310 Our initial examination suggests the top 30 coal consuming countries could prevent 1 GT of CO₂
311 emissions from entering the atmosphere annually; with a central estimate that 20% of the world's
312 coal could be switched to gas using existing, under-utilised infrastructure (the range is 13% with no
313 OCGT up to 27% with them running at 40% utilisation). This provides an immediate benefit to slow
314 the increase in cumulative carbon emissions, buying all-important time for other sectors to catch up,
315 and providing cleaner electricity with which to decarbonise them. Any effort to front-load emissions
316 reductions will ease the pressure on future generations who are faced with removing emissions back
317 out of the atmosphere⁷⁴. However, it is vital to cumulative emissions that the gains of early
318 decarbonisation from fuel switching are not squandered by the extended use of gas generation as a
319 substitute for the necessary increase in low-carbon technologies.

320 The potential for rapid and material global emissions reductions appears to have gone unnoticed
321 thus far; it is about time that the benefits of fuel switching deserved greater attention.

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