Is Seasonal Electricity Storage Needed?

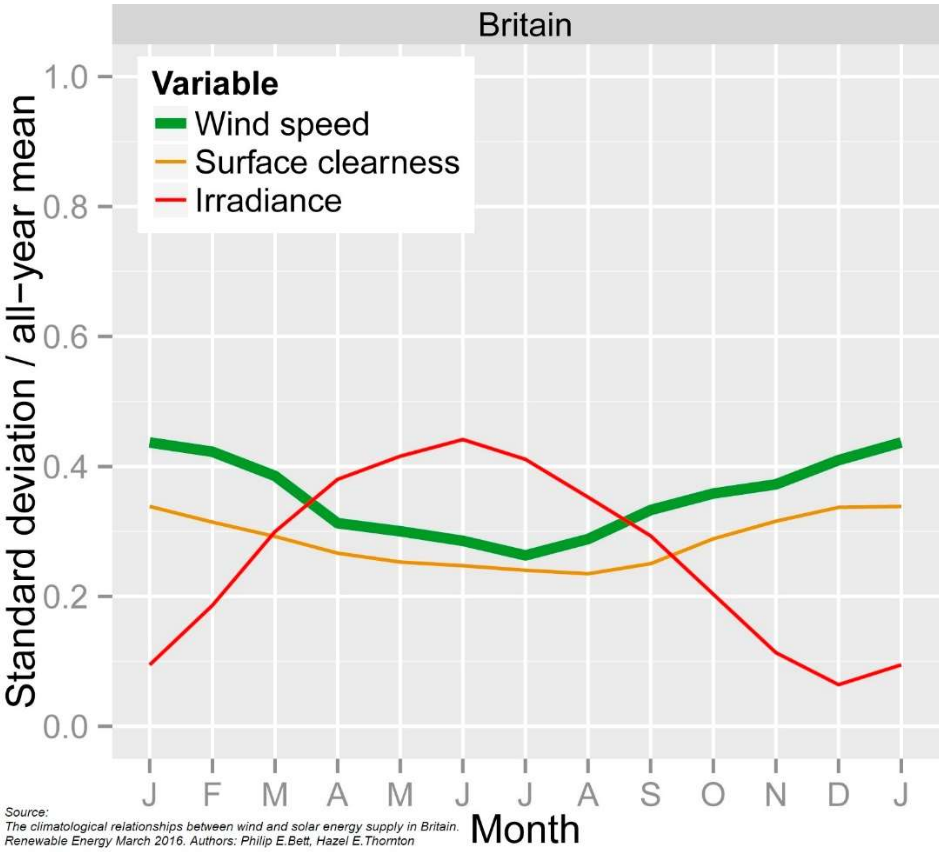
The Function of Seasonal Storage

The function of seasonal storage is to store seasonally variable renewable energy from seasons in which it is in surplus, for use when it is deficient. The classic example of this is storing solar energy in summer for use in winter, but it could apply to other renewables as in some regions wind and/or rainfall are very seasonal.

However the biggest advocates of the need for seasonal storage are those who oppose the energy transition and use its alleged need as justification for their wrongful contention that the energy transition is just too expensive to be worth doing.

This analysis looks at electricity storage. Storage of other energy "vectors" (energy carriage / storage media) will have different considerations such as, for example, their cost of storage and the need for / cost of plant and equipment to store and use it on a seasonal basis. For some types of storage, these last are very low as the same plant that uses the energy carriers day-to-day may also be the plant used for the seasonally stored carrier; e.g. once put into the gas grid, seasonally stored gas uses the same equipment that is used for daily purposes.

Different Seasonalities



Source:
The climatological relationships between wind and solar energy supply in Britain. Renewable Energy March 2016. Authors: Philip E.Bett, Hazel E.Thornton

It is notable that in most regions including Europe and North America the seasonality of solar and wind resource are the inverse of each other, when considering monthly averages. Solar generates more in summer, and wind more in winter. In many paces with large amounts of hydroelectric power, rainfall and river flows are similarly

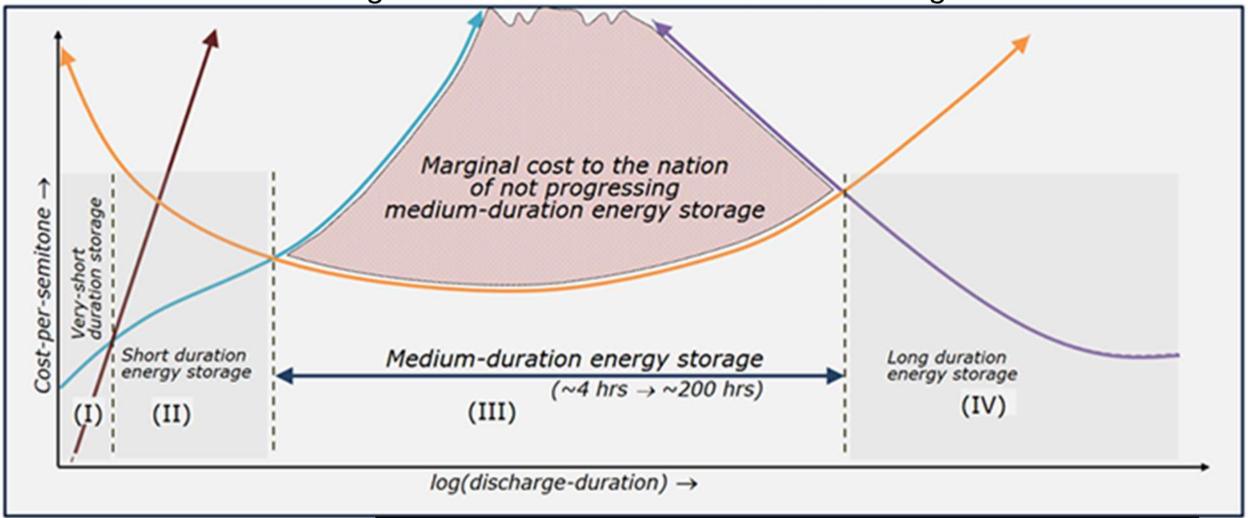
seasonal – and on a different timing from the sun and wind.

Demand is also seasonal, with (for example) more light consumed when nights are longer, and more electric heating when the weather is colder, these features usually compounding each other as they tend to occur towards similar times of the year.

Considering solar and wind generation only in Western Europe as an example, this means that the right proportions of solar and wind generation will accommodate most seasonal variation in demand.

Nottingham University / IMechE Studies

Professor Seamus Garvey of Nottingham University undertook a study[1] for the Institute of Mechanical Engineers into the need for seasonal storage in Great Britain.



Source: Nottingham University / IMechE study, Professional Engineering 19 May 2020

Comparing the marginal costs of different types of storage, he concludes that “*there would be little need for long duration storage because a mix of roughly 80% wind and 20% solar would roughly match seasonality of demand. There is strong variation between years, however.*” He therefore concludes that some seasonal storage is needed, but that such “*long duration energy storage facilities need only have relatively small power ratings.*” But he also adds that 10-15% over-capacity in generation is very cost-effective in reducing storage requirements, and higher percentages may become cost-effective as storage costs reduce.

[1] Why medium-duration energy storage is vital for a ‘net zero’ UK, https://www.imeche.org/news/news-article/feature-why-medium-duration-energy-storage-is-vital-for-a-net-zero-uk – note that what Prof. Garvey terms “medium-duration” is often termed “long-duration” or “longer-duration” by others, i.e. with durations of 4-200 hours (200 hours is 8.33 days).

In a later study[2], the University of Nottingham determined that of all the traded energy required on the system in 2050, ~1% would be from sources with durations under 4 hours, ~7% with durations over 200 hours and ~92% from durations 4-200 hours.

Eliminating Seasonal Storage

If we rely on seasonal storage, we must consider: how many gigawatts (GW) will we need when we come to use it? It is not just the store of energy that we need to consider, it's also the plant that puts that store back into the electricity system. And when such seasonal storage will be used,

1. Renewable generation will be very low (<10%);
2. All other storage will be exhausted;
3. Most such storage uses different storage media (e.g. hydrogen) from what Prof. Garvey terms medium-duration storage (mostly mechanical: pumped hydro, CAES, mechanical potential), and therefore would need dedicated plant that is seldom used and has few revenue opportunities.

Therefore the total GW[3] (i.e. how much output power, as opposed to GWh, gigawatt-hours of stored energy) of seasonal storage will have to be total demand plus 10-15% supply margin minus all zero-carbon generation, which is many GW of plant that will be used only once a year or less. Not only is such plant very expensive, but also it needs to be turned over every so often so as not to seize up; there will be an ongoing O&M burden, major depreciation and minimal potential revenue sources.

This suggests that it will be much cheaper and better to over-build renewable generation, which would have the side-benefit of ensuring a competitive energy market. In a later paper[4], Prof. Garvey and others calculate that 10-15% over-generation will not suffice, so more will be required: seasonal storage (hydrogen) drops to zero when CAES storage is 45TWh (figure 10). However this otherwise excellent paper makes two assumptions that are unlikely to be sustained in practice:

1. The round-trip efficiency of hydrogen is 45%: whereas this is the theoretical efficiency (generated electricity => electrolysis => storage => generation in hydrogen combustion turbines), the current figure is in the low twenties % and the reasonably achievable figure should be in the mid-thirties %.
2. The cross-over point is determined by allowing for the assumed capital and operational costs of each type of storage, and that the capital investment is linear with respect to the amount of storage of each type on the grid. In reality,
   - If any seasonal storage at all is required, then it will need to have a power output sufficient to support the entirety of {demand + margin – zero-carbon

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[2] Energy storage capacity vs. renewable penetration: A study for the UK. Authors: Bruno Cárdenas, Lawrie Swinfen-Styles, James Rouse, Adam Hoskin, Weiqing Xu, S.D. Garvey. Renewable Energy 171 (2021), https://www.sciencedirect.com/science/article/abs/pii/S0960148121003281

[3] For a more detailed, yet still simple, way of calculating the scale of the need for storage in any grid, see https://www.storelectric.com/calculating-the-need-for-storage/

[4] Short-, Medium-, and Long-Duration Energy Storage in a 100% Renewable Electricity Grid: A UK Case Study, Bruno Cárdenas, Lawrie Swinfen-Styles, James Rouse and Seamus D. Garvey

generation}, which will inflate the unit costs at the lower end of the storage requirements graph;

- When seasonal storage is eliminated altogether, then there will be a step-change elimination of output power required;
- At the higher end of the storage requirements graph, both technologies will reach a ceiling in power output needed, after which only duration needs to be added, which greatly reduces its capital costs and related O&M costs.

His assumption of 70% efficiency for CAES is correct for adiabatic CAES at scales in the hundreds of MW.

A Regulatory and Contractual Issue

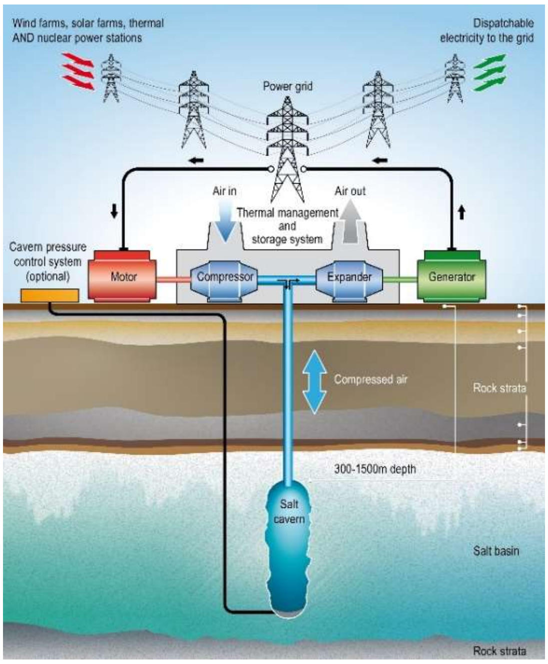
However logical this seems, raw markets will tend to eliminate excess capacity. If building new capacity will merely cannibalise existing plants' revenues, then it usually won't be built; if it is built, that is because it is more efficient, cost-effective or competitive by some other measure, which would cause existing capacity to lose out and close forever. Therefore in order to ensure that such over-capacity is retained year-on-year, there would have to be some incentivisation to do so, i.e. capacity payments that will cover at least all marginal operating costs year-on-year. Another method would be to ration contracts, e.g. to 80% of capacity for all relevant generation so that 25% excess capacity will have such contracts: while this would achieve the same results, it is not a "free" or cheap option as those plants would have to recover their costs and profits over a smaller output.

Such over-capacity is not free, but the sum of such contracts would probably be vastly cheaper than building and operating massive seasonal storage.

About Storelectric

Storelectric (www.storelectric.com) is developing transmission and distribution grid-scale energy storage to enable renewables to power grids reliably and cost-effectively: the world's most cost-effective and widely implementable large-scale energy storage technology, turning locally generated renewable energy into dispatchable electricity, ***enabling renewables to power grids cheaply, efficiently, reliably and resiliently***.

- ♦ Innovative adiabatic Compressed Air Energy Storage (Green CAES) will have zero / low emissions, operate at 68-70% round trip efficiency, levelised cost significantly below that of gas-fired peaking plants, and use existing, off-the-shelf equipment.
- ♦ Hydrogen CAES technology converts & gives new economic life to gas-fired power stations, reducing emissions and adding storage revenues; hydrogen compatible.
- ♦ Storelectric has also patented the use of the heat of compression to catalyse electrolysis, for efficiency and scalability.



Both CAES technologies will operate at scales of 20MW to multi-GW and durations from 4 hours to multi-day, more cost-effective and configurable than any other technology to suit a vast range of applications / use cases, concurrently delivering grid stability based on real inertia. With the potential to store the entire continent's energy requirements for over a week, global potential is greater still. In the future, Storelectric will further develop both these and hybrid technologies, and other geologies for CAES, all of which will greatly improve storage cost, duration, efficiency and global potential.

About the Author

Mark Howitt is Chief Technical Officer, a founding director of Storelectric. He is also a United Nations (UNECE) expert advisor in energy transition technologies, economics, regulation and politics – invitation here. He is also a member of the UK advisory team to the IEA (International Energy Agency), member of the Energy Storage Steering Group of the Renewable Energy Association, frequent consultee to the British energy ministry, regulator and National Grid, and expert speaker at many conferences.

A graduate in Physics with Electronics, he has 12 years' management and innovation consultancy experience world-wide. In a rail multinational, Mark transformed processes and developed 3 profitable and successful businesses: in commercialising a non-destructive technology he had innovated, in logistics (innovating services) and in equipment overhaul. In electronics manufacturing, he developed and introduced to the markets 5 product ranges and helped 2 businesses expand into new markets.

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