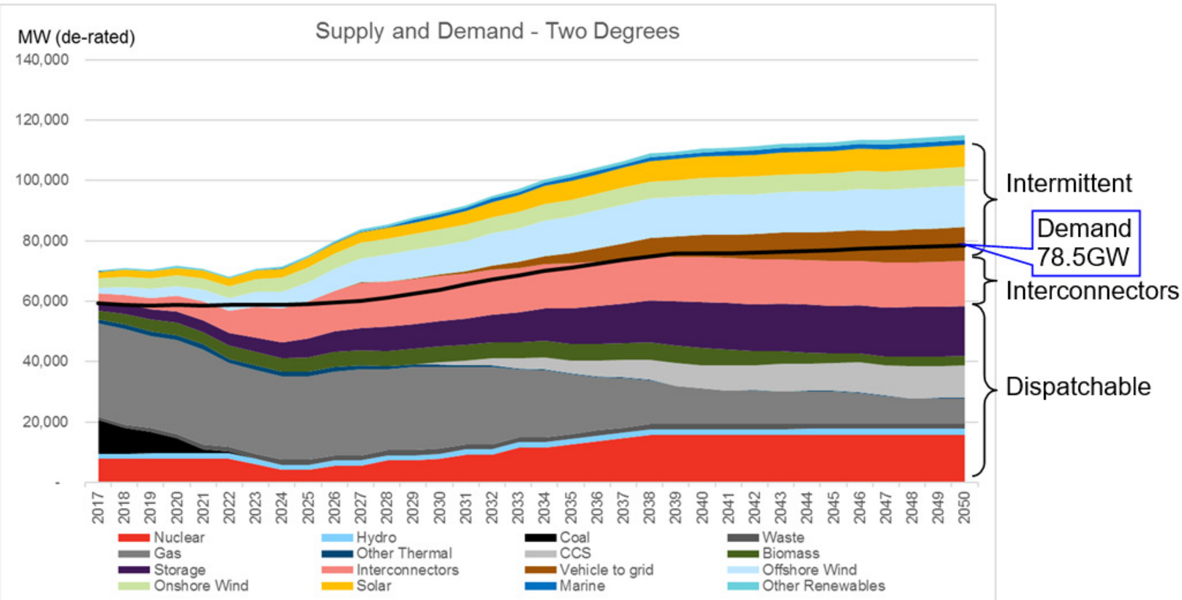
The Scale of Need for Storage

This paper gives insights into the British and European experience of the energy transition to a low-carbon future, to offer learning points to other jurisdictions.

The Energy Transition

The energy transition to a zero-carbon economy is, quite correctly, seeing widespread roll-out of tens of GW of renewable generation. The UK is already at over 30GW and, because of load factors, to supply our 56GW peak demand will need over 200GW nameplate capacity of intermittent renewables before the last fossil fueled power station can be retired. And that demand is expected to grow substantially in both power and energy as heating, transportation and industry are decarbonized - each of those three sectors consumes roughly as much energy as the entire electricity sector, so we can reasonably assume that electricity demand will increase between two-fold and four-fold. It may even be more, as conversion of energy into different forms for different uses always carries inefficiencies; and all this assumes that our total demand for energy is not going to increase.

But most of today's (solar, wind) and tomorrow's (wave, tidal) renewable generation technologies are intermittent: however predictable they are (and forecasting is getting much better at that), they generate when they want to and not when we need it. So how do we move all that electricity from when we don't want it to when we do?



Balancing the Grid

Currently the UK and Europe are proposing three solutions: demand side response (DSR), storage and interconnectors.

The economy's potential for DSR was evaluated by the UK's National Grid in 2015 (they haven't updated it since) as ~5% of total demand, about 3GW at most. But if we turn off a fridge now, we can't turn it off again for quite a while, so if we want to use it (say) thrice in an evening, we can only use one-third of it at a time, giving us about 1GW of flexibility. And its typical duration is 15-30 minutes, which means its proper role is as the best and cheapest option to cope with short duration spikes in generation and demand, whether those spikes are upwards or downwards.

Currently National Grid, BEIS and Ofgem say that we don't need lots of storage, just lots of flexibility, and each knows this because the other two say so – and that's a quote that has been told to me by all three. So they are planning on lots of batteries. These are typically up to 40MW size, with 20-60 minutes duration. And their efficiencies are much lower than advertised: while their internal gross efficiency may indeed be their quoted high-80s to low-90s %, their true net grid-to-grid efficiency has been measured at 42-69% on day one. The differences are largely due to two factors; the smaller factor is AC-DC-AC power conversion and signal conditioning, and the larger factor is heating and cooling. And by the time the cells are swapped out at 80% of capacity, they emit three times as much heat as on day one, thereby enormously reducing that efficiency. Their proper role is therefore for short duration peaks and troughs in demand and generation, not for grid balancing.

Interconnectors operate at the Gigawatt scale, and the country is planning for 19GW within a decade or so. In fact, all scenarios in National Grid's Future Energy Scenarios have UK-based dispatchable supply dropping below demand in 2020 or 2021, meaning that we will be relying on imported electricity not only for our supply margin but also for actual demand.

But this meets three challenges: natural cycles, neighbors' plans and jurisdictions.

First Challenge: Natural Cycles
The first challenge, natural cycles, are seasonal, diurnal and weather-related.

I differ from orthodox views and I don't believe we will ever need seasonal storage.

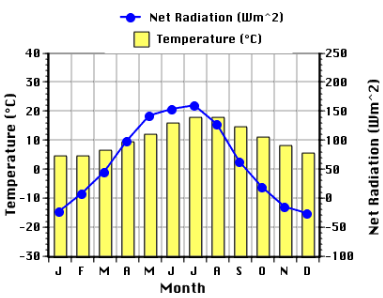
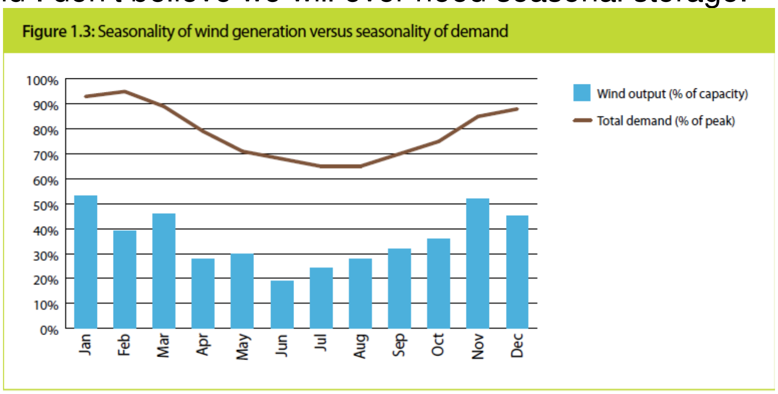


Figure 7I-7: Monthly variations in net radiation and average monthly temperature for London, England. Source: http://www.physicalgeography.net/fundamentals/7I.html



Source: CCC calculations based on modelling by Pöyry. Source: https://thegreeneconomy.org/category/blogs/renewable-energy/
Note(s): Based on observed patterns in 2006, 2007, 2008 and 2009 (averaged) and for indicative 2030 wind deployment and demand.

This is because the monthly generation profile of solar and wind are mirror images of each other, so if we have the right proportions of each we can deliver our seasonal energy needs without storage. This means that we only have to deal with daily and weather-related cycles.

Daily cycles mean that solar stops producing regularly. So when the sun goes down on a windless winter evening, we will have negligible renewable generation and will have to rely on imports. But the same thing will have happened in our neighboring countries, so they won't have any spare to export, killing all benefits from interconnectors during that time.

Weather patterns extend these daily cycles to cover multiple days at a time, often over large swathes of the continent simultaneously. The biggest and worst (from an energy point of view) of these cycles is known in Germany as the *kalte dunkel Flaute*, the cold dark doldrums. This is a high-pressure system that sits over most of the continent for up to a fortnight at a time. Its maximum occurs every couple of years, but shorter durations and narrower geographies are much more frequent, with interconnectors effectively useless for the entire duration.

So the proper use of interconnectors is for supplementary capacity above the sum of total demand and supply margin, in order to keep our normal energy prices competitive.

Second Challenge: Neighbors' Plans
The second challenge, our neighbors' energy transition plans, is critical to whether or not interconnectors can help us. France's recently published PPE plan envisages sufficient dispatchable and baseload energy for their own needs, supplemented by renewables for export. This means that their exportable energy will fluctuate approximately with ours, which doesn't help when ours aren't generating. And the German, Dutch, Spanish, Italian, Danish and Belgian plans all rely on imports during times of system stress, which are largely concurrent with both each other's and ours.

Third Challenge: Separate Jurisdictions
The third challenge is of separate jurisdictions. What will prevent our neighbors saying "I don't care how much you want to pay, our consumers are more important than yours"? In order to rely on interconnectors to provide power when we need it, we must have enforceable contracts that insist on our neighbors exporting to us when we need the energy, however much we offer to pay for it.

Solutions
So if all of the solutions targeted by British and most European governments, regulators and grid operators are inadequate for the job of keeping the lights on cost-effectively, what is the solution? Simple: large-scale, long-duration storage. To balance the grid during evening peaks, we need what the UK government itself identified in its 2014 Technology Innovation Needs Analysis, or TINA report: 27.4GW of new storage with an average duration of 5 hours. And to cover baseload demand as well, and the weather patterns we can expect, we need storage to be at least equal to:

- Power: peak demand plus supply margin, minus zero carbon dispatchable generation (in Germany, ~85GW);

- Energy: all energy that may be used over a 2-week period, minus zero carbon dispatchable generation (in Germany, average duration ~46.5 hours).

Chart 2 EN&S technology deployment scenarios *Source: Technology Innovation Needs Analysis*

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)**

And there are only two technologies available today that can deliver this: pumped hydro and compressed air energy storage.

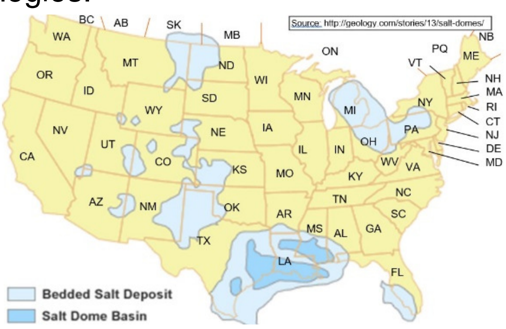
There are few potential new locations for pumped hydro, and every one of them is remote from both supply and demand. And the cost is prohibitive, besides the fact that each scheme floods two valleys.

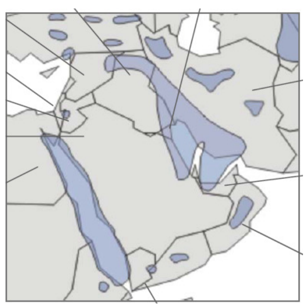
Compressed Air Energy Storage, on the other hand, is less than one-third of the cost of pumped hydro. Storelectric's versions are more efficient than batteries, and potential locations are both widespread and conveniently close to both supply and demand. There is more than enough geological capacity in the UK to store enough energy to power the whole of Britain for the fortnight's weather patterns, probably with exports too.

Global Needs

The above is an argument based on the United Kingdom's energy system. However it applies, with variants, to energy systems world-wide. Indeed, in the first and smallest phase (balancing grids to supply variable demand with low-carbon generation), Storelectric estimates that the capital investment required globally is $1trn, with annual revenues at roughly ¼ of this figure. The second (baseload) and third (supporting the decarbonization of heating, transportation and industry) phases are much bigger.

And while CAES currently targets salt basins, these are plentiful world-wide (see the maps below of Europe, USA and the Middle East); and in future Storelectric plans to develop CAES in other geologies.

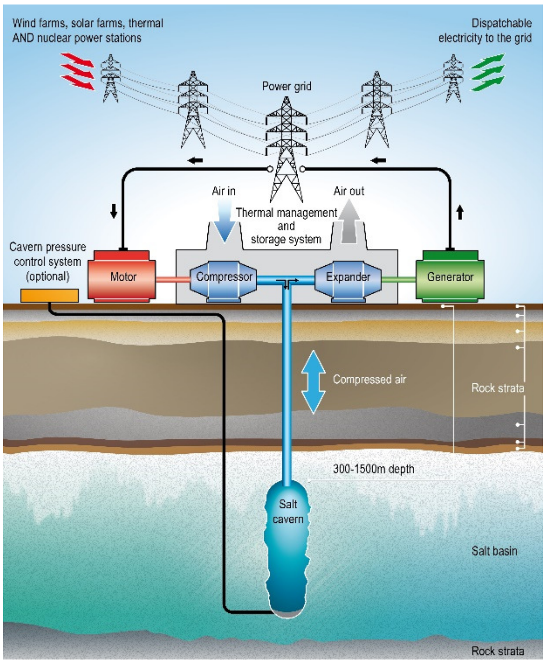




Benefits for Renewable Generators

Large-scale long-duration storage can benefit renewable generators in a number of ways, including:

- Increasing the value of electricity sold, by turning intermittent into dispatchable (i.e. on-demand);
- Adding revenue streams for balancing and ancillary services;
- Reducing the size of grid connection (reducing both capex and opex for grid access charges) by up to 50% for wind and 80% for solar.



Storelectric's CAES

Storelectric has two types of CAES. One is the world's most efficient version, entirely emissions-free and profitable in today's market. The other is uniquely retro-fittable to suitably located existing power stations, giving new life to stranded assets by almost halving their emissions, cutting costs and increasing revenue streams. Both can be built using today's technologies, and therefore have very low technical risk. And both have been supported by the analyses of engineering multinationals. All we need is the funds to build the first of each.

Biography – Mark Howitt

Founding director of Storelectric. Physics with Electronics at UMIST (now Manchester University), 12 years management and innovation consultancy in diverse industries world-wide. SME Project Manager of an EU financed R&D, commercialization program. In Bombardier Transportation, Mark developed three profitable and successful businesses: one commercializing technology he'd developed, one in logistics and one in equipment overhaul. In electronics manufacturing, developed 5 product ranges and helped 2 businesses grow strategically assembler. Mark teamed up with Jeff Draper to develop their innovative Compressed Air Energy Storage system and business, focusing on minimizing technological risk, maximizing efficiency and environmental friendliness, and speed to market.