The UK’s coal to clean journey

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About

This study is an insight on the United Kingdom's coal phase out. It charts the UK's journey out of coal and the transformation of the power system over the past decade. This study was presented at the webinar entitled "The UK's Energy Transition and Lessons Learned for Korea's Power Grid Reform" with the British Embassy in Seoul and NEXT Group, and includes the learnings from the UK experience which may benefit countries such as South Korea.

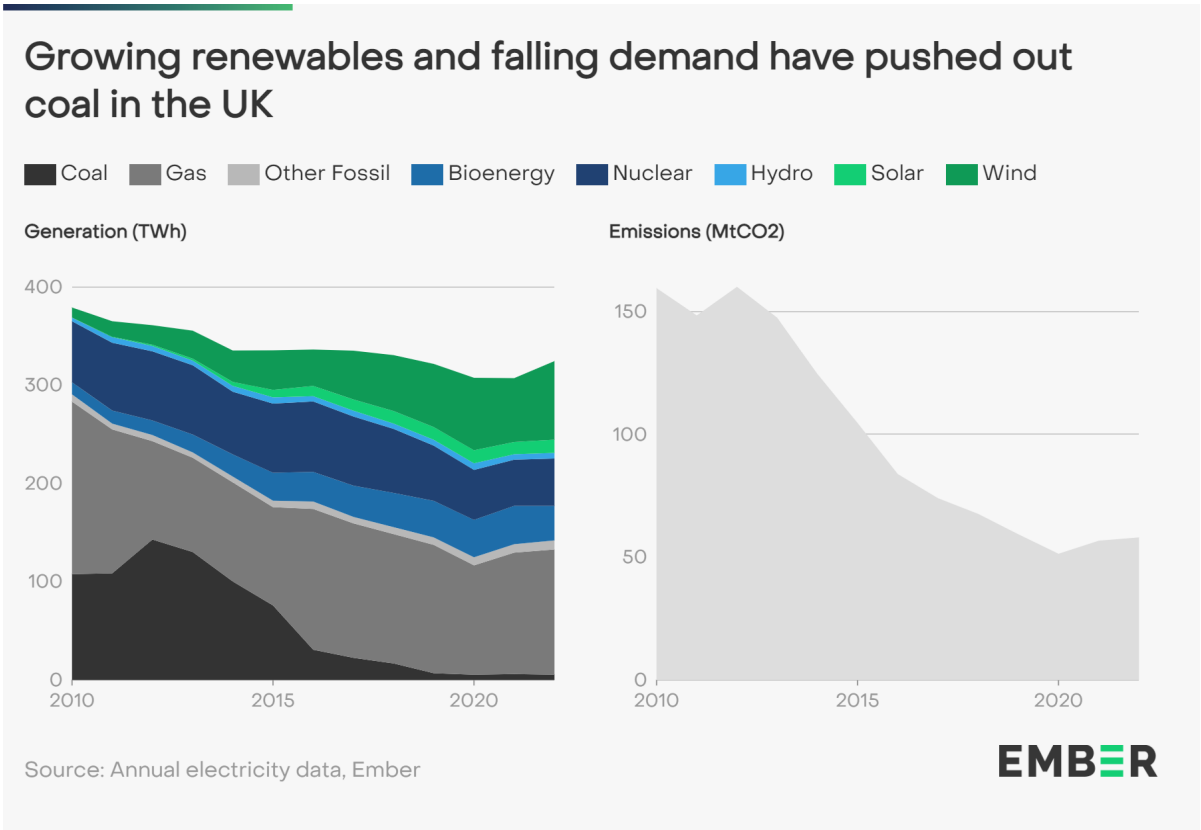
Introduction

Transformation of the UK's power system

In 2010 the UK's power supply was heavily dominated by fossil fuels, with coal alone generating almost a third of UK electricity. However, in just over a decade the UK's power system has been transformed: coal now generates just over 2% of the UK's electricity.

Crucially, coal has not been replaced with other fossil fuels—gas generation fell from 46% of the electricity mix in 2010 to 39% in 2022—or even nuclear power which has remained mostly unchanged since 2010. Instead, the fall in coal power in the UK has been driven by a huge increase in wind (3–25% share of electricity) and solar (0–4% share of electricity) generation as well as a significant drop in electricity demand (-16%).

The result has been a substantial fall in the carbon emissions of the UK power system from 160 MtCO2 in 2010 to 58 MtCO2 in 2022.



The UK is now aiming to achieve complete decarbonisation of the power sector by 2035—a world-leading target. This ambition is even more impressive given that power demand in the UK looks set to halt its decline and begin to rise rapidly—doubling by 2050—as more of the UK economy electrifies.

There is no single cause for the rapid decline of coal in the UK. Instead, the journey from fossil-fuel dependent to renewables champion can be attributed to five main factors: setting of ambitious short-term targets, the changing economics of coal, policy support for wind power, market reforms, and investments and innovations in the grid.

Although it is difficult to individually quantify the impacts of any one of these five factors, their combined effect has seen coal capacity in the UK fall from 32 GW in 2010 to 4 GW today.

Key numbers

	2010	2022	Change
Share of generation (%)			
Coal	28	2	-94%
Gas	46	39	-15%
Wind	3	25	+906%
Solar	<1	4	+>1000%
Nuclear	16	15	-10%
Power demand (TWh)	382	320	-16%
CO2 intensity (gCO2/MWh)	461	182	-61%

Source: Annual electricity data, Ember

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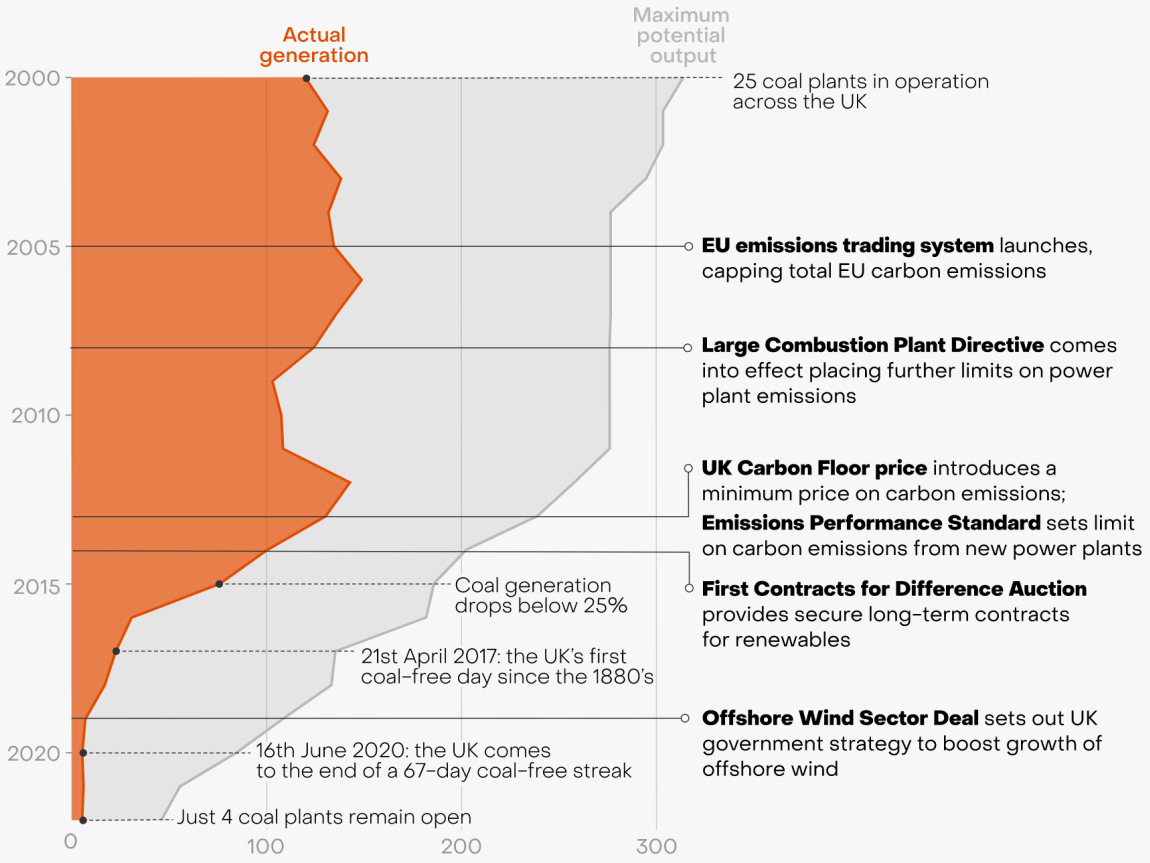
Key policies that phased out coal power in the UK

Electricity generation vs maximum potential output from coal power plants (TWh)



Source: Annual electricity data, Ember
Maximum potential output calculated as the electricity produced by all operating plants running at 100% of nameplate capacity for 1 year

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Lessons learned from the UK's journey to reach 100% clean power by 2035

Five takeaways from the UK's coal-to-clean story

1. Ambitious short-term targets

Many governments have set mid-century targets, but the UK has ambitious and legally binding power sector goals that send clear signals on its direction of travel.

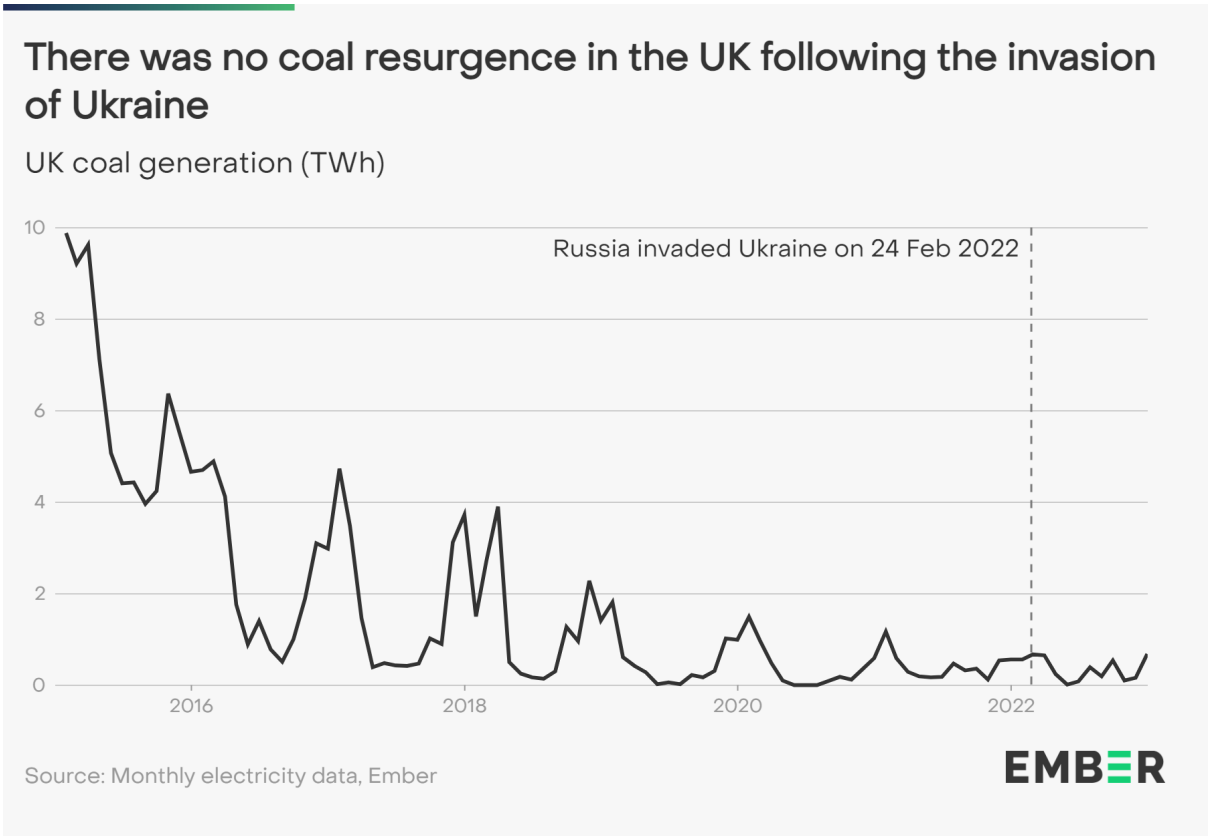
In 2008, the UK passed the world-leading Climate Change Act. This set into law a whole-economy, legally binding target of an 80% reduction in greenhouse gas emissions below 1990 levels by 2050. In 2019, in recognition of the 2015 UN Paris Agreement, the Act was revised to increase its ambition to economy-wide net zero emissions by 2050.

Coal phase-out targets

The Climate Change Act made it clear to decision-makers that use of unabated coal was incompatible with achieving a net zero economy. This fact, in combination with the worsening economics of coal, underpinned the 2025 coal phase out target set in 2015 and made it a credible goal. This target was considered to give enough time for coal to be replaced by other sources of power while ensuring security of supply and affordability.

Nevertheless, it was still an ambitious goal when set: in 2012 coal generated 40% of UK electricity. But coal use fell even more rapidly than expected (see section below), generating just 2% of electricity in 2021. Consequently, in 2021 the phase out date was officially brought forward to 2024. Russia's invasion of Ukraine and associated gas supply shortages have not seen a return to coal, and coal remains below 2% of generation in 2022.

The UK coal phase-out commitment allowed for the use of coal only with carbon capture and storage. This technology has not become viable, however, despite government support. The legislation also allows for the restart of coal plants should there be a security of supply issue, but abundant clean power means this has mainly proved unnecessary.



Aiming for clean power

In October 2021, the UK announced a target for a decarbonised power system by 2035. This sets out a concrete benchmark on the way to the country's Net Zero goal, in line with what IEA modelling recommends for OECD countries.

The target puts into place accountability and a timeline for the UK's energy transition, and makes clear that much hinges on tackling the power sector: decarbonising electricity, combined with electrification, will unlock emissions cuts for other sectors. Setting out a timeline also sends a signal to the market on the likely lifespans of any new fossil fuel investments and areas for growth as the clean power sector expands.

2. Revealing coal's hidden costs

Critical to the UK's rapid coal phase out were a series of measures that meant that coal was no longer economically viable.

The UK avoided subsidising coal or paying to close polluting plants because coal plants became uneconomic ahead of the phase-out target and closed of their own accord. The plummeting cost of renewables and ambitious power sector targets contributed to this. However, there were also other specific measures that limited coal's profitability and discouraged construction of new coal plants. This included a high price on carbon sustained by a carbon price floor, as well as air pollution and emissions standards.

Air Pollution Upgrade Requirements

In 2001 the EU set out the Large Combustion Plant Directive (LCPD). This was a piece of legislation designed to combat the acidification, ground-level ozone formation and release of particulate matter caused by large fossil fuel power plants. The LCPD did this by setting new, tighter limits on nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM) emissions on power plants larger than 50 MW in capacity. Pollution limits depended on the type of fuel burned and the size of the power plant.

These limits came into effect in 2008 and were applied to all new plants (commissioned after 1987) while existing plants (commissioned before 1987) had the option of either: complying with the limits, limiting generation to 20,000 hours between 1st Jan 2008 and 31st Dec 2015, or closing before 1st Jan 2008. The LCPD was superseded by the Industrial Emissions Directive (IED) which came into effect in 2016 and tightened emissions limits even further.

Compliance with these limits required many power plants to be equipped with new and expensive infrastructure upgrades. As much of the UK's coal fleet was very old—built in the 1960s and 1970s—many plants were coming to the end of their operational lives when the LCPD was introduced. This meant that building the necessary pollution-abatement infrastructure simply made it uneconomic for these plants to continue running.

LCPD and IED coal generation pollution limits for specified capacity plants

	LCPD	IED
SO2		
+500 MW	400 mg/mg3	200 mg/mg3
NOX		
+300 MW	500 mg/m3	200 mg/m3
Particulate Matter		
+300 MW	50 mg/m3	20 mg/m3

Source: IEA Clean Coal Centre

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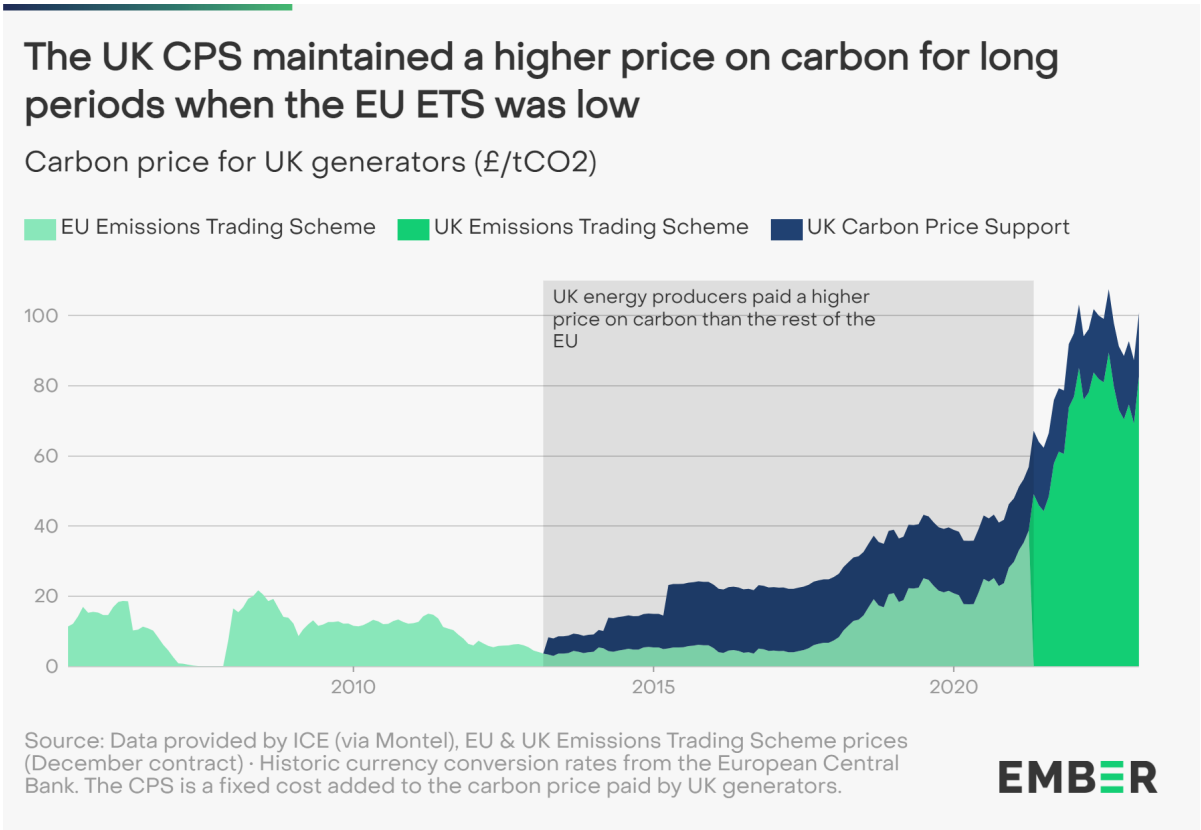
Carbon Pricing

The EU Emissions Trading Scheme (ETS) was launched in 2005. It was the world's first major carbon market and was aimed at helping the EU meet its Kyoto commitments by reducing emissions from the industry and power sectors. While the EU ETS may have driven some emissions reductions in its early years, its carbon price was highly volatile and crashed in 2007. Although the EU ETS carbon market recovered some stability in the years after 2007, the UK government still considered it too volatile and the carbon price too low to provide investors in low-carbon technologies with certainty they needed to drive the UK's transition to renewables and meet the requirements of the Climate Change Act.

As a result, in 2013 the UK introduced a mechanism to stabilise the carbon tax on electricity generation at a sufficiently high level. The 'Carbon Price Floor' (CPF) set a minimum carbon price in the UK. In order to achieve the minimum price, a 'Carbon Price Support' (CPS) was

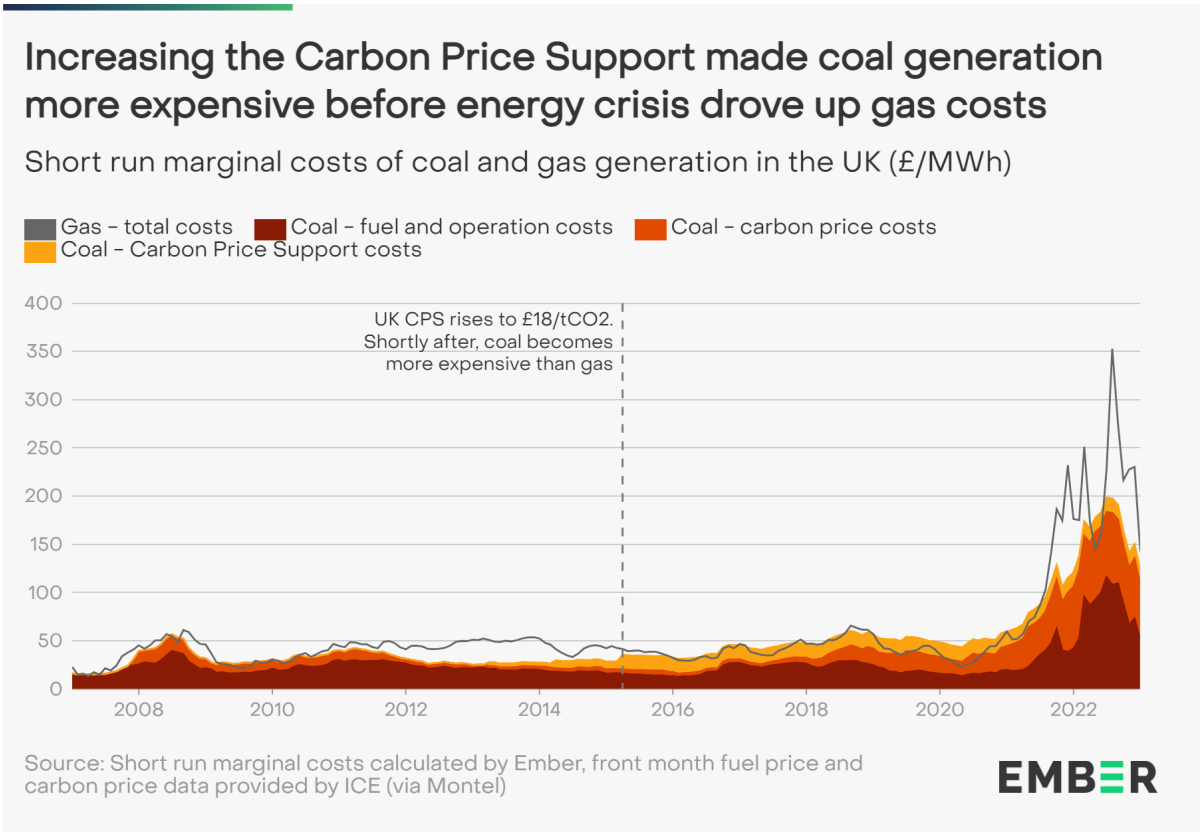
added to the EU ETS price paid by power generators. The CPF launched with a CPS price of £5/tCO_2 which rose to £9/tCO2 in 2014 and £18/tCO2 in April 2015. These prices were set by the UK government who determined them to be high enough to encourage low-carbon investments but low enough not to impact consumer bills (the cost of the CPS was passed on to consumers).



The year-on-year doubling of the CPS in April 2015 had a significant effect on UK coal power. It caused the cost of generating electricity from coal to rise above that of gas for the first time since 2010 and pushed it even further above renewable generation costs. This contributed to the sharp fall in coal generation from 2015 and the corresponding increase in gas and wind power.

The CPF was met with a mixed reaction from industry and civil society. As it was a 'top-up' tax that worked in tandem with the EU ETS, there were concerns that it would put UK industry at a disadvantage to its competitors in the EU. In the face of these concerns, in 2015 the UK

government froze the CPS at £18/tCO_2 where it remains today. As a result of the UK's exit from the EU, the UK left the EU ETS and launched the UK ETS on 1st January 2021. UK participants in the EU ETS were given until April 2021 to surrender their existing allowances in the EU ETS. The UK ETS launched with a carbon price of £45/tCO_2. The current market price on carbon emissions is £80/t.



Emissions Performance Standard

In 2013 the UK passed the Energy Act. At the core of this legislation was electricity market reform designed to deliver more renewables and a secure power supply during a decade when much existing coal capacity was coming offline. One of the Energy Act's provisions was the Emissions Performance Standard (EPS). The EPS sets limits for CO2 emissions at 450g/KWh for all new fossil fuel fired power plants built after 18th Feb 2014. This limit was chosen as it is roughly half the emissions of unabated coal meaning that new coal-fired power stations could only be built if they were equipped with carbon capture and storage (CCS). The EPS also applies to new gas plants but the limit was set at a level that was

unlikely to impact them. As coal CCS did not become an economically or technologically viable option within decarbonisation timelines, the EPS effectively ruled out investment in new coal power plants.

3. As wind grows rapidly, coal falls

Stable policy support for wind power allowed for astonishingly rapid growth.

The UK is very rich in wind resources - both in terms of atmospheric factors (lots of wind) but also in terms of site availability; much of the UK coastline is shallow water making the construction of large scale wind farms relatively easy. On the other hand the UK does not receive high levels of consistent sunlight throughout the year meaning its solar power potential is lower than wind.

The more the UK embraced wind, the easier and cheaper it became to scale up quickly. Stable policy support led to enormous investment and rapidly collapsing prices for wind, as coal became increasingly uneconomic. The more wind turbines that have been built in the UK, the greater the support for them. In April 2022, 79% of the British public supported building further wind power.

Policy support

The 2019 Offshore Wind Sector Deal identified offshore wind as one of the UK's leading industries, and provided a roadmap for how government action would coordinate with and further support industry growth.

Government commitments to the sector included:

- Assurance of long term funding through an earmarked £557m for future Contracts for Difference
- £7bn investment into research and development by 2022
- Coordination between stakeholders, and connecting industry to relevant government initiatives

- Oversight of deployment strategy on a national level, balancing security and environmental concerns
- Support for home-grown industry, including a focus on the domestic supply chain and bolstering UK wind companies internationally

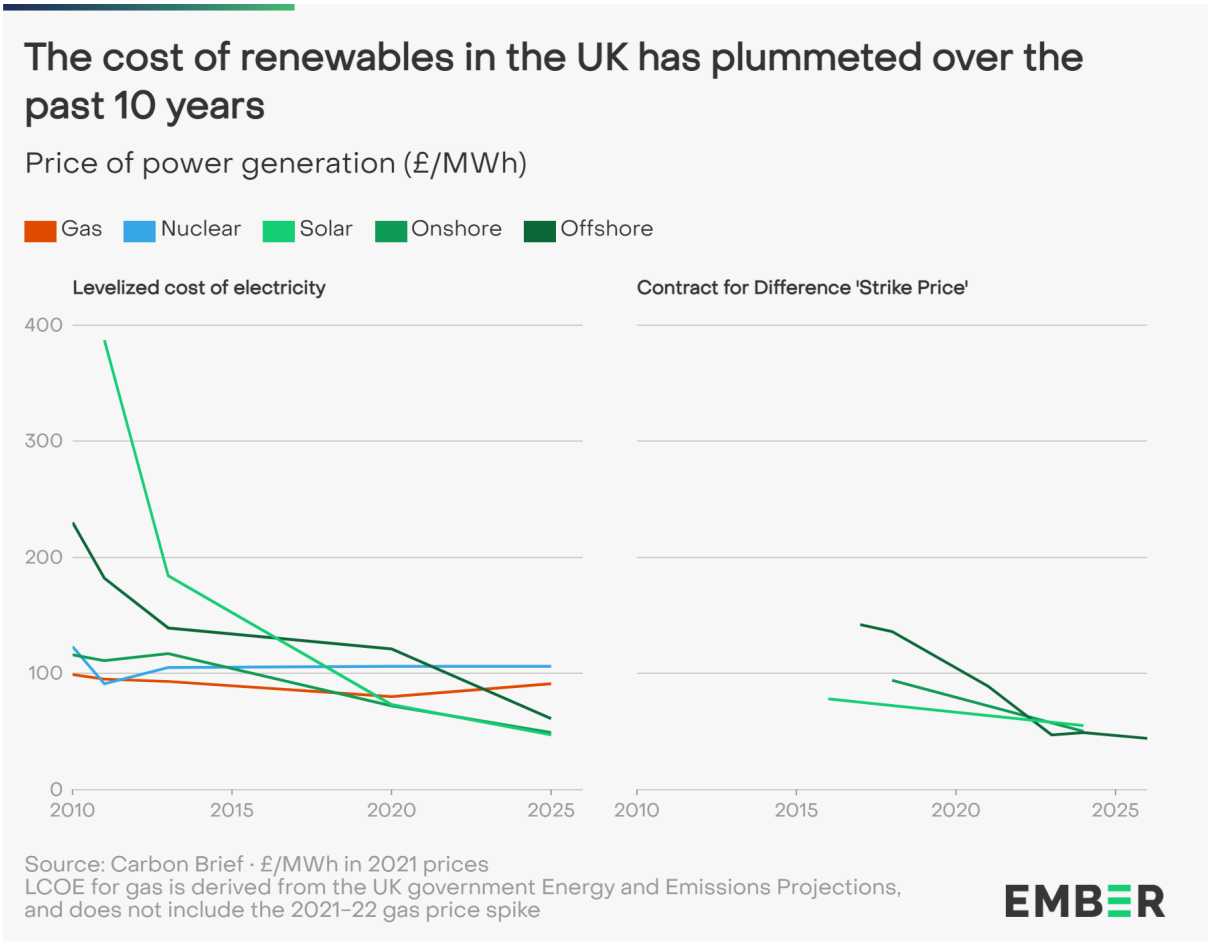
Support for home-grown industry came in the form of the Offshore Wind Growth Partnership (OWGP). The OWGP is a long-term business transformation programme. It consists of four main work streams:

1. Enhancing engagement between offshore wind developers and the UK supply chain
2. Improving business practices and capabilities within the UK supply chain to increase their international competitiveness
3. Facilitating new UK entrants into the offshore wind market
4. Supporting development of next generation technologies and innovations in offshore wind supply chains

The Offshore Wind Sector Deal also set out a series of commitments from industry — i.e. delivering on workforce diversity and regional growth goals, targets for exports and industry investments into the UK supply chain. In addition to these measures, the deal committed the sector to establishing a 'Task Group' to explore new solutions to optimising grid integration including managing variability of demand and supply, and exploring the potential role of hydrogen generation and storage in a decarbonised energy system.

Plunging costs

Scaling up wind quickly became easier and cheaper as the whole ecosystem came together: the cost of capital of wind power was brought down through a combination of consistent policy support through 'Contracts for Difference' (see below) as well as globally falling supply chain costs and technology improvements. The mixture of lower costs, increasing scale of project builds, and growing in-country expertise helped to de-risk large wind projects resulting in enormous investment and rapidly collapsing prices.



4. Market reforms

Changes to the market incentivised and de-risked investment in renewables, and ensured security of supply.

Consistent policy support for renewables, and ambitious targets on power sector decarbonisation sent clear signals to the market on where to invest. But several reforms supported the transition from coal to clean electricity by reducing the risks of investing in renewables and ensuring that a shift to higher wind and solar penetration would not lead to difficulties in ‘keeping the lights on’.

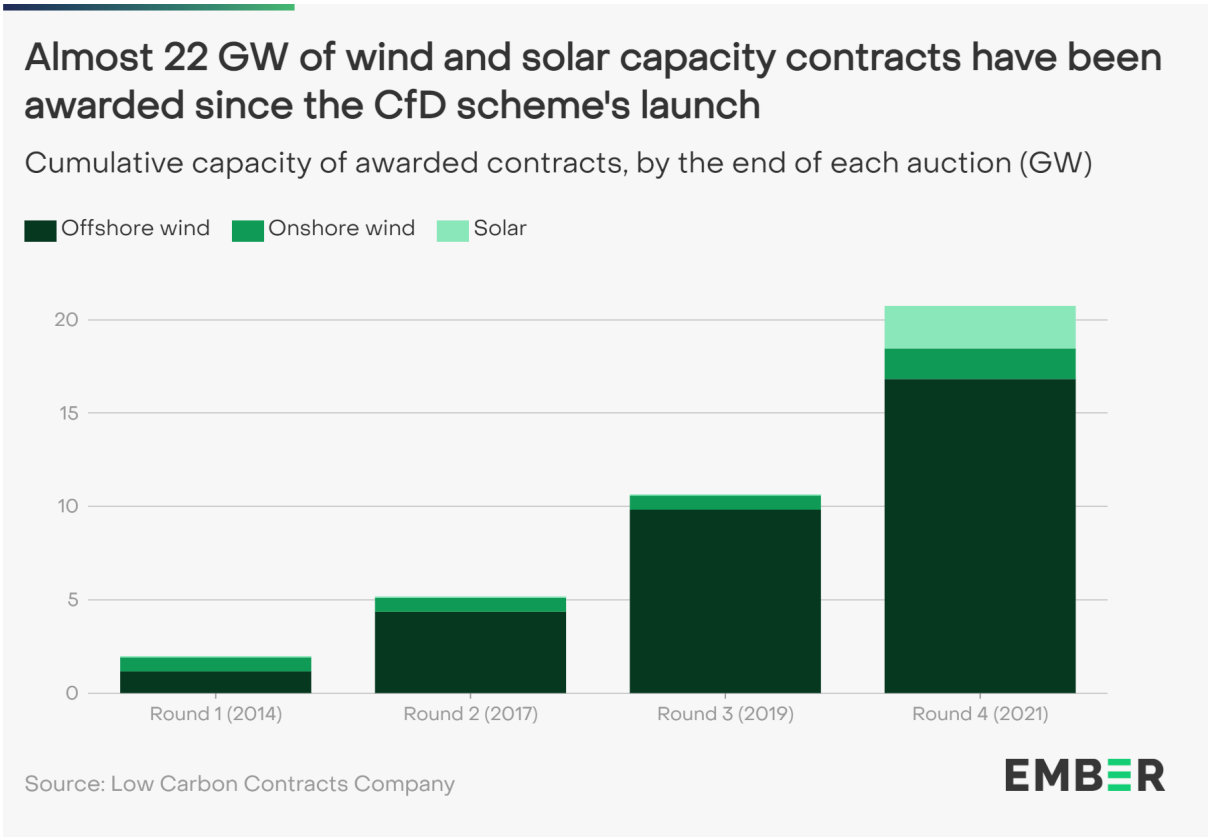
Capacity Market

The 2013 Energy Act also implemented the UK's capacity market, designed to provide payments for dispatchable sources of power to ensure they remain available to deliver energy when needed. The capacity market has funded over 14GW of new capacity - some fossil gas, but also interconnectors, demand response and storage. This has ensured security of power supply as old coal power has come offline and the share of intermittent renewables in the power mix has increased.

Contracts for Difference

As well as introducing the EPS, the 2013 Energy Act also established the Contracts for Difference (CfD) scheme. In the CfD scheme, power generators bid for a 15 year renewable electricity generation contract with a government-owned company (the Low Carbon Contracts Company, or LCCC). The contracts fix a 'strike price', which is guaranteed to be paid to the generators regardless of the market price. The LCCC pays the generator the difference if the market price is under the strike price, and vice versa if the market price is over. This has incentivised investments and lowered prices for renewables by providing certainty in future revenue.

The first CfD auction ran from October 2014 to March 2015. Auctions were previously held every two years, but this was recently changed to annual auctions to secure more renewables capacity and better reflect the fast paced improvements in technology and changing costs. There have been four auction rounds since the launch of the CfD scheme which have seen a total of almost 22 GW of wind and solar power secure long-term contracts.



5. Investment & innovation in the grid

Innovation in the grid has sped-up deployment of renewables and provided more certainty for generators of flexible sources of electricity.

Changing the way transmission projects were managed

Prior to 2010, all transmission infrastructure works would have to be completed before a new power generator could come online. Lead times for large-scale transmission projects were around a decade which drastically limited the pace at which renewables could be built in the UK. However, in 2010 a new method of transmission project management was introduced which required only local transmission works to be put in place before a power generator could come online reducing lead times to just a few years and hugely increasing the pace of deployment.

Around the same time, the 'Electricity Networks Strategy Group' (ENSG) was formed. The ENSG brought together the stakeholders in electricity networks with the government and energy system regulator. The ENSG allowed these groups to collaborate and coordinate to overcome strategic grid issues such as identifying important grid reinforcements needed to allow more renewables to join the grid.

Flexible grid system planning

Since 2015, the UK's National Grid Electricity Systems Operator has used a process called the Network Option Assessment (NOA) to set out which grid reinforcement projects should take place and when. The NOA is designed to ensure the UK grid is robust enough to deal with the future power system as demand increases and it transitions to renewables-based. NOA is a flexible system planning method carried out each year enabling the UK to modify and review its existing planning options and add new ones as necessary. The NOA process consists of four main stages: development of Future Energy Scenarios, development of the Electricity Ten Year Statement, investment proposals from Transmission Operators (TOs) and finally production of National Grid's investment recommendations.

In the first stage, National Grid produces its annual Future Energy Scenarios (FES). FES models the UK power sector to 2050 producing three scenarios that reflect different levels of decarbonisation ambition. The scenarios are not forecasts but are credible and possible pathways for the UK power system. The scenarios describe a range of power-sector indicators, including power demand, supply, electric vehicle penetration, carbon intensity etc.

In the second stage of NOA, National Grid produces its Electricity Ten Year Statement (ETYS). The ETYS uses the results of FES to model the transition system requirements of the UK across the next ten years.

In the third stage, the UK's TOs propose options to meet the grid requirements set out in the ETYS.

Finally, the fourth stage of NOA sees National Grid assess the TOs proposals using a variety of economic analyses before setting out its selection of recommended grid investments. Although the NOA only provides guidance and National Grid makes no investment decisions

of their own, it provides the UK with an effective way to plan and manage its energy system, ensuring the country meets future power demands sustainably.

The outlook going forward

The future of the UK's journey to clean power 2035

Investing in the grid

In the UK, generators are given payments to curtail their power production and help balance the grid. Historically, making these 'constraint payments' has been considered less expensive than building large grid connections. However, as renewables capacity continues to grow at a rapid pace in recent years the economics has changed. In order to reduce curtailment, National Grid are planning on investing around £10 bn to expand the UK grid. Much of this investment will be spent on better connecting Scotland, where much of the UK's wind power is generated, to England where most of the power is consumed.

In addition to expanding its grid capacity, the UK has increased its interconnection with other countries. In 2021, the North Sea Link—a 1.4GW interconnection between the UK and Norway—came online. This link will provide the UK with the opportunity to import and export more renewable power with Norway maximising value from its wind generation.

New ways of managing the grid

In the past few years, the UK's grid operator National Grid ESO has made digitalisation of grid management a top priority. In 2020 National Grid launched its 'Dynamic Containment' service which uses real time data to enable flexible and distributed energy resources—such as batteries—to more rapidly respond to changes in demand and ensure security of the grid.

Securing future system stability

National Grid is preparing the UK's grid to operate with zero carbon power from 2025. In order to ensure a reliable and secure power system based on clean power, in 2019 National Grid launched the Stability Pathfinder initiative. This project is designed to secure new sources of inertia. Through an auction process, qualified participants bid for the opportunity to offer the most cost-effective methods for securing system inertia. The initial auction secured 12.5 GVAs of inertia by 2026, providing savings of £52m to £128m. The third auction, completed in November 2022, secured 17 GWs of inertia, which is projected to save the National Grid £14.9bn from 2025 to 2035.

Historically, reactive power services have been provided by thermal power stations through the Obligatory Reactive Power Service (ORPS) system. Through the ORPS, all power plants over 47MW in are obliged to provide reactive power services. However, as more thermal power is replaced with variable renewable sources there are fewer power stations that can provide these services. As a result, National Grid is now focusing on securing reactive power services from dedicated local sources. The High Voltage Pathfinder project was established to pinpoint areas that may experience overvoltage problems. An auction held in 2019 helped the UK secure 200 MVar of reactors and 38 MVar of energy storage for reactive power absorption in the Mersey region. In March 2021, another auction was held to secure reactive power absorption in the Pennines region, securing a total of 700 MVar of reactive power absorption and expected to save £22.5m.

Supporting materials

Acknowledgements

Contributors

Tom Harrison, Ali Candlin, Seungwan Kim, Yunsik Chung, Yonghyun Song, Uni Lee, Chelsea Bruce-Lockhart, Sarah Brown, Matt Ewen

Header image

Inspection engineers standing on top of a wind turbine.

Credit: Pand P Studio / Shutterstock