April to June 2017

Electric Insights Quarterly

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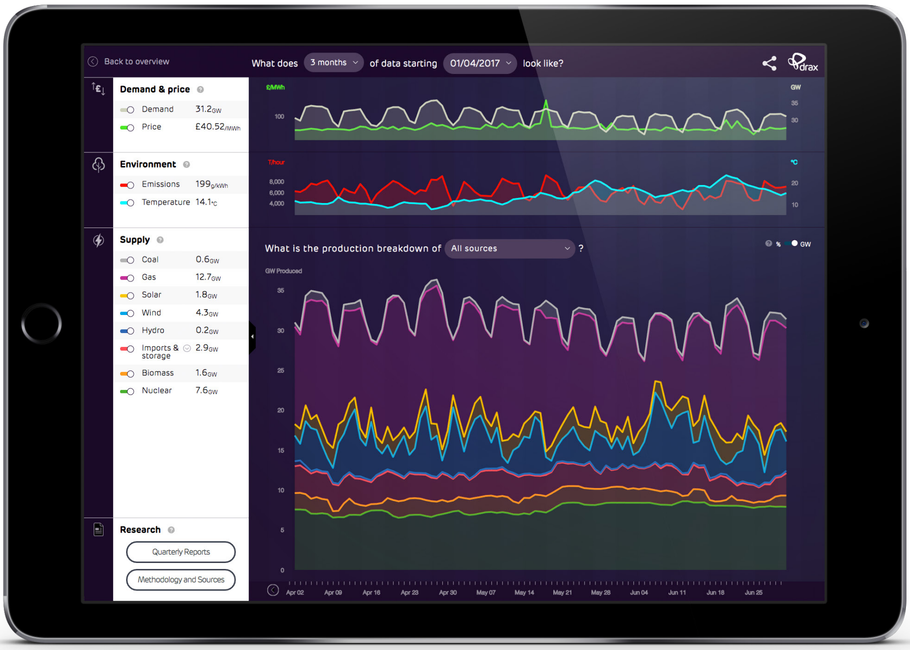


Contents

3 Headlines

4 Renewables & low carbon hit new highs

5 Reaching below 100 g/kWh

6 Electric cars get greener

7 Soaring solar power

8 Bypassing the grid

9 Capacity and production statistics

Headlines & summary

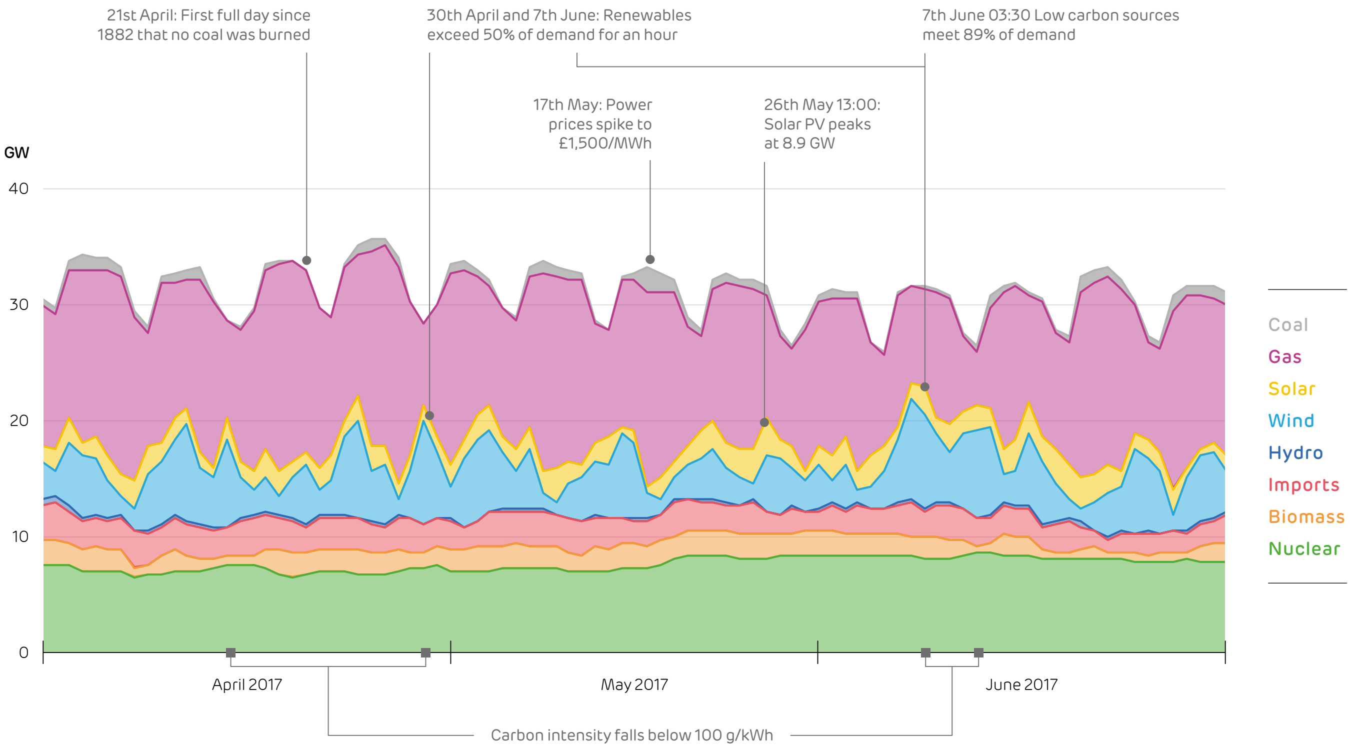
Britain's power system keeps breaking records: this issue charts the continued rise of clean electricity and its benefits across the wider energy system. Renewables hit a new milestone by producing 25% of Britain's electricity over the quarter; while all low-carbon sources together produced 55% (see Article 1).

The carbon intensity of grid electricity is now its lowest ever, falling below 200 g/kWh over the quarter. It dipped below 100 g/kWh on four days, representing an important step towards hitting the crucial 2030 target set by the Committee on Climate Change (see Article 2). Clean electricity can enable electric vehicles to deliver clean personal transport. Article 3 dispels the myth that charging electric cars raises emissions compared to petrol and diesel, showing how they now produce less than half the CO_2 per mile of the best cars on the market.

Solar power grew 17% on this quarter last year and hit three new records. Article 4 looks at the rise of solar power, its variability, and Britain's 'camel curve' of net demand. As a consequence, a growing share of Britain's electricity no longer uses the national transmission system. For the first time, more than a tenth of demand over the quarter was produced and consumed locally, highlighting the shift towards a more decentralised power system (see Article 5).

Article 6 covers the statistics for the quarter, discussing the continued decline in coal output and prices spiking to over £1,500/MWh.

Daily generation mix over the quarter



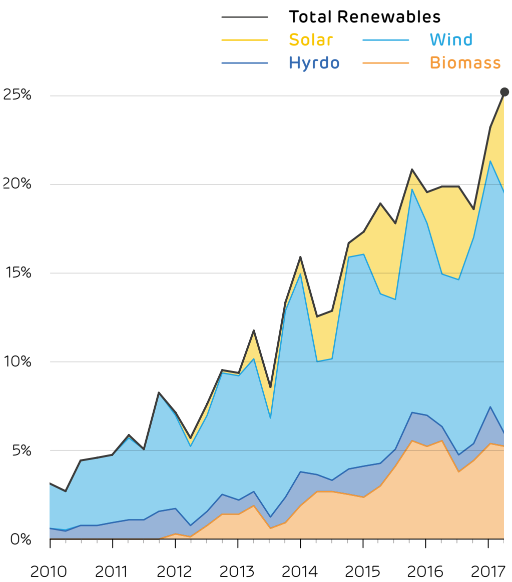
Renewables & low carbon hit new highs

Clean electricity sources are once again breaking records in Britain. Renewables powered more than a quarter of demand between April and June, as shown in the figure below-left. Output from all low-carbon sources (including nuclear and imports from France) met 56% of demand over the quarter, a tenth higher than the previous high reported in our first issue.

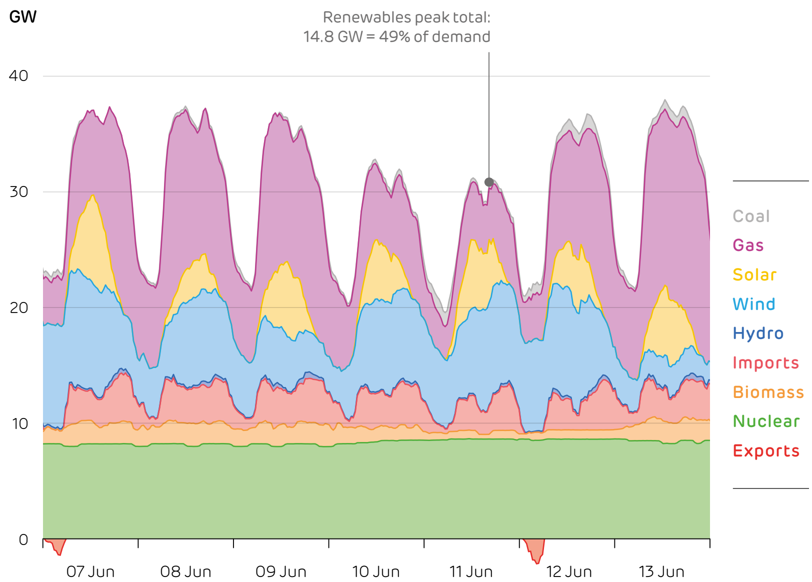
Wind, solar, biomass and hydro peaked at a 51.5% share of demand on June 7th at 1 PM, with a combined output of 19.1 GW. At the same time, the output from all low-carbon sources hit a new record of 28.6 GW, meeting 89% of demand. The figure below-right shows the generation mix during that week: on the Sunday afternoon wind and solar *each* produced more electricity than all fossil fuels combined.

For comparison, Germany hit a new record of 85% renewable electricity for an hour in May, showing that we can go further still. With more than 6 GW of wind capacity currently under construction[1] and plans to convert more of Britain's coal units to biomass,[2] it is likely these records will continue to be broken in the months to come.

Share of electricity generation from renewables averaged over each quarter



Generation mix surrounding the weekend with the highest share of lowest-carbon electricity



1 Of this, 3.6 GW is offshore (Hornsea 1&2, Race Bank, Dudgeon, Rampion, Galloper and Walney 1&2) and 2.5 GW is onshore, primarily in Scotland and Wales (Kilgallioch, Pen y Cymoedd, Clyde Extension, Muaitheabhal and Bhlaraidh are each over 100 MW).
2 Drax Unit 4 and Lynemouth are under consideration, totalling 1.1 GW.

Reaching below 100 g/kWh

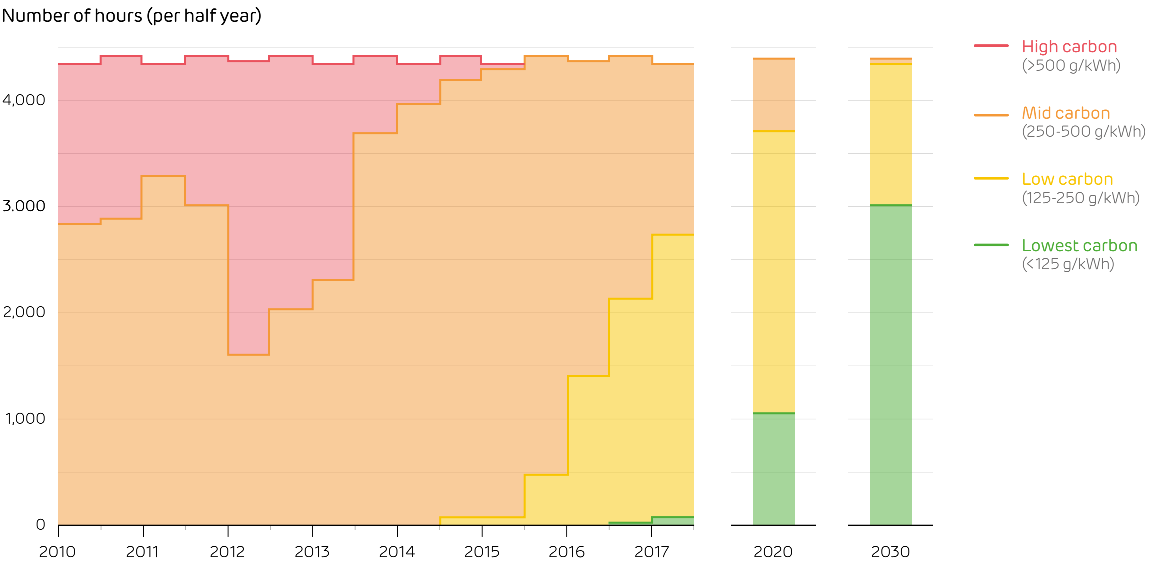
Low-carbon is the new normal for Britain's power system. Carbon intensity over the quarter averaged 199 g/kWh: 10% lower than the previous minimum set last year. For context, the carbon intensity averaged 740 g/kWh in the 1980s and 500 g/kWh in the 2000s.

The carbon intensity of Britain's electricity now regularly dips below 100 g/kWh, showing that deep decarbonisation is already plausible. The sunny and windy Sunday afternoon of June 11th (see previous figure) saw grid carbon intensity hit an all-time low of 71 g/kWh, and remain below 100 g/kWh for several hours.

The figure below shows the carbon intensity of electricity supply during each half-year. In 2010/11, a third of hours were high-carbon with emissions over 500 g/kWh, the rest were mid-carbon (250-500 g/kWh). Lower coal and higher gas prices in 2012/13 saw more high-carbon hours as coal stations displaced gas until the Carbon Price Support made coal-fired generation less economic. With strong growth of renewable output, low-carbon hours (125–250 g/kWh) are now rapidly emerging, and occurred half the time over the last twelve months. There hasn't been a single high-carbon hour in the last two years, and we are now seeing the first 'lowest-carbon' hours with less than one quarter of the carbon intensity. So far, 2% of hours in 2017 have been in this lowest carbon category, but in future these will need to become the norm to hit the country's decarbonisation targets.

The Committee on Climate Change's recommendation for 2030 (electricity below 100 g/kWh) can now be achieved for short periods of time, although meeting the target on individual days is easier than over the year as a whole. Nonetheless, the path to low-carbon electricity supply appears more certain these days, but major challenges lie ahead in decarbonising the heating and transport sectors.

The hourly generation mix in each half-year grouped by carbon intensity, with projections[3] for 2020 and 2030



3 Future projections are based on an average carbon intensity of 175 g/kWh in 2020 (from National Grid's Future Energy Scenarios) and 100 g/kWh in 2030 (from the Committee on Climate Change recommendations). The share of each category was estimated by reducing the carbon intensity of each hour during 2016 by 74 g/kWh for 2020 and 149 g/kWh for 2030. This preserves the distribution of carbon intensities across the year, which has remained similar since 2009 with a standard deviation of ± 66 g/kWh. This gives one possible share of generation that is consistent with meeting the annual target, rather than a precise forecast.

Electric cars get greener

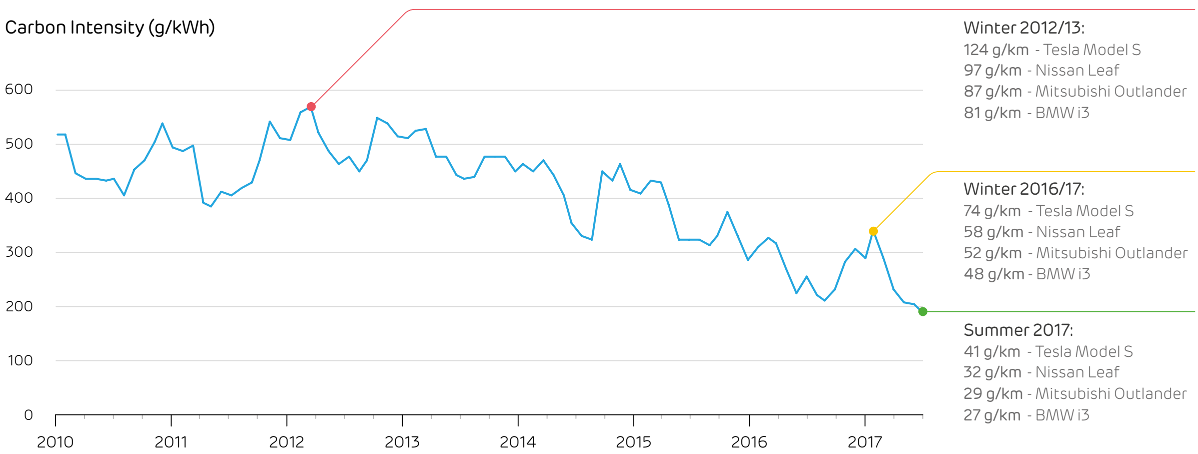
The recent switch from coal to renewables means electric vehicles now create half the CO_2 of the cleanest conventional and hybrid cars on the road. It is widely accepted that electric cars dramatically reduce air pollution in cities, but can they reduce overall CO_2 emissions when the electricity they use largely comes from fossil fuels? The lack of transparency around power systems has helped fuel the debate about how clean electric cars really are.

The calculation is complex because it depends on what time of day or night a vehicle is charged, and which power stations increase output to meet the additional demand. Nonetheless, Electric Insights can illustrate how these emissions have changed recently by assuming that vehicle charging is spread evenly across the day, and uses the average electricity mix during each period. This reflects the longer-term situation if the extra demand from electric vehicles was met by building the same mix of power stations as currently exists.[4]

The number of plug-in vehicles on Britain's roads recently surpassed 100,000, in part because batteries are rapidly becoming cheaper. Pure electric and plug-in hybrid numbers have grown 30-fold in four years, and now represent 1.8% of new car registrations.

Electric vehicles are now better than ever for lowering carbon emissions. The figure below shows the monthly average carbon intensity of electricity, and how this translates into emissions from charging electric vehicles. Producing the electricity to charge a Tesla Model S back in 2012 would have created 124 g per km driven – the same as a 180 horsepower Range Rover. Nowadays that has halved to 74 g/km in winter and 41 g/km in summer. Smaller cars like the Nissan Leaf and BMW i3 can be charged for less than half the CO_2 of the cleanest non-electric car on the market – the Toyota Prius hybrid.

The monthly average carbon content of British electricity, and how this translates into the carbon emission from driving four popular electric cars [5,6]



4 For an assessment of the marginal carbon intensity in Britain, see Staffell (2016) or Hawkes (2014).
5 The Mitsubishi Outlander is a plug-in hybrid (PHEV), emissions represent electric-only mode.
6 Based on fuel economy figures from the Vehicle Certification Agency, including 7.5% losses in electricity transmission and distribution and 4% losses in the vehicle charger.

Soaring solar power

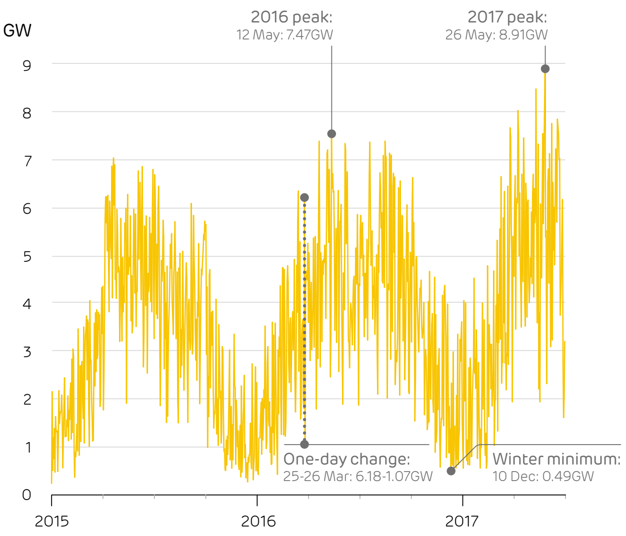
Solar power is reaching new heights in Britain, and having a growing influence on system operations. For eight hours over the quarter, solar power produced more power than all fossil fuels combined. It set two new records for instantaneous output: supplying 25% of demand on the 8th of April, and producing 8.91 GW on May 26th. Over the quarter, solar panels produced 4 TWh of electricity, 12% above the previous maximum set back in 2015.

Solar panels rely directly on the levels of sunshine, so their output varies across the seasons and also from one day to the next. The figure below-left shows the maximum solar output during each day over the last 18 months. This peak output normally occurs between midday and 2 PM, and can vary by up to 5 GW from one day to the next if the weather suddenly shifts.

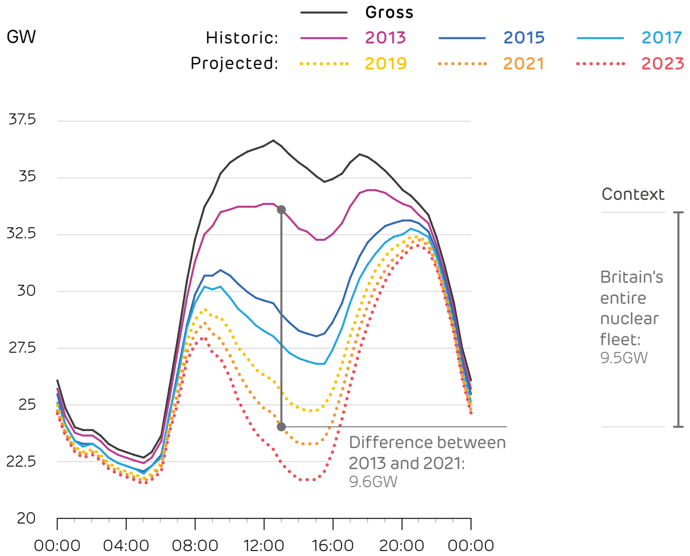
Solar output is depressing the need for other generation during afternoons, which we explored last quarter. California coined the phrase 'duck curve' to describe the shape of their daily demand profile as more PV is added. The figure below-right shows what might be better described as Britain's 'camel curve'. The increasing amount of solar power creates two humps in the profile of net demand which other power stations must produce, one at 9 AM, one at 9 PM. The difference between 2013 and the 2021 prediction is equivalent to the country's entire nuclear fleet powering up for a few hours every sunny afternoon.

The UK has 12.4 GW of solar PV capacity installed; more than many analysts once thought would be installed by 2050. The majority of this capacity (57%) is concentrated in 1,400 large ground-mounted and standalone farms, averaging 5 MW each. The rest is distributed over 910,000 small rooftop systems less than one-thousandth the size.

The peak output from solar PV during each day in 2016 and 2017



Demand in each half-hour, averaged over the 10 sunniest days of Q2 2017. Coloured lines show net demand on the transmission system with different levels of solar PV installed[7]



7 Based on National Grid's Future Energy Scenarios, with projections of 14, 16 and 18 GW of solar capacity being installed by 2019, 2021 and 2023 respectively.

Bypassing the grid

Britain is moving towards a decentralised power system as a tenth of June's electricity did not use the national grid. Small renewables (particularly solar) make up a growing portion of electricity supply. These are embedded into local distribution networks rather than connected to the high-voltage transmission system. They can meet demand locally if output comes at a useful time, though they do not necessarily reduce the need to have those transmission wires available for other times.

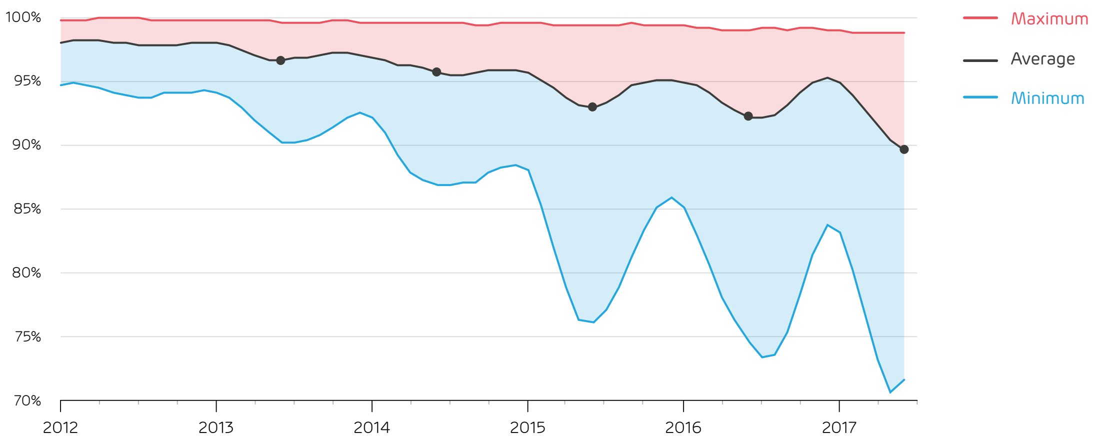
The proportion of generation that bypasses the grid has been steadily rising, surpassing 10% for the first time in June. More than 25% of demand was met by 'embedded generation' for 41 hours over the quarter, primarily on sunny weekend afternoons.

Some of this embedded generation would be consumed "behind the meter" where a building with solar panels runs appliances while the sun is shining. These consumers make no contribution towards the cost of the network when they are doing so. Since these costs are largely fixed, tariffs have to rise for everyone else, making it ever-more attractive to bypass the network: a phenomenon known as the "utility death spiral".

National Grid and the other transmission companies collect much of their revenue on the basis of the peak demand measured on the transmission system. There are still times when embedded generation provides less than 1% of total demand, so this peak is falling much more slowly.

Companies that buy power from embedded generators at peak times reduce their metered demand and hence their charges, passing on these "embedded benefits" to the generator. National Grid is still allowed the same amount of revenue, so charges for everyone else go up. Ofgem, the regulator, has recently ordered a change in the way some of the charges are calculated, and embedded benefits will be gradually reduced from April 2018.

Share of demand flowing through the transmission system in each month. Circles highlight June in each year



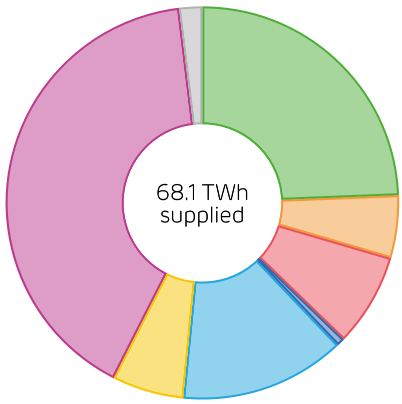
Capacity and production statistics

Output from renewables is up 25% on this quarter last year, while output from fossil fuels is down 16%. Over the last 12 months, wind and solar accounted for 80% of new capacity installed.

Coal fell to less than 2% of the generation mix. This quarter saw the first full day when no electricity was produced from coal, on April 21st. There were 315 hours this quarter with zero coal output, already twice as many as during all of 2016. Coal stations ran at just 4% of full output over the quarter, seeming to have found a new 'floor' of generating 600 MW on average, from 14,000 MW of capacity. There were only eight days in the quarter when coal produced more than biomass, and five days when it produced more than wind or solar.

Prices eased back to £40/MWh day-ahead and £41.50/MWh real-time, after a small rise over winter. Negative prices were seen in 12 hours over 7 days, including four hours overnight on June 7th, and four hours in mid-afternoon on June 24th. At the other extreme, prices spiked to £388/MWh day-ahead (over £1,500/MWh real-time) on May 17th, when wind and solar output dropped by two-thirds from the previous day, margins were tight, and several coal units were started up to fill the gap.

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



	Output (TWh)	% of mix
Nuclear	16.6	24.3%
Biomass	3.5	5.2%
Imports	5.2	7.7%
Hydro	0.4	0.7%
Wind	9.3	13.6%
Solar	4.0	5.9%
Gas	27.7	40.6%
Coal	1.3	1.9%

Installed capacity and electricity produced by each technology [8]

	Installed Capacity (GW) 2017 Q2	Annual change	Energy Output (TWh) 2017 Q2	Annual change	Utilisation / Capacity Factor 2017 Q2	Annual change[9]
Nuclear	9.5	~	16.6	+1.0 (+7%)	81%	+5%
Biomass	2.2	~	3.5	−0.3 (−9%)	75%	−7%
Hydro	1.1	~	0.4	−0.1 (−16%)	19%	−4%
Wind	15.5	+1.0 (+7%)	9.3	+3.3 (+56%)	28%[10]	+9%
Solar	12.4	+1.9 (+18%)	4.0	+0.6 (+17%)	16%	~
Gas	28.4	+0.6 (+2%)	27.7	−2.9 (−10%)	45%	−6%
Coal	14.0	~	1.3	−2.7 (−68%)	4%	−8%
Imports	4.0	~	5.3	−0.6 (−11%)	61%	−7%
Exports			0.0	−0.3 (−88%)	0%	–3%
Storage	3.1	+0.1 (+4%)	0.6	+0.0 (+1%)	10%	~

8 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 here.
9 In absolute percentage points.
10 These are the raw values from National Grid and Elexon without modification.

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