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Flexibility and resilience to 'balance the books'

Background

Running the energy system can be like managing money - supply and demand vary as do income and expenditure and for both it takes a conscious effort to 'balance the books'. Coping with the ever-changing requirements requires flexibility and resilience.

With money, ensuring the availability of sufficient working capital is key to avoiding cash-flow problems, which are one of the most common reasons for otherwise successful businesses to fail. Households and businesses that wish to be financially resilient to unforeseen changes or shocks also build up reserves that can be called upon in difficult times.

For energy there is also a need to balance the books while also satisfying the fundamental requirement to deliver when and where users need. Being resilient to shocks is also important for the energy system and its role in supporting wider society, so as well as having enough flexibility to balance the normal swings in demand and production, it is advisable to ensure adequate resilience to cover the unexpected.

Historically, fossil fuels have been energy's 'working capital' and represent the mainstay of system flexibility and resilience in GB. Even now, in 2021, it is still liquid fossil fuels that overwhelmingly provide the buffers of energy in the transport sector, while natural gas delivers the main balancing capability for the electricity generation and heating sectors.

It is worth emphasising that fossil fuels themselves are energy stores and carriers, not energy sources. They have long provided cheap, almost free energy storage at huge scale to balance across timeframes ranging from sub-second to multi-year. Such storage actually encompasses a broad range of supply side reserves and infrastructure that can be mobilised to serve the needs of the demand side.

One of the biggest impacts of Net Zero will be the need to find alternatives to the (unabated) use of the fuels with their low cost, large capacity and long duration storage options, which currently provide nearly all the flexibility and resilience that balance the GB energy systems.

Therefore, a critical element of energy planning for the evolving Net Zero system should be to understand the full technical and economic challenges as well as the impacts of suggested alternatives. As part of this, proposals for GB's future energy system should be able to demonstrate clearly how, and at what cost the inherent imbalances between supply and demand will be managed over all timescales, not just how average energy and capacity requirements can be met. They should also show how energy will be transported to where it is needed if and when existing fossil fuel pipelines, ships and tankers no longer can.

Looking forward

Currently, the heavy lifting in balancing the GB electricity and heat sectors is done by natural gas, capable of contributing 2-3 TWh towards daily balancing and over 100 TWh seasonally. Our current research into the future balancing requirements shows that this will still be the order of magnitude involved for the electricity and heat sectors going forward into Net Zero.

Traditionally system imbalance derives from swings in demand – flexible electricity generation and heat production are simply switched on and off to meet this. However, renewables like wind and solar also exhibit their own short-term, daily and annual variations in output which increasingly must also be considered.

If renewables output is correlated to demand then the resultant system imbalance will be lower, however if they are anti-correlated, then it will be higher. Our research results show some bad news and some good news in this regard:

First the bad news – on short timescales (daily and within-day) system imbalance can become considerably higher than for demand alone and reaches 65-85% of the 'worst case scenarios', i.e. where days of minimum generation coincide with days of maximum demand and *vice versa.*

… and the good news – over the year, despite its high inherent variability, wind/solar output can show a positive correlation to electricity demand and result in a cumulative system imbalance that is close to or even slightly less than demand imbalance.

… and even better news for heat – over the year wind output is well correlated to demand with more supply in the winter, less in the summer. All investigated renewable mixes ***reduce*** system balancing requirements compared to the level of demand imbalance alone. Unlike for electricity where up to 20% solar can reduce system imbalance, in the case of heat, completely eliminating solar from the generation mix better matches demand and reduces system imbalance by a further third to a half compared to a 20% solar mix.

Interestingly, because 'intermittent' output from wind is correlated to 'intermittent' heat demand cumulative system balancing requirements are much less than for firm baseload generation, like nuclear.

Therefore, the design of the future electricity system will depend on how, and how much heat is electrified if imbalance is to be kept to a minimum. The impacts of decarbonising transport and industry must also be considered, and a truly system-wide solution found.

Whatever options are chosen they must also be affordable. Consumers have already paid for the gas storage and network infrastructure which provide system balancing for the electricity and heat sectors. The costs of this are already included in the fuel price. However, the levelized costs of electricity from wind and solar do not include the costs of storage and transportation needed for system balancing. In the future, if the existing gas infrastructure is not utilised e.g., for decarbonised gases like hydrogen, significant additional balancing costs will arise.

To understand what these costs will be we must ask all the necessary questions. If we inquire about short-term balancing of a little energy, locally, the right answer may well be batteries. However, we must also ask how large amounts of energy can be balanced, system-wide, nationally or internationally, and over prolonged timescales. This is the real challenge, both technically and economically and it is hard to see how this can be done without low/zero-carbon chemical fuels.

Batteries are often also put forward as a solution for these seasonal and multi-year, grid-scale applications but fall several orders of magnitude short in terms of both capacity and duration. Even if they were to become technically capable of providing the necessary energy and duration, each 10TWh of batteries would cost at least £4 trillion.

We must be realistic about what solutions are available to meet the timescales of Net Zero. Progress should be based on the principles of pragmatic deployment and improvement, not overly optimistic technology innovation. We do not have the luxury of waiting in the hope that something better will come along.