LoT-NET

Low Temperature Heat Recovery & Distribution Network Technologies

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REFRIGERATION AIR CONDITIONING HEAT PUMPS

sirach

Thermal Energy Storage in the UK Energy System

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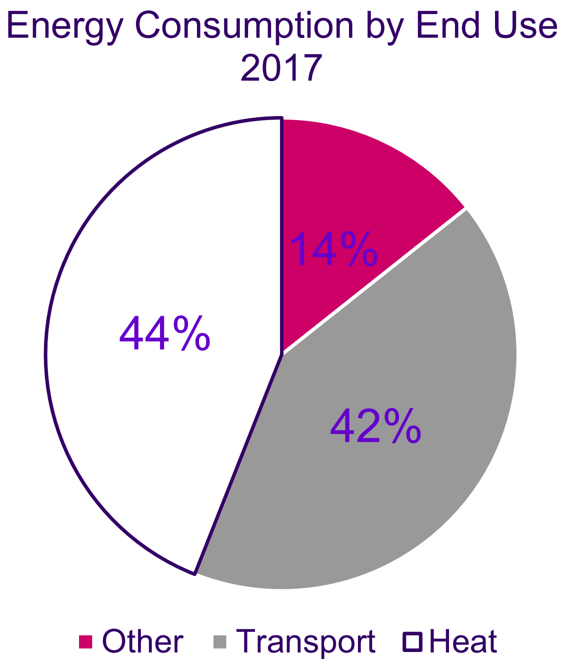
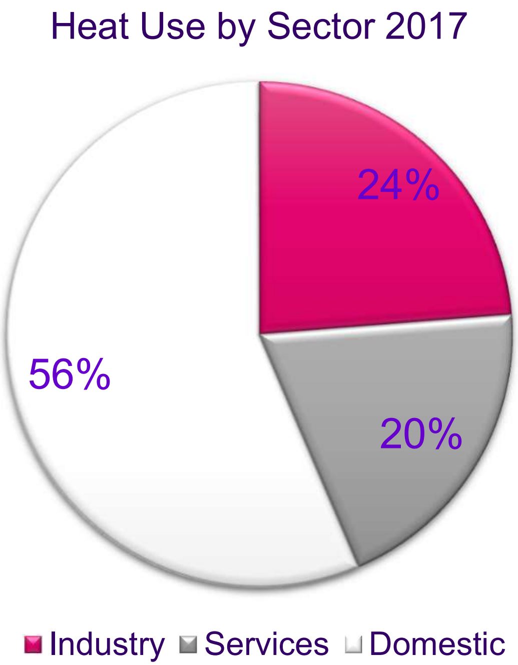
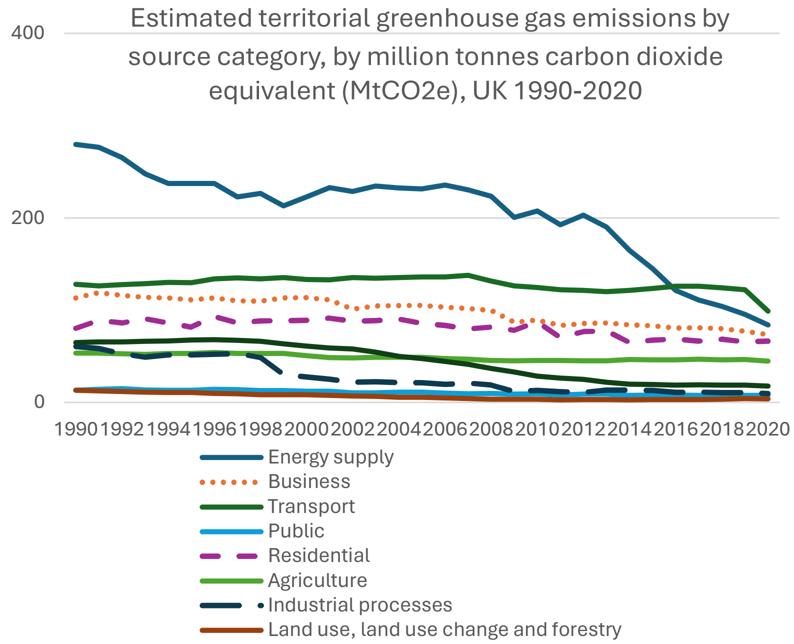
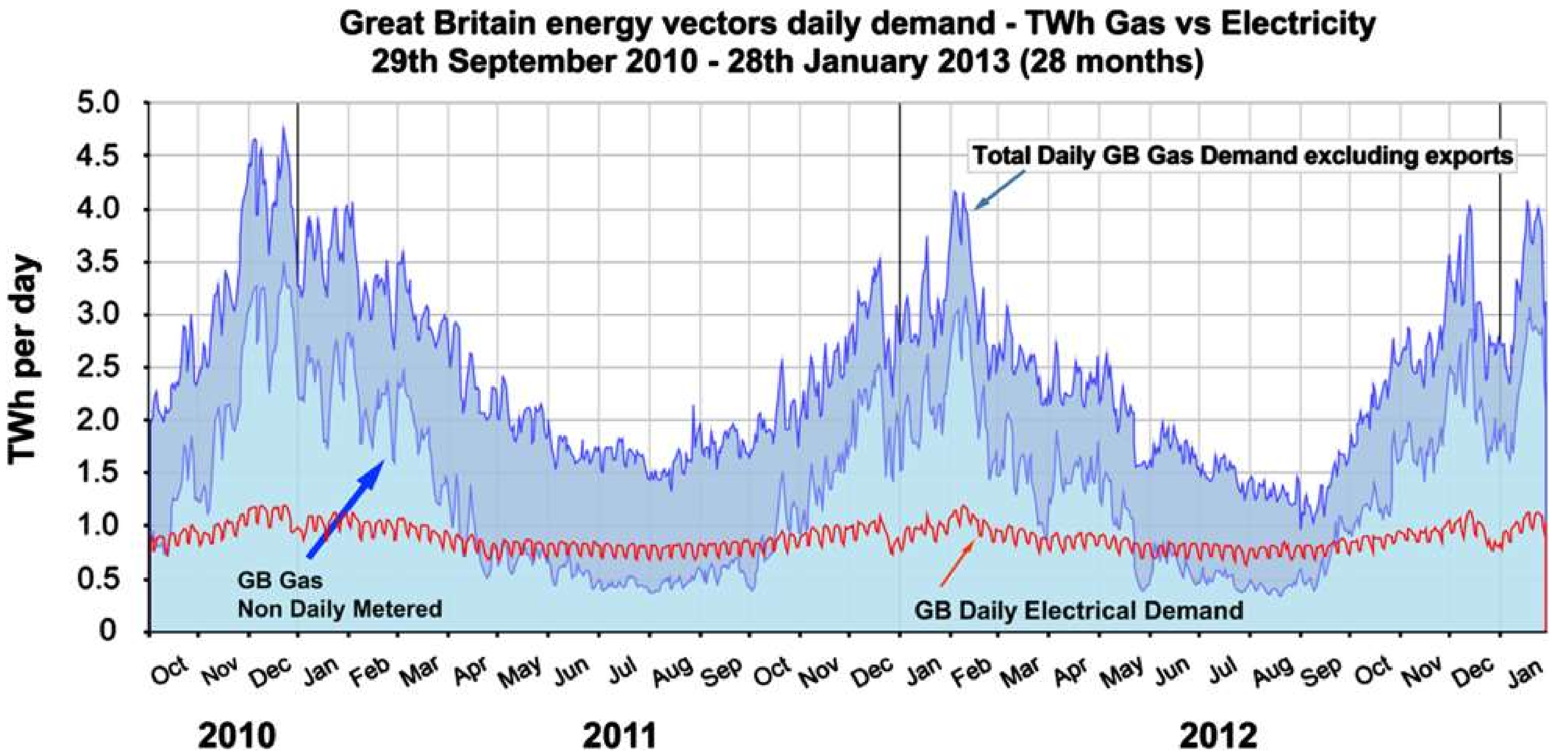
Heat demands







Heat Demands



When analysed on a 30 minute basis winter peak demand for low grade heat can peak at values of approximately 300GW compared to electricity demand which peaks at about 60 GW.

Wilson, I. G., Rennie, A. J., Ding, Y., Eames, P. C., Hall, P. J., & Kelly, N. J. (2013). Historical daily gas and electrical energy flows through Great Britain's transmission networks and the decarbonisation of domestic heat. *Energy Policy*, *61*, 301-305.

Roles for thermal storage

Main routes being considered for decarbonisation of heat delivery include:-

- electrification of heat / district heating
- use of low carbon alternative fuels

Space heating and cooling loads strongly influenced by weather, leads to limited diversity in a specific geographical area. (Peak loads occur concurrently.)

Applications of thermal energy storage with electrification of heat / district heating

- Thermal storage can be used to take advantage of i) electricity cost variations ii) maximise use of low/zero emissions generation, iii) reduce/manage peak electricity demand & iv) times to operate ASHP to improve COP
- Time between charge and discharge ranges from hours for small distributed stores to months/seasons for large centralised stores.

Thermal storage

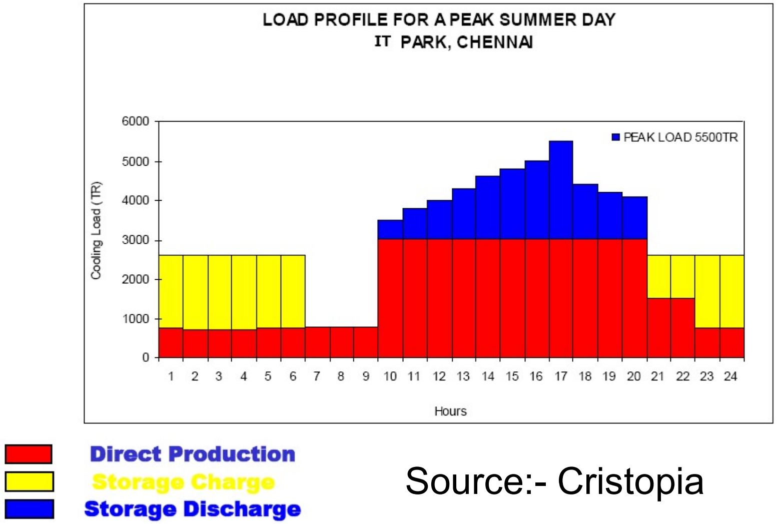
Sensible

Latent

Thermochemical

Specific application requirements determine the approach

- Temperature,
- Load characteristics,
- Storage capacity required,
- Cycle characteristics, charge/discharge rate, time,
- Energy storage density,
- Round trip efficiency/parasitic heat loss,
- Materials requirements,
- Controls,
- Durability,
- Cost.

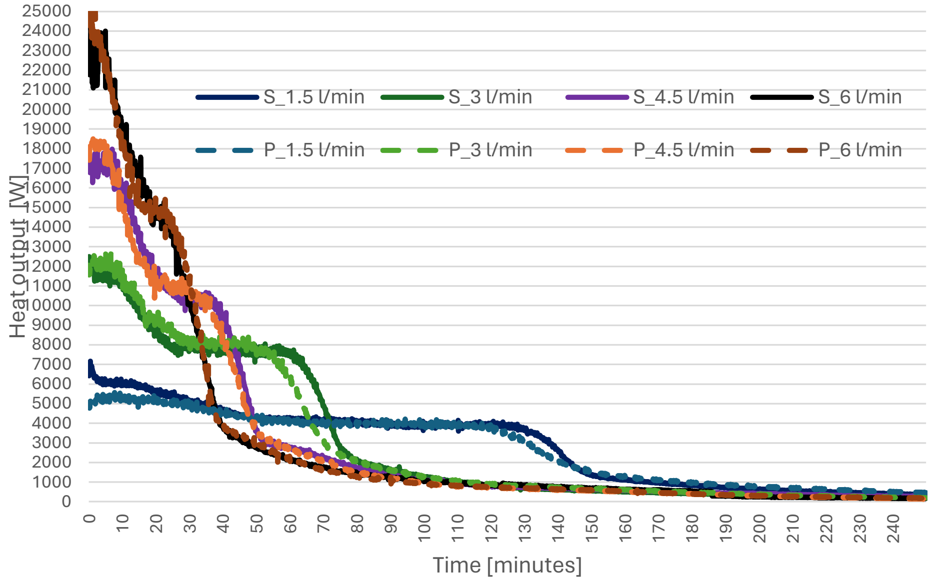


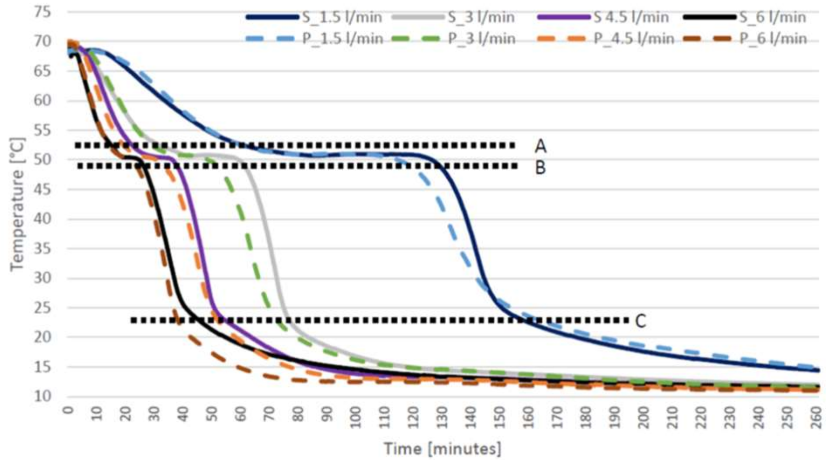
Source:- Cristopia

Thermal storage approaches (In day load shifting)

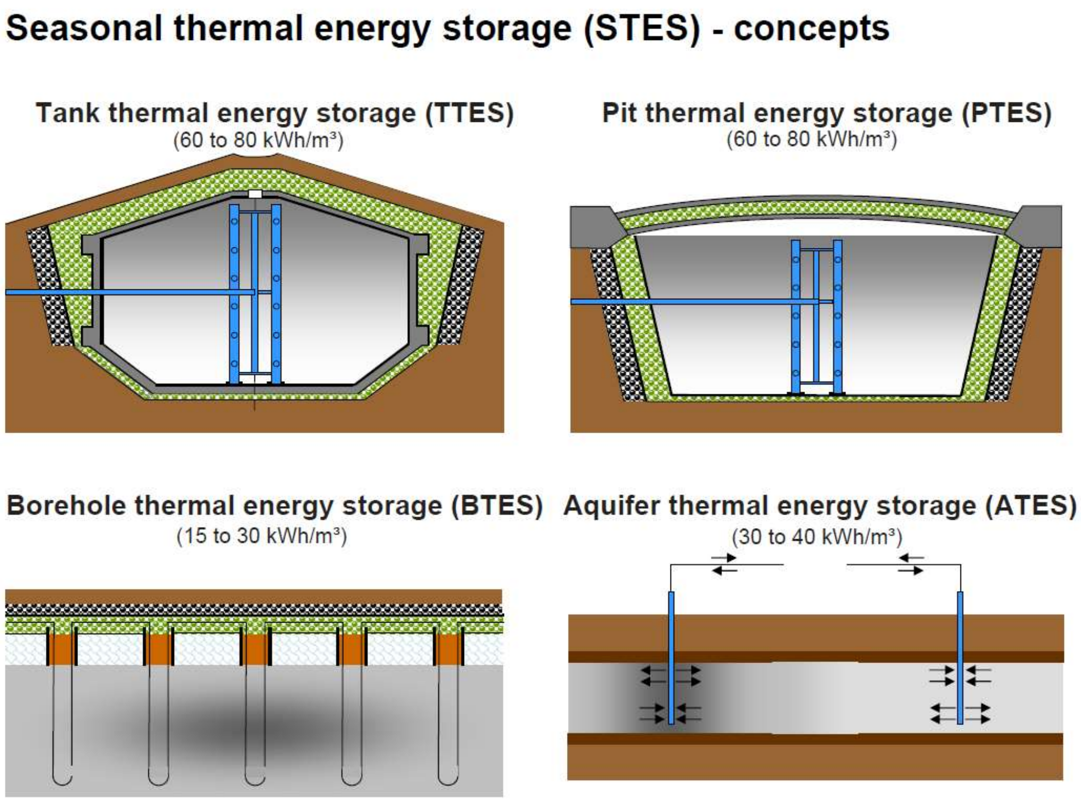
Modular PCM thermal stores

Dwelling based heat storage ≈12.5 kWh capacity
Time shift heat pump/DHN operation
PCM phase transition temperature 54°C
Now being trialled in DESNZ funded Long Duration Energy Storage project ADSorB





Thermal storage approaches (long duration)



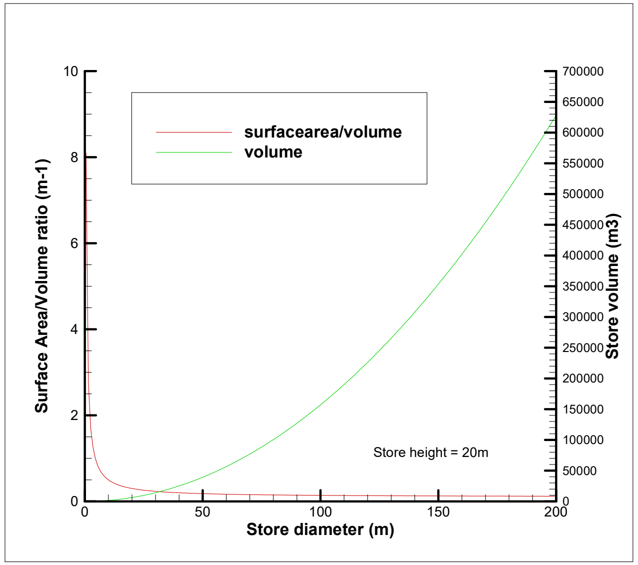
Mangold, D. Seasonal Heat Storage – Pilot Projects and Experiences in Germany. *Solites.* [Online] http://www.solites.de.

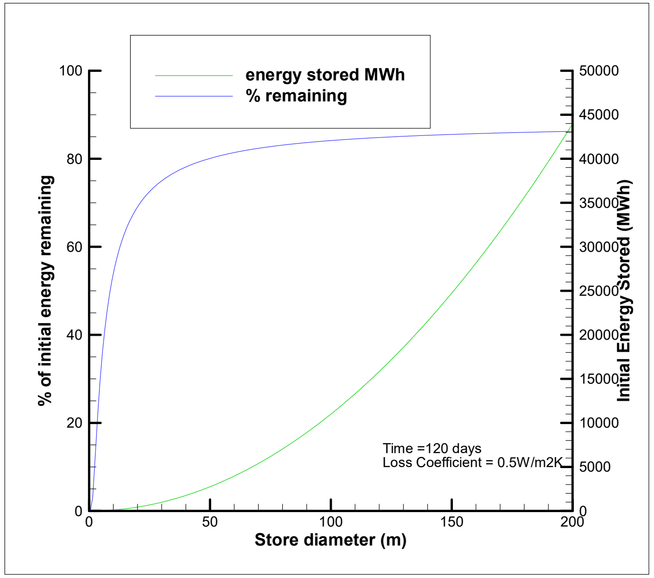
The importance of surface area/volume ratios and store size for long duration energy storage

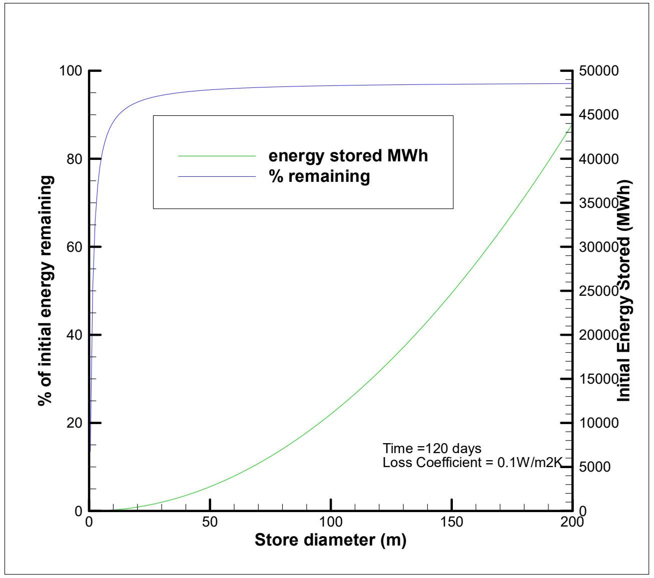
Heat stored is proportional to volume
Heat loss is proportional to surface area

For a sphere SA/Vol= 3/r,
For a cylinder SA/Vol = 2/r+2/h

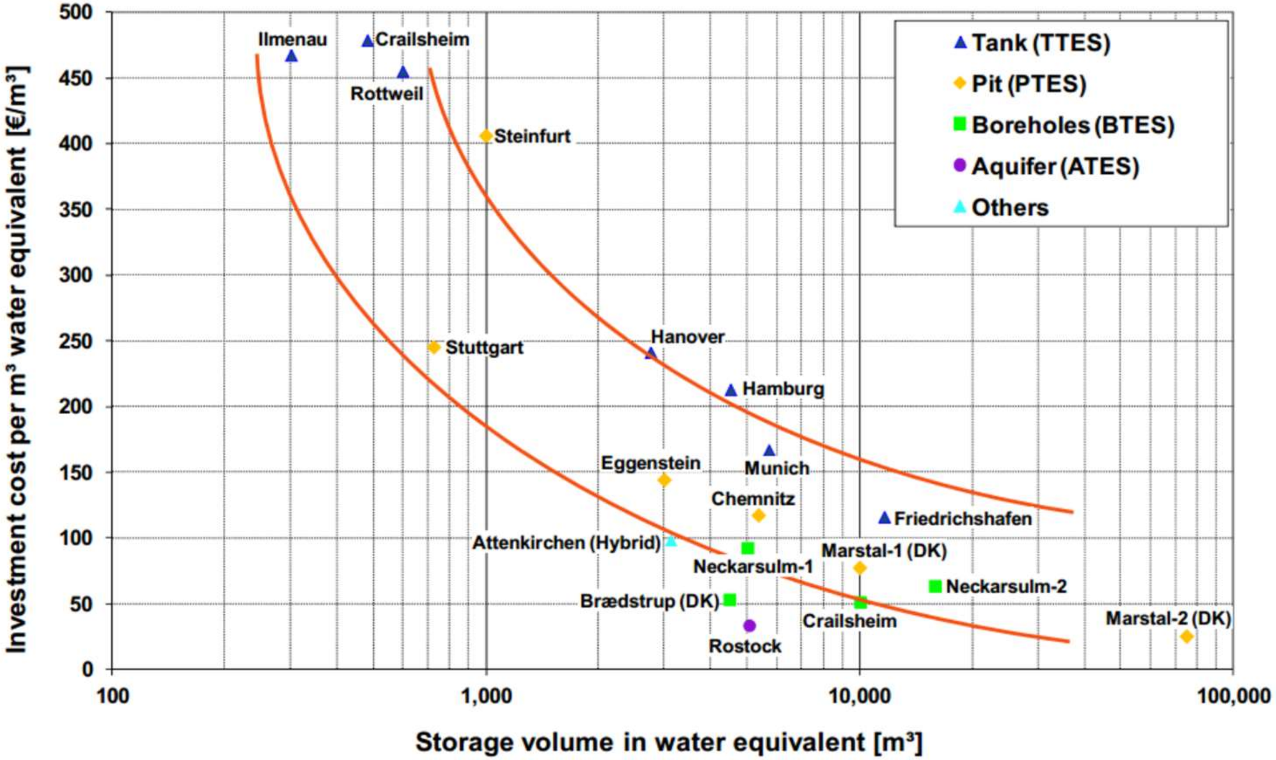
For thermal stratification store height is important







DH system modelling



Specific storage costs of demonstration plants (cost figures without VAT) Schmidt T, Miedaner O, *Solar District Heating Guidelines, Storage*. Solar District Heating, 2012.

Pit storage   60-80kWh/m^3
Investment cost Marstel-2 30€ /m^3
Investment cost/kWh ≈ 0.5€

Thermal storage for an average town

Stores of volumes up to 2,000,000 m^3 have been proposed in Austria. With an effective 60°C operating temperature and perfect thermal stratification storage capacity is 140 GWh. (2,000,000 m^3 = 20x316x316m or 30x258x258m) (316x316 = area of 14 football pitches)

Annual heat loads (Space and domestic hot water) for average existing UK dwelling is approximately 12 MWh, (new build should be half this), 140GWh store is thus equivalent to total annual heat load for 11,666 current dwellings.

Population of Loughborough (2021) 64,884, average UK household size 2.4 people implies approximately 27,000 dwellings.

Total annual domestic heat demand for Loughborough 324 GWh could be stored in 2.3 stores of this capacity.

Thermal storage for an average town

Assuming 8MWh space heat load per dwelling is spread over the 6 month winter heating season, with the peak load week being 3 times the average load in this period, the peak week heat load will be approximately 0.9MWh

The combined peak winter weekly heat load for the 27,000 dwellings is 24,300MWh

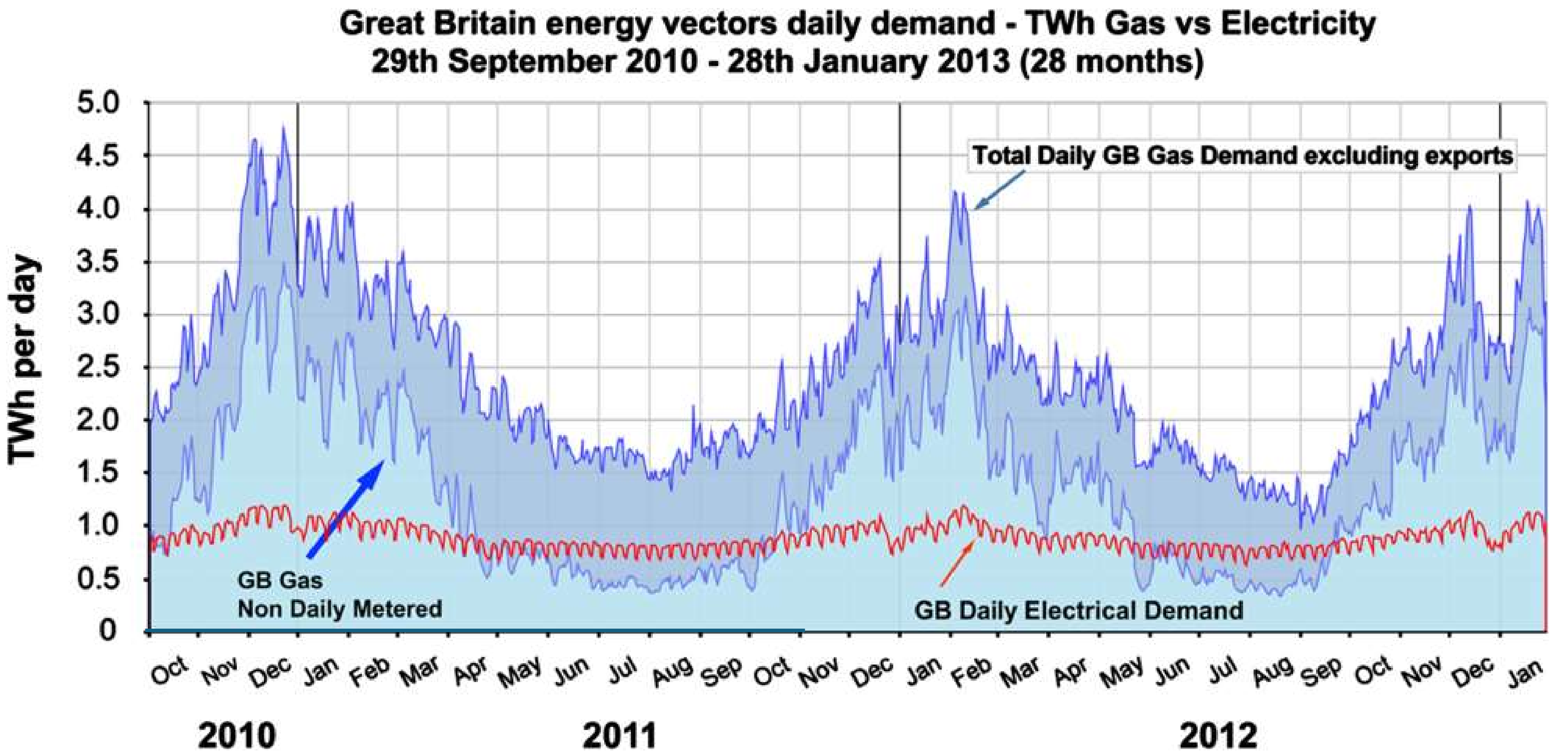
The store size to meet this load assuming no heat generated in this period (blocking anticyclone over UK for 7 days reduces wind generation, solar generation minimal) would require a store of 347,142m^3 (20x132x132m or 20m deep with an area of 2.44 football pitches (7120m^2) (approx. 0.9 football pitches per 10,000 dwellings)

Approximately 28,000,000 dwellings in the UK so approximately an area of 2,520 football pitches required to store the peak domestic heating seasons weeks heat load.

Area of 2520 football pitches 17,942,400$m^{2.}$ (20 m deep stores)

Heat storage capacity of 25.12 TWh

Checking back to Heat Demands



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Non daily metered gas peak is around 3.5 TWh.
If sustained for 7 days 24.5 TWh of demand.

Calculated value with assumptions 25.12 TWh

Flexibility afforded by small distributed stores

Modular PCM thermal store presented previously provides 12.5 kWh of heat storage.

Assuming 90% of dwellings either supplied by DH or heat pumps and each includes a store there would be 25,200,000 stores with a combined storage capacity of 315 GWh of heat storage sufficient to meet 9% of the peak winter demand (3.5TWh) or approximately 70% of a summer days demand (450GWh).

What are the indicative minimum amounts of renewable generation required?

Area	Loughborough		UK	
Renewable Source	Wind	Solar	Wind	Solar
Capacity Factor	0.3	0.15	0.3	0.15
Heat Pump COP	3	3	3	3
Annual heat demand (AHD) GWh	324	324	336,000	336,000
Annual Renewable Generation GWh/MW installed capacity	2.628	1.314	2.628	1.314
AHD/COP GWh	108	108	112,000	112,000
Indicative installed capacity required MW	41.09	82.18	42,618	85,236

Hydrogen pathway using gas boilers

Electrolyser efficiency 50-80%, lower if not operating at ideal conditions.

Assume hydrogen boiler is 90% efficient.

Hydrogen Effective COP= 0.45 to 0.72.

Indicative installed generating capacity required for a green hydrogen pathway using gas boilers can be found by multiplying values by Heat Pump COP/Hydrogen effective COP, 6.66 to 4.16.

If the heat pump COP is reduced to 2.5 then the multiplication values are 5.55 and 3.47.

Conclusions

Energy demand associated with space and water heating for domestic and none domestic buildings is a major component of the UKs greenhouse gas emissions.

Due to the variability of renewable electricity generation, energy storage is essential, heat storage when the demand is for heat is more efficient than alternatives, particularly so if heat pumps with good COP are used.

Large thermal energy stores can store heat effectively for long periods of time, summer to winter.

Small distributed stores can provide significant in day flexibility in meeting loads.

The volumes of storage required appear high however TWh storage capacities that will be needed if we are to transition to net zero are achievable.

High temperature heat storage although not covered here can play a role in large scale electricity storage.

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Questions?

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