THE ASSOCIATION FOR RENEWABLE ENERGY & CLEAN TECHNOLOGY

REA Thermal Energy Storage Briefing

Context

The need to facilitate the deployment of energy storage technologies and flexibility is well recognised as essential to the delivery of the energy transition. However, early policy development has largely focused on the storage of electricity to help balance a flexible and decentralised energy systems with a high penetration of renewables. This has been predominantly through the use of lithium battery technologies, but other forms of storage can also provide alternative benefits and grid services, as well as industrial decarbonisation opportunities. Such alternatives are also going to have a critical role to play in a diverse and decentralised energy system.

This paper particularly looks at the role of thermal energy storage which to date has not been fully considered within either storage or heat decarbonisation policy developments. This briefing outlines the key use cases for thermal energy storage and provides a number of case studies, as well as highlighting the need for it to be better recognised in energy policy to ensure that these energy-efficient technologies can be applied more readily in the future.

The need for thermal storage in a low carbon decentralised energy system

A 2014 study by Element Energy found that 11 TWh of industrial heat was being wasted from industrial processes across eight key energy intensive sectors every year.[1] Thermal energy storage, in a variety of forms, offers the opportunity to recover and store such heat from both industrial and domestic heat sources. This allows for its use in further heat application, when most required, or for other activities, such as renewable power generation. Fresh consideration is required to look at how thermal heat storage can therefore be utilised to decarbonise our energy needs and be an important element of decentralised energy systems.

In addition to this, thermal storage is well placed to benefit the electricity grid by charging during periods of overcapacity. This has the dual benefit of charging cheaply and reducing the need to expand grid capacity as renewable generation is added.

There is significant work required to meet the 2050 net zero target in a timely way. Thermal energy storage technologies have the potential to play a critical role as part of this solution, this includes:

- facilitating heat decarbonisation within our homes.
- buffering recovered waste heat to despatch on demand, not just on availability.
- reducing curtailment of renewable electricity by generating industrial scale green heat during periods of low demand and low tariffs.

[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/294900/element_energy_et_al_potential_for_recovering_and_using_surplus_heat_from_industry.pdf

- providing a grid scale energy storge solution able to provide responsive power to the grid when it is most needed.
- make it possible to enable fuel switching away from fossil gas and oil to renewable energy alternatives in industrial situations.
- extend the life of existing low carbon energy generation assets, such as existing biomass or energy from waste sites, through the addition of thermal storage.

However, to date thermal storage technologies have received limited focus within government decarbonisation policy. While the original Industrial Heat Recovery Scheme was designed to support investment in waste heat recovery, it failed to consider potential of heat recovery during periods of low demand, and did not facilitate investment in thermal storage technologies, presenting a missed opportunity.

In 2016, BEIS published a thermal energy storage report, which provided a comprehensive review of the different considerations relevant to thermal storage.[2] The report outlined key research gaps, covering commercialisation challenges, uncertainty around the performance of thermal energy storage - technologies and specifically around the carbon savings and benefits. However, since this review, little research has been done to progress the report's findings or address barriers to deployment. Since publication, thermal storage technologies have developed further, making the technology easier to deploy, enabling it to provide yet greater opportunities for application and flexibility, while overall making the technology yet more important to the delivery of the transition to net zero.

Different technologies offer solutions for domestic and grid scale thermal storage services:

- **Sensible-** stores heat by increasing the temperature of the material in store, with examples including hot water tanks, electrical storage heaters (both domestic and industrial scale) and boreholes.
- **Latent-** storing energy in phase change materials where the temperature of the material does not change but energy is stored in changing the state of the material.
- **Thermochemical-** Energy is stored in reversable chemical reactions

Thermal stores based on these systems can be used in domestic and industrial applications, where they can be used to 'soften' the peak of heating demand. In domestic systems, they can be used to store heat energy in a far more efficient way than traditional hot water storage tanks and can be co-located to bring additional benefits with other low carbon technologies such as a heat pumps and solar thermal

[2] https://www.gov.uk/government/publications/evidence-gathering-thermal-energy-storage

panels. Thermal stores can work on an industrial scale and offers time shifting or buffering capacity for heat demand, where they can store excess heat from industrial processes, to be deployed at a future time, reducing demand for further heating. The use of thermal storage can often reduce or even eliminate the use of fossil fuels in industrial processes as they can benefit from co-located thermal storage providing an improved business case through the options of peak shaving, fuel flexibility and provision of both positive and negative balancing power.

Different technology applications:

In general, all thermal storage devices can be termed as Power to X or Heat recovery to X**.** Whereby they take excess energy off the grid to use as a heat/ steam store for later use, when required. Flexibility allows the system to utilise surplus electricity on the grid and shift thermal store charging time to minimise cost and provide grid benefits.

- **Power to Steam** (Chemicals, Paper & Pulp, Food & Beverages, etc) - Provision of high grade "green" steam (or oil, or air) to manufacturing or batch industrial processes. Flexibly to exploit low-cost electricity in heat production to achieve competitive cost.
- **Heat to Heat** - (Metallurgy, Chemicals, Cements, Petrochemical, etc.) Effectively recover variable waste heat sources in energy-intensive industries. This allows for time-shift delivery and balance energy supply.
- **Steam to Steam** - (Pulp & Paper, Chemical industry clusters) - Integrate directly into plant/cluster steam grid and charge with excess steam. This avoids dumping or back-cooling of valuable steam and allows for the optimisation of combined heat and power-plants (CHP) on site.
- **Steam to Power** - (Conventional, Biomass, CCGT, Waste-to-Energy, etc) – Storage can be integrated directly into plant steam cycles. This lowers the plants' must run minimum output, while increasing its maximum output.
- **Power to Power –** this form of storage technology can use excess electricity generated from renewable sources and concentrate it as heat energy through a storage device. This can later be used to be converted back into electrical power via a generator when demand is higher than supply, helping to immediately respond to stress situations. These are typically applied on the industrial scale in specific instances where the electricity generated can be used on site. However, grid scale connection is possible.
- **Domestic**- aiding heat pumps and other small scale flexible renewable technologies to soften the peak heat demands within domestic settings.

Case studies

Use case one: Use of waste steam to be used in industrial process which removes the need for fossil fuel based steam generation

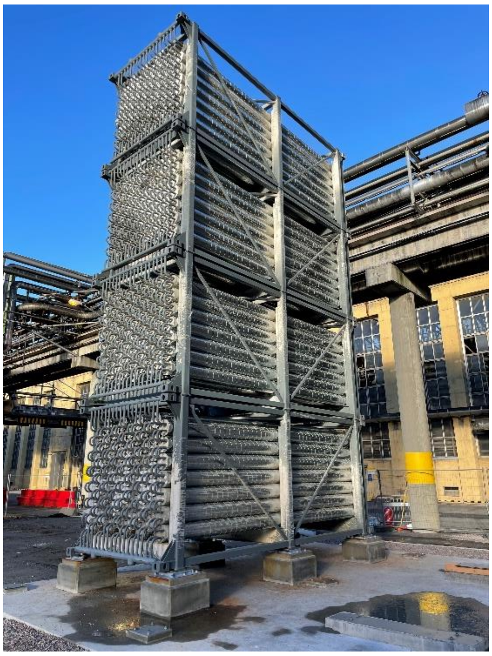
Energy Nest: Steam grid balancing in the chemcial industry

Project details: The EnergyNest ThermalBattery™ charges using overcapacity steam from a medium pressure steam line. The energy of the steam is stored as high-grade heat, ready to be dispatched when required in fertiliser production to the low-pressure steam line. Charging and discharging can happen several times an hour.

What heat is used for: The energy content of the charging steam is used to offset the use of natural gas during higher demand than the grid can provide.

Why is thermal storage the optimal technology in this situation? The ThermalBattery is operating fully automated, charges and discharges on demand and avoids the use of fossil-based fuels to generate the required steam.

What is the estimated thermal capacity: The full-scale project will have a nominal storage capacity of 15 MWh.



Left: The energy nest thermal store on site.

Use case two: replacement of fossil fuel-based steam production, using off peak electricity in heat store.

Lumenion: Scottish Distillery Energy System

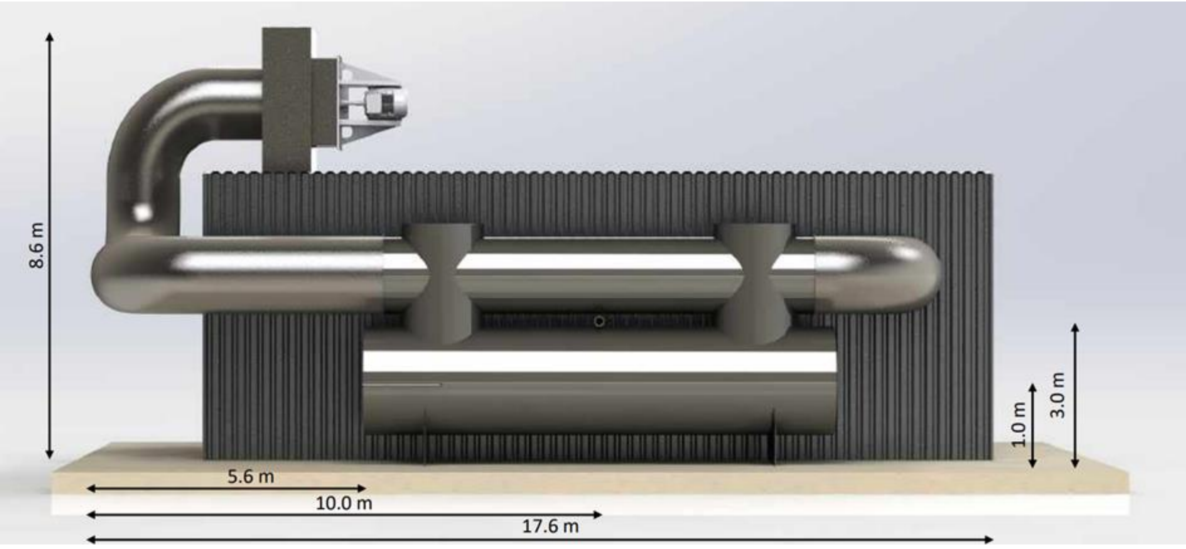
Project details: The LUMENION heat store takes electricity, stores it as heat and then produces steam which can be fed straight into the distillery to drive the mashing and distillation processes, which avoids the CO2 emissions which can be produced from Kerosene.

What heat is used for: The heat store allows the distillery to capture low-cost curtailed electricity when available to offset the higher greenhouse gas (GHG) emissions when compared to kerosene**.**

Why is thermal storage the optimal technology in this situation? Thermal storage is the perfect solution to convert electricity to on demand steam.

What is the estimated thermal capacity: 15 MWh,

Any other benefits of the project: The thermal store is able to make use of cheaper electricity at night times and offload the grid due to its high thermal efficiency. The store can be fully manufactured and sourced in the UK.



Above: A conceptual image of the Lumenion thermal store installed in the distillery

Use case three: Replacement of fossil-based heating with renewable co located technologies.

Sunamp: Heat batteries and heat pump in high-rise tower block

Project details: An integrated system design allows the removal of gas combi boilers from 364 space constrained homes, increasing tenant safety and reducing CO2 emissions. An integrated system using Sunamps compact phase-changing materials made best use of the space available**.**

What heat is used for: The heat is used for space heating and water heating designed to replace a traditional combi boiler with a space efficient net zero solution. Heat is supplied by a ground source heat pump and is then stored in each apartment via the heat batteries which allow for individual control.

Why is thermal storage the optimal technology in this situation? This combined system of a heat pump and heat batteries results in a near 70% reduction in carbon emissions each year. The heat battery allows for greater control of temperature for each apartment than would be possible with just a heat pump.

Any other benefits of the project: The project resulted in a significant improvement in building safety, by removing the risk of gas related explosion and carbon monoxide poisoning. In addition, maintenance costs are significantly reduced.

What is the estimated thermal capacity: Each heat battery has a capacity of 9 kWh

Left: Heat battery installed in flat.

Barriers to market

Multiple thermal storage technologies are now ready for deployment but are being halted from wide market uptake due to a range of factors. The most significant of which is network access charges, which inefficiently charges flexible technologies with a grid connection. The REA have been calling for fairer charging arrangements for many years, as it remains a significant barrier to all energy storage technologies, limiting the business case for delivering storage services to the grid. If these charging arrangements could be improved, a business case for thermal storage would be immediately feasible and greatly reduce the need for further specific policy arrangements. Below is a list of further barriers to market which are currently present.

- Lack of market rewards for the services provided by thermal storage.
- Low levels of market awareness due to the need for independent analysis for specific industrial use cases.
- Lack of revenue certainty in the current market to enable strong bankable business case for investors to get behind.
- Direct and tailored inclusion of thermal storage in current heat or energy storage policy support mechanisms, in order to encourage thermal storage to be seen as a viable solution for deployment.
- Slow and uncertain uptake of partner technologies including heat pumps, smart gird and changes in consumer behaviour.

Residential:

- Lack of up-front funding.
- There is a skills shortage in terms of enabling the design of smart renewable heat systems with the inclusion of thermal storage systems.
- Flexibility is poorly rewarded in Smart Export Guarantee tariffs, as charges and rewards are fixed

Commercial:

- Network visibility is limited, restricting peak and trough smoothing
- Flexibility services are poorly rewarded across distribution networks making it hard to stack revenue streams and make a project bankable.
- There is a significant policy gap around commercial and industrial heat decarbonisation, with no route to market for industries wanting to invest in heat decarbonisation, including designing systems by which they could benefit from thermal storage.
- Analysis of the whole site to perform cost benefit analysis and project planning is expensive and has uncertain outcomes which makes it difficult to fund internally.

Key policy asks

To address these barriers, we call for:

- Creation of more favourable charging and reward mechanisms, including a focus on the ending of effective double charging for network access of flexible grid assets, active network management for commercial thermal storage and the development of more dynamic import tariffs to reward demand side flexibility.
- Policies supporting the electrification of heat to reward flexibility services offered by thermal storage devices.
- Creation of more favourable tax environment, including the reduction in VAT for energy saving materials, including thermal storage systems, to help lower the cost of domestic installations and enhanced capital allowances for commercial thermal storage investments.
- Explicit inclusion of thermal storage in government policy relating to renewable energy generation, by following on from the learnings of the green distilleries competition.
- Financial incentives- inclusion of thermal storage within existing government support mechanism. E,g, Longer and larger Duration Energy Storage Business Models and the Green Heat Network Fund. Funding made available for thermal storge through the Net Zero Innovation Portfolio fund for both feasibility studies and demonstration plants of innovative thermal storage solutions, and a specific remit from the UK infrastructure bank to invest in thermal energy storage deployment to deliver commercial scale demonstration projects. Finally, thermal storage should also be supported at the domestic scale within the Boiler Upgrade Scheme.
- Provide a Sandbox for innovative approaches, within a looser regulatory environment, allowing for the development of network access and usage regulations

Conclusion

Thermal storage technologies have advanced significantly since they last received policy attention from government. Despite this, without the barriers to market being addressed, significant quantities of thermal energy will remain wasted. This document has outlined several policy initiatives which would accelerate the deployment of these technologies. The REA invites further discussion on thermal energy storage from stakeholders.