Novel Storage and Control Technologies for Decarbonisation of Domestic Heat

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Project partners:
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Challenge Statement

Domestic heating accounts for around 18% of UK carbon emissions[1]. Reducing this figure forms a key element of both national and regional approaches to meeting the UK Government's legally binding net-zero targets. Achieving an equitable transition to low-carbon domestic heating is also key to South Yorkshire's regional priorities around safe, secure and sustainable housing.

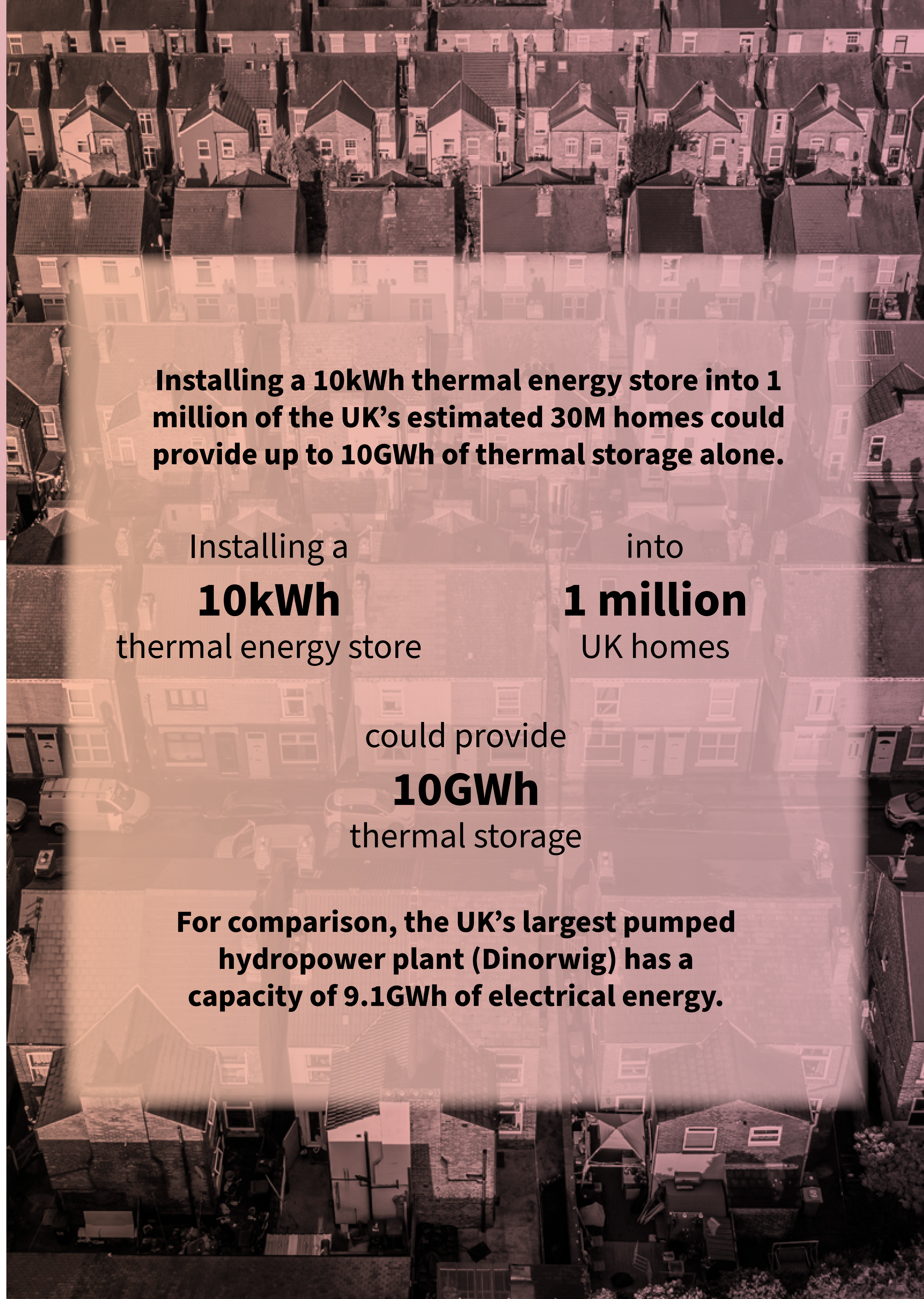
However, there are significant technical, social and economic challenges that must be addressed to deliver on a fast, fair and effective low carbon heating transition. Key challenges include low voltage (LV) network constraints, variation in the supply of low carbon energy generation (i.e. wind and solar generation), a perceived lack of public acceptance, increased operating costs for consumers, architectural challenges within the existing UK housing stock, and skills gaps.

Domestic thermal storage and automatic control technologies hold the potential to enhance the UK's energy flexibility by charging energy stores during off-peak periods and supplying homes with electricity during peak demand. These storage options can be deployed in various ways, for example to address space heating (SH) or domestic hot water (DHW) needs within an individual dwelling, or to provide additional flexibility within communal heating loops. Local storage systems could have significant benefits across the network, avoiding grid constraints during periods of peak electrical demand. This will become increasingly important as heat and transport electrify, adding burden to already challenged energy networks.

The potential is significant; installing a 10kWh thermal energy store into 1 million of the UK's estimated 30M homes (such as the phase change material store developed in the the first stage of the project, described below) could provide up to 10GWh of thermal storage alone. For comparison, the UK's largest pumped hydropower plant (Dinorwig) has a capacity of 9.1GWh of electrical energy.

Deployment of low carbon domestic energy systems with storage at scale has the potential to deliver substantial regional cost and carbon savings, as well as consumer comfort benefits without wholesale grid upgrades, facilitating the energy transition. However, further work is required in several areas in order to progress the technical, commercial and social readiness

1 https://www.nao.org.uk/reports/decarbonising-home-heating/?nab=0



levels of these solutions. One of the key enablers for progress is testing and refinement at system level - i.e. with all components assembled into an integrated heating system - and in real-world operation once appropriate technical maturity has been demonstrated. This allows potential barriers to deployment to be revealed and addressed.

Research Response

Researchers within the Faculty of Engineering at the University of Sheffield are leading a muti-phase research programme that is developing, optimising and demonstrating how novel storage solutions (e.g. thermal, electrical) and control (principally hierarchical predictive control) technologies could be integrated with established low carbon heating solutions (e.g. heat pumps, solar PV) to address grid and end user challenges.

The inclusion of storage enables the end user to take advantage of time of-use-tariffs (TOUTs) as well as current and future flexibility services to reduce their energy bills and carbon impact. Interoperable predictive control allows such systems to operate at their optimum without requiring ongoing input from the end user.

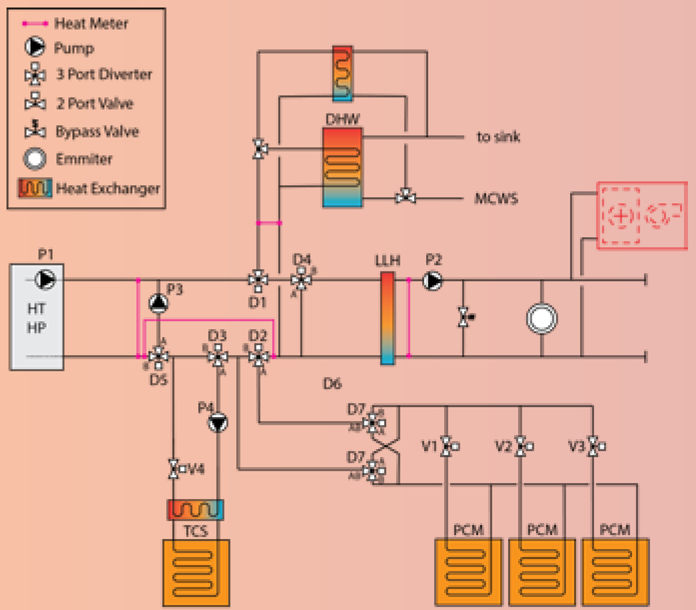


Figure 1a and 1b: ADSorB & Low Carbon Laboratory (LCL)

The LCL represents a replica of a domestic heating system installed within a set of trial properties in Nottingham, enabling developments in the design, operation and control of the storage systems and associated heating and emission equipment to be tested at system level prior to deployment.

The lab allows testing of an extensive set of system modes and offers extension to alternative heat sources and storage options. Extensive sensing and metering enables quantified testing of different technology combinations at system level, derisking in-home trials.

Thermal storage can be deployed in various forms, ranging from sensible storage - raising and lowering the temperature of the active material, as in a standard hot water tank – to advanced options that can enable higher energy storage densities and longer storage durations. These include phase change material (PCM) storage devices that involve melting and resolidifying an active material, and thermochemical storage (TCS) which involves drying out and rehydrating the active material.

The DESNZ-funded ADSorB project investigated the potential of TCS and PCM at a domestic scale as part of an automated low carbon home heating system. Both technologies offer energy storage at far greater densities than traditional hot water stores; both use materials with minimal environmental impact; both offer storage at extended durations - up to inter-seasonal in the TCS case - enabling storage of heat during the summer for later use in the winter.

During the project, trials were conducted in existing, real world testbeds at the University of Nottingham: a 1930s house retrofitted to modern standards, a low energy house and a small-scale District Heat Network (DHN) that provided a communal store to multiple properties.

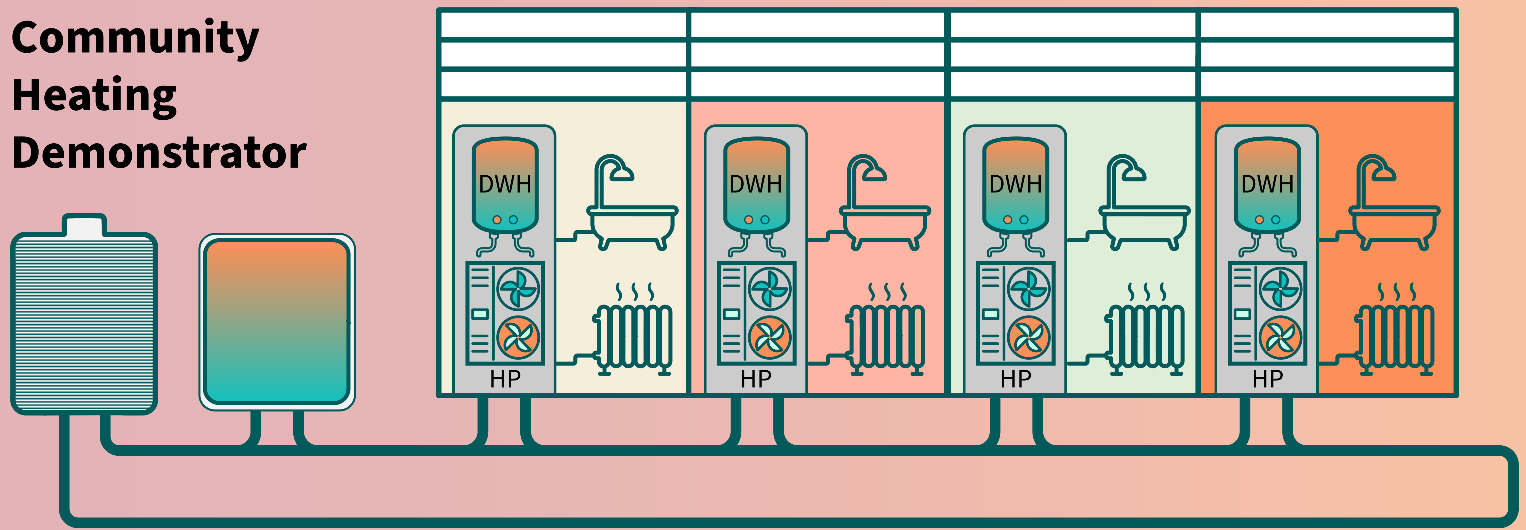
The performance of the individual stores was characterised in detail using the environmental test chamber facilities at the Laboratory for Validation and Verification (LVV) at TUoS. A further laboratory-based testbed - the Low Carbon Lab - was installed at TUoS to enable the evaluation and development of dwelling-level low carbon heating systems incorporating storage, enabling novel storage and control methodologies to be tested and refined.

Funded by the South Yorkshire Sustainability Centre (SYSC) capital fund (provided by the South Yorkshire Mayoral Combined Authority (SYMCA)) and the Grantham Centre for Sustainable Futures (GCSF) Regional Readiness Fund (RFF), the next phase of the project is currently underway and will:

- Develop the laboratory further to test dwelling level options appropriate to the region.
- Develop a new demonstrator focusing on community and district heating in the Gleadless Valley.

The latter has potential to work very well for high density building stock, minimising disruption within individual dwellings.

Community Heating Demonstrator



Community heating schemes can address decarbonisation of heat in both new and existing properties at scale, without requiring installation of entire low carbon heating systems (such as ASHPs) in each dwelling.

This minimises disruption and ongoing maintenance obligations for the end user and can address challenges around grid connection and energy flexibility (e.g. through peak shifting).

Community heat networks (CHNs) share many of the characteristics of large-scale district heat networks (DHNs), enabling research questions relevant to both to be addressed.

Evidence and Outputs

ADSorB Findings

- The research has shown that PCM stores could be suitable for direct use for either domestic hot water or low temperature space heating.
- The PCM stores have been demonstrated to be effective in enabling load shifting between peak and off-peak periods in real-world environments with scope for further development and optimisation.The commercial case could be strengthened by simplifying the product implementation and reducing costs.
- The research achieved a first-of-a-kind demonstration of a full-scale TCS device intended for use within a domestic setting. However, the TCS proposition remains some way from commercial viability, particularly in a domestic setting. More development and optimisation is needed.
- A simplified implementation method has the potential to aid commercial viability through improving system performance and minimising capital and operational costs, bringing the costs down below that for gas boilers[2]

The final report on the ADSorB project will be available here.

2 Winter 2025 energy prices and available Time of Use Tariffs.

What does this mean for the region?

The current costs of running low-carbon energy systems are linked to electricity tariffs, the price of which is largely dictated by wholesale gas prices rather than the true cost of delivering electricity. This means that space heating using an Air-Source Heat Pump (ASHP) without other interventions - for example, fabric retrofit, thermal storage or use of TOUTs - can be higher than the cost of heating the same space with a gas boiler. This is a key barrier to increasing the uptake of ASHPs in the UK and in South Yorkshire. Thermal storage has the potential to deliver reduced operating costs for ASHPs without the costs and disruption associated with deep fabric retrofit.

Developing intelligent, low carbon systems with local thermal storage holds the potential to deliver a modern, sustainable heating system for residents at a comparable and potentially lower operational cost to gas heating. Without central government's actions to address the electricity and gas markets, implementing ASHP's on their own, without storage solutions or fabric retrofit to the buildings will increase energy bills in spite of the fact that they are more efficient than gas boilers during cold periods, particularly for properties that require a high system flow temperatures for space heating.

Innovation in these technologies is essential to secure a just transition to net-zero for those already grappling with fuel poverty and for those who may be tipped into fuel poverty if heat pump deployment increases energy bills. Moreover, to build public consent for low carbon heating systems, tangible benefits need to be identified and marketed, for example that the inclusion of storage may allow lower bills without requiring any additional input by the end user. Finally, innovation, development and optimisation in partnership with industry is needed. Innovation is particularly important in this space as a measure to mitigate the growing risk of grid overload during peak periods with more and more homes transitioning to electrified heat and electric vehicles.

However, equally important is the socialisation of the technology with residents and the demonstration of the benefits of the system, such as efficient, effective and affordable heat, with minimal maintenance requirements.

Next Steps

With funding from the SYSC (provided by SYMCA) and GCSF, this research is ongoing and features continued laboratory developments as well as the set-up of a demonstrator at the Gleadless Valley in partnership with Sheffield City Council, E.ON and Daikin.

The laboratory developments include the incorporation of solar PV generation, electrical battery storage, electric vehicle charging , and electrical plug loads alongside the existing ASHP-driven heating system, enabling development of optimal control techniques that span multiple low carbon technologies. The laboratory allows simulation of real-world behaviours, such as different space heating and hot water demand profiles, de-risking future deployments. In addition, a new thermal storage testing rig will facilitate further development of the prototype devices developed within ADSorB, and benchmarking against competing options. Next steps would be a range of in-home trials, ideally in South Yorkshire.

The demonstrator at Gleadless Valley will showcase a low temperature district heating system in the Tenants and Resident Association office. In addition to building a detailed understanding of the in-situ technical performance of this system, the project includes a Social Science work stream that will run Implicit-Association-Tests (IATs) to measure people's unconscious biases and attitudes towards low carbon heating technologies before and after engagement with the demonstrator. This will be followed by qualitative interviews to dig deeper into people's experiences, feelings and attitudes. In parallel, E.ON and Daikin will conduct a programme of public engagement activities to show residents the technology and provide information on how to manage costs.

The results from both the laboratory and demonstrator projects will be available from July 2026.