July to September 2016

Electric Insights Quarterly

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Contents

Electric Insights launches

Welcome to the first edition of the Electric Insights Quarterly, a new report to inform the debate on Britain's electricity system.

The sector is undergoing unprecedented changes from obligations to decarbonise, pressure to keep bills down and fears about 'keeping the lights on'. We are seeing old coal driven off the system, new nuclear given the go-ahead, prices reaching new highs and lows, and clean energy overtaking fossil fuels for the first time. It is an exciting, but challenging, time for this 130 year old system.

Electric Insights contributes to these important topics by bringing to life the wealth of raw data that are made publicly available by National Grid and Elexon, who run the electricity network and balancing market respectively. It will focus on supply and demand, prices, emissions, the performance of the various generation technologies and the network that connects them.

Electric Insights will be published once a quarter, and is backed up by an interactive website www.ElectricInsights.co.uk which provides live data from 2009 until the present. The data sources and methodology used in Electric Insights are listed in full on the website.

This project was commissioned by Drax Group, owners of Drax Power Station in Yorkshire, once the UK's largest source of CO_2 emissions and now the largest biomass-fuelled station in Europe. It is delivered independently by a team of academics from Imperial College London, facilitated by the College's consultancy company - Imperial Consultants.

The quarter's headlines

This issue focusses on the period July to September 2016 and looks at the rise of clean energy, how it has halved CO_2 emissions in the last five years, and the impacts this is having. For the first time, low-carbon energy sources have produced more than half of Britain's electricity, fuelled by the dramatic rise of renewable energy. Wind, solar and biomass have grown to supply 20% this quarter.

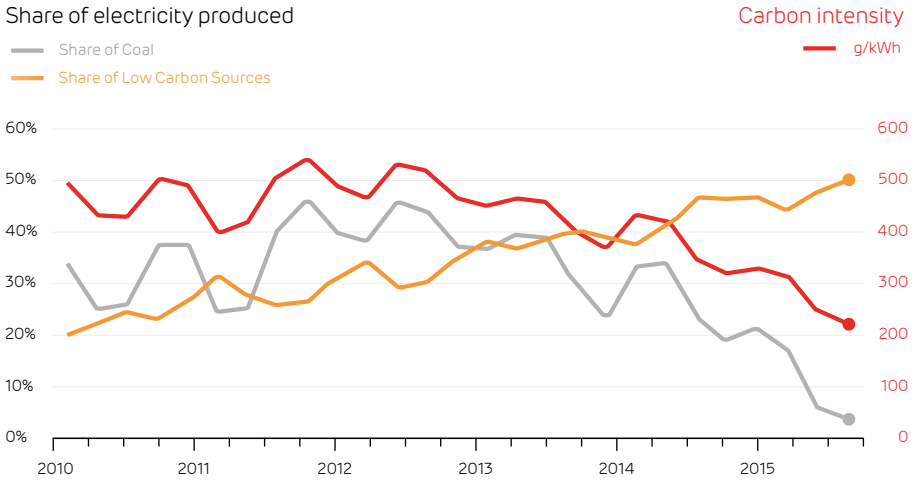
Combined with renewed competition from gas as fuel prices fall, this has pushed coal almost completely off the system. This time four years ago coal supplied 38% of Britain's electricity; this quarter year it was just 3%. Coal provided a smaller share than either wind, solar or biomass, a symbolic moment in the transition towards clean energy.

As a result, per-unit carbon emissions from electricity consumption are at their lowest ever. Each unit of electricity now contains less than half the carbon it did four years ago, falling to a low of 221 kg of CO_2 per megawatt hour. This pace of decarbonisation is a welcome surprise, coming well ahead of the UK's legal requirements to reduce emissions.

The rise of intermittent renewables is dramatically changing the way the electricity system works. The operating patterns of conventional plants are having to change, and the 'breathing space' for flexible plants is being eroded during times of low demand and high renewable output. This is being seen in wholesale market prices, with this quarter seeing both the highest price for several years (£802/MWh) when supply was tight during the September heatwave, and an all-time low price of –£99/MWh due to surplus renewables.

Rising low-carbon generation, falling coal and emissions and volatile prices – is this the 'new normal' for British electricity?

The share of low-carbon and coal generation over the last six years, and the average carbon content of electricity:



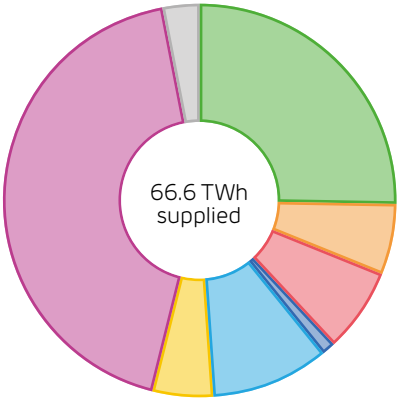
Clean electricity hits 50%

This quarter saw a major milestone quietly creep up on the industry: for the first time more than half of Britain's electricity came from low-carbon sources. The share of nuclear, biomass, hydro, wind, solar and French imports peaked at 50.2%. This share has risen gradually from just 20% in 2010 and the trend is showing no signs of slowing down, although high-carbon generation will be greater in the winter months due to higher demand.

Nuclear provided the largest share, at 26%. Renewables provided a further 20%, spurred on by continued growth in capacity. Britain now has over 26 GW of wind and solar installed, a six-fold increase on six years ago; while biomass has increased from nothing to 2 GW.

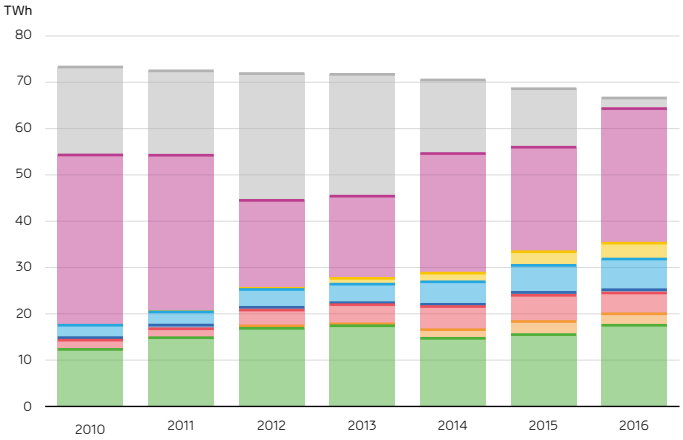
Britain imported 7% of its electricity this quarter. Three-fifths of this came from France, where 94% is produced from nuclear and renewables, and so deserves to be classed as low-carbon. The remainder came from the Netherlands and Ireland, which are still predominantly powered by coal and gas.

Britain's electricity supply mix in the third quarter of the year:



Nuclear	26%
Biomass	4%
Imports	7%
Hydro	1%
Wind	10%
Solar	5%
Gas	44%
Coal	3%

And how this compares to the same quarter in previous years:



	Change since 2010
Coal	-88%
Gas	-21%
Solar	65x
Wind	+147%
Hydro	+31%
Imports	+124%
Biomass	16x
Nuclear	+42%

Carbon intensity at an all-time low

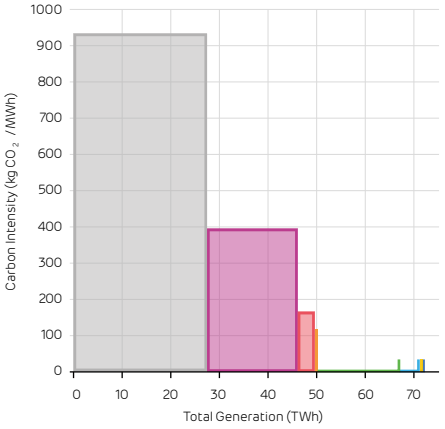
With the rise of clean energy and the switch from coal to gas, the carbon intensity of Britain's electricity is at an all-time low. Emissions are down a third from this time last year and 56% lower than four years ago. During Q3, electricity consumption released 15 MT of CO_2, around two tonnes per second.

Three quarters of emissions came from burning gas and 14% from burning coal. The rest were released abroad either in producing electricity we imported (8%) or producing and transporting biomass fuel (2%). The charts below show the amount of CO_2 released by each technology, comparing Q3 2012 with 2016. The height of each block shows the carbon content per unit of electricity generated – coal releases more than twice the carbon of gas, which releases more than three times as much as biomass.* The width of each block shows how much electricity they produced each quarter. Putting these together, the area of each coloured block relates to the total emissions.

Most striking is the switch from coal to gas. Emissions from gas are up 55% in absolute terms, but this has pushed down coal output to give a considerable net saving. The total Q3 output from fossil fuels also fell 32% over these four years, from 46 to 31 TWh. Demand fell 7% over the four years so less output was needed, and the growth of low-carbon biomass and zero-carbon wind and solar can be seen to the right.

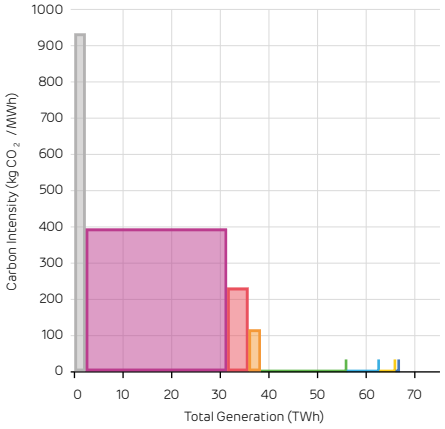
Carbon emissions from each generation technology, comparing Quarter 3 this year with 4 years ago. Each grid square represents 1 million tonnes of CO_2 released:

Q3 2012 33.7 MT CO_2 emitted



Coal	76%
Gas	22%
Solar	-
Wind	-
Hydro	-
Imports	2%
Biomass	-
Nuclear	-

Q3 2016 14.9 MT CO_2 emitted



Coal	14%
Gas	76%
Solar	-
Wind	-
Hydro	-
Imports	8%
Biomass	2%
Nuclear	-

Footnotes:
** We report the supply chain emissions of biomass, but not of coal and gas for the sake of simplicity. In reality, emissions from producing and transporting fossil fuels increase the carbon intensities shown in the chart by around 10% for coal and 25% for gas.*

Moving towards coal-free electricity

Britain's electricity was completely coal-free for nearly six days over the last quarter. Coal plants have been pushed off the system by competition from gas, nuclear and renewables. May the 5th 2016 was a historic day, the first time since 1881 that Britain burnt no coal to produce its electricity. Far from being a one- off, this has continued to become the norm over summer.

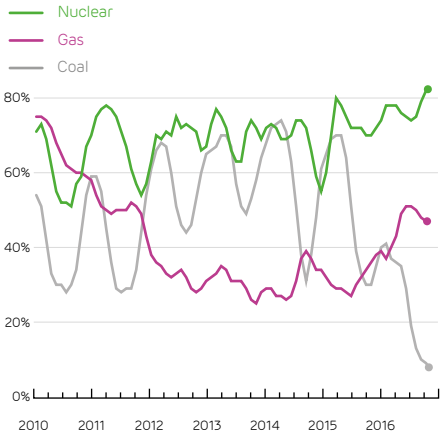
Coal plant utilisation has fallen to its lowest ever levels, producing just 7% of their maximum capacity – less than half the productivity of Britain's solar panels over the quarter. Coal output normally swings with the seasons, falling in summer when demand (and gas prices) are at their lowest, and when plants go offline for their annual maintenance.

A quarter of Britain's coal stations shut down over the last 12 months due to clean air legislation or to stem their financial losses. The plants which remain still ran with utilisation around 30 percentage points lower than in previous years.

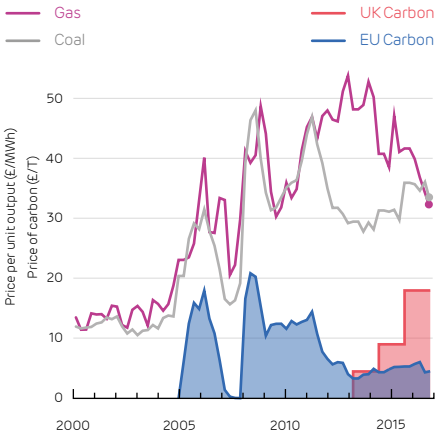
After five years being cheaper, generating electricity from coal is now more expensive than from gas. While international gas prices have been falling for the last two years, so has the price of coal, and the switch is largely due to the UK's Carbon Price Floor, which rose to £18/TCO_2 last year. Without that boost over the (much lower) EU carbon price, gas would still be around 20% more expensive than coal (per MWh output) and emissions would undoubtedly be higher.

While very little coal has been needed during the summer months, some fear that the system will find it harder to cope during times of winter stress without these dispatchable plants.

Average utilisation of nuclear and fossil plants:



The cost of generating 1 MWh of electricity, based on fuel prices, plant efficiencies and the cost of carbon emissions:



Volatile power prices are the new normal

Average electricity prices over the quarter remained stable at £37/MWh, but from hour to hour they are becoming more volatile. Negative power prices are happening more frequently, and this quarter saw the highest power prices for several years.

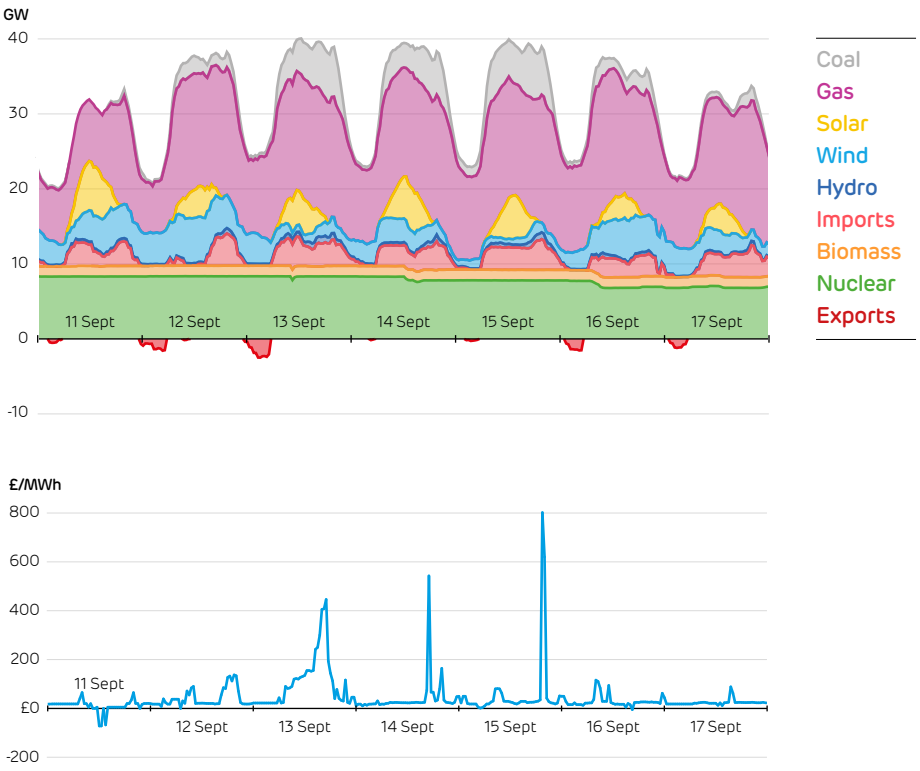
The price of electricity on the wholesale spot market has been falling gradually from a high of £56/MWh in 2013, whereas the cost of balancing the system has doubled over the same period to £2.75/MWh this quarter.

Britain saw its first negative power prices during the summer of 2015, following in the footsteps of Germany and Denmark which have seen negative prices since 2008 and 2009. This quarter saw 45 trading periods with zero or negative prices – twice as many as during the whole of 2015. These ranged down to –£99/MWh, and mostly occurred on weekend afternoons with high wind and solar output.

At the other extreme, Thursday 15th of September was notable as it saw the highest peak prices in 3 years. Evening peak prices rose above £200/MWh for three days in a row, culminating in a price of £802/MWh on the 15th. Such prices are not unheard-of; they were a regular feature in the 2000s, and are a signal to investors to build more capacity.

The likely cause: difficult circumstances coming together at once. Demand was high due to the unexpected Indian summer, wind output was low, and several thermal plants were offline for maintenance. The cost of bringing on extra coal and gas units to meet evening demand was higher than usual, as they were required at short notice and for only a short period of time.

Generation mix and electricity prices during the September mini heat-wave:



Challenging system stability

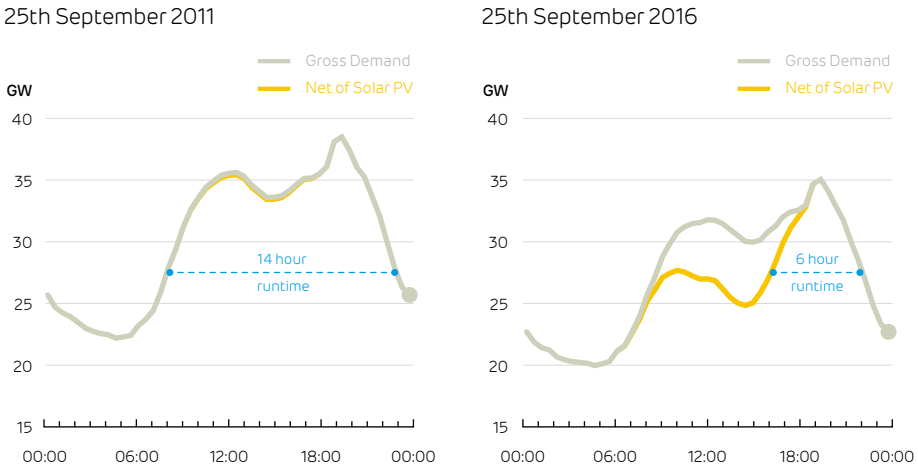
The move from dispatchable fossil towards weather-dependent renewables is forcing the power system into new territory. Britain experienced its lowest ever demand net of renewables, due to high wind and low demand overnight on Sunday 21st of August.

At its minimum, less than 13 GW came from synchronous generators, the spinning turbines that act as shock absorbers for the system. Of this, only 4.7 GW were flexible plants (i.e. non-nuclear). Prior to 2013, this minimum had never fallen below 10 GW. Renewables are reducing the need for conventional supply, while consumption is falling 1.5% per year.

The chart below compares September 25th in 2011 and 2016: both Sundays which averaged 15.5–16°C. Demand was 3 GW lower in 2016 because of improving efficiency and other societal changes. Solar PV reduced net demand by a further 5.5 GW at its peak, pulling daytime demand down to levels previously seen overnight.

The resulting shape of net demand (red line), which dispatchable generators must follow, is very different from five years ago. The daytime peak from 8 AM to 10 PM has been replaced by a much shorter evening peak starting at 4 PM. 10 GW of dispatchable plant had to ramp up in the afternoon, but these were only needed for six hours instead of 12 hours or more, meaning they have to charge more per hour to recover their start-up costs.

Electricity demand, gross and net of solar output on the same day, five years apart:



Capacity and production statistics

The last twelve months saw 3.2 GW of new wind and solar farms come online and a quarter of the country's coal capacity go offline. Ironbridge, Ferrybridge and Rugeley closed, as did Longannet – the last coal plant in Scotland.

Nuclear capacity also fell slightly as Wylfa retired. Output from gas and nuclear was up on this quarter last year, with nuclear plants recording their highest availability for seven years. Coal output plummeted as a result.

The average capacity factor of wind was around a third lower than its long-term average, and for solar it was around a third above its average. This is typical for the time of year as summer has the lowest wind speeds and highest sunshine hours.

Installed capacity and electricity produced by each technology:

	Installed Capacity (GW)	Change from 2015 Q3	Energy Output (TWh)	Change from 2015 Q3	Capacity Factor
Nuclear	9.5	–0.6 (–6%)	17.5	+2.0 (+13%)	83%
Biomass	2.0	–0.4 (–15%)	2.5	–0.4 (–12%)	57%
Hydro	4.1	~	0.7	+0.1 (+13%)	23%
Wind	15.0	+0.7 (+5%)	6.6	+0.8 (+14%)	20%
Solar	11.4	+2.5 (+28%)	3.4	+0.5 (+17%)	14%
Gas	28.3	+0.6 (+2%)	29.1	+6.5 (+29%)	47%
Coal	14.0	–4.3 (–23%)	2.3	–10.3 (–82%)	7%

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