Department for
Energy Security
& Net Zero

RAF062/2324: Exploring the take-up and usage of thermal energy storage in heat networks

Technical annex

May 2025

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Detailed methodology

This technical annex describes the methodological approach and supporting materials for this research, Exploring take-up and usage of thermal storage in heat networks. It outlines the research questions addressed in the study and describes the main approaches to gathering data: a review of relevant literature, stakeholder interviews, and a District Network Operator focus group. A description of the analysis follows this.

Finally, we provide examples of research tools (interview guides, focus group topic guides, and analytical tools).

Research questions

The five research questions and sub-questions that this study aimed to answer were:

1. How does TES currently feature (with regard to usage and technologies) in heat networks in the UK and internationally?
    a. What TES technologies are used (or available for use) in the UK and internationally?
    b. How do TES technologies contribute to the operation of the heat network overall?
    c. What is the extent of TES usage among heat network operators included in the study?
    d. Has there been a perceived increase in demand for TES technologies in the past five years?
    e. Are there locations where TES would benefit the system where it is not being used and why?
2. Why is TES used in heat networks in the UK currently?
    a. What benefits of TES have been realised in existing heat networks?
    b. What are the barriers to TES implementation, in relation to costs, policy, operations and expertise?
    c. Are there any problems/barriers associated with TES performance?
3. How will TES be used in heat networks in the future?
    a. What are the perceived benefits of TES applications in future low carbon heat networks?
        i. How could heat networks combined with TES help us reach Net-Zero or decarbonisation goals?
    b. Is there a role for heat networks combined with TES in providing flexibility to the electricity grid?
        i. What is the power sector's understanding of TES?
        ii. What benefit does the power sector envision for such an integration?
        iii. What support is necessary for effective integration of heat networks with TES and the electricity grid?
    c. Are there any barriers associated with TES applications in future low carbon heat networks?
    d. How should integration of TES into DHN be optimised in the future? Are there other enablers that may help to unlock the value?
    e. Does planning support a strategy for installation of large TES systems above ground in urban areas, given the space requirements of e.g. Tank TES?

4. What are the current costs and future cost projections associated with TES for a heat network operator?
    a. What are the capital costs?
    b. What are the operating costs?
    c. What are the maintenance costs?
    d. What evidence is there of historic cost reductions from other related markets?
    e. What are the main cost drivers for TES – e.g. materials, economies of scale, import/export supply chain restraints?
5. What can we learn from international examples of TES use in district heating?
    a. What examples are there of TES use in district heating internationally? For the examples found, how and why is it being used?
    b. How do international approaches differ from those in the UK?
    c. What are the benefits of TES use from the international examples identified? Do these benefits differ from the UK benefits identified?
    d. Are there examples of best practice in TES adoption?
    e. Are there examples of poor/failed TES adoption? What were the lessons learned?
    f. Who are the main TES manufacturers and where are they based?
    g. How do UK TES manufacturers compare, both for UK and international DHN deployment?
    h. What is the stability of the investment environment and strategic planning for TES deployment in existing and new DHNs?

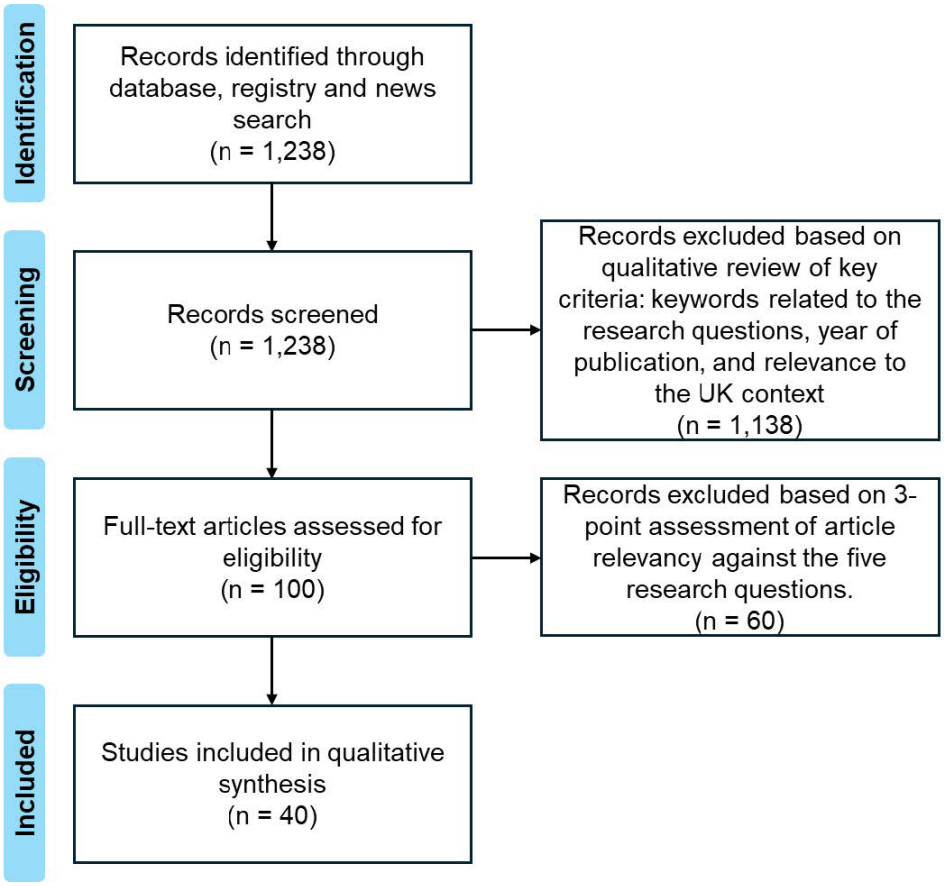
Rapid Evidence Assessment (REA)

For the REA, a long list of research documents was identified to downselect for detailed review. The long list was gathered by searching databases and institutions of quality and relevance. The protocol for selecting and identifying evidence to answer the research questions was developed in collaboration with DESNZ. The primary phases of the REA were:

1. Evidence inclusion and exclusion criteria
2. Document search strategy
3. Document prioritisation strategy
4. Data extraction

The PRISMA flow diagram below details the data collection approach. It is followed by details on the different phases of the REA, e.g., search strategy.

Figure 1: Record of the REA article review process



Inclusions and exclusion criteria

The following inclusion criteria informed the selection of papers:

- Geographical references:
  - Europe: Emphasis was placed on the UK, Denmark and Sweden. Additional examples from Europe were sourced, with a preference for Germany, Norway, Netherlands, and France as these have distinct heat network markets that produce different conditions for TES deployment.
  - North America: Papers from both Canada and the USA were prioritised.
  - Additional countries were considered as part of an international comparison of heat networks published through, e.g., the International Energy Agency District Heating and Cooling Technology Collaboration Programme.
- Technology category:
  - Conventional short-duration TES.
  - Long duration / interseasonal TES, including aquifer (ATES), borehole (BTES) and pit energy solutions (PTES), among more common forms of water TES. Innovative technologies such as sand heat batteries and PCMs were also considered.
  - Additionally, emerging short-duration TES, in the form of new ‘heat battery’ technologies, operate at household and industrial levels at various temperatures depending on the material used.
- District heating generation stage:
  - District heating is sometimes split into different “generation” stages depending on the age of the network, temperatures generated and circulated, and types and sources of heat used in the network. Literature was not excluded based on its generation, usually classified between 1st and 5th generation (although there are emerging designs for 6th generation schemes). The literature is unlikely to have many examples of 1st, 2nd and 6th generation schemes, so these were (largely) naturally excluded.
  - Communal heating systems that included thermal storage were also considered if particularly relevant.
- Language restrictions:
  - Searches were conducted in English, Swedish and Danish.
- Date restrictions:
  - 2010 was chosen as the absolute lower bound for publications selected, with an emphasis on publications from 2014 onwards. The preference was to prioritise newer publications, except for particular use cases and examples of relevance to the UK market.

- Publication restrictions:
  - The search emphasised grey literature (industry publications) and peer-reviewed academic literature in the first instance, supplemented by news articles where appropriate.

Search strategy

The following sources were searched:

- Google Search
- Google Scholar
- Scopus
- Web of science
- UK, Swedish, and Danish government
- Key authorities, including the International Energy Agency, Energy System Catapults, and International Renewable Energy Agency.

Search terms included:

The Search needed to include either (1) (“District Heat” **OR** “Heat Networks”) **AND** (2) (“Thermal Storage” OR “Energy Storage.”)

The Search also needed to include one or more of the following “Costs”, “Performance”, “Usage”, “Benchmarking”, “Benefits”, “Innovation”, “Flexibility”, “Future”, “Operations”, “Barriers”, “Challenges”, “Net Zero”, “Low Carbon”

An example of a search could be: “District Heat” **AND** “Energy Storage” **AND** (“Flexibility” **OR** “Costs”)

Screening

Studies were screened for inclusion at two stages – title and abstract, and full text. At title and abstract 1,000 papers were screened and 900 excluded. At the full text screening stage 100 were screened and prioritised.

At both stages studies were screened against the inclusion criteria set out above. In addition, the below criteria were also used to ensure high quality papers were selected:

1. Academic articles: The article must have been peer-reviewed to be included.
2. Grey literature: Articles from governments, government-funded institutes, and think tanks were accepted.
3. Grey literature—industry or interest group: Only factual information from trade organisations or corporates, such as costs, timelines, or technical details, was included. This approach aimed to avoid gathering biased information.

4. Other literature: Information from other sources, such as news or company reports, was used to fill gaps or conduct deep dives for case studies after evaluating any potential biases and caveating findings.
5. Reviewing references: When papers included high-quality references likely to contain relevant information, these were included in the long list.

Ahead of full text screening documents were also assessed on their relevancy and ability to answer the research questions. A 4-point scoring system was utilised:

- 0 - No relevant information stated in the document
- 1 - Information included relevant for the research question
- 2 - Sections or paragraphs focused on the research questions
- 3 - The main theme of the article answers one of the research questions

If a paper scored zero on all research questions it was not taken forward to full text screening.

Prioritisation

The aim was to prioritise 40 articles for inclusion in the REA and there were100 sources read at full text and considered at prioritisation. The primary consideration for the down selection was to get enough depth and breadth of insights against each question. The following parameters were used to select papers:

- For each research question, 2-3 articles were selected that scored 3 against it in the screening stage outlined above.
- For the remaining articles, articles were chosen where they covered the most research questions with scores of two or above.

Interviews (District heating and thermal storage stakeholders)

Background and purpose

Forty stakeholder interviews were conducted which explored the research questions and sub-questions in detail to identify common themes, points of consensus, and points of disagreement across the relevant groups. Stakeholders from the following groups were interviewed:

- Heat network operators
- Heat network designers/consultants
- Heat network trade bodies
- Heat network/infrastructure investors and developers
- TES manufacturers (incumbent)
- TES manufacturers (innovators)
- Heat and energy researchers
- Heat and energy security policymakers
- Adjacent heat-producing sectors that have a use-case(s) for TES, e.g. waste incineration

Interviews were held online from June to August 2024. A sample frame was developed using CLT and DESNZ contacts (Table 1). Stakeholders were recruited to the sample via email, along with an accompanying information sheet and privacy notice. Participants were notified that their views would remain anonymous from DESNZ unless permission were explicitly granted. Cost proformas were also issued to participants to voluntarily share any TES cost information to inform understanding of industry economics.

All interviews were recorded, transcribed, and then anonymised. The recordings were solely made for transcription and were only accessible to researchers involved in the study; they were not available to DESNZ or external stakeholders. The transcripts were thematically analysed using fireflies.ai, a GDPR, SOC 2, and a HIPAA-compliant notetaking and transcription tool.

Sampling

DESNZ and CLT established a sampling strategy based on stakeholder types to gather a range of perspectives from the district heating and TES ecosystems. The stakeholders were subdivided by UK versus international stakeholders, with the strategy aiming for a 50/50 division. Emphasis was placed on district heating stakeholders, specifically operators, as they (in most instances) directly interface with TES in heat networks.

Table 1: Interview sampling strategy - stakeholder group

Interview group	Target	Actual
International Consultant	5	5
UK Consultant	5	5
Manufacturer	6	5
Investors	4	4
International Operator	7	6
UK Operator	8	10
Other	5	5
Total interviews	40	40

A region-based sampling strategy was also developed to gather international answers to the research questions. Speaking to international stakeholders was necessary to understand the non-UK landscape, identify any UK-specific barriers and drivers for TES adoption and identify international learnings from more mature district heating markets.

Table 2: Interview sampling strategy – country

Country	Target	Actual
UK	20	24
Sweden	5	2
Denmark	5	7
Other European	5	5
Outside Europe	5	2

Using an existing knowledge base and after conducting initial background research, it was determined that Sweden and Denmark should be prioritised after the UK due to the prevalence of TES-integrated heat networks. Other European and North American geographies were included for a breadth of understanding from regions with relatively extensive TES-integrated heat networks.

Style and format

Five topic guides were developed in collaboration with DESNZ to support the facilitation of interviews. The topic guides were structured in line with the research questions, prompting the interviewer to ask broad, unbiased, and open-ended questions. Specific probing questions were asked depending on the direction of the interview (these directions were planned in advance).

The five topic guides were tailored to the following stakeholder groups: UK heat network operators, international heat network operators, UK heat network designers and consultants, international heat network designers and consultants, and TES manufacturers. For other relevant stakeholders, e.g. researchers or trade associations, these guides were adapted as needed. A complete guide can be found in the **Interview topic** guide Section.

Distribution Network Operator (DNO) Focus Group

Purpose and participants

The purpose of this focus group was explicitly to answer research question 3b restated here:

> Is there a role for heat networks combined with TES in providing flexibility to the electricity grid?
>
> i. What is the power sector's understanding of TES?
>
> ii. What benefit does the power sector envision for such an integration?

The target participants for this focus group were stakeholders from the UK grid transmission network and the UK's distribution network. DESNZ and CLT utilised existing networks for the focus group invitations and received attendance from the transmission and distribution networks.

The stakeholders held positions related to flexibility, innovation, and operations/commercial to get varied themes on the technical and commercial aspects of the benefits TES-integrated heat networks could provide to the electricity grid.

Format

The focus group was held during a 90-minute virtual session with two CLT facilitators and six stakeholders. Ahead of time, stakeholders were familiarised with the project background and research questions at hand, as well as being provided with a purpose statement for the focus group itself:

> "The objective of the focus group is to gauge current understanding and views on thermal storage in heat networks and determine the requirements for effectively utilising it for **grid services such as balancing and flexibility**. Your unique perspective on grid management challenges and opportunities is crucial for developing a comprehensive understanding of how thermal storage can be leveraged for grid services, complementing the views of district heating stakeholders."

During the focus group four themes were presented to participants to keep in mind during discussions:

i. Potential **benefits** and **opportunities** DNOs and Electricity System Operators (ESOs) see in leveraging thermal storage in heat networks for grid services such as balancing, flexibility, and more.

ii. Technical, regulatory, and operational challenges DNOs and ESOs foresee in integrating heat networks with the power grid.

iii. Current capabilities and preparedness to integrate thermal storage solutions.

iv. Thoughts on formal and informal relationships that could be developed between DNOs, district heating operators, and other stakeholders.

Open questions were asked in line with these themes, followed by probing questions. The specific structure of questioning was detailed in a topic guide, presented in full in the **DNO topic guide** Section. Participants were instructed to respond to the questions as honestly as possible to encourage natural discussion, with minimal intervention by the facilitators.

Before the research discussion, the session began with introductions.

Analysis: REA, interviews, and focus group

Interviews, the DNO focus group, and existing literature were analysed using a two-stage approach. First, each method was analysed separately. For the second stage, findings were then aggregated in a common analytical framework (in the form of a large matrix/table).

Thematic analyses for the literature review, interviews, and DNO focus group were both deductive and inductive. They utilised themes based on the research questions and interview guide and added emergent themes.

Broad themes and sub-categories and sub-sub-categories (“codes”) were identified through iterative data review. Due to the depth and breadth of data, a three-tiered approach was necessary to capture all relevant insights. An extensive framework (matrix table) was developed where each cell captured insights corresponding to a stakeholder or paper and a code. The matrix can be found in the **Analytical framework guide** section. Interviews were analysed against these themes and coded to be entered into the framework.

Interview topic guide

Below is one of five interview topic guides developed for the project. This guide is for UK heat network operators. “Likely directions” and “additional considerations” are included in questions and sub-questions where additional information was found to aid the interviewer.

Notes for interviewer

- Encourage open and honest dialogue, allowing the interviewee to speak freely and to control the narrative.
- Sub-questions represent follow-up prompts that should be asked as probing questions if they are not addressed naturally.
- Likely directions and additional considerations are provided where relevant to provide steers and support adaptability.

Before the interview begins confirm:

- The interviewee has received the privacy policy and interview information sheet.
- The interviewee is familiar with the anonymization process.
- The interviewee is happy for the call to be recorded and transcribed using the fireflies.ai software.

After the interview ends, confirm:

- If the interviewee is willing to be contacted for permission to use their name, position, and organisation against any quotes in the report or in communication with DESNZ.
- If the interviewee is willing to complete a cost proforma for any TES costs.

Section A: Background

(three minutes)

1. Can you please give me a brief overview of your position in your organisation and your experience with district heating networks

   Additional considerations: *Level of decision-making power when it comes to design/operations of heat networks. Clarify if in addition to district heating expertise, they also have communal heat network expertise.*

   a. How many years have you been working within the UK district heating industry?

   b. Do you have any parallel or complementary experience?

2. Can you please give me a brief overview of your heat network(s)?

   a. What type of heat sources and primary heat production technology do you use?

   Likely directions: *The interviewee may mention high-carbon heat sources (e.g., natural gas CHP systems and gas boilers) or low-carbon heat sources (e.g., geothermal, waste heat, or biomass).*

   b. Does your heat network(s) own the heat generation source?

   Likely directions: *Interviewee may mention partial ownership, e.g. of the back-up gas or electric boilers*

   Additional considerations: *There is a different commercial case for heat networks that purchase heat, versus those that own/control the heat source*

   c. Who are the heat networks' customers, and what type of buildings have the heat networks served?

   Likely directions: *Interviewee may mention building type, specific geographies, specific organisations, or something else.*

   d. What secondary heating technology does your network(s) use as a backup?

   Likely directions: *Interviewee may mention high carbon heat sources, low carbon heat sources, or interviewee may not use backup heating sources for their networks.*

Section B: TES coverage and application

(estimated time: five minutes)

3. If you use TES, do you use any type of TES besides hot water tanks?

    a. (If yes) What type?

    Likely directions: *Interviewee may mention aquifer TES (sensible heat storage), pit TES (sensible heat storage), borehole TES (sensible heat storage), phase-change material (latent heat storage), or thermochemical heat storage.*

    b. Why do you use that type?

    Likely directions: *Interviewee may mention cost, performance, skills, policy incentives, idiosyncrasies of the network(s') demand or technological maturity.*

    c. (If not) Why not?

    Likely directions: *Interviewee may mention technology limits, costs, reliability, skills, or policy incentives*

    d. (If interviewee doesn't use TES) Why not?

    Likely directions: *Interviewee may mention cost, performance, skills, policy incentives, idiosyncrasies of the network(s') demand or technological maturity.*

4. Are your TES systems located anywhere besides the energy centre?

    Additional considerations: *While TES at energy centres may balance overall supply and demand, any decentralised TES systems may address local needs and challenges within the heat network to integrate other heat sources, reduce heat losses, balance intermittent renewable sources, and more. These would be idiosyncratic depending on the network.*

    a. (If yes) Where?

    Likely directions: *Interviewee may mention TES in distribution network, at customer sites, or somewhere else.*

    Additional considerations: *Interviewee may challenge/ask for examples of non-conventional locations (e.g., not in energy centre). Suggest post interview follow up if so.*

    b. (If yes) Why that location(s)?

    Likely directions: *Local needs and challenges (see additional considerations above).*

    c. (If no) Why not?

    Likely directions: *For balancing overall supply and demand.*

5. Are there any other examples of TES technologies you have seen in the UK or abroad?

   Additional considerations: *Depending on time, might also be worth asking the penetration of TES implementation, and additional best practice/worst practice examples of TES deployment in the UK and abroad*

   a. Which types did you notice in the UK and which types have you come across that are not in the UK? Why is this the case?

Section C: Drivers and barriers for TES adoption at heat networks

(estimated time: 20 minutes)

6. What are the reasons for the network(s) using TES, if you do?

    a. (If managing demand fluctuations or demand resilience mentioned) How granular are the fluctuations that TES helps manage?

    Likely directions: *Interviewee may mention hourly demand fluctuations. daily demand fluctuations, weekly demand fluctuations, longer term seasonal storage, or something else.*

    b. (If managing supply fluctuations or heat availability mentioned) How granular are the fluctuations that TES helps manage?

    Likely directions: *Interviewee may mention hourly demand fluctuations. daily demand fluctuations, weekly demand fluctuations, longer term seasonal storage, or something else.*

    c. (If carbon savings mentioned) What carbon impact has TES had on your network?

    Likely directions: *Interviewee may mention reduced emissions from peak generation, improved integration of renewable energy sources, increased energy efficiency and reduced waste heat, or something else.*

    d. (If economics mentioned) What economic/cost benefits have you seen as a result of TES?

    Likely directions: *Interviewee may mention reduced energy costs, increased revenue from demand response programs, deferred or avoided capital investments (in equipment such as new boilers or peak* generation assets), revenues from ancillary services to the grid such as frequency regulation or spinning reserves, or something else.

    e. (If economics not mentioned) Why is economics not considered?

    f. (If future network expansion mentioned) How will TES contribute to expansion of the network?

    g. (If something else mentioned) How and why did TES enable or improve this area?

7. (If answer to question three, "do you use TES?", is yes) Did you seek any advice on implementing TES at your heat network?

    a. (If yes) What kind of advice did you seek?

    Likely directions: *Interviewee may mention technical feasibility assessments, guidance on selecting the appropriate TES technology, recommendations on sizing and designing the TES system, economic and financial analysis, regulatory and*

policy guidance, procurement and project management, system integration and optimization, or something else.

b. (If yes) How helpful or necessary was it, and why?

c. (If no) Why did you choose not to seek advice?

Likely directions: *Interviewee may mention internal skill capabilities in above areas, simplicity or inherent ease of process, or something else.*

8. Are there any benefits from TES integration into your network(s) that you're aware of but feel you can't access?

Additional considerations: *This might include ability to incorporate time of use electricity tariffs, onsite renewable generation or similar.*

a. (Ask for elaboration if yes or no)

9. Have you noticed a change in demand for/interest in TES in the heat network sector in the past five years?

a. (Ask for elaboration if yes or no)

Likely directions: *Interviewee may mention renewable energy integration, decarbonisation efforts, favourable policies, tech advancements, high upfront costs for TES technologies, something else (positive or negative), negative policies, space constraints or lack of awareness.*

10. Have you experienced any barriers in deploying TES at your heat network?

a. (If skills/expertise mentioned) You mentioned skills and expertise as a barrier. Could you elaborate on the specific areas where you face difficulties?

Likely directions: *Interviewee may mention barrier(s) regarding expertise on TES system design, expertise on TES system installation, expertise on TES system operation or something else.*

Additional considerations: *In-house expertise, supply chain and contractor knowledge.*

b. (If policy/regulations mentioned) You mentioned policy and regulation as a barrier. Could you elaborate on the specific areas where you face difficulty?

Likely directions: *Interviewee may mention specific policies and regulation, permitting and compliance policies, policy gaps or inconsistencies, or something else.*

Additional considerations: *Planning, grid connection rules, regulations, Health and Safety. Interviewee may specifically mention CP1 (CIBSE Code of Practice). Observed policy gaps/incentives.*

c. (If costs mentioned) You mentioned costs as a barrier. Could you elaborate on the specific areas where you face difficulty?

Likely directions: *Interviewee may mention operating costs as a barrier, capital costs as a barrier, something else.*

Additional considerations: *Inflation and materials costs change over time.*

d. (If performance mentioned) You mentioned performance as a barrier. Could you elaborate on the specific areas where you face difficulty?

Likely directions: *Interviewee may mention system integration, system control, maintenance, or something else.*

Additional considerations: *Consider system integration, control, maintenance, commissioning and handover.*

e. (If weather/climate mentioned) What about the weather or climate was a barrier for current TES deployment?

Likely directions: *Interviewee may mention current or future climate and/or weather patterns.*

f. (If planning/space mentioned) Could elaborate on why physical space was an issue for deploying TES at your heat network?

Likely directions: *Interviewee may mention planning requirements (regulations) or a physical space issue.*

g. Anything else?

Likely directions: *Interviewee may discuss other barriers (interviewer to refer back to "Prompts" column).*

Additional considerations: *Awareness of and familiarity with alternate TES technologies may be a factor.*

h. How does the control or ownership of the heat source (see answer to 1b) influence the deployment of TES at your heat network?

Likely directions: *Interviewee may mention flexibility, load shifting and peak saving, intermittency, operational coordination, economic benefits.*

Additional considerations: *Benefits may accrue directly to the heat network operator if heat source is owned/controlled by the network. Third party ownership of the source complicates the investment decision.*

i. How were the barriers overcome?

j. (If none mentioned) Why do you think implementation went so well?

11. To what extent is the installed TES system(s) being fully utilised and exploited?

    a. (If not at full operating capacity) Is running below full capacity deliberate, or are there any barriers affecting full utilisation?

    Additional considerations: *This question (and the following question 11b) may not be applicable depending on how the concept of "fully* utilised and exploited/full capacity" is understood. If there is confusion, skip to question c.

    b. How often are the installed TES in your heat networks not operating at full capacity?

    c. What factors influence the level of TES utilisation?

    Likely directions: *Interviewee may mention energy price dynamics, demand patterns and load profiles, the availability and integration of renewable energy sources, operational constraints and system configuration, economic incentives and market participation, policy or regulations, or something else.*

12. Do you think there are differences between TES use in heat networks in the UK versus internationally?

    a. (Ask for elaboration if yes or no)

Likely directions: Interviewee may mention technology leadership, cultural differences, climate/weather changes, policy frameworks, urbanisation patterns, or something else.

13. Are there any UK specific barriers to TES implementation or exploitation?

    a. (If space mentioned) Why do you think space is more or less of a problem in the UK?

    Likely directions: *Interviewee may mention urbanisation patterns or something else.*

    b. (If infrastructure mentioned) What kind of infrastructure is an issue in the UK for TES integration that isn't a problem elsewhere?

    Likely directions: *Interviewee may mention retrofitting challenges, retrofitting regulations, or something else.*

c. (If weather/climate mentioned) What about the UK's weather/climate is a problem?

Likely directions: *Interviewee may mention seasonal variations or something else.*

d. (If public perception mentioned) What about public perception makes TES integration trickier in the UK?

Likely directions: *Interviewee may mention cultural differences or something else.*

e. (If something else mentioned, e.g. barriers listed above) Why do you think this is more of a problem in the UK?

Likely directions: *Interviewee may mention technology availability, costs, or something else.*

f. (If none mentioned) Why do you think the UK does not face any specific barriers that aren't realised in other countries?

g. What about vice versa: how does the UK fare better, and why? (Refer back to prompts and likely directions above).

h. Of all the barriers we have discussed, was there any barrier which you would describe as the biggest?

Section D: Future role of TES at heat networks

(estimated time: 8 minutes)

14. Do you think there's a role for combining heat networks and TES to provide benefits to the wider electricity system?

    Additional considerations: *Check participants' awareness of the Innovate UK Strategic Innovation Fund programme.*

    a. Why or why not?

    Likely directions: *Interviewee may mention electricity demand management, costs, emissions or decarbonisation or something else.*

    b. (If yes) Have you attempted to engage with your energy supplier or the DNOs to explore this further?

    c. (If yes) What has been your experience of this?

15. What support do you think the heat network market would need in order to provide any benefits to the wider electricity system?

    a. What do you think the impact of this support would be?

    b. What are the perceived benefits of TES applications in future low-carbon heat networks?

    Likely directions: *Interviewee may mention reaching Net Zero or decarbonisation goals, costs, futureproofing against regulations, more reliability or better service offerings, or something else.*

16. Do you expect to see any changes in the TES market/sector in the future? If so, what changes?

    a. (Ask for elaboration if yes or no)

    b. Do you expect to see changes in costs, policies, incentives, awareness?

17. Is there anything that would enable greater TES usage?

    a. What would or wouldn't help and how or why would this be the case?

    Likely directions: *Interviewee may mention regulations/policy, technological innovations, market mechanisms and pricing structures, skills upgrades and design capabilities, integration of renewable sources, public perception and cultural changes, something else.*

18. Do you expect any new barriers to emerge specifically in future low carbon heat networks?

    a. If yes, what barriers might emerge, how would they emerge and why? If no, why don't you expect any barriers to emerge.

    Likely directions: *Interviewee may mention competition from emerging technologies, changes in energy mix and fuel sources, changes in regulation, changes in infrastructure and building stock, supply chain disruptions and resource scarcities, or something else.*

Section E: Wrap-up

(estimated time: 4 minutes)

19. Is there anything else you think is worth highlighting based on our discussion today?
20. Is there anything you'd like to add to any of your responses?
21. Is there anything you would like me to repeat?
22. Are there any other key benefits, challenges, or opportunities related to TES at heat networks that we haven't covered?
23. If you had a magic wand, what would you change about the market to increase the impact of TES technology at your network?
24. Is there anyone else you would recommend we speak with to further understand the roles of TES in the UK heat network sector?
25. Remind interviewees to complete the cost proforma.

Interview information sheet

The interview information sheet was distributed to prospective interviewees alongside the invitation and the CLT privacy policy.

Project Name: Exploring take-up and usage of Thermal storage (TES) in district heat networks

Interview instructions

Thank you for agreeing to the interview. Below is information regarding the interview process and the questions we'd like to ask you.

Aims and purpose of this research

We are working for the Department of Energy Security and Net Zero (DESNZ) to collect insights and evidence on thermal storage's role in heat networks. This initial stakeholder interview fieldwork process is part of a broader project to inform the UK Government's knowledge on the role of thermal storage in district heat networks (DHN).

Why have I been asked to participate?

You have been identified as having substantive experience deploying thermal storage (TES) in district heating systems. While you may or may not consider yourself an expert in TES technologies, we recognise that you have influenced decisions around the use of these technologies. We would, therefore, value your insight in supporting the government’s knowledge of how thermal storage is or can be used as part of heat network delivery and operation.

What are the primary objectives of this research?

We want to cover the following topic areas with you in our interview:

1. How do thermal storage technologies currently feature (with regards to usage and technologies) in heat networks in the UK and internationally?
2. Why is TES used in heat networks in the UK currently?
3. How will TES be used in heat networks in the future?
4. What are the current costs and future cost projections associated with TES for a heat network operator?
5. What can we learn from international examples of TES use in district heating?

How will the information gathered from the interview be processed, stored and used?

To ensure we maximise the value captured from our interview with you, we would like to record and transcribe the interview using the AI tool Fireflies. Neither the recording nor the transcript will be shared outside of the Carbon Limiting Technologies' delivery team on this project, and both will be deleted from our secure servers by the 31st of March 2025. **We kindly ask that you let us know ASAP if you are uncomfortable with the interview being recorded**. We will re-confirm with you at the start of the interview before we start recording.

The lead interviewer will take detailed notes and issue these to you for review after the interview. You will have the opportunity to amend, delete, and mark any confidential elements that you do not wish to be included in or have attributed to your organisation in the final findings. We kindly ask that any edits be made within 3 working days of the transcript being issued.

All information you provide will remain confidential, in line with the General Data Protection Regulation (GDPR) 2018. This means that we will not tell anyone, including the DESNZ, what your organisation has said. However, owing to a small pool of people and examples, there may be identifiable respondents. There may be instances where we would like to name your organisation as a case illustration in the report. In these instances, we would seek your consent before doing this.

You are fully entitled to withdraw from the research at any time, and we will delete any information relating to interviews or other correspondence within 48 hours of this notice.

A note on the TES data proforma

For some interviewees (mainly operators), we will issue a TES data proforma before the interview to help us understand technical data and capital investment in Thermal storage technologies. The proforma MS Excel file will include instructions on its use. We request that, where reasonable, this be completed and returned to us before the interview date.

Privacy Notice

Please review our privacy notice for further details on fair processing and how personal data is stored, processed, and used.

DNO topic guide

Below is the topic guide for the DNO focus group. Questions and sub-questions where additional information would aid the interviewer include “Likely directions” and “additional considerations.”

Notes for facilitator:

- Encourage open and honest dialogue, allowing the interviewee to speak freely and to control the narrative.
- Sub-questions represent follow-up prompts that should be asked as probing questions if they are not addressed naturally.
- Likely directions and additional considerations are provided where relevant to provide steers and support adaptability.

Before the interview begins confirm:

- The participants have been made aware of the privacy policy.
- The participants are familiar with the anonymization process.
- The participants are happy for the call to be recorded and transcribed using the fireflies.ai software.

After the interview ends confirm:

The participants may be contacted for their permission to use their name, position, and organisation against any quotes in the report or in communication with DESNZ.

Introduction:

(10 minutes)

Cover the following pillars of the focus group:

Confidentiality: Explain that while the overall findings may be shared, individual comments will remain anonymous. Participants should agree not to discuss others' contributions outside the group.

Respectful discussion: Emphasise the importance of treating all participants with respect, even when disagreeing. No personal attacks or offensive language should be tolerated.

One speaker at a time: Ask participants to avoid talking over each other. This ensures all voices are heard and aids in clear recording of the session.

Active participation: Encourage everyone to contribute their thoughts and experiences. There are no right or wrong answers.

Stay on topic: While some deviation is natural, remind participants to keep their comments relevant to the research questions at hand.

Honesty: Stress the importance of genuine responses. The government is seeking authentic feedback, not what participants think they want to hear.

Time management: Inform participants of the session's duration and any breaks. Ask them to be mindful of time when speaking to ensure all topics are covered.

Clarification is welcome: Encourage participants to ask for clarification if they don't understand a question or concept.

Voluntary participation: Remind participants that while their input is valued, they have the right to not answer specific questions if they feel uncomfortable.

Recording consent: Inform participants that the session will be recorded and obtain their consent. Explain how the recordings will be used and stored.

Section A: Background and current heat network interaction with the electricity system

(15 minutes)

1. Can you please explain your role in the DNO and your background in the industry?
    a. How many years have you been working within the electricity distribution industry?
    b. Did you work with other (gas?) utilities, and if so, how?
2. Have any of you worked with electricity networks experiencing capacity issues?
    a. If so, what are they?

    Likely directions:

    i. The group may mention supply bottleneck affected by planning permissions, limited investments and community resistance

    ii. The group may mention increase demand for connection not met by supply

    iii. The group may mention reliability issues due to more renewable generations

    iv. The group may mention something else

    b. How are these issues resolved or managed currently?

    Likely directions:

    i. The group may mention greater network reinforcement

    ii. The group may mention peak demand management via electricity optimisation or flexibility

    iii. The group may mention something else

3. What is your understanding of district heating and how it interacts with the electricity grid currently?
    a. What type of heat sources and primary heat production technology in district heating are you aware of?

    Likely directions:

    i. The group may mention electricity generation (e.g. via CHP, EfW)

    ii. The group may mention electricity consumption (via heat pumps, electro-boilers)

    iii. The group may mention something else

4. Are you aware of the use of thermal storage in district heating?
    a. If yes, what do you think are the main reasons for heat networks to use TES?

Section B: Drivers and barriers for utilising heat networks with TES for electricity system optimisation

(estimated time: 40 minutes)

5. Do you expect the UK electricity grid to experience capacity issues as we move towards a low carbon future?

    a. If yes, how so?

    Likely directions:

    i. The group may mention increase in peak demand or grid capacity

    ii. The group may mention reliability issues due to more renewable generations

    iii. The group may mention something else

    b. If not, why not?

    c. What innovations have you or are you looking to explore to improve the efficiency and reliability of future electricity network?

    Likely directions:

    i. The group may mention smart or intelligent grid

    ii. The group may mention integration with other utilities

    iii. The group may mention something else

6. Do you see a role for combining low carbon heat networks and TES to provide benefits to the wider electricity system?

    a. Why or why not?

    Likely directions:

    i. The group may mention grid capacity, electricity demand and supply fluctuations, management and/or optimisation

    ii. Grid balancing

    iii. The group may mention costs

    iv. The group may mention emissions or decarbonisation

    v. The group may mention something else

    Additional considerations:

    vi. Check awareness of the Innovate UK Strategic Innovation Fund programme

7. What is your view on whether low carbon heat networks can still provide benefits to the wider electricity system without TES?

    a. If so, in what ways?

    b. If not, why not?

    Likely directions:

    i. The group may mention electrified heat networks increase the load of the grid.

8. (If yes to Q6) Have you had any engagement, or intend to engage with heat network developers to work on realising these benefits?

    a. If yes, can you elaborate?

9. How might thermal storage in low carbon heat networks help manage future peak electricity demand in the area your DNO operates?

    a. The group may mention energy price dynamics

    b. The group may mention electricity demand and load profile changes and peak demand management

    c. The group may mention the excessive electricity generation from greater renewable integration

    d. The group may mention operational constraints and system configuration

    e. The group may mention economic incentives and market participation

    f. The group may mention policy or regulations

    g. The group may mention something else (see especially barriers above)

10. What support would the electricity market need to overcome the barriers mentioned in order to realise the benefits of TES integrated heat networks?

    a. The group may mention policies / regulations

    Likely directions:

    i. The group may mention electricity market reform and pricing

    ii. The group may mention energy security

    iii. The group may mention the Network Innovation Allowance / Competition (NIA / NIC)

    iv. The group may mention balancing mechanism

    v. The group may mention demand response or flexibility services

    vi. The group may mention frequency response

b. The group may mention investments

Likely directions:

i. The group may mention the RIIO framework - where DNOs can additional value through delivering value to customers through innovation

c. The group may mention supply chain

Likely directions:

i. The group may mention smart grid, AI, electricity optimisation technologies

ii. The group may mention skills/expertise or workforce

d. What do you think the impact of the aforementioned support would be?

Likely directions:

i. See RIIO, NIA, NIC, flexibility services, customer satisfaction, decarbonisation goals, network loss reduction

11. Are you aware of, or do you expect any barriers in realising the benefits that low carbon heat networks with TES could bring to the electricity system?

Likely directions:

i. The group may mention insufficient expertise or knowledge on how heat networks can integrate with and help optimise the electricity networks.

ii. The group may mention insufficient skilled workforce.

iii. The group may mention policy and regulation gaps or inconsistencies

iv. The group may mention supply chain issues and resource scarcity

v. The group may mention costs and investments

vi. The group may mention something else

b. If yes, what barriers might emerge and why?

c. If no, why don't you expect any barriers to emerge.

Section E: Wrap-up

(estimated time: 10 minutes)

Analytical framework guide

After initial analysis (as described in the Analysis section) for the stakeholder interviews, DNO focus group, and literature review, insights were marked against the following large framework analysis (this was kept in table form on an Excel). An example interview is shown for expository purposes.

The following five themes emerged from the research questions, topic guides, and emergent themes from data-gathering.

1. Current State and Benefits of TES in Heat Networks
2. Barriers to TES Deployment
3. Costs and Economic Considerations
4. Efficiency and Storage Duration
5. The future of TES in heat networks

Insights were captured against categories and codes that emerged for each theme as highlighted below in the example interview with an Icelandic district heating consultant. If an interview did not cover a code, the cell was marked as a blank ("-"). Note that content has been abridged for expository purposes.

Table 3: Analysis framework for literature, interviews, and the DNO focus group (example interview presented)

Category	Code
1.1. Current use of TES	1.1.1 Types of TES technologies in use/ recommended/ manufactured 1.1.2. Types of TES technologies considered 1.1.3. Advice sought on TES 1.1.4. Integration with existing systems
1.2. Benefits of TES	1.2.1 Cost savings 1.2.2 Carbon reduction 1.2.3 Energy security 1.2.4 Performance 1.2.5 Other benefits

Category	Code
2.1. Technical Barriers	2.1.1 Technological maturity 2.1.2 Integration with existing infrastructure 2.1.3 Space and location constraints 2.1.4 Operational inefficiencies 2.1.5 Expertise and skills 2.1.6 Other Technical Barriers
2.2. Economic Barriers	2.2.1 Upfront capital costs 2.2.2 Operational costs 2.2.3 Financial incentives and funding 2.2.4 Other Economic Barriers
2.3. Evidence Gaps	2.3.1 Lack of comprehensive case studies 2.3.2 Insufficient performance data 2.3.3 Gaps in economic impact analysis 2.3.4 Integration challenges 2.3.5 Uncertainty in long-term performance 2.3.6 Variability in system performance across regions
2.4. Regulatory and Policy Barriers	2.4.1 Planning regulations 2.4.2 Policy support and frameworks 2.4.3 Market structure and incentives 2.4.4 Other Regulatory and Policy Barriers
3.1. Current Costs of TES	3.1.1 Installation costs 3.1.2 Maintenance and operational costs 3.1.3 Cost comparisons with alternatives
3.2. Cost Trends and Projections	3.2.1 Historical cost trends 3.2.2 Future cost projections 3.2.3 Economic drivers of cost changes
4.1. Efficiency Metrics	4.1.1 Peak demand shift percentages 4.1.2 Seasonal efficiency variations 4.1.3 Comparative efficiency with other storage solutions

Category	Code
4.2. Storage Duration	4.2.1 Short-term storage capabilities 4.2.2 Long-term storage capabilities 4.2.3 Impact of storage duration on network performance
5.1. Technological innovations and integration	5.1.1 Emerging materials and advanced technologies 5.1.2 Integration with smart grids, IoT, and renewable energy sources
5.2. Policy, market trends, and future research	5.2.1 Future policy directions, regulations, and other incentives which will increase TES usage 5.2.2 Predicted market growth, consumer demand, investment opportunities 5.2.3 Ongoing research, pilot projects, collaboration between stakeholders
5.3. Future barriers that are not currently realised	5.3.1. Technical barriers 5.3.2. Regulatory barriers 5.3.3. Economic barriers 5.3.4. Other barriers

Separate from the analytical framework above, any case studies or quotes that the researchers thought were particularly relevant were kept and categorised separately based on stakeholder (for interviews and focus groups) and/or geography (for literature).

This publication is available from: www.gov.uk/government/publications/exploring-the-take-up-and-usage-of-thermal-energy-storage-in-heat-networks

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