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Electric Insights Quarterly

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1. Headlines

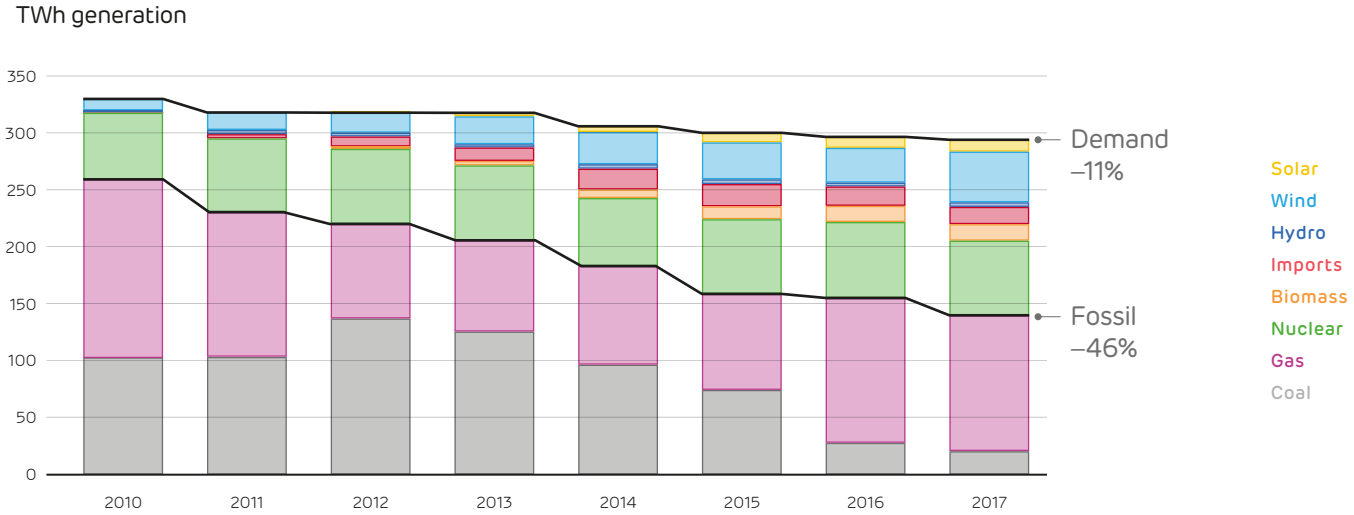
2017 finished by continuing the familiar trends for Britain's electricity: renewables replacing fossil fuels and carbon emissions falling. Article 2 begins with a review of events in 2017 – which saw half of Britain's electricity come from low-carbon sources, as coal and gas output fell by a tenth and wind farms posted a record year.

Wind generation grew 45% between 2016 and 2017. Article 3 explores how higher wind speeds and the completion of several onshore and offshore wind farms contributed to record-breaking wind output over the year, and especially in Quarter 4. Together, wind, solar, biomass and hydro produced 96 TWh of electricity in 2017, enough to power the whole of Britain sixty years ago. Article 4 looks at the long-term diversification of electricity supply, and how far low-carbon energy has come.

Together, these changes meant that carbon emissions from Britain's electricity consumption fell by 12% last year. This saving amounts to 10 million tonnes of CO_2 in a year, equivalent to taking one in seven of Britain's cars off the road (see Article 5).

After seeing record electricity imports in Quarter 3, Article 6 explores why net trade between Britain and France fell to zero during Quarter 4. Article 7 rounds up the statistics for the quarter.

Generation mix in Britain over the last eight years. Generation from fossil fuels has almost halved since 2010, demand has fallen by a tenth, and output from renewables has increased six-fold.



2. 2017 in review

Britain's power system once again enjoyed its greenest year, with 50% of electricity coming from low-carbon sources. 2017 saw generation from fossil fuels fall by a tenth; driven down by lower demand and greater wind output (see Article 3). Even after the historic reductions in carbon emissions in 2016, the CO_2 from British electricity fell by another 12% in 2017 (see Article 5).

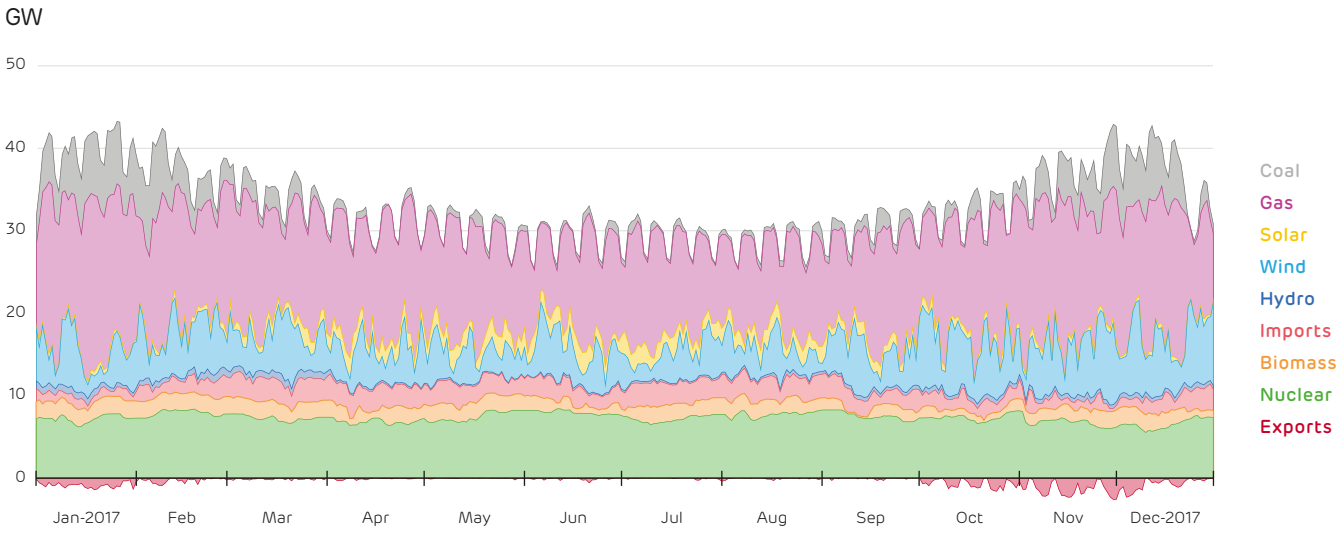
The share of fossil fuels has fallen from 80% to 50% since 2010, and with it the share of flexible, controllable capacity. Coal and gas produced just 140 TWh of Britain's electricity last year, having fallen for seven consecutive years from 260 TWh in 2010. Nuclear, renewables and low-carbon imports together produced 139 TWh, and as Carbon Brief reported, the share of low-carbon generation rose to over 50% averaged over the year.[1]

The chart below shows how the daily mix of generation varied through the year. After plummeting 60% in 2016, coal generation fell by a further quarter in 2017. Coal is now the preserve of the colder months when demand is over 35 GW. April saw the first ever full day with no coal generation, and across the year there were 618 hours that were coal-free. Solar power has become a major supplier during the summer months, with more electricity coming from the sun than from coal on 183 days last year.

Despite demand for electricity being highest during the winter months, this coincided with times when Britain was exporting electricity, primarily to France. With French nuclear reactors offline again during Quarter 4 for safety upgrades, France was willing to pay more for electricity and so our generators profited from exporting (see Article 6).

With more low-carbon capacity due to come online during 2018, the coming year may also see the majority of Britain's power coming from low-carbon sources.

Daily average generation mix during 2017



1 This milestone includes the output from smaller generators which are 'invisible' to the electricity system. Some 'captive' power stations – or 'autogenerators' – are used to power industrial sites and never export electricity onto the national grid. No estimates of their half-hourly output exist, so they cannot be included in the Electric Insights data.

3. Wind power grows 45%

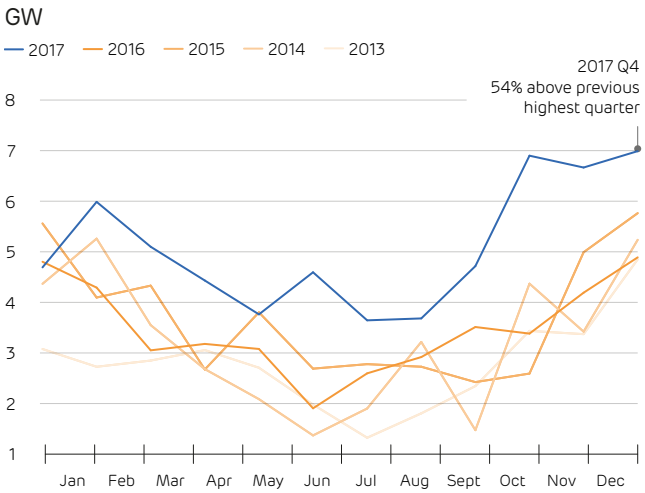
Wind farms produced a record 15% of Britain's electricity last year, up from 10% in 2016. They produced 45 TWh of electricity over the year, more than twice the output from coal. The dramatic increase comes from both higher wind speeds and a jump in installed capacity. Several large offshore farms came online and onshore wind had a record year for deployment.

Quarter 4 saw Britain's wind farms smash previous records, producing 15 TWh in three months, or 19% of electricity consumed. Their production averaged 6.6 GW in each of the three months – double the anticipated production from the Hinkley Point C nuclear plant. However, the output from wind is more variable than from nuclear and thermal power stations. During Quarter 4, wind farms spent 24 hours producing less than 1 GW, and 24 hours producing more than 11.7 GW (chart, below right).

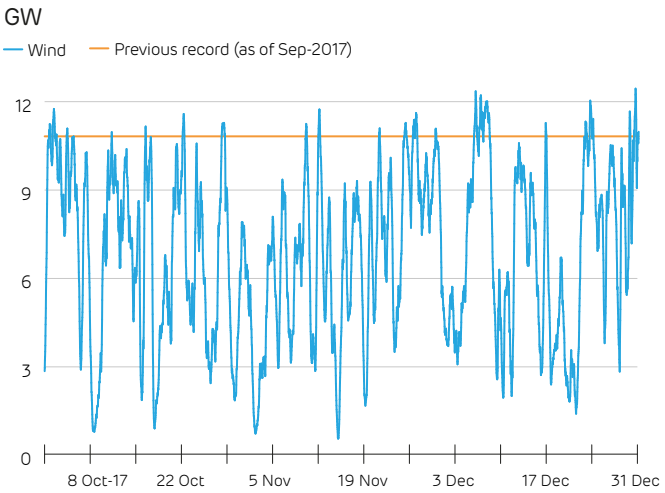
The very active hurricane season boosted wind speeds, which were 5% higher in 2017 than 2016.[2] However, the year-round average of 10.1 mph was in line with the long-term average for Britain, meaning expectations for 2018 should be just as good. Quarter 4 brought three named storms and an 'ex-hurricane',[3] and saw Britain's record for peak wind output broken four times. Wind output surpassed 11 GW for the first time in October then 12 GW in December. It hit 12.4 GW on New Year's Eve as Storm Dylan swept across the North Sea – and wind has continued breaking records into the New Year.

Registered wind capacity also increased by 20% (3.2 GW) over the last twelve months.[4] Several large offshore farms and record new onshore wind capacity were installed in 2017, as reported by RenewableUK. Dudgeon and Race Bank on the east coast, Walney in the north-west and Rampion off the south coast each added over 400 MW (powering approximately 400,000 houses). These farms span dozens of square miles, and the latter two are still being commissioned, so operating capacity will continue to grow over the coming months.

Monthly average output from wind farms over the last five years



Half-hourly wind output during Quarter 4



2 Based on provisional data from BEIS Energy Trends.
3 See the Met Office UK Storm Centre.
4 From October 2016 to October 2017. Based on BEIS Energy Trends and RenewableUK.

4. Powering the past

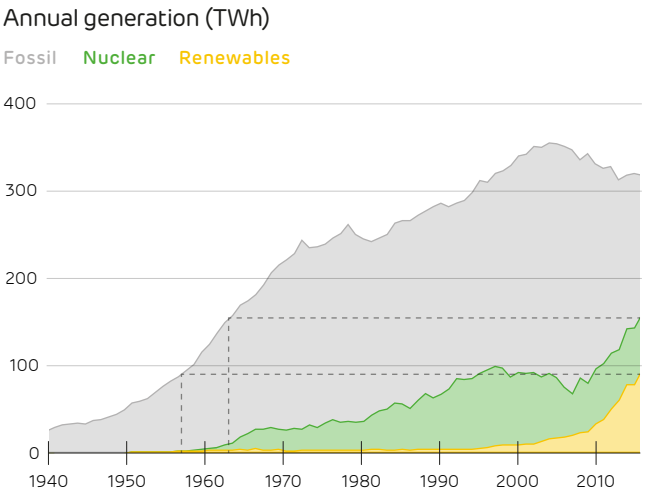
Britain's renewable output grew 27% last year, and would have been sufficient to power the entire country 60 years ago. This year's renewables produced more than the country's annual electricity demand in 1958. At the height of Beatlemania in 1964, electricity use had risen sharply, but putting this year's renewables and nuclear together could have powered Britain without fossil fuels.

Renewable energy surged in 2017 thanks to windier weather and more capacity coming online. Of the 294 TWh of grid-supplied electricity consumed in Britain, a quarter came from biomass, hydro, wind and solar plants. Electric Insights recorded 73 TWh of renewable output from plants which operate in the electricity market or export to the national grid. Adding on the many smaller 'embedded generators' which produce electricity locally,[5] the renewable total rises to 96 TWh.[6]

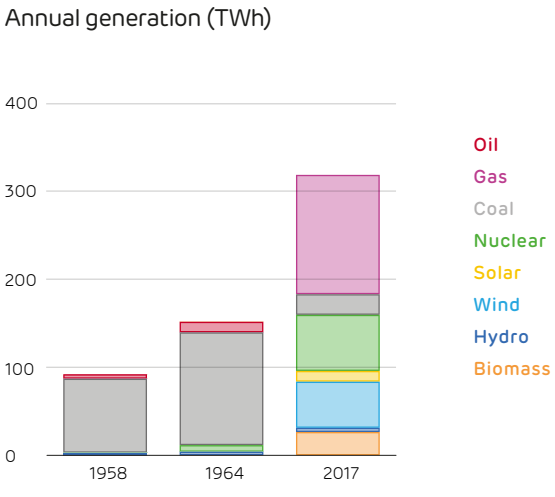
In 1958, Britain's 52 million people consumed a little less than this – 91 TWh. The year that brought us Blue Peter, "A Bear Called Paddington" and the Hula Hoop, could have been powered by today's renewable electricity – averaged over the year. At the time, 92% of electricity came from coal, and the power system emitted 93 million tonnes of CO_2. Last year, Britain's renewables produced as much electricity with just 3 million tonnes of emissions (due to processing and importing biomass).

Of course, producing the same amount of energy over the year is very different to balancing the nation's electricity demand hour by hour. Running the country on renewables and nuclear would need tremendous support from integrating technologies (energy storage, responsive demand and interconnection) – but still, this shows just how far clean energy has come in Britain.

Britain's electricity generation mix since 1940. Dotted lines show how last year's renewable output equalled total demand in 1958; and total low-carbon output equalled demand in 1964.



Breakdown of Britain's electricity mix in these three years show how much electricity supply has diversified



5 For example, biomass generators feeding industrial facilities.
6 This difference partly explains why BEIS annual statistics differ to those from Electric Insights. Additionally, BEIS covers the entire UK whereas Electric Insights reports on the British power system which excludes Northern Ireland.

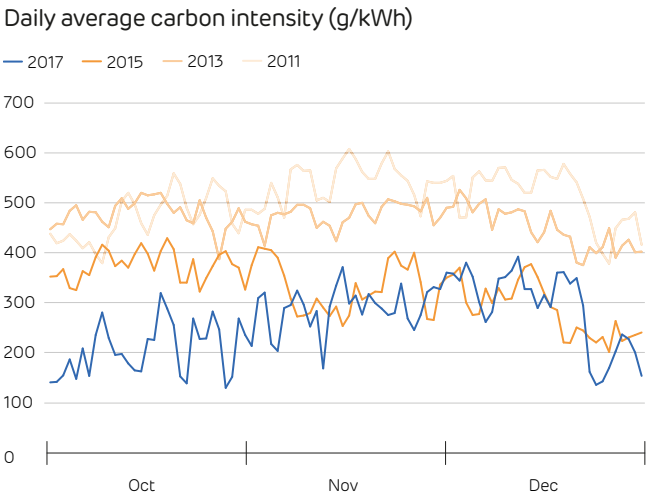
5. Carbon emissions down 12%

2017 was once again the cleanest year for electricity production in Britain. Carbon emissions (including those from imported electricity) were 72 million tonnes over the year, down 12% on 2016 due to lower coal and gas production. This amounts to 150 kg of CO_2 saved per person – equivalent to taking one in seven cars off the road (4.7 million in total).[7] Yet this saving comes without requiring any active change in people's lifestyles.

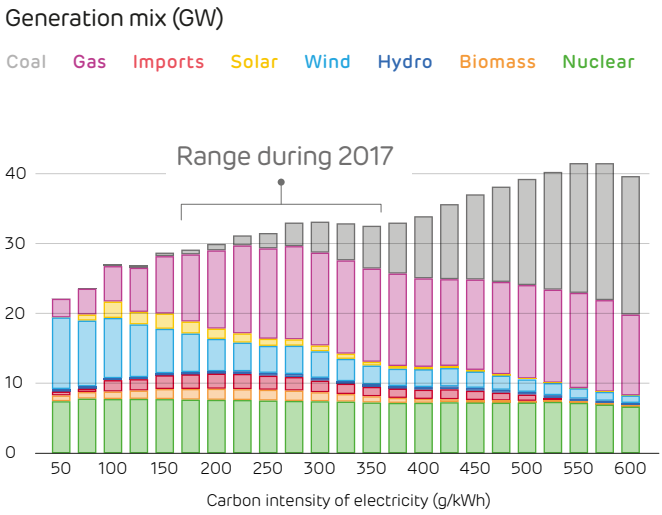
The average carbon content of electricity has fallen to 237 g/kWh over 2017. The average during Quarter 4 was 272 g/kWh, greater than the year-round number as more fossil fuels are used when demand is higher. The range[8] last quarter was 140–360 g/kWh, compared to 400–510 g/kWh just four years ago (*see chart bottom left*). The instantaneous carbon intensity hit a record low of 56 g/kWh just after midnight on the 2nd of October (20% below the previous minimum in June). At the time, just 12% of electricity came from gas, the rest was low carbon. Q4 saw 41 hours with a carbon intensity under the important threshold of 100 g/kWh, bringing the total for the year to 139 hours (up from just 4 hours in 2016).

What does a low-carbon grid mix look like? The chart below-right shows Britain's average grid mix for different levels of carbon intensity. The cleanest mixes are only seen during times of low demand (e.g. overnight in summer). Reaching below 100 g/kWh generally requires 50% renewable energy and demand below 30 GW. An absence of coal is generally needed to stay below 200 g/kWh. As all of these features are becoming more common, we expect more time under 100 or 200 g/kWh in the future.

Daily average carbon intensity of electricity in 2017 and previous years



The average generation mix for different levels of carbon intensity. The cleanest mixes on the left are mostly seen in recent years, and the dirtiest mixes on the right were mostly seen before 2013.



7 Based on there being 31.7 million cars in the UK which emit 68.5 $MTCO_2$ per year.
8 5th to 95th percentile of daily averages – meaning 90% of days in the quarter lie within this range.

6. Moving electricity across the channel

Electricity trade between Britain and France was exactly balanced, but still worth nearly £34 million this quarter. Since the interconnector between France and England was built, Britain has tended to import electricity from France. There have been periods when the power flows in the other direction, such as in Quarter 4 of 2016 when many French nuclear reactors were offline for safety tests. This quarter, the flows were almost exactly in balance with 1.57 TWh going in each direction.

The complex pattern of flows *(see chart below left)* cannot be explained by looking at Britain alone. There is no correlation between the amount of power imported from France in each half hour and the level of electricity demand, wind and solar output, or wholesale electricity prices in Britain.

Flow are more strongly related to, but not completely explained by, the cross-channel difference in day-ahead electricity prices *(see chart below right)*. The blue points show 'efficient arbitrage' – times when electricity is bought cheap and sold expensive. These trades earned around £36 million over the quarter, less the cost of using the interconnector.

There are also many periods when power appears to flow the wrong way (shown in orange). 13% of Britain's imports and 15% of exports were sent to a market where the price was at least £1/MWh lower than where the power came from. These wrong-way flows were smaller and less common, but still substantial. If the traders had bought and sold power in the two countries' day-ahead markets, they would have lost £2.7 million, before deducting interconnector costs.

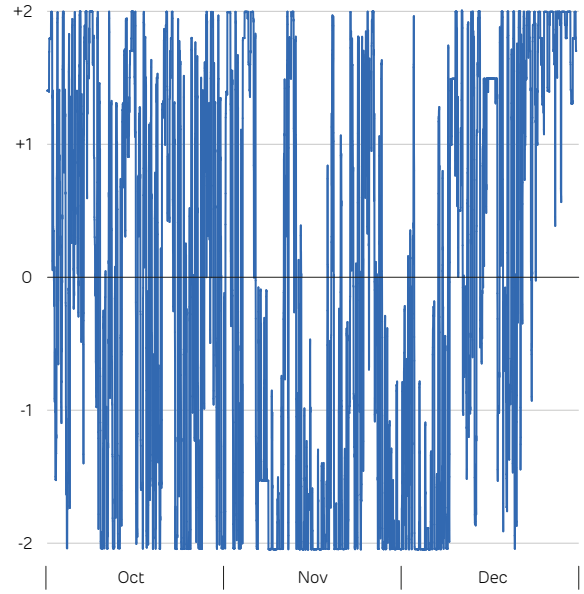
In practice, flows may have been agreed before the day-ahead prices were known. They may also be adjusted in response to real-time events that changed the situation after those prices were determined. National Grid sometimes have to counteract the profit-driven trades to preserve system security.

While the interconnector responds reasonably well to economic signals, does it respond to the system's needs? There were eight half-hours with very high demand (over 50 GW) in which Britain exported power. This might be the 'neighbourly thing to do' if the French grid was under greater stress, but in four of those periods, the day-ahead prices suggest that traders would have lost money.

The interconnectors are taken into account in the government's annual auctions for generating capacity. It would be silly to ignore them, but we should keep track of their actual ability to deliver electricity when required, as with any other power source. National Grid, as the electricity system operator, have the authority to directly control British generators if the situation calls for it. With interconnectors, power flows will follow the money.

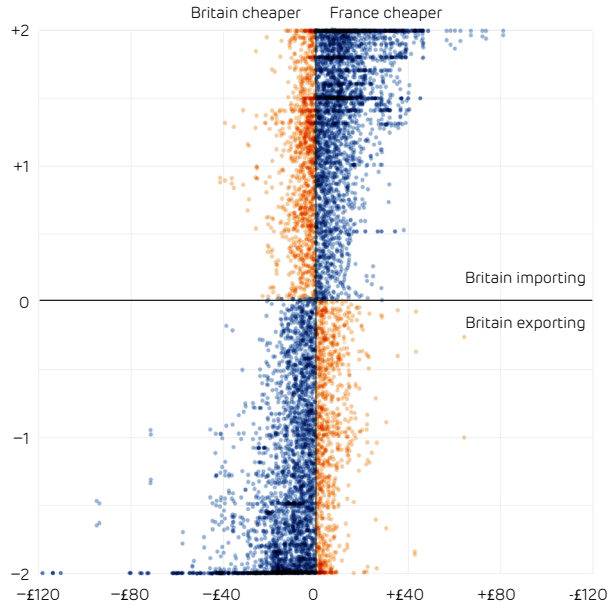
Half-hourly power flow across the French interconnector during Quarter 4. Imports to Britain are above, and exports to France are below the axis.

Power flow (GW)



The relationship between power flow between Britain and France and the difference in day-ahead power price in each country. Profitable trades are shown in blue, loss-making trades in red.

Power traded



7. Capacity and production statistics

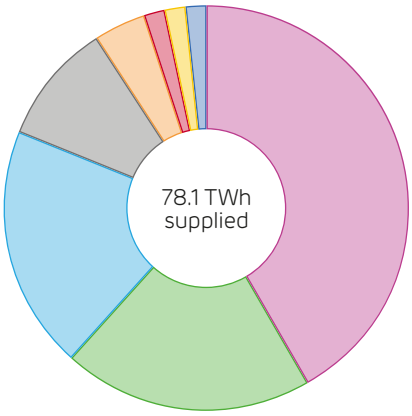
This quarter saw wind output grow by 65% on this quarter last year, increasing its share of generation by 8 percentage points. This extra wind pushed down output from gas plants, which lost 6 percentage points of the mix versus Quarter 4 2016. Output from nuclear and biomass plants was lower than last year due to outages. Sizewell B went offline for statutory maintenance in November, and a small fire closed two biomass units at Drax in late December.

Coal supplied 3.5 GW averaged over the quarter, meaning the coal fleet ran at only ¼ utilisation. At its peak though, four fifths of coal capacity ran simultaneously, producing 12.4 GW. The only new capacity to come online during 2017 was wind and solar farms. Over 4 GW of capacity was commissioned, bringing the total to almost 31 GW.

Power prices were stable and similar to last year, averaging £50/MWh over the quarter. Prices were negative for 15 hours, and there were no extraordinary price spikes. The marked reduction in volatility meant the highest price over the quarter was £178/MWh – down from £1500/MWh seen earlier in the year.

The year ended on a green note. Once again British electricity had its cleanest ever Christmas, as high winds combined with low demand, caused by Christmas Day being the second warmest on record (averaging 9.7°C). One third of electricity came from renewables, and one third from nuclear, meaning the carbon intensity ranged from just 72 g/kWh overnight up to 208 g/kWh at lunch time.

Britain's electricity supply mix in the fourth quarter of 2017



	Output (TWh)	% of mix
Gas	32.6	41.8%
Nuclear	15.6	20.0%
Wind	15.1	19.4%
Coal	7.7	9.9%
Biomass	3.1	3.9%
Imports	1.4	1.8%
Solar	1.3	1.6%
Hydro	1.2	1.5%

Installed capacity and electricity produced by each technology[9]

	Installed Capacity (GW) 2017 Q4	Annual change	Energy Output (TWh) 2017 Q4	Annual change	Utilisation / Capacity Factor 2017 Q4	
					Average	Maximum
Nuclear	9.3	–0.2 (–2%)	15.6	–1.9 (–11%)	76%	90%
Biomass	2.2	~	3.1	–0.4 (–13%)	65%	100%
Hydro	1.1	~	1.2	+0.4 (44%)	49%	92%
Wind	17.9	+2.7 (+18%)	15.1	+6.0 (+65%)	40%	70%
Solar	12.9	+1.4 (+12%)	1.3	–0.0 (–1%)	5%	48%
Gas	27.7	–0.6 (–2%)	32.6	–5.1 (–13%)	53%	92%
Coal	13.5	~	7.7	–0.2 (–3%)	26%	78%
Imports	4.0	~	3.7	+0.8 (+26%)	43%	80%
Exports			2.2	+0.8 (+58%)	25%	97%
Storage	3.1	~	0.7	–0.0 (–6%)	11%	78%

9 Other statistical sources give different values because of the types of plant they consider. For example, BEIS Energy Trends records an additional 900 MW of wind, 600 MW of biomass and 500 MW of solar, respectively producing 1.4, 1.2 and 0.2 TWh extra per quarter. These plants and their output are not visible to the electricity system and so cannot be reported on in Electric Insights.

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