Curtailment is the Tip of a Growing Iceberg

Electricity Services

The UK electricity grid consumes up to 54 Gigawatts (GW) of electricity at peak times. That's 54 million kilowatts – a lot of electricity. So all we need to produce is 54GW electricity, plus a bit in case anything goes wrong – say, 57-60GW, right?

Wrong. It's not as simple as that. Although all electricity is the same (electrons down a wire), we consume four types of service: baseload, dispatchable, balancing and ancillary.

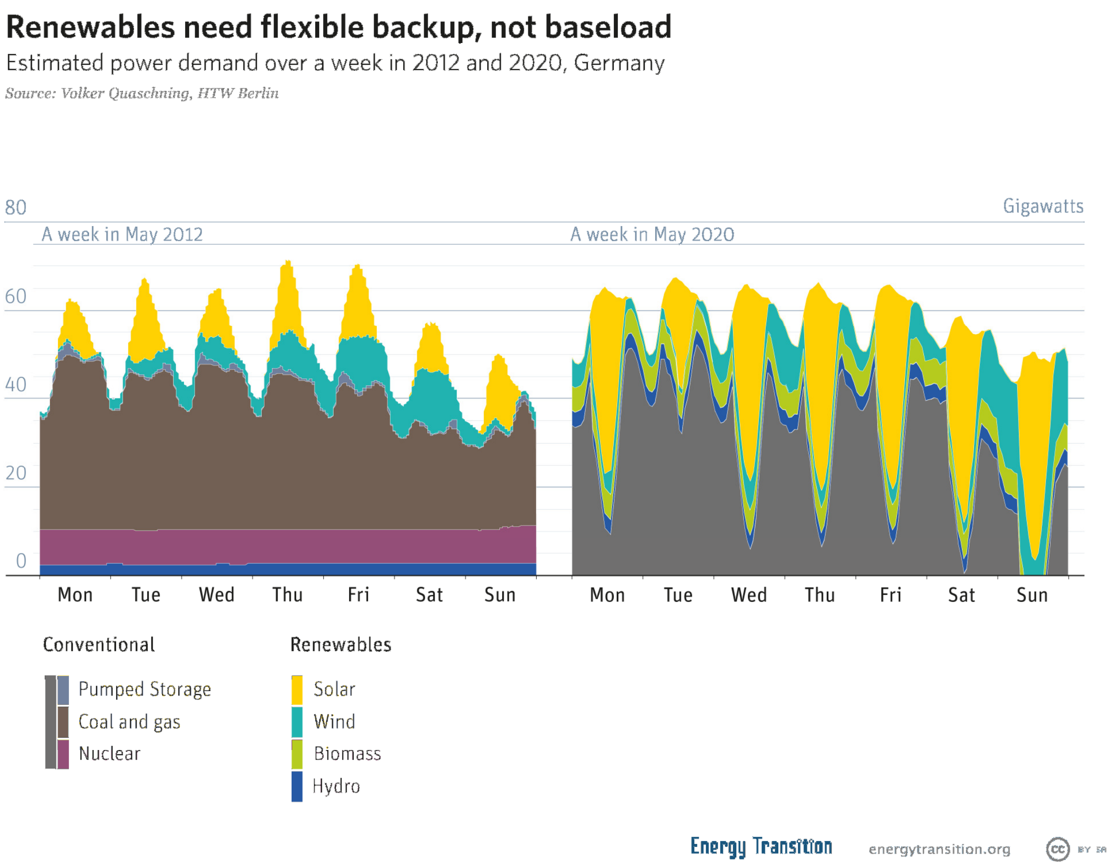
- Baseload is the minimum demand, that is, the always-on requirement. In the UK it's about 60% of peak so, in winter, that's around 32GW.
- "Dispatchable" means that it's there when we need it: we can turn it up or down at will. This accounts for the remaining 40% of peak demand.
- Balancing services are for when things get out of kilter: too much here, not enough there, a power station down for its annual service (this is the major one, in terms of energy needs) and so on.
- Ancillary services are for when things go wrong: rapid reaction when a fault develops, and suchlike.

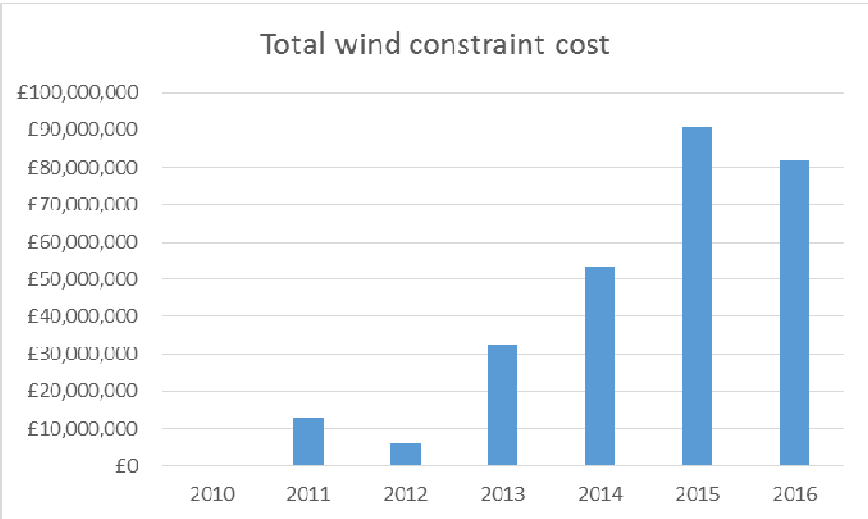
In the olden days of the Central Electricity Generating Board, we delivered baseload with coal and nuclear power stations while the rest was delivered by gas. How simple things were then! Now, because we realised that we're cooking the world with our emissions, we're replacing coal (first) and gas with renewable generation: mostly biomass, wind, solar, wave, tidal flow and tidal range. Of these, only biomass (with by far the smallest potential capacity of the five) is dispatchable or baseload. The rest are a new category of generation: intermittent.

Effects of Intermittent Generation

Intermittent generation doesn't mean that the generation is unpredictable: forecasting is excellent these days, and improving. But it does mean that it is there when it wants to be, not when we want it – forecasting just gives us better notice of the surpluses and shortfalls. As the Managing Director of Siemens Oil and Gas UK says[1], "the wind blows when the wind blows, but you want your dinner when you want your dinner". This means that sometimes it's generating when we don't want it, and it needs to be backed up when we want it and it's not generating. The former leads to curtailment (payment for the renewable generation not to generate) and the latter leads to ever increasing balancing and ancillary services costs. This graph[2] shows how intermittent generation would eliminate baseload generation in Germany, unless curtailed in some way.

[1] https://www.youtube.com/watch?v=m4UgOO_uhug
[2] https://book.energytransition.org/flexible-power-production-no-more-baseload





Curtailment is growing annually[3], reaching £80-90 million for each of the last two years for wind alone – thought that is the major portion of it. While it's fair to say that this is not a large problem, only being about 1% of the total cost of energy paid to wind farms over the year. But curtailment generates bad headlines, so the system is operated to minimise those headlines.

How is that done? By cycling the power stations increasingly aggressively, turning them down when intermittent sources are generating and up again when they stop. That is like drag racing your car around town instead of driving it sedately up a

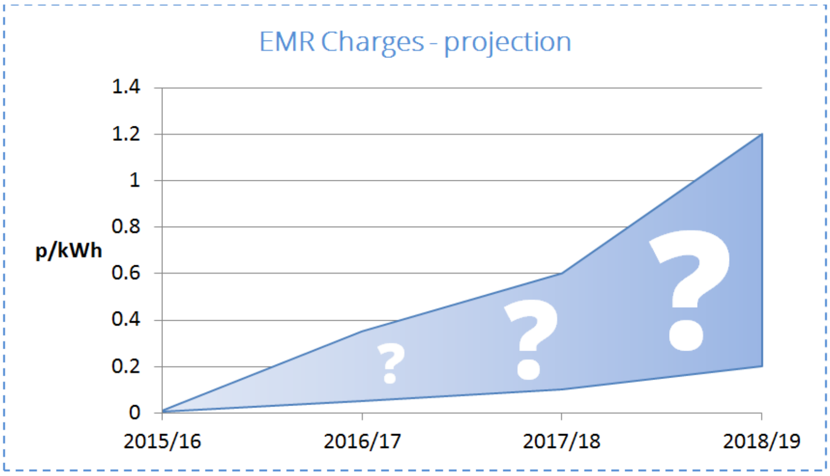
[3] http://www.ref.org.uk/constraints/indextotals.php

motorway: fuel efficiency plummets, emissions per unit output (miles for the car; megawatt-hours [MWh] for the power station) rocket, maintenance increases, plant longevity drops and chargeable output (miles / MWh) drops like a stone. And gas prices increase because the majority of usage tilts towards peak times when gas prices also peak. So almost every single element of costs increase while invoiceable power generation (MWh) decreases, making them unsustainable. That is why they are closing at a very rapid rate.

Costs of Balancing and Ancillary Services

So what does the government do to keep the lights on? There are two alternatives: keep the power stations open, or support the grid at large scale with zero-emissions balancing services. The British government and grid have chosen the former, though the latter is considerably cheaper over the medium to long term as well as being more sustainable (zero emissions).

How does the government keep the power stations open? Subsidies.



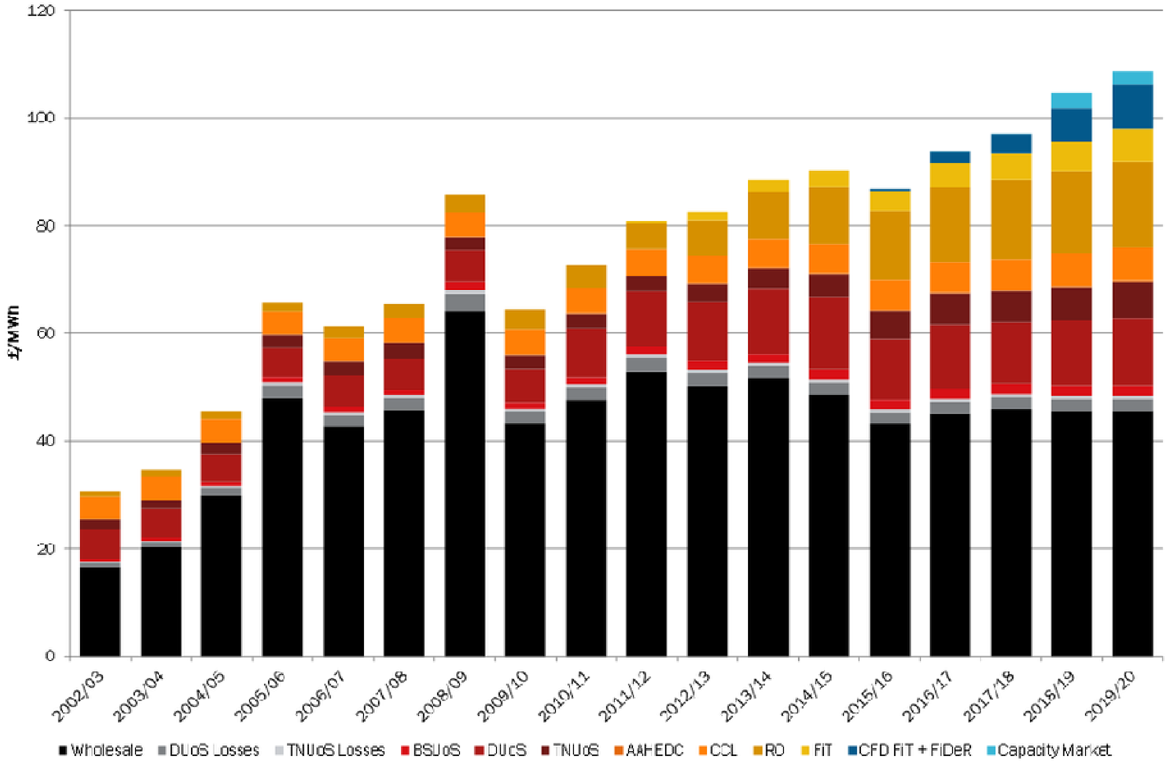
There are two general types of subsidy: overt and covert. Overt ones are out of fashion, so the government tries to disguise these with the word “market”. The main overt subsidy is the Capacity Market. These haven’t really hit us yet: the main costs are for four years ahead, and the market isn’t four years old yet. But these costs already contracted total £1bn per annum and are rising each year. This provides an increasing charge on electricity bills[4]. There is an argument that the Capacity Market is necessary to provide an incentive for new build[5], but this would be unnecessary if standard contracts were available with 15-year durations for new-build plants, especially if the start date of those contracts were to allow for grid connection time (transmission grid connections take 4-10 years).

The covert subsidies are, of their very nature, more difficult to spot. These are mainly known as “charges”. Of the charges depicted in this graph,

- Some (DUoS, TNUoS) are for using the grid and therefore not subsidies: we have to pay to maintain and upgrade the distribution and transmission grids. AAHEDC makes a bid difference to those who live in remote areas.

[4] http://www.costadvice.co.uk/latest-news/the-rise-and-rise-of-non-commodity-costs
[5] https://www.gov.uk/government/publications/cost-of-energy-independent-review p90-96

- A second group of charges (CCL, RO, FiT, CFD) are subsidies to encourage the development and roll-out of renewables. These are a ligitimate charge determined by our political priorities: do we want the world to cook, or not? And how much are we willing to pay to keep it at the right temperature?
- The smallest of these groups is the one we're interested in: BSUoS, Balancing Services use of System. This is the cost of balancing and ancillary services. Some of these will always be necessary, but their rapid and increasing growth indicates that they are spiralling out of control.



National Grid forecast "a growth in balancing tools and technologies such as energy storage and flexible demand"[6], all of which are paid for by these charges. Currently they total £1bn (having increased from £800m in 3 years), but National Grid forecast that this "could double to £2bn a year within five years due to the growth of renewable technologies"[7]. This is an increasing rate of change.

There is another category of hidden subsidy: bilateral contracts. Many of these enable National Grid to support things that it needs and that are not common enough to put into standard contractual conditions – including some innovative technologies being tried out on the system. But last year Fiddlers Ferry power station decided to close because it reckoned that the fines for failing to deliver its Capacity Market contracts were cheaper than the costs of fulfilling them. So National Grid

[6] http://fes.nationalgrid.com/fes-document/fes-2017/ p63
[7] http://www.telegraph.co.uk/business/2016/06/26/balancing-demand-could-cost-national-grid-2bn/

entered into a bilateral contract at undeclared cost to keep it open[8] – and Eggborough did a similar deal[9]. These deals appear to be both new and rapidly increasing.

Therefore while it is not possible to determine total level of overt and covert subsidies that are required due to a failure to follow alternative routes to balancing intermittent generation, it is safe to suggest that it is already over £1bn and will double within 3-5 years.

The Challenge of Reducing Emissions

The urgent questions posed by climate change were addressed by the world's agreed reaction to it: to cut emissions sufficiently to keep global warming to within 2°C, and preferably 1.5°C[10]. Consequently the British government laid out its carbon budgets, which have the force of law. The fifth carbon budget, for the period 2028-32, requires that by 2030 the electricity sector can emit only one quarter of its 2010 emissions[11]. This means that we can emit no more CO2 than was emitted by the gas-fired power stations at that time, having closed all the coal-fired ones – which precludes a second "dash for gas"[12].

The government's response to this is to seek a second "dash for gas"[13] (!) and a vast ramp-up in interconnectors[14]. But interconnectors are not truly dispatchable: our neighbours face similar generation shortfalls to the UK, and similar demand patterns, so if we need the electricity when they do then we will have to pay through the nose for it[15]. This was demonstrated last winter when 75% of French nuclear generation was down due to a combination of planned and unplanned outages, leading to price spikes of £1,500/MWh in the UK[16] – against an average price of under £50/MWh. And that's with only 4GW of interconnection: what would happen if we rely on interconnectors for 20GW of our demand? That's the forecast[17].

Worse, with Brexit we will be exiting the single market and the jurisdiction of the European Court of Justice[18]. (National Grid assume that there will be no change

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[8] https://www.ft.com/content/3a72f256-f681-11e5-96db-fc683b5e52db
[9] http://uk.reuters.com/article/uk-eggborough-coal-extension/life-of-uks-eggborough-coal-plant-extended-to-march-2017-idUKKCN0VI0W2
[10] http://unfccc.int/paris_agreement/items/9485.php
[11] https://www.theccc.org.uk/publication/sectoral-scenarios-for-the-fifth-carbon-budget-technical-report/
[12] www.ukerc.ac.uk/publications/the-future-role-of-natural-gas-in-the-uk.html
[13] https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy and www.dailymail.co.uk/news/article-3472260/New-dash-gas-head-blackouts.html
[14] https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors
[15] https://www.ofgem.gov.uk/publications-and-updates/electricity-capacity-assessment-report-2013 p41-44
[16] https://www.ice.org.uk/news-and-insight/the-civil-engineer/february-2017/what-caused-the-recent-spike-in-power-prices
[17] http://fes.nationalgrid.com/fes-document/fes-2017/ pp57-58, but most analysis needs to look at the supporting data that is also available through this website ("Charts Workbook").
[18] http://www.bbc.co.uk/news/uk-politics-41012265

arising from Brexit[19], which is the one scenario that cannot occur.) Therefore our neighbours will be able to say that their consumers are more important than ours at any price. But if we rely on them for 25-30% of our peak demand, that will lead to black-outs.

And a second “dash for gas” depends on widespread roll-out of Carbon Capture and Storage[20] (CCS), which is a triumph of hope over experience as there are no ongoing initiatives in the power sector[21]: it was too expensive, and nobody would foot the ongoing risk liability[22] that would last until the tectonic plate is subducted. Yet FES 2017 depends on CCS for 15GW of generation by 2050.

Alternative Balancing of Intermittent Renewables
How can we balance the grid with no fossil fuel power stations? By a combination of balancing technologies:

- Large scale, long duration storage
- Grid connected batteries for shorter term spikes both up and down in demand
- Demand side response (DSR), ditto
- Interconnectors (yes, they do have a role)

In FES 2016[23] National Grid sized the potential for DSR at 1.8GW now (of which 2/3 is diesel generation and therefore must be discounted) plus 3.4GW by 2040, making a total (excluding diesel) of 4GW. But, put simplistically, if we turn off a fridge now we can’t do so again in half an hour, so we have to split this capacity for a number of interventions, i.e. the maximum DSR available for any given intervention is 1-2GW.

Batteries average about 30 minutes’ duration, but peaks last for 5 hours. So they too are suitable only for the shorter spikes in demand, whether those spikes be increases or decreases. And being of megawatt scale, they cannot deliver tens of gigawatts: it is reasonable to expect only 2GW of batteries also. More than this would jeopardise the system because then we are into longer spikes than 15-30 minutes.

The government identified a need for **new** storage of 27.4GW, 128GWh[24] – that is, 5 hours’ average duration. Only pumped hydro and Compressed Air Energy Storage

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[19] FES 2017 p66 “Given the lack of clarity on future trading provisions, our analysis currently assumes tariff free access to EU markets under all scenarios.”
[20] Again, see FES 2017
[21] https://www.theguardian.com/environment/2017/jan/20/carbon-capture-scheme-collapsed-over-government-department-disagreements
[22] http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32009L0031&from=EN para.36 and chapter 4
[23] http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Documents-archive/ 2016 FES pp.64-65
[24] https://www.carbontrust.com/resources/reports/technology/tinas-low-carbon-technologies/ Energy Networks and Storage report chart 2 p9 which splits it down into various technologies without considering the costs of doing so (batteries of all kinds with the required 5-hour durations and pumped hydro are much dearer than CAES) or availability (they exceed the country’s pumped hydro potential), or the availability / practicality of the technology (thermal-to-electric stopped when Isentropic went into

can deliver this. But pumped hydro only has very limited potential in the UK, which is both remote and expensive. This leaves CAES.

Storelectric
Storelectric's CAES are the two most efficient and cost-effective forms of CCS available in the world:

- TES CAES (TES = Thermal Energy Storage) costs about the same as traditional CAES but has higher round trip efficiency (68-70% v 50-54%) and zero emissions (v 50-60% of the emissions of an equivalent sized CCGT)
- CCGT CAES (CCGT = Combined Cycle Gas Turbine) is much cheaper, is more efficient (~60%) than existing CAES, emits correspondingly less, and uniquely can be retro-fitted to existing CCGT or OCGT power stations, thereby reducing capital costs much further and giving a new lease of life (with new revenue streams) to existing stranded assets, and almost doubling the generation that is permissible within emissions limits.

Uniquely, both of these technologies generate double digit whole-project IRRs even under existing regulatory and contractual framework – which is improving all the time. This means that Storelectric's two CAES technologies do not add to the costs of the electricity system – as compared with the current strategy of ever-increasing subsidies building a system that will soon breach all carbon budgets and emissions limits. (And 27GW of CAES by 2050, as per the TINA report, is a very big business – and 100 times bigger still when rolled out globally.) Thus, working with the other clean balancing technologies, Storelectric's CAES can enable renewables to power the world cost-effectively.

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administration in 2016 http://www.eti.co.uk/programmes/energy-storage-distribution/distribution-scale-energy-storage, long before FES 2017 was published, despite £14m investment by ETI, http://www.eti.co.uk/news/eti-invest-14m-in-energy-storage-breakthrough-with-isentropic).