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Electric Insights Quarterly

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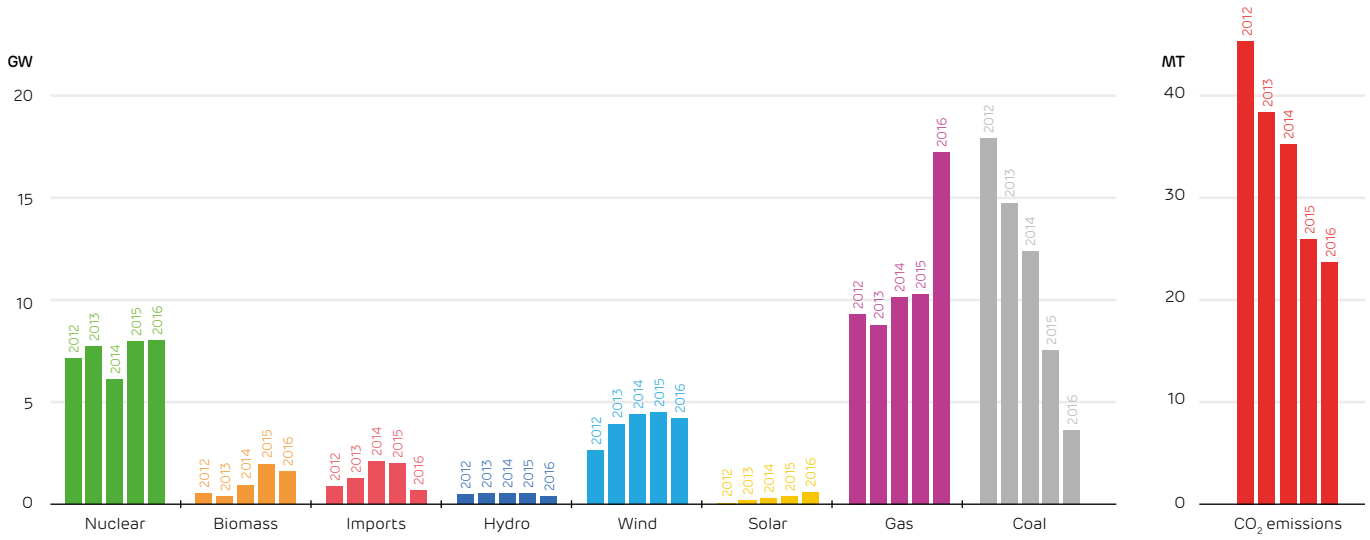
Headlines & summary

This issue sees low carbon generation break new records whilst France's interconnector and nuclear plants break down. Low carbon generation averaged 40% over the quarter, and hit a new record of 81% during Christmas *(see Article 2)*, demonstrating that it is possible to run the system with very little fossil fuels. Wind output is slightly down on last year because of the weather and new projects are beginning to dry up, but peak wind output exceeded 10 GW for the first time *(see Article 3)*.

Britain became a net exporter to France for the first time in six years because of a crisis with French nuclear reactors, but these exports were limited as the interconnector was damaged during Storm Angus *(see Article 4)*. The loss of imports from France left the power market tight, forcing National Grid to issue its first 'Capacity Market' notices. Power price volatility grew further, with prices peaking above £1,500 / MWh in Q4 *(see Article 5)*.

Coal has recovered slightly from the historic lows we reported in Quarter 3, but only to half its level this time last year. Coal output continued its strong downward trend, being displaced by cleaner gas because of falling fuel prices and the UK's Carbon Price Floor. CO_2 emissions were 23 MT, down 9% on this quarter last year, and 48% on Q4 2012. This issue finishes by looking back at 2016 for the power sector *(see Article 6)*, and the capacity and production statistics over the quarter *(see Article 7)*.

Average power output from each technology (left), and total CO_2 emissions from the power sector (right) during the fourth quarter of the last five years:



A low carbon Christmas

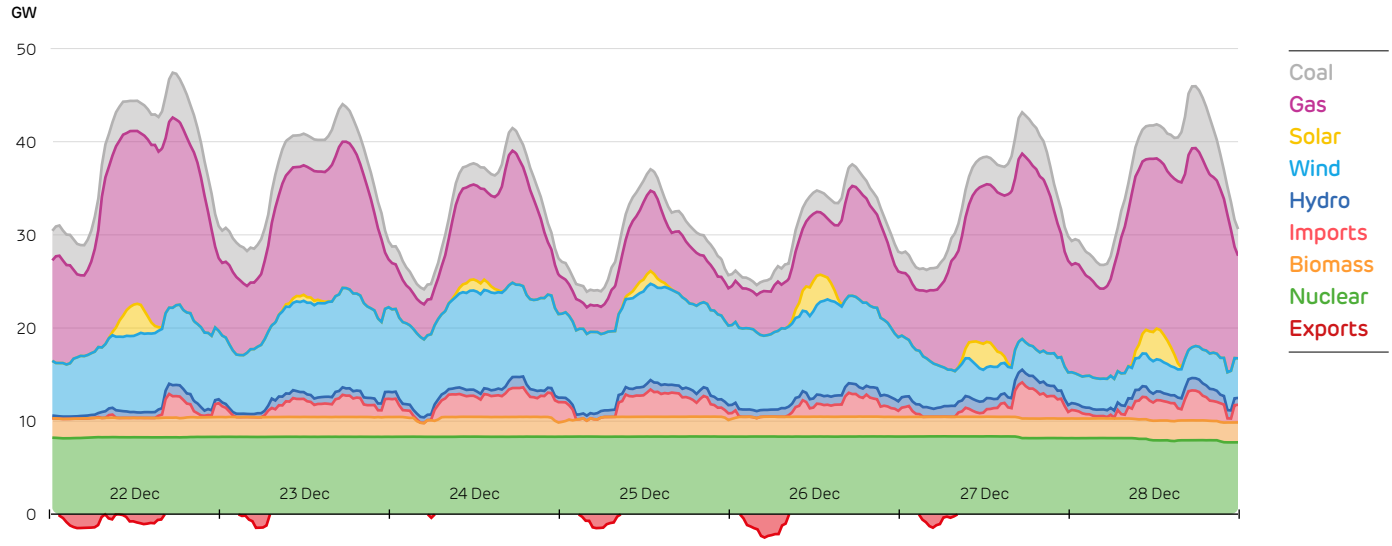
2016 saw Britain's cleanest Christmas: up to 81% of electricity was supplied by low-carbon sources as Santa delivered his presents. The share of nuclear, biomass, hydro, wind and solar did not fall below 60% during the three days between Christmas Eve and Boxing Day.

Over the three months, the average share of low carbon electricity was down from 50% in Q3 to 40% in Q4, due to higher demand (met by gas and coal) and the collapse of French imports. This share was especially high over the Christmas period due to low demand combined with high winds. Electricity demand was reduced as workplaces shut down for the holidays, whilst Storm Barbara hit Britain with 90 mph winds from the 23rd.

At their peak, wind farms met 37% of British demand – powering around 15 million people, or everyone (and everything) north of Nottingham. Despite being just days after the winter solstice, solar PV still produced a notable amount of power on clear days, peaking at 3.4 GW (or 9% of demand) over the Christmas week.

This proves it is technically possible to run the power system with very little fossil fuels; although the market's response was for prices to fall negative in the early hours of the morning on all three days.

Generation mix over the week surrounding the Christmas period:



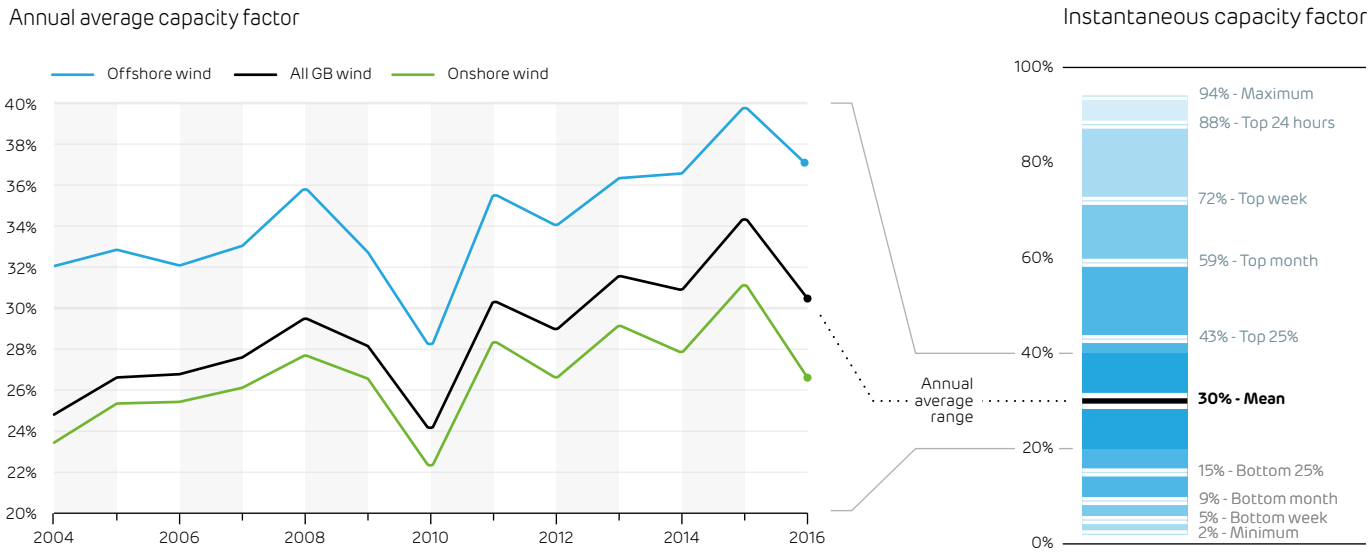
Highs and lows for wind power

Wind power surpassed 10 GW for the first time in Britain, but output over the quarter is down 7% on the previous year, and fewer new projects were developed. Storm Barbara brought high winds across the whole country, raising peak wind output to 10.8 GW on the 23rd of December, beating the previous record of 9.4 GW set back in 2014. Overall, wind spent 24 hours producing over 10 GW during December, but equally it spent as many hours producing less than 0.7 GW. While the wind never stops blowing over the whole country, it does vary over nearly the whole range from 0–100% output (see below right).

Average wind output over the quarter was 7% lower than in Q4 2015. This is part of the natural year-to-year variability in the weather. Fewer winter storms meant wind speeds over 2016 were down 15% on the previous year, their lowest since 2012. This variability can be seen in the historic productivity of Britain's onshore and offshore farms (see below left).

Britain's average wind capacity factor has risen steadily from around 27% in the 2000s to 31% so far this decade. Turbine technology is improving, and a growing share of capacity is now offshore (35% in 2016). Britain's offshore wind farms produce a third more energy per unit of capacity because they use bigger machines on taller towers, with access to much better wind resources.

The historic annual averages from both onshore and offshore farms (left)[1], and the range of capacity factors for Britain's wind farms during 2016 (right):



Despite improving productivity, fewer wind farms were brought online in 2016 than in previous years. Installed capacity grew by 6% to 15.2 GW, down from 25% annual growth from 2010 to 2015. This reflects the near-halt of new onshore building in light of policy changes, and a hiatus in the large 'lumpy' investment in offshore farms between Round 2 finishing and Round 3 starting.

Globally, investment in renewable energy fell 18% in 2016, the largest drop on record during the hottest year on record. The UK bucked this trend though with a 2% increase in investment, making it the largest renewables investor in Europe for three years in a row.

Footnotes:
[1] Includes data and analysis from Staffell & Pfenninger (2016) and BEIS Energy Trends.

French nuclear crisis cuts imports

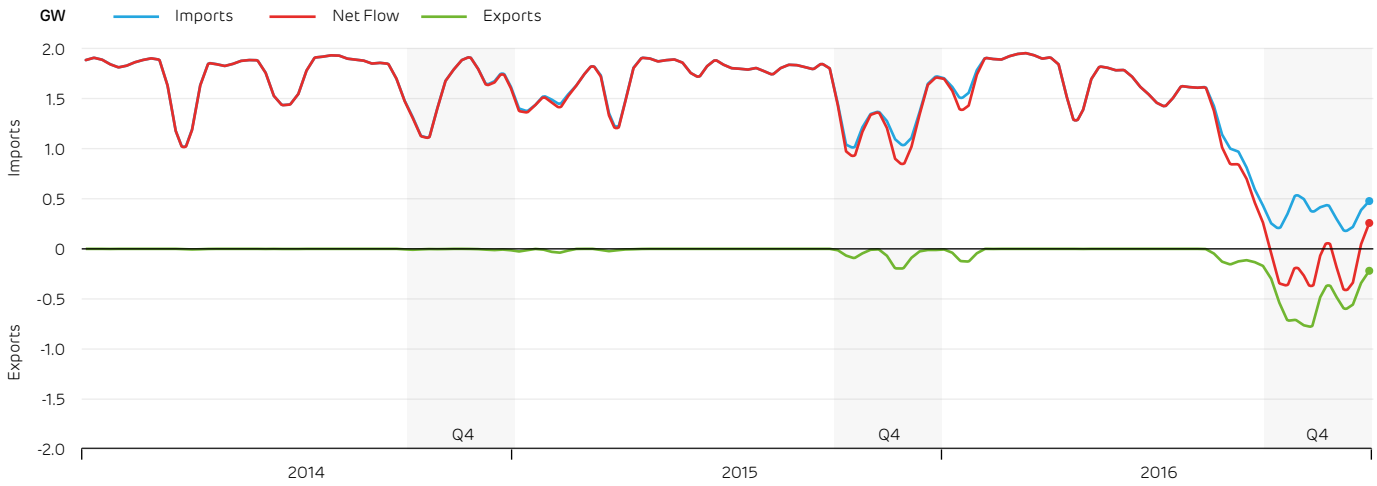
Q4 was the first time in six years that Britain was a net exporter of electricity to France. Britain exported more power in one week of November than over the whole of 2014 and 2015 combined. The French nuclear industry went through its "worst situation ever" with up to twenty nuclear reactors offline for safety tests, leaving the country at risk of a capacity shortage in the event of severe cold weather.

Britain has typically been a net importer as prices on the continent have been lower – helped in part by French imports not paying the carbon price floor or fees for using our transmission system. However, power prices are now around three times higher in France than in Britain, trading at €140 / MWh for January.

Britain cannot make the most of this export opportunity though, as half of the French interconnector was taken offline in November. A boat is thought to have dropped anchor during Storm Angus, damaging four of the eight cables which are buried in the seabed. The link is now limited to 1,024 MW, and repairs by National Grid will take until the end of February to complete.

Interconnectors are expected to play an increasing role in Britain's generation mix and security of supply, so it is important to be aware of the many external influences affecting their availability.

Weekly average power transfer over the French interconnector:



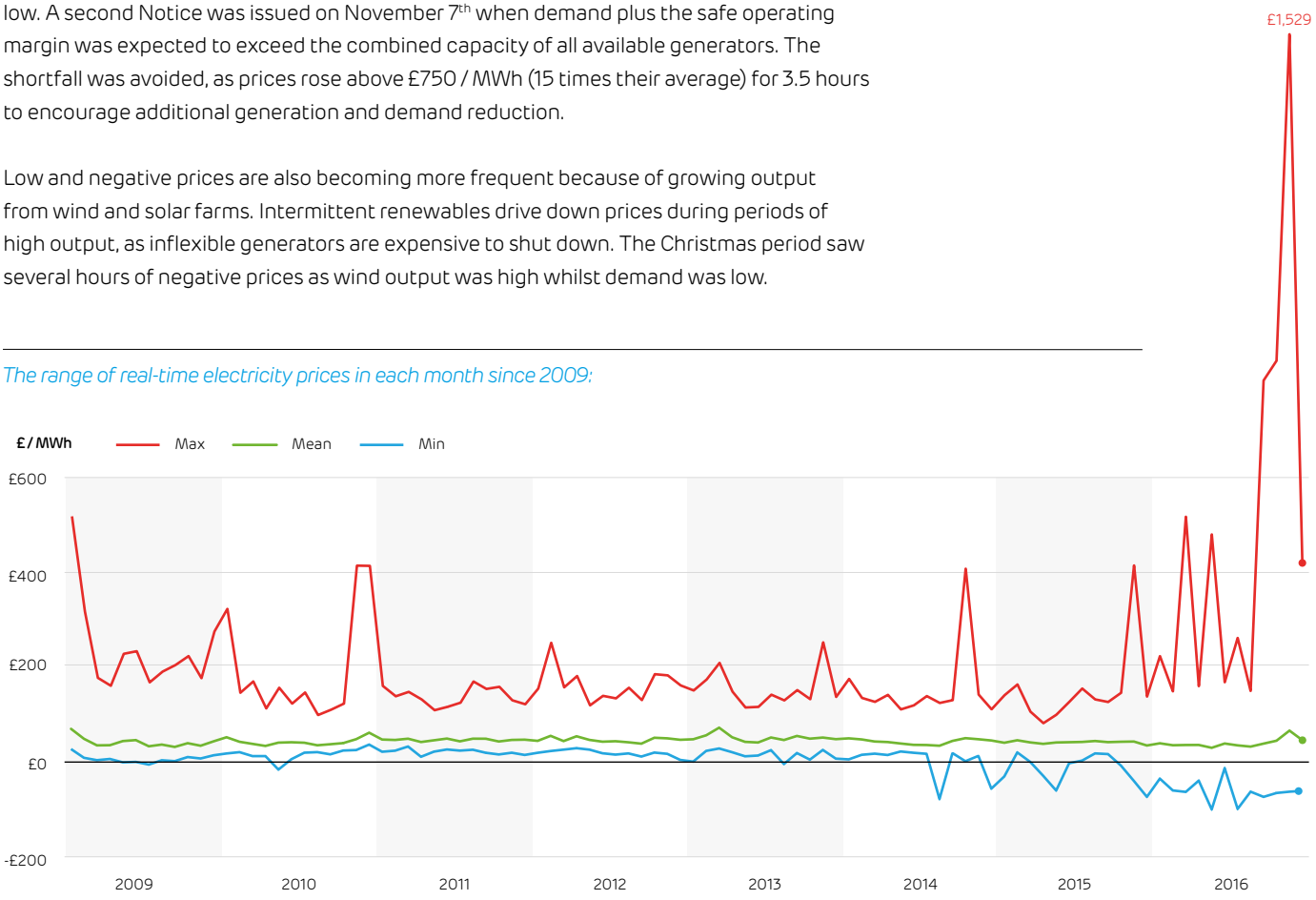
Price volatility continues rising

British power prices are becoming ever more volatile, and peaked at £1,529 / MWh during the quarter, their highest for at least a decade. Prices also spent 19 hours at or below £0 / MWh at times of high renewable output.

Britain's system margin (the amount of spare capacity) was unusually low due to ongoing problems with the French nuclear fleet. National Grid issued their first 'Capacity Market Notice' on October 31st, when several plants were off for maintenance and wind output was low. A second Notice was issued on November 7th when demand plus the safe operating margin was expected to exceed the combined capacity of all available generators. The shortfall was avoided, as prices rose above £750 / MWh (15 times their average) for 3.5 hours to encourage additional generation and demand reduction.

Low and negative prices are also becoming more frequent because of growing output from wind and solar farms. Intermittent renewables drive down prices during periods of high output, as inflexible generators are expensive to shut down. The Christmas period saw several hours of negative prices as wind output was high whilst demand was low.

The range of real-time electricity prices in each month since 2009:



Finally, the design of the electricity market changed in November 2015. Ofgem changed the pricing rules to better reflect the 'marginal' price (i.e. the price of the last MW required to meet demand). Prior to 2014 the price was the average of the top 500 MWh of electricity traded, but since November 2015 this was narrowed to consider only the top 50 MWh. The rules will be tightened further in November 2017 to consider only the top 1 MWh.

2016 - The year in review

2016 was a dramatic year for Britain, not least for its electricity system. Generation from coal fell 61% from the previous year. Gas was up by 51% and low-carbon generation reached its highest ever share. This was the largest annual swing in fuel shares since the miners' strike of 1984, and the largest ever in percentage terms.

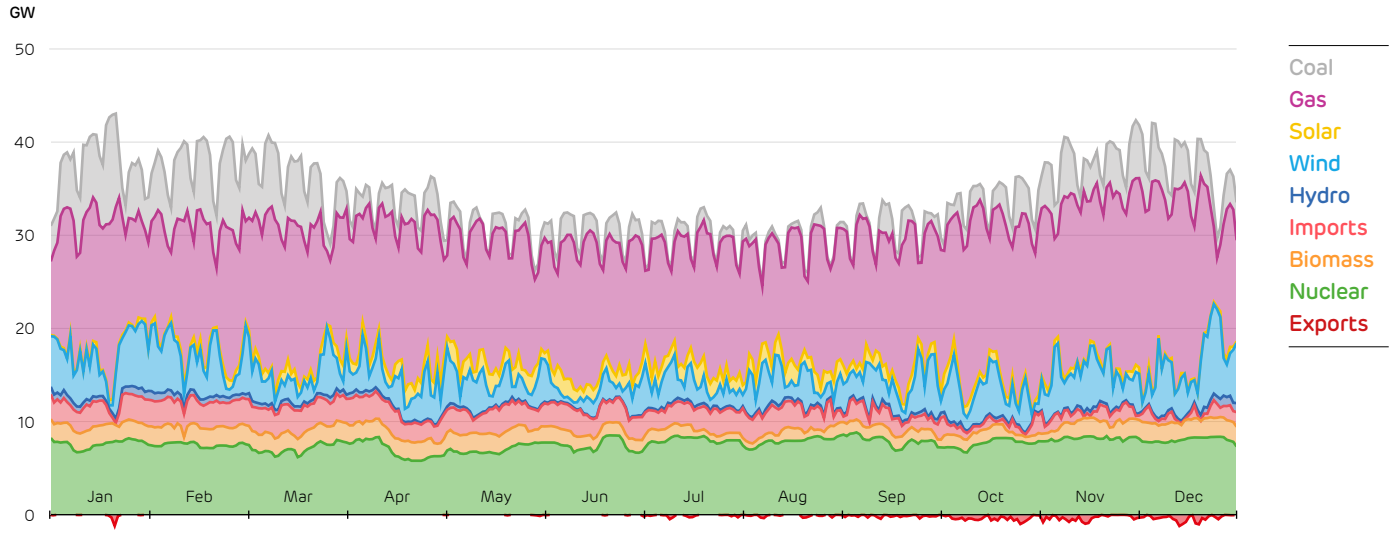
Coal's share of output fell to just 9%, with 28 TWh produced – the lowest amount since the start of World War II. This placed coal behind wind for the first time ever, which provided 10% (31 TWh) of electricity: a symbolic shift in the transition to low carbon sources.

Over the last five years 75 TWh of generation from coal has disappeared. Replacing it are 25 TWh from wind and solar, 15 TWh from biomass and 15 TWh that were imported. The remaining 20 TWh did not need to be generated due to efficiency improvements. While gas generation has shot up in the last year, it now stands at the same level as five years ago. The fact that it is gas which rebounded and not coal was largely due to the UK's Carbon Price Floor (CPF) increasing the total cost of coal relative to gas. This has relegated coal to a more 'climate-friendly' role of providing infrequent peaking power at times of greatest need, allowing lower-carbon gas to take over as the baseload generator.

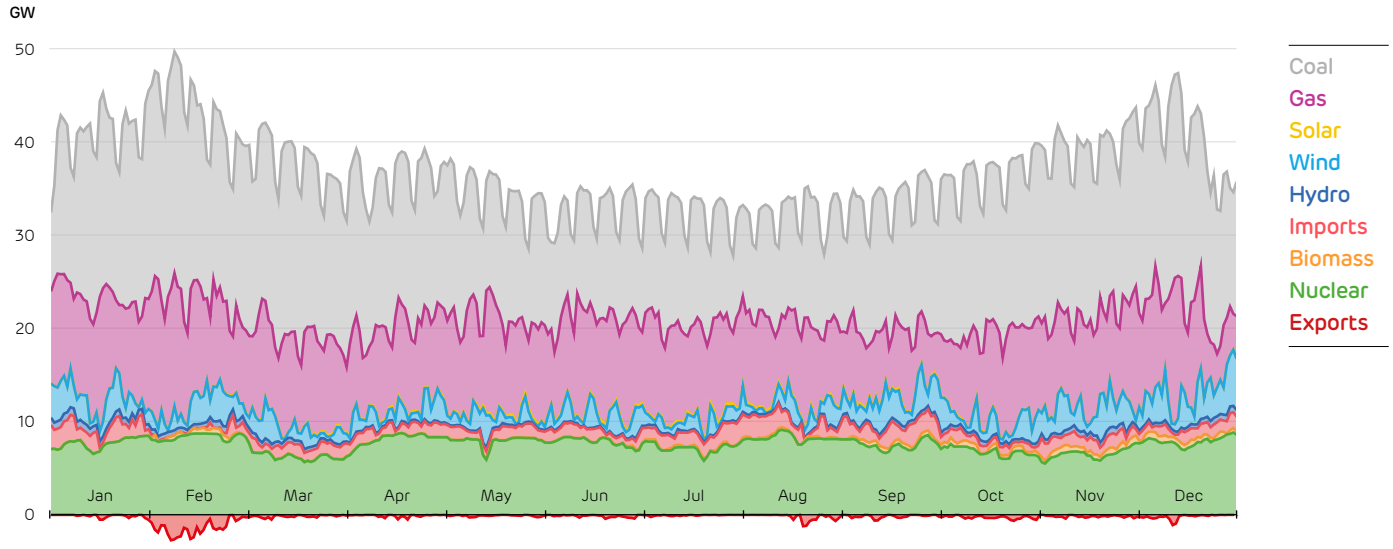
Over the last two years, the CPF has added around 0.5 pence per kWh to the cost of generation.[2] In return it has played a major part in reducing carbon emissions from Britain's electricity to their lowest for 60 years. The charts below compare the generation mix in 2016 and 2012 – showing the scale of the change over the last four years.

Footnotes:
[2]Based on the four quarters to 2016 Q3 (where latest prices are available), taking the most expensive fuel (coal or gas) with carbon charged at £18 per tonne versus the most expensive with £4.90 per tonne as under the EU ETS.

Daily generation mix during 2016:



Daily generation mix during 2012:



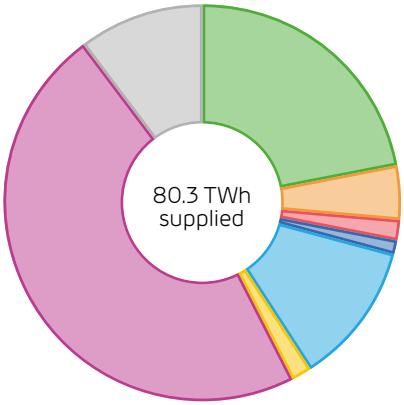
Capacity and production statistics

Generation in Q4 was dominated by gas, which supplied nearly half of all electricity.
Coal recovered slightly from its historic low in Quarter 3, but only provided 10% of generation. This is down from 21% in Q4 2015 and 34% in Q4 2014.

Low-carbon technologies provided 40% of output, down from 50% in Q3 and from 47% in Q4 of 2015. Within this, wind output was down 7% due to the weather, biomass was down 18% due to ongoing maintenance carrying over from the summer, and hydro was down 30% – albeit from a very low level. Solar output, on the other hand, was up 50% on this time last year, but again the weak winter sunshine means this rise is relatively insignificant.

Britain spent much of the quarter importing from Ireland and the Netherlands only to export to France. The reversal of the French interconnector means that imports are down 40% and exports more than doubled.

Britain's electricity supply mix in the fourth quarter of 2016:



	Output (TWh)	% of mix
Nuclear	17.5	22.0%
Biomass	3.5	4.4%
Imports	1.5	1.9%
Hydro	0.8	1.0%
Wind	9.2	11.6%
Solar	1.3	1.6%
Gas	37.7	47.4%
Coal	8.0	10.1%

Installed capacity and electricity produced by each technology:

	Installed Capacity (GW)	Change from 2015 Q4	Energy Output (TWh)	Change from 2015 Q4	Capacity Factor
Nuclear	9.5	–0.6 (–6%)	17.5	+0.1 (+0%)	84%
Biomass	2.2	~	3.5	–0.8 (–18%)	70%
Hydro	4.1	+0.1 (+2%)	0.8	-0.4 (-30%)	33%
Wind	15.2	+0.9 (+6%)	9.2	-0.6 (-7%)	35%[3]
Solar	11.5	+2.4 (+27%)	1.3	+0.4 (+52%)	6%
Gas	28.3	+0.5 (+2%)	37.7	+15.2 (+68%)	57%
Coal	14.0	–4.3 (–23%)	8.0	–8.6 (–52%)	22%
Imports	4.0	~	3.0	-2.2 (-43%)	34%
Exports			1.4	+0.8 (+132%)	15%

[3] *A note on wind capacity factors: We find that combining data from National Grid and Elexon on wind capacity and output yields lower average capacity factors than given by other sources. Over the four quarters to 2016Q3, BEIS reports an average capacity factor of 31.1% compared to 24.6% from our data. Until 2014 these sources agreed to within ±1.3%, but a discrepancy grew over the winter of 2014/15 and has persisted through 2016. Over 2015 and 2016, the capacity factors we calculate are one-fifth lower than those reported by BEIS. The raw data from National Grid and Elexon suggests that the capacity factor for wind was 27.7% over Q4. We have adjusted this upwards by one quarter (1 ÷ 0.8) in the table above. This is expected to give better agreement with BEIS, and is in line with numerical modelling based on 2016 wind speed data (Staffell & Pfenninger, 2016). One potential explanation would be if our data only covers the output from four-fifths of the installed wind fleet (i.e. 12.2 GW out of the 15.2 GW registered capacity). We hope to resolve this discrepancy in a future issue*

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