Matching the Solution to the Problem

By Mark Howitt, Director of Storelectric, www.storelectric.com

Introduction

The current market consensus points strongly to the following

1. The UK electricity industry is failing to recognise the scale of the problems facing it;
2. A full range of technologies is needed to address these problems;
3. Current plans fail to recognise the problems (the scale of the problem being severely underestimated);
4. Regulations continue fail to recognise storage, impeding its development;
5. The government recognises the problems in words, but these have not translated into actions;
6. The renewable energy industry needs to create a single, coherent and affordable proposal, incorporating all technologies, to address the needs of tomorrow;
7. With a planned import of ~1/3 of the country's electricity needs by 2040, failure to invest now in large scale storage will make the country's Brexit negotiations hostage to our dire domestic energy shortage.

This analysis focuses on National Grid's Gone Green Scenario in their Future Energy Scenarios 2016 document, which maximises the amount of grid-connected renewable generation and which the National Grid states is the only scenario to deliver the country's 2050 legal obligations (under both domestic law and climate change treaty) for carbon emissions reduction – though even Gone Green fails to deliver 2020 commitments. It also incorporates a review of the National Grid's Winter Outlook Report 2015, and recent government policies and actions. As much of the useful information of the 2015 FES report has changed unhelpfully in format, significant use is made of FES 2015. Most of the analysis will apply very similarly throughout Europe and beyond.

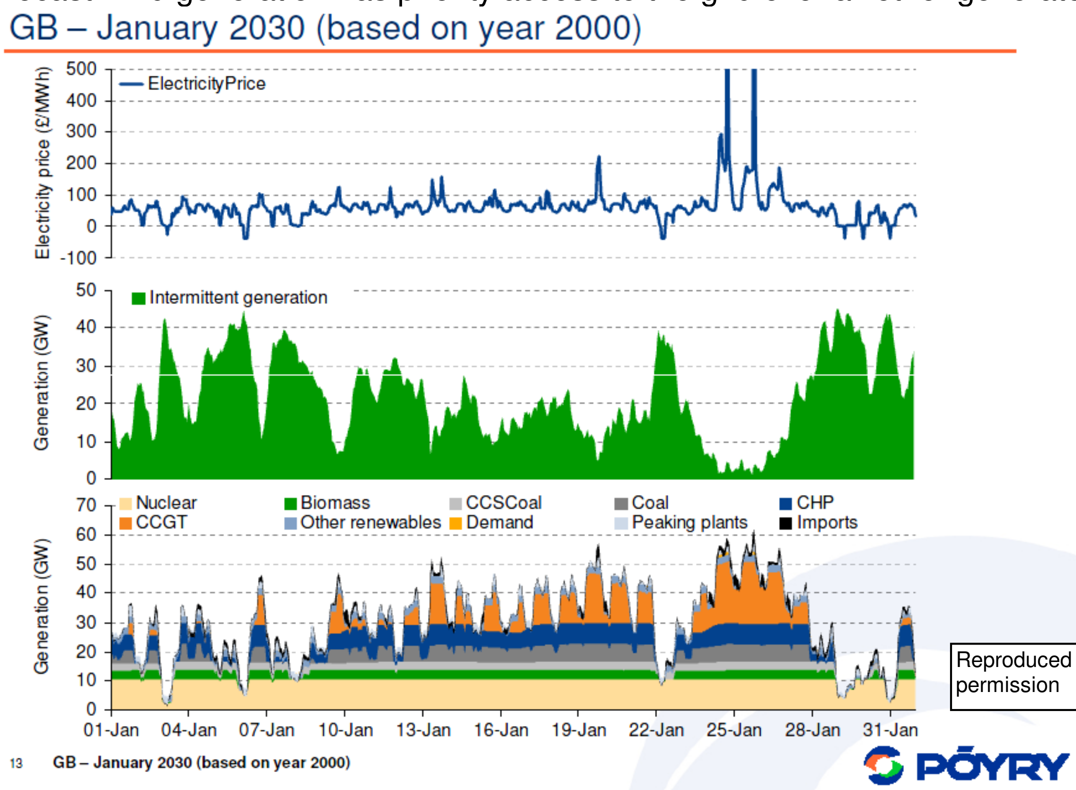
Conclusion

The problem of matching intermittent generation to variable demand, while simultaneously controlling the cost of electricity and meeting the country's legal climate change obligations has been recognised by government is huge. However their (and National Grid's) investment is not directed towards solving the problem at the right scale, but is looking at small-scale, partial and sometimes inappropriate solutions to big-scale problems – which can be described as "tinkering at the edges". In the last few years this disconnect has got worse and will continue to do so. The longer it takes to address the root causes the fewer options will exist and the more expensive the solutions will become. From a purely commercial perspective investments made today into CAES storage will benefit the country much more than future investments, and additional generate opportunities for substantial returns from export of the technology.

The government's and National Grid's best attempt at a solution is to increase the number and size of interconnectors to 23GW by 2050. Interconnectors are an important part of the solutions, but as we cannot rely on interconnectors to deliver energy cost-effectively at all times that we need it, this is a very imperfect solution. Given that the longer interconnectors cost more per MW than CAES, it is an expensive solution. And given that it out-sources the country's electricity generation to neighbouring countries, an over-reliance on them can be seen to compromise Britain's security of supply.

Addressing these issues by supporting Storelectric's CAES would enable us to build a first operating plant (at ~20MW scale) within 2-3 years and a first large-scale plant (>100MW) within 6-7 years. Further plants can be built continuously, both in Britain and world-wide.

The Scale of the Problem – Poyry
The graph below superimposes the actual wind pattern of January 2010 on the forecast generation mix and demand pattern of 2030 on the assumption that all forecast wind generation has priority access to the grid over all other generators:



Reproduced with permission

The following results stand out clearly:

1. When the wind blows strongly, even baseload generation (which should never be turned off – mainly nuclear and coal) has to be turned down / off – six times during one month for nuclear. When demand is lower (e.g. in summer), this could happen more often. Instead of switching them down / off, the system is made much more efficient if that amount of wind energy is stored.

2. Even variable generation (such as gas) operates much more efficiently and with lower emissions if operated as baseload – like driving a car on a motorway rather than round town. This is only achieved if there is sufficient storage. Incidentally, this is why traditional generators are currently going through very difficult financial times: while their revenues are reduced (due to being switched off / down so much), their costs are increased (wear and tear, efficiency of burn, average cost of fuel – because a greater proportion of their fuel is being bought at peak).
3. The scale of variability of wind production is 60GW. Therefore to absorb such variation, 60GW storage would be ideal. However some of this can be made up by, principally, Demand Side Response and batteries – each to an economically feasible level of 2-3GW.
4. For long periods (e.g. from late December to 10th January, and from 29th January onwards, in this example), there is highly fluctuating wind generation that remains almost continually above 30GW, meaning that the amount of energy needed to be stored is enormous (up to 5TWh) in order to make other power stations operate efficiently and with minimal pollution.
5. This power is needed when the wind doesn't blow, e.g. from 24th to 27th January. Such non-generating weather systems can stand over most of western Europe for up to 10 days at a time, every three years (estimated by us at 5-10TWh) – and more often for shorter periods and/or smaller regions. Therefore, if peaking and back-up power stations are to be shut down completely, at least 10 days' non-baseload energy needs to be stored.
6. And all this ignores the effect of solar, wave and tidal generation….

So the scale of the problem is 60GW, 5-10TWh.

Scale of the Problem – TINA

Another analysis of the problem, the Technology Innovation Needs Analysis[1] by the Low Carbon Innovation Co-ordinating Group (LCICG), which is the biggest inter-departmental group in the British Government's civil service, identifies that Britain requires 27.4GW of storage (in the range of 7.2 to 59.2GW), with a capacity of

Chart 2 EN&S technology deployment scenarios

Area	Sub-area	Units	2020 deployment		2050 deployment	
			GW	GWh	GW	GWh
Storage	Pumped hydro	GW or GWh	4.3 (3.1 - 6.6)	21 (15 - 33)	8.2 (3.3 - 17.3)	41 (16 - 87)
	CAES		1.8 (0.2 - 3.8)	9 (1 - 19)	7.1 (0.7 - 15.3)	35 (4 - 76)
	Sodium-based batteries		0.5 (0.1 - 1.1)	2 (1 - 6)	1.9 (0.5 - 4.6)	9 (3 - 23)
	Redox flow batteries		0.3 (0.1 - 0.9)	2 (1 - 4)	1.4 (0.4 - 3.5)	7 (2 - 18)
	Lithium-based batteries		0.4 (0.3 - 0.9)	0 (0 - 3)	1.7 (1.2 - 3.6)	2 (2 - 10)
	Flywheels		0.1 (0.1 - 0.1)	0 (0 - 0)	0.5 (0.3 - 0.6)	0 (0 - 0)
	Supercapacitors		0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	Thermal-to-electric storage		1.7 (0.2 - 3.6)	8 (1 - 18)	6.7 (0.8 - 14.3)	34 (4 - 72)
	Total		**9.1 (4.1 - 17.1)**	**43 (19 - 83)**	**27.4 (7.2 - 59.2)**	**128 (31 - 286)**

128GWh (31 to 286GWh). This is 5 hours' storage at rated capacity: almost no grid-connected battery in the world has more than 2 hours' storage because it is not cost-effective.

1 http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/electricity_networks_storage/

This analysis only looks at supporting the country's currently forecast variable demand, assuming that baseload demand will continue to be supplied by nuclear and gas plants. Therefore if nuclear is to fail to materialise in sufficient volume (which looks increasingly likely), and we cannot increase the gas generation lest we exceed our treaty obligations on emissions, this storage requirement must be increased greatly to accommodate baseload generation.

Even taking the 27.4GW figure at face value and looking at cost-effective developments only, we can expect it to be made up of (additional to what was in place at the publication of the report) 2-3GW (2-3GWh) demand side response, 2-3GW (2-3GWh) batteries, 8-12GW interconnectors and 2GW (20GWh) total of all existing pumped hydro planning applications. This totals 12-18GW (24-26GWh), leaving an unmet need for 7.4-13.4GW (102-104GWh) which Storelectric can supply more cheaply than gas-fired peaking plants.

Electricity Storage Solutions

Most so-called "grid-scale" storage is at a scale of 10s of MW, and 10s of MWh. While extremely useful for local issues (e.g. capacity enhancement, islanding at small scale, maximising output from small to medium scale renewable generation) and for short timescale issues (e.g. frequency and voltage response), it completely misses the big problem. It may be grid connected, but it's not grid scale. Doubling either size or capacity increases capital costs of an installation by typically 85% as the number of cells needs to be doubled.

In contrast, Storelectric offers truly grid-scale electricity storage, with each 500MW, multi-hour plant costing only £350m (£460m for the first-off), and a levelised cost less than that of a gas-fired peaking plant. It can be up to 100% renewable. This complements all the other storage technologies on offer, and works equally with renewables and fossil fuel generated power, thereby supporting the transition also. Doubling its size or capacity (assuming that the capacity increase is matched with thermal storage – the higher-cost but lower-emissions option) typically increases its capex by about one-third.

What is needed is an entire raft of electricity storage technologies, which we split:

Scale	Power	Capacity
Domestic	<100 kW	<250 kWh
Local	<1 MW	<5 MWh
Area	<10 MW	<50 MWh
Regional	<100 MW	<500 MWh
Grid	>100 MW	>500 MWh

The market can also be segmented by response time.

There is room in the market for all the technologies that deliver one or more services cost-effectively. For the next decade or two, our main competition is not each other – it's ignorance and bad policy.

Distributed Schemes

Many propose that distributed generation and storage will solve the problem. It is true that they will go a long way towards solving the problem, but every single distributed storage scheme of attainable (not even cost-effective) cost relies on the grid to provide back-up power when batteries are exhausted and generation is lower than demand. So where does the grid get its power from, to provide this back-up?

Demand Side Response (DSR)

Currently DSR is defined to include both consumer-owned generation which accounts for 80% of capacity, and demand displacement (temporary reduction in demand when required, to be made up later, e.g. switching off freezers for 15 minutes, to be re-cooled later) which accounts for 20% of capacity. This is unfortunate: consumer owned generation (mostly diesel generators) is the costliest and most polluting form of generation, whereas demand displacement uses very little extra energy overall and is the most cost-effective means of absorbing peaks and surges in demand. The former needs to be abandoned, while the latter deserves its place in the energy mix.

But how much?

The Grid identifies up to almost 6GW of DSR potential in the economy (fig. 3.5.1) by 2025, shrinking to 5GW by 2038, in the most optimistic scenario. A proportion of that will never be realised, as many customers will never want to hand over control of their washing machines or other equipment to electricity companies. Another reducing factor is that if needed two or three times during a peak (e.g. the classical advertisement breaks during a popular programme), different DSR assets need to be used for each. Note that peak demand will already have been reduced by 1.6GW by widespread adoption of time-of-use tariffs (figure 3.5.4), reducing scope for DSR.

The prevalent market view is that DSR is valid for up to 3-5% of peak demand. Beyond that, we would be paying £billions to degrade our first-world grid to a third-world grid. (In a first-world grid, when I switch on a switch, the electricity is there; in a third world grid, it will think about it.) But 5% of peak demand is still 3GW, an immense 75 times current capacity – there's room in the market for all these suppliers, too.

National Grid's Outlook

Is the grid looking to address the issue? Consider these figures:

	2015 act.	2020 f/c	2030 f/c	2040 f/c
Peak demand	61 GW	60 GW	67 GW	75.5 GW
Intermittent renewables	23 GW	38 GW	38 GW	65 GW

♦ *Onshore wind*	*8 GW*	*12 GW*	*18 GW*	*20 GW*
♦ *Offshore wind*	*5 GW*	*10 GW*	*29 GW*	*29 GW*
♦ *Solar*	*10 GW*	*16 GW*	*31 GW*	*37 GW*
♦ *Marine*	*0 GW*	*0 GW*	*3 GW*	*5 GW*
Energy Storage	3 GW	4 GW	8 GW	11 GW
♦ *Virtually all pumped hydro*				

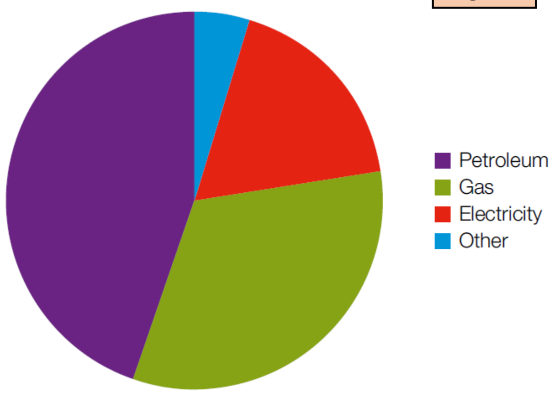
(*Source: National Grid's Future Energy Scenarios (FES) 2016, Gone Green)*

Not only is the National Grid failing to address the scale of the problem, but also they are ignoring many factors that make the problem even bigger, including:

1. The above peak demand ignores electrification of transport & heating;
2. It assumes that economic growth is balanced by increasing efficiency, without accommodating the ever-increasing gadgetisation of society;
3. It relies on a proportion of intermittent generation (i.e. generation which, though largely predictable, cannot be relied upon to deliver power exactly when wanted) to provide for both actual peak demand and the required generation margin.

Figure 85
Final energy consumption by fuel, 2013

From FES

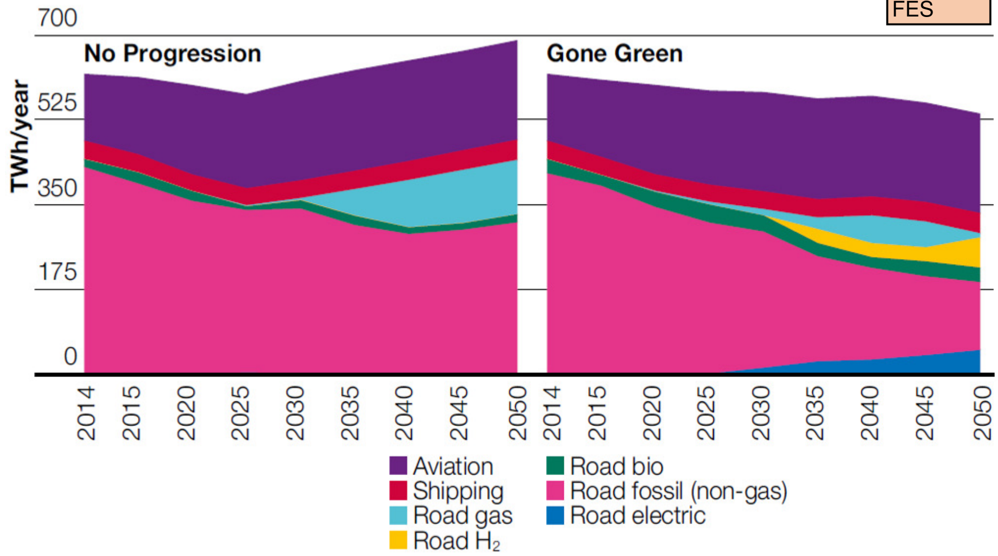


Point 1 would increase demand by up to 5-fold, because there is 5 times as much energy consumed in other forms than as electricity. This assumes a 1:1 exchange between the different energy vectors, which is not necessarily so: it could be worse, as energy conversion to electricity is less efficient, or it could be better, as more efficient use may be made of the electrical energy which may also be generated locally or even within the system. However (especially transport) this conversion to electricity will have unpredictable effects on the daily profile. Gone Green assumes that 90% of cars are plug-in hybrids by 2050, yet there is not a corresponding growth in demand to reflect the huge amount of energy that would have to be converted from petroleum to electricity. They seem to have overlooked that the preferred means of producing hydrogen is electrolysis, which demands electricity, currently at well below 40% efficiency.

Grid-scale electricity storage
using an innovative form of
Compressed Air Energy Storage

Figure 92
Transport demand: No Progression and Gone Green

From FES



Gone Green forecasts that electric vehicles' peak demand (above) will increase from very low in 2015 to 3GW by 2030, and 6.7GW by 2040. Unfortunately they don't comment on total demand, so we refer to the FES 2015 report which shows an expected decrease in road fossil fuel consumption of around 60% while electric vehicles only take up a fraction of that energy.

The story is even more emphasised when we look at heating:

Figure 93
Gas demand: No Progression and Gone Green

From FES 2015

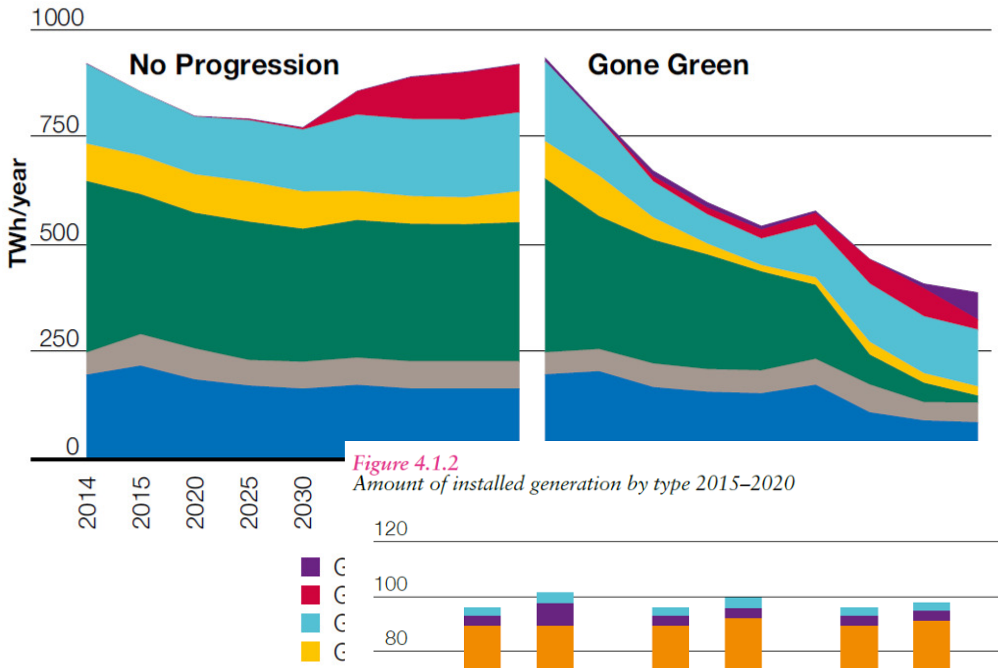
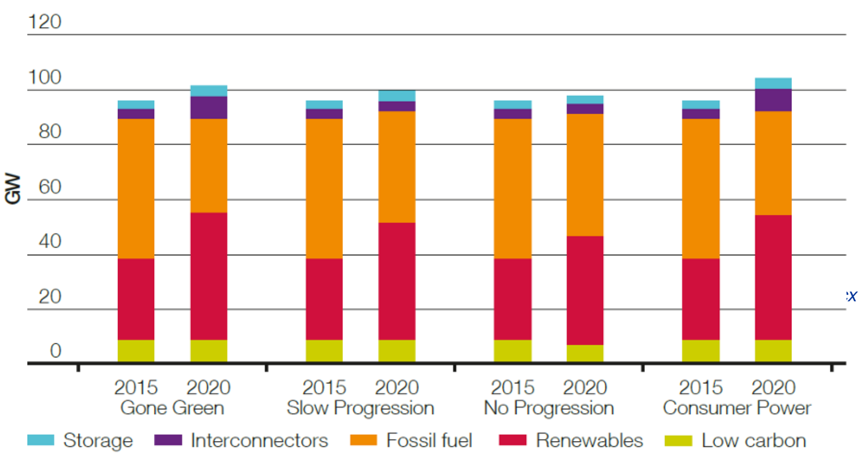


Figure 4.1.2
Amount of installed generation by type 2015–2020

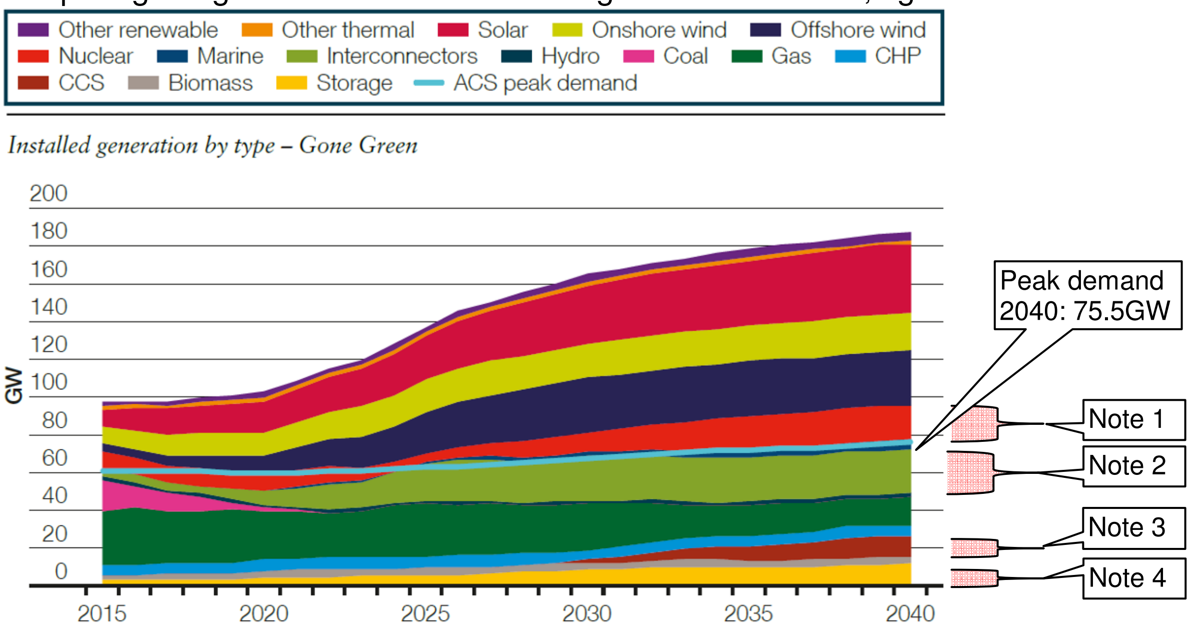


Point 2 (the
increasing

gadgetisation of society) is largely unpredictable: mobile phones and hand-held computers have grown from nothing to immense in just one decade, and if we could predict the next high volume gadgets we'd be billionaires.

Point 3 is evident in the Grid's own graphs (figure 4.1.2), however much they are hidden by inverting fossil fuel generation above renewables and splitting it from low carbon generation: the sum of dispatchable fossil fuels and low carbon is less than the 63GW forecast demand in all scenarios.

Comparing the generation mix with evolving forecast demand, figure 4.1.6:



Notes from the diagramme:

1. Capacity margin from 18.6GW nuclear power: expensive, and will it happen?
2. 23.3GW interconnectors: possibly excessive (see below).
3. An 11.2GW triumph of hope over experience: both CCS projects cancelled.
4. 11.4GW storage: can this be supplied by MW scale batteries?

Total uncertainty 53.3GW

In summary, by 2040 National Grid is relying on MW-scale storage to deliver 11.4GW, unlikely CCS to deliver a further 11.2GW, interconnectors to overseas generation to deliver 23.3GW, and nuclear power the entire 5-10% (3.8-7.6GW) capacity margin. (Note: total nuclear power is forecast to be 18.6GW.)

Considering all these issues together leaves a gap in the electricity supply of 49.7-53.5GW, a considerably larger need for energy storage even than that identified (see above) by the government's TINA analysis.

Interconnectors

In their Electricity Capacity Assessment Report 2013, Ofgem completely discounted reliance on any power from interconnectors – though they have modified their views since then. Not only do all our neighbouring countries suffer comparable shortfalls in generation capacity with Britain's, but also their demand patterns are similar. The corollary of these two factors is that if we are allowed to draw power through interconnectors when our neighbours also want it, we are likely to be paying high prices in order to do so. Nevertheless, at times when these neighbours' systems are not stressed, interconnectors provide ample electricity at reasonable marginal prices, and serve an excellent purpose in lowering Britain's overall energy prices.

"However, GB is not the only European country expecting de-rated margins to fall in the next six winters. … Our analysis also suggests that, at the moment, there are no evident complementarities between GB and its interconnected markets as we have very similar patterns of demand and supply availability."
- Ofgem Electricity Capacity Assessment Report 2013

Note: the BritNed interconnector costs £0.5bn for 1GW of uncertain supply; longer interconnectors are dearer. Storelectric will in future provide 1GW of certain supply for

As if to emphasise this point, "In February 2015 National Grid Nemo Link Limited and Elia, the Belgian Transmission System Operator, signed sign a joint venture agreement to move ahead with the Nemo Link"[2] even though Belgium was the first country in Western Europe to be planning openly for rolling black-outs[3] to make up for potential generation shortfalls, and Belgium's interconnection capacity is 3.5GW, or 25% of their 14GW peak demand[4], as compared with Britain's current 4.15GW, or under 7% of peak demand.

Yet National Grid is accelerating its reliance on interconnectors, from the current 4.15GW to 23.3GW by 2040 (Gone Green scenario).The fact that we saw strong flows into the UK during peaks in winter 2014 is due primarily (in my opinion) to the

2 www.nationalgrid.com
3 http://datafable.com/rolling-blackout-belgium/viz/
4 http://energy.sia-partners.com

exceptionally warm winter noted in the Winter Outlook Report 2014, rather than to their reliability when demand is high: as stated, “French and Belgian supply is expected to be relatively tight until 2020 due to closure of old fossil fuel plant and some nuclear reactors. As conditions vary and put more stress on the market in coming years, this could lead to more volatile prices and therefore interconnector flows between GB and the continent. This is particularly the case over the peak demand of the day.”

Because of their function in lowering overall energy prices and making up for domestic energy shortfalls, Storelectric’s CAES does not supplant the need for interconnectors, but works with them. Indeed, CAES at either end of one could increase the energy transported by that interconnector by up to 6 times, depending on the energy profile at either end of the interconnector. Like CAES, interconnectors are therefore not the solution, but an important part of the solution.

Interconnectors and Brexit

It is worth noting that this entails importing roughly 1/3 of the country’s peak demand and, by 2023, almost one quarter of our total demand, through interconnectors from neighbouring countries. Not only does this indicate a massive domestic energy generation shortfall, but it also risks making Brexit negotiations hostage to our needs: we will be compelled to come to whatever agreement is necessary in order to be able to import these volumes, potentially weakening our opportunity to negotiate countervailing export market access such as for financial and other services.

It is also worth noting that interconnectors are part funded by the European Commission’s Connecting Europe Facility (CEF), and rely on this to a greater or lesser extent for their financial viability. The innovation budget of the EU is funded by 6 countries more than the membership, including Norway, Switzerland and Azerbaijan, so it is possible for the UK to continue to use it – provided we pay into the budget, which may cause political issues in the UK. It is also possible for the UK to provide its own equivalent to CEF (and Horizon 2020 etc.) money, but that would require duplicating administration and an administrative layer to co-ordinate with the EU at both governmental and project levels.

Supply Margin

MW	2016	2020	2030	2040
Peak Demand	60,800	59,700	67,300	75,500
Dispatchable *	60,549	47,347	45,426	44,664
Margin	-0.4%	-20.7%	-32.5%	-40.8%
FES 2016 Gone Green	* Coal, gas, nuclear, hydro, biomass, CHP			

MW	2016	2020	2030	2040
Peak Demand	60,800	59,700	67,300	75,500
Dispatchable *	64,699	54,897	68,681	67,919
Margin	6.4%	-8.0%	2.1%	-10.0%
FES 2016 Gone Green	* Including interconnectors			

If we consider coal, gas, nuclear, biomass, CHP and hydroelectricity to be dispatchable, then under the Gone Green scenario the supply margin is -21% by 2020 and -41% by 2040. Including interconnectors (which is not correct, as above) would only improve those margins to -8% and (with an unrealistically high volume of interconnection) -10% respectively. Note that this shortfall is increased by the fact that supply margins should be between +5% and +10% at a minimum, preferably another 5% more than that.

Supply Margin	**2016**	**2020**	**2030**	**2040**
Gone Green	-0.4%	-20.7%	-32.5%	-40.8%
Slow Progression	0.1%	-10.9%	-26.3%	-31.5%
No Progression	0.5%	-8.7%	-17.9%	-18.4%
Consumer Power	-0.8%	-17.2%	-28.8%	-30.1%
National grid FES 2016	* Coal, gas, nuclear, hydro, biomass, CHP			

Supply Margin	**2016**	**2020**	**2030**	**2040**
Gone Green	6.4%	-8.0%	2.1%	-10.0%
Slow Progression	6.9%	-4.0%	-1.2%	-4.8%
No Progression	7.3%	-1.9%	0.9%	3.6%
Consumer Power	6.0%	-3.1%	8.0%	4.2%
National grid FES 2016	* Including interconnectors			

Many consider the Gone Green scenario to be unwarrantedly optimistic, so we need to review all the scenarios:

Therefore there is an urgent need for over 20GW of dispatchable energy, in two scenarios (~10GW in the others) to ensure that the lights don't go out. This can be supplied by storage, but only if it has sufficient duration at the rated capacity to deliver energy for the entire period for which renewables may not generate: that is, 12 hours or more. Batteries cannot do that scale or that duration: while they help greatly with grid balancing and ancillary services, they cannot provide dispatchable back-up to renewables. Unless this issue is addressed now, the country's security of supply is jeopardised severely.

The Energy Trilemma

Governments and grids in Britain and throughout Europe (ENTSO-E is the trade body for transmission service operators of 38 countries) have defined their future needs as an energy trilemma: a need simultaneously to deliver affordability, clean energy and security of supply.

Affordability

The Gone Green scenario relies on 18.6GW nuclear power. This is proving to be one of the most expensive energy sources available. It also relies on 11.2GW CCS which would be even more expensive than nuclear, (£27bn p.a. plus capital costs for 8MW abated coal fired power stations, without allowing for the inefficiencies introduced into the power generation process), according to aspirational figures from DECC's website which they removed when cancelling the two CCS power station projects in 2015. In contrast, Storelectric's CAES has a cheaper levelised cost of electricity than a gas-fired peaking plant and can therefore balance the entire system cost-effectively and (on a level playing field) without subsidy.

- Note that while policy makers talk about energy cost, they mostly focus on its price. These have become divorced from each other, with cost (including both overt and covert subsidies) rising as fast as price (£/MWh wholesale) falls. Already more than half of most commercial bills is made up of non-price levies and costs; this should be under one-quarter, preferably <20%, to pay for transmission and distribution costs alone, and to penalise anti-social behaviour such as excessive consumption of fossil fuels.

Clean Energy

The Gone Green scenario, the only one which delivers the country's 2050 emissions obligations, still relies on 14.7GW unabated gas generation, which leaves no room for missing targets in other energy types. It relies on (as above) 47.9-53.5GW electricity of types on which we cannot currently rely – or even see a clear path to relying. The scenario includes 109.2GW predictable but not dispatchable renewable generation: Storelectric's CAES has the capability of balancing all of this, as well as providing storage for periods of low renewable generation.

Security of Supply

Security of supply means two things principally: keeping power reliably in the grid to meet variable demand, and being in charge of the source of that power. Not only does this scenario fail on the first measure, as above, but also it fails on the second: the reliance on 23.3GW interconnectors (13.6GW under the lowest interconnector scenario, No Progression), added to 18.6GW (38.4GW under No Progression) gas-fired power stations using imported natural gas means that the country will depend on other countries for over 55% of its electricity needs.

Costly Responses

In response to these shortfalls, National Grid is taking increasingly costly measures such as creating the Capacity Market in which, according to the government's recent consultation document[5], "Two CM auctions have now been held, for delivery in 2018/19 and 2019/20 respectively. Whilst, given the target levels that were set, the auctions procured relatively little new capacity…" for about £2bn.

Added to that, the Winter Outlook Report 2015 states that to cope with narrowing markets, National Grid "developed a set of new balancing services (NBS) to help us to manage the uncertainty and tightening margins over last winter. … Demand-Side Balancing Reserve (DSBR) and Supplemental Balancing Reserve (SBR)". "The total costs incurred in the procurement and testing of the new balancing services was £31.2m." This total is likely to increase in future years: "On 3 June 2015, we announced the procurement of the 2.56 GW of additional electricity reserve for the winter 2015/16", compared with the 1.05GW purchased the previous winter.

Since then, further market mechanisms have also been created, adding to the costs of maintaining the system, such as Supplemental Balancing Reserve, Enhanced Frequency Response and Demand Side Top-Up. It appears that additional patches are being added to a worn-out regulatory framework at ever-increasing rates.

OFGEM Recognition and Actions

While Ofgem have expressed the need for storage in the past, currently all storage requires special consideration. This vastly increases regulatory uncertainty for investors and developers alike.

There is no regulatory category for energy storage, so storage equals consumption plus generation, neither of which is related to time or demand. This means that:

1. For grid connection applications, if DNOs propose the storage (e.g. Leighton Buzzard, Eigha, Orkney), it is deemed to create capacity; if anyone else proposes it, it is deemed to consume capacity;

5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/504217/March_2016_Consultation_Document.pdf

2. Although charging and discharging are countercyclical and will largely be determined by the Grid's / DNO's needs, grid connections must be paid for that are sized for maximum charging during peak demand and discharging during trough demand, adding ridiculous and unnecessary costs to the project (unless the DNO is proposing it…);
3. DNOs are prevented from investing in storage over the 5MW waiver;
4. Although National Grid can invest in interconnectors, which take and return grid power, they cannot invest in storage (or even research into storage technologies via NIA / NIC or other mechanisms) even though they and the consumer would greatly benefit from it;
5. There can be no contracts for storage services;
6. Electricity has to be purchased and sold regardless of when balancing services is wanted, therefore if the services are wanted off-peak using energy stored at other times, there will be a loss – though this will only become a substantial issue when availability of dispatchable electricity drops to levels below the levels of off-peak demand variability, and therefore not for more than a decade.

Government Recognition and Actions

Some people have recognised the scale of the problem:

> "Electricity storage has the potential to provide savings of more than £10 billion per year by 2050—that is £400 per household" – Lord Grantchester in parliament, 18/7/13
>
> "......... we have designed the enduring capacity market to ensure that demand reduction and storage can participate effectively by running capacity auctions both four years ahead and one year ahead of when capacity is expected to be required.   ...." – Baroness Verma, DECC minister, in parliament 18/7/13
>
> "Electricity demand peaks at around 60GW, whilst we have a grid capacity of around 80GW – but storage capacity of around just 3GW. Greater capability to store electricity is crucial for these power sources to be viable. It promises savings on UK energy spend of up to £10bn a year by 2050 as extra capacity for peak load is less necessary." – Chancellor of the Exchequer George Osborne, 9/11/12
>
> "Reports from Imperial College show that the cumulative value to the UK of flexibility [in power generation] is £60bn by 2030." – Electricity Storage Network in 2014 (not on website now, www.electricitystorage.co.uk)

So where has the government's and other public / semi-public bodies' financial support gone?

- £billions to subsidise fossil fuelled power stations, through the Capacity Market;

- £1bn to subsidise fossil fuelled power stations, through CCS demonstrators (while these 2 projects were cancelled after considerable costs, CCS power generation remains a government priority and continues to attract funding);
- £10s of millions to subsidise area scale projects such as Quarry Battery, Highview and Isentropic;
- £10s of millions to subsidise batteries, at similar or smaller scale;
- Negligible support to regional or grid-scale storage.

Likewise, all government incentives (Capacity Market, CfDs, ROCs etc.) are geared towards production regardless of the time at which it is needed, and none towards either storage or making electricity available at the time needed. This could easily change: for example, the government could increase substantially the value of CfDs and ROCs to renewable generation on condition that it generate baseload power, or dispatchable power, thereby incentivising renewable generation to contract with storage and to support its development.

Since June 2015 the government has announced large restrictions to CfDs and the end of ROCs. This greatly reduces the investability of new technology projects: CfDs provided the only guaranteed sales, albeit with prices fluctuating with the market, within limits. The National Grid is not permitted to offer contracts for longer than 2-3 years, which does not create financial-market “bankability” for new technology investment. Moreover, all of these (as well as CfDs, from 2014) are let by auction which means that even such short term contracts cannot be relied upon. The government needs to permit long term (10-20 year) contracts, some of which are awarded without auction for new technologies in the widest sense.

National Grid Recognition and Assessment
The Grid recognises that “Electricity storage could be significant for the future balancing toolkit. It has the potential to offer valuable services to the SO [System Operator], broader industry, and ultimately the end consumer.” (FES 2015) Even on this restricted remit, National Grid assesses every area of policy and action relating to storage as either very poor (“red”) or inadequate (“amber”):

- Policy and regulatory developments are amber, with a regulatory definition of storage and other regulatory changes promised but not yet delivered. There remain many issues with levies and charges (including double charging of storage with the Levy Control Framework and Climate Change Levy).
- Commercial development is amber due to lack of multiple clear revenue streams, or price signals – especially Time of Use tariffs, though they omit Time of Use generation contracts which would provide a much stronger signal. The outlook is improving, with Demand Turn Up and other enhancements, but these are mostly focused on small scale storage and there are issues with stacking some revenue streams at scale. There is no business model to evaluate network reinforcement deferral or other benefits.
- Technological developments are amber because the levelised cost of electricity of batteries and flywheels is too high. There are improvement in Li-ion battery storage costs, but they don’t see other technology improvements –

still failing to see or support Storelectric's more cost-effective and better-designed system.

- System need (i.e. how well the system is coping without storage) remains amber, with good response to the new EFR service being more than balanced by growing flexibility challenges and the uncertainties of an ever-changing regulatory framework. In the 2015 report this section then describes how storage can match non-dispatchable supply with variable demand, and identifies a need for storage to "provide a cost-effective solution to that need" – but this year's assessment gives no thought at all to larger scale storage.

National Grid concludes: "Storage has the potential to be a significant contributor to the future flexibility requirements of the system. As storage becomes more cost-competitive and the identified barriers are removed, we anticipate a significant rise in new storage deployment."

Storage in FES 2016

Electricity storage was recognised, for the first time, in FES 2015 and amplified in 2016 – though not remotely to the degree of need identified above.

Storage forecasts by 2040 range from 11.4GW (of which 5.5GW distribution connected) in Gone Green to 18.3GW (13.2GW distribution connected) in Consumer Power; the other scenarios have little more than today (6.4GW and 3.6GW). But it is worth asking: are 5.5GW and 13.2GW transmission connected storage realistic?

The Tesla Powerwall is rated at 3.3kW. Therefore 1GW storage is 300,000 such batteries each costing $3,500 plus inverter, controller, installation etc.[6] – say, £5,000. A typical grid connected battery is 2.5MW costing £4.6m[7]; 1GW is 400 such batteries. Their cell life is ~5 years, requiring regular replacement. Their duration of storage is (in each case) 2 hours, requiring additional back-up for longer durations of up to 2 weeks (336 hours) of low generation due to weather and climactic conditions. The costs are prohibitive. Batteries can provide a part of the answer, not the whole solution.

The Politics of Storage

Yet energy storage (both grid and battery scale) and DSR can help deliver the energy priorities of every single significant national political party:

1. By providing a market for nearly every MWh generated by renewables, it reduces or eliminates the need for renewables subsidies – assuming fossil fuels are not subsidised, thereby reducing the subsidies part of both energy prices and tax bills;
2. By supplying peak demand, the most polluting, expensive and unprofitable fossil fuelled power stations can be not only switched off but also (if we have

---

[6] https://www.theguardian.com/environment/2016/feb/05/welsh-home-installs-uks-first-tesla-powerwall-storage-battery

[7] http://www.networkrevolution.co.uk/network-trials/electrical-energy-storage/ p8

enough storage capacity) demolished, benefitting energy prices, the environment and the profitability of the generating companies;
3. By absorbing power during peaks in renewable generation and troughs in demand, the remaining power stations can operate as baseload, again benefitting energy prices, the environment and the profitability of the generating companies;
4. By working with both non-dispatchable power generation and the grid as a whole, storage and DSR can smooth the transition to a fossil fuel free grid;
5. By enabling non-dispatchable generation to supply variable demand at all scales, storage and DSR enable the transformation of transportation, heating and industry to clean electricity sources;
6. By relying on locally generated electricity, storage and DSR can enhance energy security and grid resilience both nationally and regionally.

Combined with renewable power generation, these can deliver:
7. Falling energy prices, as the input power is free;
8. Vastly reduced pollution and emissions; and
9. Energy security, as they are all generated from local resources like wind, sun, tide and waves, rather than imported fossil fuels or interconnected electricity.

Energy Industry Actions
Until now, the renewable energy industry has been balkanised, with each industry association and consortium pressing for special treatment, subsidies, market instruments etc. The result is increasingly costly and incoherent, and provokes counterproductive reactions like the creation of the Capacity Market.

Since the politics means that we should be pushing on an open door, the renewable energy industry (generation, storage and DSR) should get together and propose one single, viable and affordable road map that outlines a single, coherent set of actions that government and grid should take in order to achieve one of a small range of potential solutions.

The potential solutions should include maximum and minimum scope for each technology in the mix. The technologies should include, for the electricity industry:
- Onshore and offshore wind;
- Rooftop and farmed solar (focusing on wide scale rooftop deployment);
- Tidal range and flow;
- Biomass (limited due to other future demands on farmland, globally);
- Wave;
- Storage at every one of the five scales outlined above;
- Demand side response (up to 3-5% of maximum demand).

This should be backed up by a comparable portfolio of technologies, including:
- Storage at all 5 identified levels (domestic, local, area, regional, national);
- Flywheels;
- Demand side response;

- Interconnectors.

In order to be both comprehensive and coherent, this road map (and also Future Energy Scenarios) should also include actions that will need to be taken to accommodate the transfer from fossil fuels to renewable electricity of:

- Heat (especially through heat pumps);
- Transportation;
- Industry.

The list of actions included in the proposal should include:

- Support for research and early stage development;
- Support for later stage development, proportional to the scale of solution being provided (e.g. more finance for a tidal or grid-scale storage demonstrator than for a heat pump or domestic-scale storage demonstrator);
- Support for first deployments, on a sliding scale, e.g. full CfD for 100% of the capacity of the first-off, decreasing linearly by 10% of capacity and 5% of price for each subsequent one, with particular designs to be suited to the need –
  - Incentivising the generation of power when it is wanted,
  - Recognising input costs as well as output costs,
  - Recognising the particular features of each group of technologies;
- Serious carbon tax or carbon permit price, matched by corresponding subsidies to prevent serious damage to the fuel poor, and to industry – but the subsidies must not be matched with consumption, in order to incentivise economy and the development of alternatives;
- A government office in charge of all this, with sub-offices for each part of it;
- Regulatory definition of storage, so that Grid and DNOs can invest in it, so its countercyclical operation and grid control of energy flows must be taken into account during any connection study / action, and so there can be recognition that storage requires both power purchase and power sale;
- Regulatory definition of a way in which Grid and DNOs can act purely as carriers between two private contractors, e.g. major generation and storage, storage and major consumption, major generation and major consumption.

Actions Required

The only ways to avoid such a situation would be to invest in either lots of new generation (if gas-fired, this would be in breach of international treaty and moral obligations that would survive Brexit), or massive-scale storage. The latter will enable us to meet our emissions obligations by enabling us to use renewable generation to power not only peak demand but also much baseload demand. To do this without any ongoing subsidies would require:

1. Long term contracts (15 years) for energy, which would actually deliver cheaper electricity over their term than a succession of 1- and 2-year contracts, and therefore pay for themselves;

2. Regulatory definition of storage, to avoid double charging in both capital and operational costs for grid connections, and to enable contracts to be let for storage services;
3. Phasing out of subsidies to fossil fuel generators (e.g. the Capacity Market);
4. Support for the construction of a first-off plant of each large-scale technology, sufficient to help build an appropriate scale of first-off – in our case, ~20MW;
5. Preferably, a re-design of the market to base it around renewable generation and storage with some nuclear baseload, rather than today's market structure which is essentially based on nuclear and coal baseload with gas variable generation, and patch after patch (new contracts and rules are being introduced at an ever-increasing rate) to cope with a modern generation mix.

About Storelectric

Storelectric (www.storelectric.com) is developing truly grid-scale energy storage using an innovative form of Compressed Air Energy Storage (CAES). This uses existing, off-the-shelf equipment to create installations of 500MW, 6-21GWh with zero or low emissions, operating at 68-70% round trip efficiency, at a cost of £350m (€500m) (estimated for 3rd – 5th plant), and a levelised cost cheaper than that of gas-fired peaking plants (OCGT). Capex is one-third that of pumped hydro per MW and 1/75th per MWh; similar to 10-year target prices of batteries per MW and less than 1/1,000th per MWh. There is potential in the UK to store the entire continent's energy requirements for over a week; potential in mainland Europe and the USA is greater still, with global roll-out planned.

The next stage is to build a 20MW, >100MWh pilot plant with over 60% efficiency, using scale versions of the same technology, for which Storelectric is currently raising funds. Construction will take 2-3 years from funding, and the first full-scale plant a further 3-4 years. The consortium includes global multinationals who cover all the technologies involved, their installation, financial and legal aspects.

About the Author

Mark Howitt is a founding director of Storelectric, with Jeff Draper. He leads Storelectric's technical and operations, minimising technological risk, maximising efficiency and environmental friendliness, and speed to market. His degree was in Physics with Electronics. He has 12 years' management and innovation consultancy experience world-wide. In a rail multinational, Mark developed 3 profitable and successful businesses: in commercialising his technology, in logistics and in equipment overhaul. In electronics manufacturing, he developed 5 product ranges and helped 2 businesses grow strategically.