The role of Thermal Energy Storage in future system balancing

ACTIVE BUILDING CENTRE RESEARCH PROGRAMME

1 Introduction and objectives

Future UK Energy Scenarios will require significant system balancing, understanding how Thermal Energy Storage (TES) can play a role using national level analysis is important to frame a use case for TES. Increased proportions of renewables integrated into the electricity system will change the peak / off-peak times.

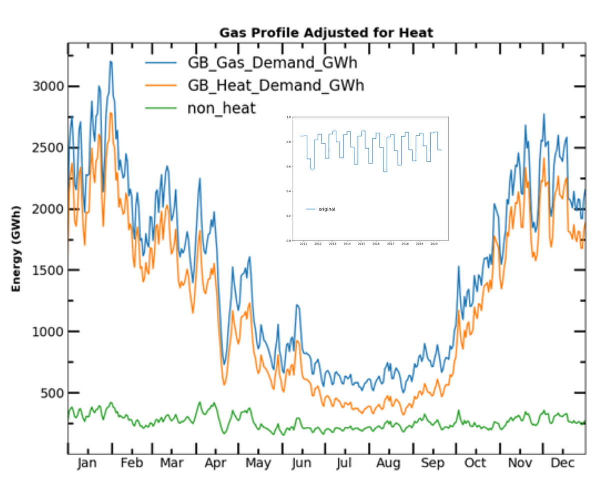
Transitioning from a demand driven balancing challenge that we see present day, towards a generation driven balancing challenge. With the idea of smoothing the demand curve becoming potentially detrimental to the grid balancing requirements, demand will be required to more closely match a generation profile to make maximum use of peak and off-peak generation.

This analysis frames the use case for TES across a daily time-period optimised for overall balancing requirements at a national level. Although the analysis is at a national level the TES itself will be highly distributed throughout electrical distribution networks, e.g., household level TES being developed by colleagues in WP3.

2 Methodology

Datasets from BEIS and National Grid were combined to create a gas adjustment for heat and hot water in buildings. This quarterly profile is then manipulated and applied to an hourly gas profile obtained from individual operators for each GDN. This creates an hourly profile for heat and hot water in buildings.

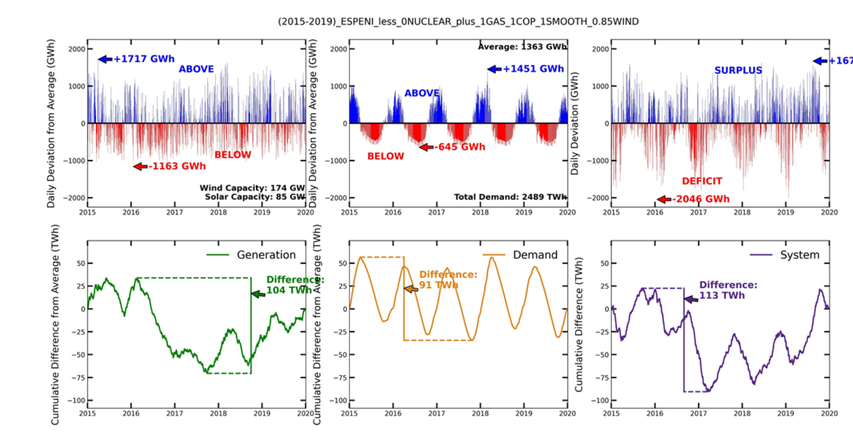
In order to apply this data to the simulation tool, in a future orientated way, the heat profile needed to be manipulated to better represent a heat pump profile. A Savitzky-Golay filter was applied with a window of 25 units and a 4th order polynomial, a winter-summer CoP was used to represent temperature based efficiency. This methodology allows the profile to maintain its distinct twin peak shape whilst smoothing the 'peakyness'. Simulations were run for heat met with resistive heating and heat met with heat pumps.



3 5-Year analysis

Initial analysis used a simple methodology where the generation and demand profiles were analysed separately and then combined. When disaggregated the profiles have their average subtracted and this shows the degree of imbalance that exists in each profile.

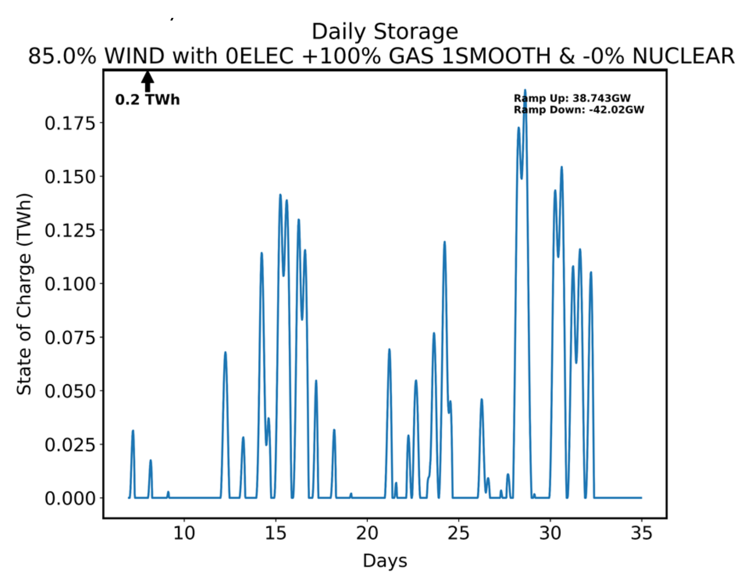
When the datasets are combined we can analyse the system imbalance created with the corresponding generation and demand profile. An example of this analysis is shown below where 5 years of real data for electricity and heat demand, as well as wind and solar generation, are analysed and the results shown. This example is for a multi-vector system with heat being met with heat pumps.



Demand (middle/yellow) shows a clearly annual cyclical profile, and so the multi year impact of the demand imbalance is small. Generation (left/green), however, has one bad year for wind in 2016 and subsequently the system imbalance in greatly effected.

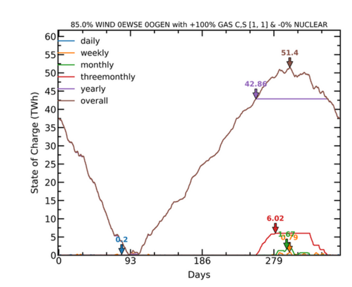
4 System usage

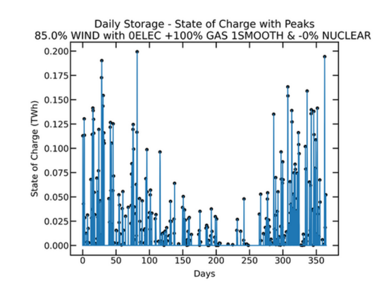
The improved simulation tool provides data on when an exact amount of data is stored and then when it is subsequently used. This allows us to break down the storage profile into individual bins of a certain duration. In this analysis, for TES, the most useful bin to explore is the within day duration. Due to the high renewable generation portfolio the typical charge each night and discharge during the day profile is not seen. Instead the system imbalance and storage use case is driven by the generation profile and so the daily storage profile follows a more random pattern. See below for an example of a snapshot over 30 days.



Improved simulation tool for further exploration

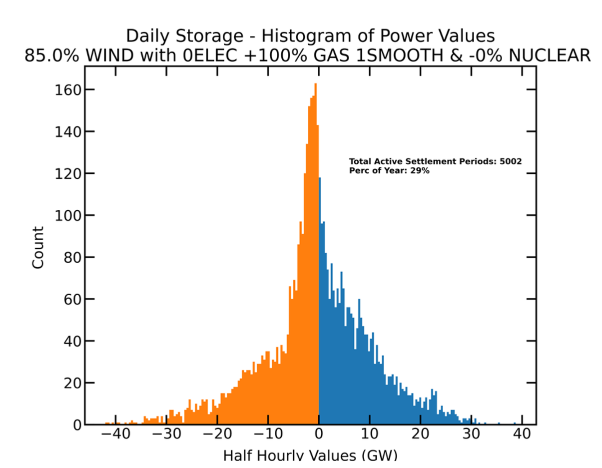
- Uses perfect foresight to unpack the relationship between a generation profile and a demand profile to best determine the profiles of storage across any time period.
- Includes time dependent round trip efficiencies to more accurately simulate a future energy system.
- Now built to include over-generation and basic extreme weather stress events.
- Data Updates: Improved generation profile normalisation for capacity to allow for better comparison between years.

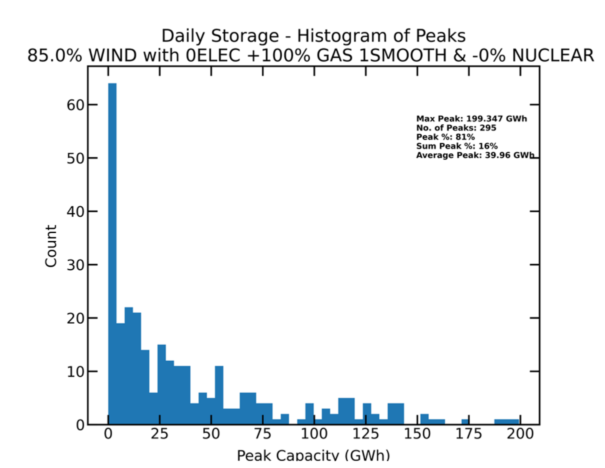




5 Daily TES usage

Using a peak detection algorithm alongside other analysis techniques we can begin to summarise the use case for TES at a within day duration. That is the energy is stored for less than 24 hours, irrespective of the actual date time. We can begin to see that for a heat only scenario, shown in the analysis cases, that the peak storage capacity was 199 GWh which is around 8 kWh per house in the UK. There are peaks on 83% of the days in the year, however if you applied the max capacity at a daily use case then this proposed usage only covers 16% as a load factor. The daily storage is in fact only active for 29% of the year. Further analysis is being undertaken to understand the average charging and discharging time.





6 Decarbonisaton

Understanding the theoretical use case for TES in a high penetration renewable system is imperative to frame the conversations around technology, control and penetration.

With knowledge around when and how much a storage medium will be used we can begin to understand how to build a future energy system that will work in real-life scenarios.

With a use-case identified, then funding and promotion will help this technology decarbonise the UK energy system.

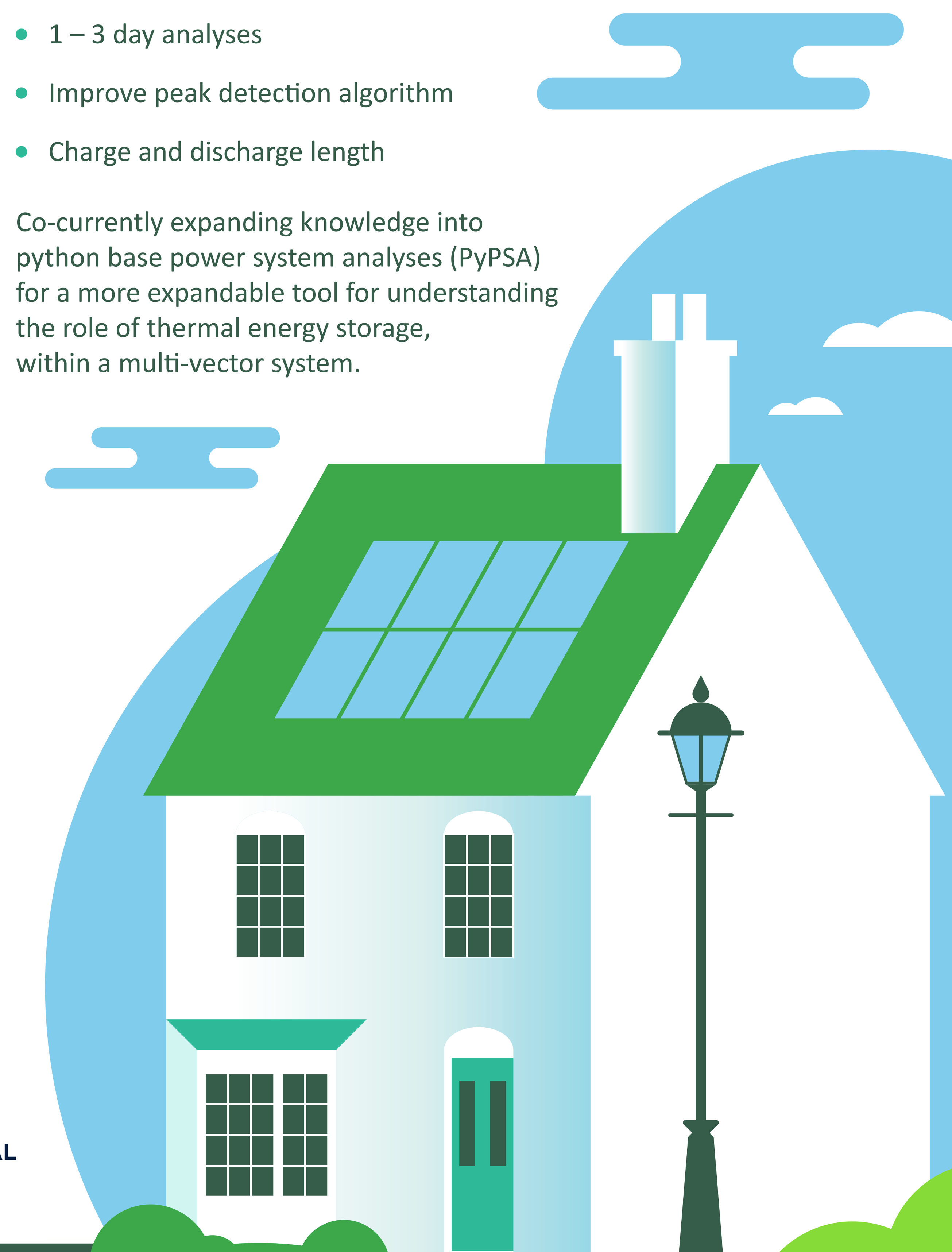
7 Conclusions

TES Usage is Renewable Generation Profile Driven in a High Penetration System

Further Work:
Continue analysis and write up for TES use case in wider system balancing:

- Seasonal variability
- 1 – 3 day analyses
- Improve peak detection algorithm
- Charge and discharge length

Co-currently expanding knowledge into python base power system analyses (PyPSA) for a more expandable tool for understanding the role of thermal energy storage, within a multi-vector system.



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