UK Government

RAF119/2122: Evaluation of the Green Heat Network Fund

Interim Process and Impact Evaluation of the GHNF Main Scheme: Report Annexes

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Contents

Annex 1: Evaluation Questions

The evaluation is designed to respond to a set of evaluation questions. This annex lists the evaluation questions considered as part of this evaluation report.

Process Evaluation Questions

Overarching process evaluation question

- PEQ1: What works and what does not, for whom, when, how, and in what context for the different types of applicants throughout the scheme's stages, for commercialisation and construction awards and for construction only awards?

Questions on the design of the GHNF

- PEQ7: Which parts of the design and delivery of the scheme enable or frustrate the desired impact of the programme? How, why, and in what ways?
- PEQ5: What lessons can be learned for future heat network capital schemes in terms of barriers and enabling forces /trends, and how they interact with other heat network policies (zoning, market regulation) and other policies (e.g. levelling up, fuel poverty etc.)? How has the time-limited nature of government capital expenditure impacted on the outcomes seen?
- PEQ4: How are projects interacting with and navigating the supply chain to deliver the market transformation commitments (MTCs)?
- PEQ6: To what extent have projects changed their initial design to: a) integrate a LZC heat source as a result of GHNF Main Scheme funding? B) comply with the exclusion of residential new build "island" networks?

Questions on the GHNF application

- PEQ8: What is the experience of the overall application process, and how does this vary by applicant or project type and why?
- PEQ9: Are the eligibility and scoring criteria suitable? A) How have scheme changes from R6 impacted the suitability of eligibility and scoring criteria? Has there been any impact on the number or quality of bids? B) Is there any gaming, and if so, how does this impact the delivery of GHNF Main Scheme?
- PEQ10: What types of projects are successful/unsuccessful at the application stage, and why? At what points are applicants dropping out and why?

Questions on the GHNF delivery

- PEQ3: How is the scheme being delivered and what improvements can be made?

- PEQ11: What happens between application success and initiation and are there any recurrent procedural blocks?

Questions on communication and guidance

- PEQ2: How effective has the communications, support and guidance been in supporting projects progress in all stages of the GHNF Main Scheme project cycle (pre-application, application, post-award)?
- PEQ15: How is GHNF Main Scheme being communicated to applicants? Are certain methods more or less effective depending on the applicant type?
- PEQ19: How effective have the post-award communications, guidance and support for sponsors been in ensuring projects efficiently move through the development, commercialisation, build, commissioning and initial operation stages?
- PEQ20: Is the guidance and support meeting the needs of projects?

Questions on barriers to application

- PEQ12: What has prevented potential applicants from applying? a) Have any changes to the scheme requirements posed a barrier to applicants from those who would otherwise have applied? Have changes had any impact on applicant intentions to apply? b) Had changes been in place for R1-5 applicants, what would the impact have been for these applicants?
- PEQ13: How has the low-carbon requirement impacted the types of projects that are successfully applying?
- PEQ14: To what extent are the following barriers to applying to GHNF Main Scheme? Finances, legal expertise, technical expertise, availability of data for baselining/ estimating benefits, process being complicated, policy landscape (e.g. zoning), rising energy and inflation costs, Brexit related supply chain issues. Electricity grid constraints, access to skilled contractors and materials.

Questions on project experience

- PEQ16: What has the overall experience been for project types and different stakeholders? A) Has the experience of LAs grantees been different to the experience of other public sector and private sector grantees, and have their outputs and outcomes been different as a result? B) What has the experience been of local authorities in managing their heat network project? C) How has experience of projects been impacted by scheme changes (e.g., investment decisions, delivery timelines, approach to project)? D) What has the experience been of projects who were able to secure alternative funding?
- PEQ17: What types of projects are successful/unsuccessful at the development, commercialisation and build stages and why?
- PEQ18: How do outcomes differ between projects and why? In particular, how does this vary across different contexts? – e.g., in terms of accessing funding or in terms of readiness in applying to GHNF Main Scheme.

- PEQ21: Has the low-carbon requirement created any difficulties for projects during the application, commercialisation and construction phases? How has the embodied carbon element of the MTCs impacted projects/applicants?

Questions on project progress

- PEQ22: Are projects on track to deliver forecast benefits and outcomes?
- PEQ23: Are projects on track to deliver on time and budget? If not, what barriers have influenced this?
- PEQ24: Will annual funding allocations be spent? If not, why? What bottlenecks have been identified? If not, what are the actual/ anticipated consequences of this, and are mitigations being planned?
- PEQ25: Do particular types of projects experience delays or unexpected costs, and could these be identified earlier at application stage? In particular, what has been the role of the wider context (e.g. inflation, energy pricing, Brexit related supply chain issues)?
- PEQ26: What has the experience been like with projects providing timely and/or accurate application and monitoring data? Where reporting has been poor, what are the reasons for this, and what further support can DESNZ offer to improve reporting?

Impact Evaluation Questions

General

- IEQ1: What are the impacts of the scheme and how were these achieved, for whom, when, how, and in what context – for the different types of projects and stakeholders, namely private vs LA, applicants /grantees, investors, supply chains, heat network customers? a) what have successful projects done and achieved with the funding? What have unsuccessful projects done and achieved without the funding? b) how has the overall heat network market composition shifted as a result of the fund?
- IEQ2: Is the scheme delivering on its objectives?
- IEQ4: What impact did projects' Market Transformation Commitments have (and how were these perceived) by: projects/applicants; supply chain; collaborators; local economy? Were these managed effectively? To what extent have projects developed against their commitments?

Impact on Carbon Savings and Heat Delivered

- IEQ3: What outcomes is the scheme delivering in terms of: - carbon savings and carbon intensity; the number and type of heat networks; the amount of additional low-carbon heat delivered.

Impact on the Projects

- IEQ6: What effect is GHNF Main Scheme having on sponsors/projects' capability, capacity and skills, and what are the mechanisms involved? a) To what extent would changes have occurred without GHNF funding? b) What impact, if any, have scheme changes had on local authority capacity to deliver heat network projects
- IEQ23: What was projects experience of seeking and securing finance prior to applying to GHNF?
- IEQ24: What effect has offering commercialisation and construction funding separately had? Does the amount of additionality differ between the different types of funding or by different types of organisations?

Impact on Consumers

- IEQ7: What effect is GHNF Main Scheme having on consumer awareness, attitudes and behaviour towards heat networks and transitions to sustainable heating, and what are the mechanisms involved? Are there any specific groups of consumers for whom the intervention worked better /worse?
- IEQ21: To what extent are projects facing difficulties in terms of consumer willingness to connect with heat networks and how does this differ by stakeholder type (e.g. domestic, commercial and public sector)? Did project expectations of connection to Heat Networks at application stage match reality?

Impact on Investors

- IEQ10: What effect is GHNF Main Scheme having on the heat networks investment and what are the mechanisms involved, in terms of: the number and type of investors; whether investor behaviour has changed; if investors are planning to invest more into heat networks in the future?
- IEQ11: How has GHNF Main Scheme contributed to overcoming barriers to heat networks investment? To what extent is demand risk and construction risk still a barrier for investment?
- IEQ12: Did GHNF Main Scheme effectively address funding gaps and low-carbon technology competitiveness? If so, how? If not, why?
- IEQ13: How are investors making their decisions? What support is needed? a) for projects who have received debt / equity prior to GHNF, how does this influence investor decision-making?
- IEQ22: What impact, if any, has the requirement for projects to seek alternative finance had on the heat network investment market and on investor confidence?

Impact on the Supply Chain

- IEQ14: What effect is GHNF Main Scheme having on the supply chain and wider market (e.g. on awareness, attitudes, needs and behaviours) and what are the mechanisms

involved? Has it affected particular groups of supply chain actors better /worse than others? What effect did the scheme have on projects engagement with the supply chain and market. Have they seen any new market entrants?

- IEQ15: Have projects experienced any barriers or constraints that have impacted on their ability to access low-carbon heat? (for example, waste heat)? Have projects been able to utilise the opportunity of mine water as a heat source? Are there any specific barriers relating to this?
- IEQ16: How is supply chain behaviour changing and what further barriers remain to a sustainable heat networks market?
- IEQ17: How is the scheme creating and supporting jobs in the energy efficiency and low-carbon heat sector? Are these jobs new market entrants or existing installers reskilling or certifying to the required standard? Is there evidence of investment in skills in the supply chain?
- IEQ18: Did the Delivery Partner's Social Value commitments support building capability, capacity and skills in the supply chain and wider market?

Impact on Wider Policy / Context

- IEQ19: To what extent has GHNF Main Scheme successfully integrated with other BEIS policy objectives, such as the future homes standard or heat network market framework, or other HNTP policies? What are the barriers or enablers to this integration?

Annex 2: Realist Analysis

Introduction

This annex presents findings from an analysis of 20 qualitative interviews conducted by CAG Consultants as part of the evaluation of the Green Heat Network Fund (GHNF). The work involved conducting semi-structured interviews with GHNF Non-Applicants, Applicants, Unsuccessful applicants, Successful applicants, and Investors, as agreed with the Department for Energy Security and Net Zero (DESNZ).

The candidate CMOs that were tested for each stakeholder group are presented, along with a summary of the findings in one table per stakeholder group. Each of these tables are followed by a table detailing the revised CMOs for each stakeholder group, based on the findings.

The insights generated through this analysis are summarised within the synthesised findings in the main report.

Non-applicant theory

Candidate CMOs for non-applicant theory

The candidate CMOs for the 'non-applicant theory' are set out in Table 1 below. They describe the research team's starting hypotheses about why, and in what circumstances, eligible applicants decided not to apply for GHNF support. The candidate CMOs were intended to be mutually exclusive (i.e. it was expected that one CMO would apply to each case) and are summarised here:

A1 – Interested but scheme ineligible for GHNF support

A2 – Viable and eligible low-carbon scheme but lack of support

A3 – Viable low-carbon scheme but lack of capacity and or capability

A4 – Would have applied if had been aware of the scheme

A5 – Has an eligible scheme, considered GHNF, but found it be unattractive and chose to proceed with a 'high carbon' scheme

A6 – Alternative funding available for a low-carbon scheme and preferred to use this rather than bid for GHNF.

Only three non-applicants were interviewed for this research, meaning that not all of the candidate CMOs were tested for this stakeholder group.

Table 1: Candidate CMOs for non-applicant applicant theory

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
A1: Prospective applicant has a potential scheme, but it is ineligible for GHNF support.	Potential applicant is involved in heat network development and has a potential low-carbon project. They have looked at the scheme guidance, but their proposed scheme(s) is/are ineligible for GHNF support. • Organisation is aware of the GHNF. • Organisation attracted by the prospect of grant funding. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Local and/or national policies are strongly supportive of low-carbon heat network developments. • Some level of non-GHNF match funding available but business case and internal support reliant on GHNF support. • Access to alternative sources of financial support for low-carbon DH solutions either don't exist or, where available, the associated	GHNF grant funding for commercialisation and or capital works.	We view GHNF support as being attractive and we would have considered applying if our heat network project had been eligible.	GHNF application NOT submitted.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	conditions would make the business case non-viable. • GHNF scheduling fits with the applicant's project development cycle.			
A2: Prospective applicant has a viable and eligible low-carbon scheme but lacks senior support.	Potential applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation is aware of the GHNF. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • There is a lack of internal support for the proposed scheme (this may be owing to multiple factors including lack of match funding, other projects being deemed higher priority, concerns about cost inflation, scheme terms and conditions are deemed unattractive). Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Local and/or national policies are strongly supportive of low-carbon heat network developments.	GHNF grant funding for commercialisation and or capital works.	We considered applying to the GHNF, but the anticipated balance of risk vs reward associated with the proposed heat network development was unattractive to internal, particularly senior, stakeholders.	GHNF application NOT submitted (but may bid in a later funding round).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• GHNF scheduling does NOT fit with the applicant's project development cycle. • Heat networks (in general) are not an organisational priority.			
A3: Prospective applicant has a viable low-carbon scheme but lacks the capacity and or capability to develop a bid.	Potential applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation is aware of the GHNF. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Applicant organisation lacks the time and or the expertise to submit a bid. • GHNF scheduling does NOT fit with the applicant's project development cycle. Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Heat networks are not an organisational priority. • Local and/or national policies are strongly supportive of low-carbon heat network developments.	GHNF grant funding for commercialisation and or capital works.	We view GHNF support as being attractive and considered making a bid but decided that we did not have sufficient internal capacity or capability to develop a potentially successful bid.	GHNF application NOT submitted (but may bid in a later funding round).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• Some level of non-GHNF match funding available but business case and internal support reliant on GHNF support. • Access to alternative sources of financial support for low-carbon DH solutions either don't exist or, where available, the associated conditions would make the business case non-viable.			
A4: Prospective applicant, would have applied if had been aware of the scheme.	Potential applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation became aware of the GHNF too late to allow it to submit an application. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling Up strategy or similar). • GHNF scheduling fits with the applicant's project development cycle.	GHNF grant funding for commercialisation and or capital works.	We view GHNF support as being attractive and considered making a bid but didn't find out about the scheme until late in the day at which point it was too late to develop and submit a bid.	GHNF application NOT submitted (but may bid in a later funding round).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Local and/or national policies are strongly supportive of low-carbon heat network developments. • Some level of non-GHNF match funding available but business case and internal support reliant on GHNF support. • Access to alternative sources of financial support for low-carbon DH solutions either don't exist or, where available, the associated conditions would make the business case non-viable.			
A5: Prospective applicant, has an eligible scheme, considered GHNF, but found it be unattractive and chose to proceed with a 'high carbon' scheme') **Counterfactual**	Potential applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation is aware of the GHNF. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Business case supports a 'high' carbon solution without low/zero cost external funding. • Funding for a 'high' carbon solution available.	Availability of alternative (non-GHNF) funding.	We considered making a bid for GHNF support but chose not to as we have access to an alternative funding source which better suits our organisational needs and preferences.	GHNF application NOT submitted. Organisation chose to proceed with a 'high' carbon heat network development.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Local or national policies are not perceived/experienced as being strongly supportive of low-carbon heat network developments. • GHNF scheduling does not fit with the applicant's project development cycle.			
A6: Prospective applicant has access to alternative funding and preferred to use this rather than bid for GHNF) **<u>Counterfactual</u>**	Applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation is aware of the GHNF. • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). • Organisation has capacity and capability to develop a heat network scheme.	Availability of alternative (non-GHNF) funding.	We considered making a bid for GHNF support but chose not to as we have access to an alternative funding source which better suits our organisational needs and preferences.	GHNF application NOT submitted but organisation proceeds with a low-carbon HD development.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• Organisation prefers not to proceed with a bid to the GHNF as they have a preferred alternative funding option. Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Local and/or national policies are strongly supportive of low-carbon heat network developments.			
Summary of findings				
Evidence was found to support a refined version of CMO A4; two of the cases featured organisations with an active interest in developing a heat network and thought the GHNF was attractive, but both had only found out about the scheme relatively close to the time of interview. At the time of interview, neither had applied for GHNF support, but both anticipated doing so in the future. In the other case, the organisation did not apply because, despite being aware of and interested in securing GHNF support, they had determined that a partner organisation would make a more suitable lead applicant for funding. A new CMO (A7) has been developed to fit this applicant scenario. None of the cases provided evidence to support or refute CMOs A1, A2, A3, A5 or A6.				

Table 2: Revised CMOs for non-applicant theory (A4 and A7 only)

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
n/a	n/a	Common contexts (observed in all three cases): • Organisation became aware of the GHNF too late to allow it to submit an application. • Potential applicant is interested in heat network development and has a potential low-carbon heat network project.	n/a	n/a	n/a

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
		• GHNF scheduling fits with the applicant's project development cycle (implied not made explicit). • Organisation attracted by the prospect of grant funding.			
A4: Would have applied if had been aware of the scheme	Revised version of candidate CMOA4	In addition to common contexts: Potential applicant has a potentially eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). Other contexts (observed in one or more cases): • Potential applicant has not undertaken a techno-economic feasibility study and is unsure if they have a technically feasible scheme. In this case the potential applicant hopes GHNF funding can be used to assess the feasibility of a heat network. • The potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. In this case the potential applicant was unsure if match-funding for GHNF funding would be possible.	GHNF grant funding for commercialisation and or capital works.	We view GHNF support as being attractive but didn't find out about the scheme until late in the day at which point it was too late to develop and submit a bid. We hope to submit a bid in a later funding round.	GHNF application NOT submitted (but may bid in a later funding round).

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
A7: Prospective applicant considers application for an eligible scheme but determines that a project partner is better placed to submit an application.	New CMO	Potential applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • Organisation is aware of the GHNF. • Organisation attracted by the prospect of grant funding. • Another project partner is more suited to leading the project. Other possible contexts: • The applicant has previously received public support for the proposed heat network project.	GHNF grant funding for commercialisation and or capital works.	Another project partner was more suited to lead the scheme and therefore submitted the GHNF application and is now leading on the project.	GHNF application submitted by another organisation.

Applicant theory (reasoning behind application)

Candidate CMOs for applicant theory

Section Introduction

The candidate CMOs for 'applicant theory' describe the research team's starting hypotheses about why organisations applied to the GHNF, and the contexts that encouraged and enabled applications. The candidate CMOs potentially applied to both successful and unsuccessful applicants as the expected 'outcome' of submitting a GHNF application was the same in both cases. These candidate CMOs were intended to be mutually exclusive (i.e. it was expected that one CMO would apply to each case), as summarised here:

B1 – GHNF incentivises applicants to pursue a potential low-carbon heat network project rather than a 'high' carbon heat network.

B2 - GHNF is enabling the organisation to progress with a stalled low-carbon heat network project.

B3 – Applicant is keen to pursue a low-carbon heat network, but more information is needed to enable a final investment decision.

B4 – GHNF is not strictly necessary, but prospect of grant funding is too attractive to overlook.

The applicant theory was tested for two unsuccessful applicant cases and thirteen successful applicant cases. No distinction is made between successful and unsuccessful applicants in the findings below, as they all made the decision to apply to GHNF. The impact of GHNF funding in enabling projects to progress with an heat network development is discussed in the following sections on 'successful' and 'unsuccessful' applicant theories. The findings below focus solely on why applicants applied to GHNF and why they applied for commercialisation and/or capital funding.

Table 3: Candidate CMOs for applicant theory

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
B1: GHNF incentivises applicants to pursue a potential low-carbon heat network project rather than a 'high' carbon heat network.	Applicant has an eligible heat network project (could be a new heat network, expansion of an existing heat network, or a green retrofit). • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Access to alternative sources of financial support for low-carbon district heating solutions either don't exist or, where available, the associated conditions would make the business case non-viable. • Business case supports a 'high' carbon solution without low/zero cost external funding. • Funding for a 'high' carbon solution available. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling Up strategy or similar). • Organisation has sufficient time, and access to the necessary expertise, to prepare a bid. • Local and/or national policies are strongly supportive of low-carbon heat network developments. • GHNF scheduling fits with the applicant's project development cycle.	GHNF commercialisation and capital grant funding.	We had planned to develop a 'high' carbon heat network scheme but the availability of GHNF funding, together with internal Net Zero drivers, has incentivised us to explore the possibility of developing a low-carbon scheme.	GHNF application submitted for capital funding (may also bid for commercialisation funding, if B4 applies).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• Organisation confident that it can develop and manage the implementation of a low-carbon heat network solution. Other likely contexts: • Application is driven by local champion(s). • There is customer demand for/interest in low-carbon solutions. • Availability of grant funding is attractive in and of itself to key stakeholders. • The applicant has previously received public support for the proposed heat network project.			
B2: GHNF is enabling the organisation to progress with a stalled low-carbon project.	• Applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme, but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Access to alternative sources of financial support for low-carbon DH solutions either don't exist or, where available, the associated conditions would make the business case non-viable. • Some level of non-GHNF match funding available but business case and internal support reliant on GHNF support. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic	GHNF commercialisation and capital grant funding.	We have been wanting to develop a low-carbon heat network scheme but have been unable to do so owing to financial constraints. We applied to the GHNF as it provides us with an	GHNF application submitted for capital funding (may also bid for commercialisation funding, if B4 applies).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). • Organisation has sufficient time, and access to the necessary expertise, to prepare a bid. • Local and/or national policies are strongly supportive of low-carbon heat network developments. • GHNF scheduling fits with the applicant's project development cycle. Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Application is driven by local champion(s) • Customer demand for/interest in low-carbon solutions. • Organisation is confident that it can develop and manage the implementation of a low-carbon heat network solution. • Availability of grant funding is attractive in and of itself to key stakeholders.		opportunity to pursue our planned project.	
B3: Potential applicant keen to pursue a low-carbon heat	Applicant has an eligible low-carbon heat network project (could be a new network, expansion of an existing network or a green retrofit) • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible scheme,	GHNF commercialisation and capital grant funding.	We are keen to develop a low-carbon scheme but need to secure	GHNF application submitted for commercia

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
network but more information needed to enable a final investment decision.	but low/zero cost external funding is required for a low-carbon scheme to be financially viable. • Access to alternative sources of financial support for low-carbon DH solutions either don't exist or, where available, the associated conditions would make the business case non-viable. • Applicant has completed techno-economic studies and has 'a high degree of confidence' that the project will proceed but additional 'commercialisation' work is required to secure final buy in from internal stakeholders (finance and senior management) and investors. • Proposed heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). • Organisation has sufficient time and access to the necessary expertise to prepare a bid. Other likely contexts: • The applicant has previously received public support for the proposed heat network project. • Application is driven by local champion(s). • Local and/or national policies are strongly supportive of low-carbon heat network developments.		more information to inform our business planning and to enable us to make a final investment decision.	lisation and capital funding.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
B4: GHNF not strictly necessary, but potential applicant finds the prospect of grant funding too attractive to overlook. **Counterfactual**	Applicant has an eligible heat network project (could be a new network, expansion of an existing network or a green retrofit). • As a minimum, the potential applicant has undertaken a techno-economic feasibility study and has a technically feasible and economically viable low-carbon scheme. • Applicant has access to funding and an intention to develop a low-carbon heat network project. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). • Organisation has sufficient time, and access to the necessary expertise, to prepare a bid. • Local and/or national policies are strongly supportive of low-carbon heat network developments. • GHNF scheduling fits with the applicant's project development cycle. • Organisation confident that it can develop and manage the implementation of a low-carbon heat network solution. • Availability of grant funding is attractive in and of itself to key stakeholders. Other likely contexts:	GHNF commercialisation and capital grant funding.	We were planning to proceed with a low-carbon heat network project and are able to finance this work but were attracted by the idea of securing grant funding.	GHNF application submitted for capital funding (may also bid for commercialisation funding).

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• The applicant has previously received public support for the proposed heat network project. • Application is driven by local champion(s) • Customer demand for/interest in low-carbon solutions.			

Summary of findings

This section summarises findings on applicant theory. Evidence was found for refined versions of candidate CMOs B1-B3. CMO B4 was replaced by new CMOs B5 and B6.

There were multiple cases where the applicant applied to GHNF so that they could pursue a low-carbon heat network differently from what would have happened without GHNF funding. Several of these cases involved pursuit of a low-carbon heat network rather than building-level low-carbon heat solutions. Others involved pursuit of a low-carbon heat network that was bigger than it would have been without GHNF. Some cases involved a different heat source, while some involved local authorities applying to GHNF so that they could pursue a low-carbon heat network development over which they were able to exert control to better enable them to pursue wider strategic goals. In one case GHNF funding provided the incentive for a private firm to enter the market for low-carbon heat network development.

The revised CMOs for applicant theory are presented in Table 4. These CMOs are not mutually exclusive. For example, GHNF may have enabled earlier progression of a heat network project (B2) and also enabled a final investment decision to be made (B3) while also influencing the scale of the heat network project so that it better fitted the applicant's strategic objectives (B5).

Table 4: Revised CMOs for applicant theory

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
n/a	n/a	Common contexts for all applicants:	n/a	n/a	n/a

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
		• Techno-economic study completed. • Internal stakeholder support for outline business case. • Heat customers identified. • Fit with the organisation's strategic objectives. • Time and expertise to prepare application (from internal and/or external sources). • Local and national policies supportive of low-carbon heat network development. • Timing of GHNF application and delivery fitted with the applicant's project development cycle. • Applicant confident that they could develop and manage the implementation of their low-carbon heat network solution or procure a delivery partner to provide this expertise (subject to supply chain concerns).			
B1: GHNF is expected to enable applicants to pursue a	Refined	In addition to common contexts: • The applicant wanted to progress an eligible low-carbon heat network project.	Potential availability of capital funding from the GHNF.	GHNF capital funding made our upfront costs of pursuing a low-carbon network	Application made to the GHNF scheme for capital funding.

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
potential low-carbon heat network project rather than a 'high' carbon heat network.		• There was urgency to replace an existing high carbon heat network system. • Replacement with gas just fitted within the organisation's decarbonisation trajectory. • Capital contributions for the new system was required from private leasehold residents. • Leaseholders represented a significant minority of customers for the scheme.		equivalent to that of a gas replacement system, with future benefits for residents in terms of lower running costs and 'future proofing.	
B2: GHNF is expected to enable the organisation to progress a stalled low-carbon project.	Refined	In addition to common contexts: • Applicant wanted to progress an eligible low-carbon heat network project (including projects that would decarbonise and expand an existing high carbon heat network). • The project was complex and challenging to progress. The economic viability of the project was unattractive or marginal without GHNF funding.	Potential availability of capital funding from the GHNF and timelines for this funding.	GHNF capital funding provided us with a time-limited opportunity to use grant funding to improve the viability of our project, thereby enabling our internal stakeholders to progress the project and incentivising us to resolve the	Application made to the GHNF scheme for capital funding

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
				challenges involved in doing this.	
B3: Organisation is keen to pursue a low-carbon heat network, but more information is needed to enable a final investment decision.	Refined	In addition to common contexts: • Applicant wanted to progress an eligible low-carbon heat network project. • Remaining uncertainties to be resolved before the applicant and their partners reached a final investment decision. • Either the applicant or their partners were not readily able to fund additional commercialisation work themselves.	Potential availability of commercialisation funding from the GHNF.	GHNF commercialisation funding helps us to resolve remaining uncertainties about the project, without needing to take additional time to attempt to source 'at risk' funding from within our financially strapped organisation or partner organisations, with the risk that our project would be delayed or stalled.	Application made to the GHNF scheme for commercialisation funding.

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
B5: GHNF is expected to enable the organisation to progress a low-carbon heat project differently.	New	In addition to common contexts: • The applicant had strategic reasons for wanting to progress a low-carbon heat network project in a 'better' way (e.g. using a lower carbon or more innovative technology; at a larger scale; retaining more control by the applicant). • The capital cost of the project was greater (or the economic case was less viable or riskier) than for the alternative low-carbon option. • A less strategically advantageous version of the network would probably have been investable.	Potential availability of commercialisation and/or capital funding from the GHNF.	GHNF capital funding would improve the viability of our low-carbon heat network project compared to the alternative and enable us to progress the low-carbon heat network project rather than the alternative option.	An application being made to the GHNF scheme for commercialisation and/or capital funding.

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
B6: GHNF incentivises entry to the low-carbon heat network development market.	New	In addition to common contexts: • The applicant had the capability to progress low-carbon heat network projects. • The applicant perceived a significant scale of opportunity in low-carbon heat network development. • The applicant had a potential investment partner interested in investing in low-carbon heat network projects. • The applicant identified suitable, stalled low-carbon heat network projects which the relevant local authority did not want to progress. • The applicant's business model was dependent on initial grant funding.	The potential availability of commercialisation and/or capital funding from the GHNF.	GHNF funding supports the early stages of our business model and justify involvement of our investment partner.	Applications being made to the GHNF scheme for commercialisation and/or capital funding.

Unsuccessful applicant theory

Candidate CMOs for unsuccessful applicant theory

Section Introduction

The candidate CMOs for unsuccessful applicant theory presented the research team's starting hypotheses about why, and in what circumstances, organisations might or might not proceed with a project after an unsuccessful application. The candidate CMOs were intended to be mutually exclusive (i.e. it was expected that one CMO would apply to each case), as summarised here:

C1 – Applicant is unsuccessful and decides not to proceed with any form of heat network project.

C2 - Applicant is unsuccessful but considers that it still has a viable scheme and intends to continue to explore opportunities to develop its project.

C3 – Applicant is unsuccessful but able and willing to move forward with a 'high' carbon heat network project.

C4 – Applicant is unsuccessful but still able to pursue a low-carbon heat network project.

Only one unsuccessful applicant was interviewed during the research and therefore the candidate CMOs remain largely untested.

Table 5: Candidate CMOs for unsuccessful applicant theory

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
C1: Applicant is unsuccessful and decides not to proceed with any form of heat network project.	Internal support for a low-carbon heat network project has declined relative to other priorities as a result of the organisation's bid being unsuccessful. Other likely contexts: • Applicant feels unable to address the identified failings in its original submission. • Local or national policies are not perceived/experienced as being strongly supportive of low-carbon heat network developments. • Organisation has no interest in developing a 'high' carbon heat network project or is unable to do so owing to a lack of resource.	N/A	Our failure to secure GHNF support has led to a reduction in senior level interest in the proposed scheme and it has been shelved. We are now focusing on alternative priorities but may return to the project should circumstances change.	The applicant abandons its interest in developing an heat network development, at least for now.
C2: Applicant is unsuccessful but considers that it still has a viable scheme and intends to continue to	Continued strong support for a low-carbon scheme. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling Up strategy or similar).	GHNF commercialisation and capital grant funding.	Although unsuccessful our organisation remains keen to develop a low-carbon heat network project. We intend to explore our	The applicant continues to explore opportunities to develop a low-carbon heat network project.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
explore opportunities to develop its project.	• Local and/or national policies are strongly supportive of low-carbon heat network developments. Other likely contexts: • Application is driven by local champion(s).		options, but the absence of funding will delay us and compromises our ambitions.	
C3: Applicant is unsuccessful but able and willing to move forward with a 'high' carbon heat network project.	Internal support for a proposed low-carbon heat network scheme has declined, but there is support for a 'high' carbon project. • Local and/or national policies are not perceived/experienced as being strongly supportive of low-carbon heat network developments. • There is a business case for a 'high' carbon heat network project. • Funding for a 'high' carbon solution is available. • A 'high' carbon heat network development is supported by internal and external stakeholders as it enables them to deliver at least some of their strategic objectives. • Organisation has sufficient capacity and capability to develop a 'high' carbon heat network scheme.	Availability of alternative (non-GHNF) funding.	Our failure to secure GHNF support has led to a loss of senior level interest in a low-carbon heat network solution. However, we have a viable business case for a 'high' carbon development and are moving forwards with such a development as this will still help us to deliver against our ambitions.	The applicant moves forward with a 'high' carbon heat network project.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
C4: Applicant is unsuccessful but still able to pursue a low-carbon heat network project. **<u>Counterfactual</u>**	Applicant has a technically viable and economically feasible low-carbon heat network project opportunity, access to funding and an intention to pursue a low-carbon heat network development. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling • Up strategy or similar). • Local and/or national policies are strongly supportive of low-carbon heat network developments. • Organisation is confident that it can develop and manage the implementation of a low-carbon heat network solution. Other likely contexts: • Application is driven by local champion(s). • There is customer demand for/interest in low-carbon solutions.	Availability of alternative (non-GHNF) funding.	GHNF support was a nice to have rather than a necessity and we are still planning on proceeding with a low-carbon heat network project. This though may be smaller or take longer to deliver than would have been the case with GHNF support.	The applicant proceeds with a low-carbon heat network project.
Summary of findings				
Evidence was found to support a variant of candidate CMO C1. As there was only one interview conducted with unsuccessful applicants, no evidence is provided in relation to the other candidate CMOs.				

Table 6: Revised CMO for unsuccessful applicant theory

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
C1a: Applicant is unsuccessful and is unable to proceed with any heat network project due to development partner opting for a more cost-effective low-carbon heating technology.	New variant	Development partner support for a low-carbon heat network project has declined relative to other low-carbon heating solutions as a result of the organisation's bid being unsuccessful. Other contexts: • Applicant is dependent on its development partner's support in order to go ahead with a low-carbon heat network. • The development partner does not consider a low-carbon heat network to be financially viable without GHNF funding. • Reapplication to GHNF not considered feasible (e.g. development project timescales, changes to GHNF eligibility criteria). • The development partner has no interest in developing a 'high' carbon heat network project because of future building regulation changes (Future Homes Standard). • Developer's focus is on securing most cost-effective low-carbon heating solution. • Individual air source heat pumps offer a cheaper solution for heating new residential homes in the development than a low-carbon heat network.	Availability of alternative (non-GHNF) funding.	Our failure to secure GHNF support has led to our development partner losing interest in the proposed scheme because it is now not as cost-effective as an alternative low-carbon heating solution, and it has been shelved. The development partner is now (likely to be) focusing on an alternative heating solution for the development.	The applicant's development partner abandons its interest in developing an heat network development, at least for now.

Successful applicant theory

Candidate CMOs for successful applicant theory

The successful applicant theory applies to those cases where organisations were awarded commercialisation funding, capital funding or both. The successful applicant theory was tested for thirteen successful applicant cases. All applicant cases were successful in applying for capital funding, and eleven of the thirteen cases also received commercialisation funding. The findings below focus on the impact that access to commercialisation and capital GHNF funding has had on enabling heat network projects.

The candidate CMOs for successful applicant theory are summarised in Table 7

The candidate CMOs applied to those applicants who successfully applied for commercialisation, capital or both funding streams. As with the CMOs for applicant theory, these candidate CMOs for successful applicants were intended to be mutually exclusive. The candidate CMOs were:

D1: Commercialisation funding enables a final investment decision.

D2: Capital grant funding incentivises the development of low-carbon heat network projects rather than a ‘high’ carbon alternative.

D3: Capital grant funding enables the development of low-carbon heat network projects that would not otherwise have proceeded.

D4: Capital grant funding was useful but not essential to the development of low-carbon heat networks.

D5: ‘Participation in the GHNF scheme improves the capability of the heat network project development team (sponsor organisation).

Table 7: Candidate CMOs for successful applicant theory

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
D1: Commercialisation funding enables a final investment decision	Applicant has made a successful application to GHNF for commercialisation and capital grant funding. • Commercialisation activities needed to clarify project uncertainties and risks; process enables a final investment decision to be made. • Internal/external stakeholders are cautious about investing time and funding in heat network developments. • Government support provides reassurance to internal and external stakeholders (the assessment process is seen as providing an external sense/quality check of the project and the investment of funding provides tangible evidence that the Department for Energy Security and Net Zero feel that the project has a genuine chance of being successful and attracting external investment).	Commercialisation grant funding, in tandem with what is perceived as a rigorous approval process, overseen by an expert external agency (Triple Point).	We needed to undertake additional commercialisation work to inform the final business case. This process, in tandem with expert support from Triple Point, has been essential in assuring senior internal/external stakeholders that the process has been robust, and has been pivotal in enabling us to make a final investment decision.	Commercialisation work enables a final investment decision to be made. (project may or may not proceed depending upon findings).
D2: Capital grant funding	Applicant has made a successful application to GHNF for capital grant funding.	GHNF capital funding	The receipt of GHNF capital	A low-carbon heat network project

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
incentivises the development of low-carbon heat network projects rather than a 'high' carbon alternative.	• Organisation was considering developing a 'high' carbon heat network project but was incentivised to go low-carbon by the availability of the GHNF. • Non-GHNF match funding available but business case and internal support reliant on GHNF support. • Organisation confident that it can develop and manage the implementation of a low-carbon heat network solution. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). Other likely contexts: • The applicant has previously received public support for the proposed heat network project.		funding has allowed us to proceed with a low-carbon scheme that we would not otherwise have pursued.	(as opposed to a potential high carbon alternative) that would not otherwise have gone forward, proceeds.
D3: Capital grant funding enables the development of low-carbon heat	Applicant has made a successful application to GHNF for capital grant funding. • Organisation had previously identified a technically feasible low-carbon heat	GHNF capital funding.	The receipt of GHNF capital funding has allowed us to proceed with a	A low-carbon heat network project, that would not otherwise have

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
network projects that would not otherwise have proceeded	network, but it had been assessed as not economically viable. • Non-GHNF match funding available but business case and internal support reliant on GHNF support. • Organisation confident that it can develop and manage the implementation of a low-carbon heat network solution. • Low-carbon heat network development is supported by internal and external stakeholders as it complements their strategic objectives (e.g. heat network fits with Net Zero/jobs/regeneration/Levelling up strategy or similar). Other likely contexts: • The applicant has previously received public support for the proposed heat network project.		low-carbon scheme that we would not otherwise have pursued.	gone forwards (owing to a lack of commercial viability) proceeds.
D4: Capital grant funding was useful but not essential to the development of low-carbon heat networks.	Applicant has made a successful application to GHNF for capital grant funding despite being able to self-fund most/all of the proposed project.	GHNF capital funding.	We were planning to proceed with a low-carbon heat network project and did not need the capital grant funding, but it	A low-carbon heat network project proceeds.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
	• Organisation had previously identified a technically feasible and economically viable low-carbon heat network project. • Applicant intended to pursue a low-carbon heat network development and had access to funding. Other likely contexts: • The applicant has previously received public support for the proposed heat network project.		would have been irresponsible not to pursue it.	
D5: Participation in the GHNF scheme improves the capability of the heat network project development team (the sponsor organisation).	Applicant has made a successful application to GHNF for commercialisation and capital grant funding. • Project development team within sponsor organisation have scope to develop further capability, particularly around low-carbon heat networks.	Interaction with expert advisers (Triple Point and consultants) who undertake commercialisation activities.	We have developed greater technical and commercial expertise and understanding of low-carbon heat network developments as a result of our participation in the GHNF. This will better enable us to develop additional	Participation in GHNF helps to grow the sponsor organisation's capabilities in relation to low-carbon heat networks.

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
			projects in the future.	
Summary of findings				
Evidence was found to support revised versions of four candidate CMOs (D1, D2, D3 and D5). Revisions to the candidate CMOs principally involved changes to the mechanism (resources and reasoning). No evidence was found for the candidate CMO D4 where it could have been possible to proceed without the GHNF capital grant funding.				

Table 8: Revised CMOs for successful applicant theory

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
n/a	n/a	Common contexts for all applicants: • Projects not able to immediately go ahead. • Projects are impacted by changing markets and regulations.	n/a	n/a	n/a
D1: Commercialisation funding facilitates a final investment decision.	Refined	In addition to common contexts: • Additional expertise is needed due to technical challenges in adapting projects. • Managing complex relationships with partners and stakeholders.	GHNF commercialisation funding.	The commercialisation funding was key in finalising our detailed design, obtaining planning approval, or	A final investment decision (or similar decision) being made.

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
		• Co-ordination complexity increased by concurrent infrastructure projects in the same areas.		drafting our customer agreements and was important in securing support from senior stakeholders and project partners.	
D2: Capital grant funding incentivises the development of low-carbon heat network projects rather than a 'high' carbon alternative.	Refined	In addition to common contexts: • Increasing high carbon fuel costs. • Increase volatility in high carbon fuel costs. • Match funding for the heat network project helped to secured internal commitment.	GHNF capital funding.	GHNF capital funding made the costs to the final customers of our low-carbon heat network project equivalent to that of a gas replacement system.	A low-carbon heat network scheme going ahead that would not otherwise have proceeded.
D3: Capital grant funding enables the development of low-carbon heat network projects that would not otherwise have	Refined	In addition to common contexts: • Successful applicants aim to leverage current projects for future, larger-scale heat network expansions. • Perception that economies of scale crucial for heat network financial viability.	GHNF capital funding.	The GHNF funding helped to make our project financially viable by offsetting high capital costs, reducing cash flow risks and	The low-carbon heat network project proceeding in an enhanced, more

Summary description	Status	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
proceeded in an enhanced form.		• Support is needed to address funding gaps and commercial viability for heat network projects.		shortening timeframes.	strategic form.
D5: Participation in the GHNF scheme improves the capability of the heat network project development team (the sponsor organisation)	Refined	In addition to common contexts: • Successful applicants have a perceived lack of internal technical expertise. • Capacity constraints extended beyond technical areas, including needs for procurement, contractual, and legal expertise.	GHNF capital and or commercialisation grant.	Our involvement in the GHNF required us to engage more closely with the heat network development process.	Increased capacity, confidence and skills transfer in the sponsor organisation.

Investor theory

Candidate CMOs for investor theory

The candidate CMOs for investor theory describe the research team's starting hypotheses about why, and in what circumstances, investors were expected to respond to the GHNF. The candidate CMOs were not intended to be mutually exclusive, i.e. each CMO was expected to apply to each interviewee.

The candidate CMOs were:

- E1: Investors keen to invest in green projects
- E2: GHNF support increases investor confidence
- E3: GHNF capital grant support essential in ensuring a viable business case

Only three investors were interviewed for this research. All three were investment fund managers. This means that the revised CMOs were tailored to reflect the findings associated with this group. Research with other types of investors would be expected to generate a different CMO set, and those presented in this report should not be taken as representative of other types of actor within the wider investor community.

Table 9: Candidate CMOs for Investor theory

Summary description	Contexts	Mechanism – resources	Mechanism – reasoning	Outcome
E1: Investors keen to invest in green projects.	• Investors have access to capital and are motivated to invest in low-carbon projects. • External investors aware of heat network pipeline as a result of awareness and engagement activity undertaken by the Department, its predecessors and/or Triple Point. • Government support provides reassurance that the project is genuinely viable.	Investor has access to match funding.	We have strategic priorities relating to the Net Zero agenda and as a result we are keen to invest in economically viable low-carbon initiatives. GHNF supported schemes are attractive as they will have been carefully scrutinised and there is therefore a good chance that they represent a genuine investment opportunity.	Investors are actively looking at opportunities to invest in low-carbon heat network projects.
E2: GHNF support increases investor confidence.	Investors require high levels of due diligence work to minimise investment risk. Key context • External investors may require additional expert scrutiny of GHNF	Expert support (including paid for commercialisation studies), and a rigorous approval process,	We are risk averse. Schemes which are awarded GHNF capital grant support will have been subject to	Investors see GHNF supported schemes as relatively low risk.

	supported business plans, but the cost of such work is reduced.	overseen by an expert, external, agency (Triple Point).	considerable scrutiny and this gives us confidence that the project has a genuine chance of being successful (economically viable).	
E3: GHNF capital grant support essential in ensuring a viable business case.	In the absence of GHNF grant aid investors would consider the supported projects to be un-investable. Key context • Investors have minimum expectations in terms of return on investment.	GHNF capital grant support.	We would consider the business case for the supported project to be un-investible without grant support.	Investor chooses to invest in a GHNF supported low-carbon heat network project.
Summary of findings				
Evidence was found to support, in broad terms, each candidate CMO, i.e. investor interviewees confirmed that they are looking to invest in heat network projects and valued the role of the GHNF in reducing risk and underpinning the viability of low-carbon heat network business cases. However, the research generated considerable additional detail and a more nuanced understanding (albeit only for a single type of investor: investment fund managers) of investor motivations and concerns, and therefore the candidate CMOs were extensively revised. In the revised set, E1 provides insight into investment fund managers' wider perspective and decision-making process in relation to investment in the UK heat network market, and the role of GHNF in general terms. E2 and E3, meanwhile, focus on investor perspectives relating directly to the role of GHNF support in relation to project level investment decision making.				

Table 10: Revised CMOs for Investor theory

Summary description	Status	Observed contexts	Mechanism – resources	Mechanism – reasoning	Outcome
E1: Strategic investor attracted by supportive policy environment and significant market growth potential.	Refined	Investment fund manager manages one or more funds focused on low-carbon energy infrastructure. Key contexts: • Established infrastructure investor (not just energy). • Long-term investor holds assets for 10+ years. • Experienced heat network investor, holds non-UK assets, now looking to build up a UK portfolio and have acquired a UK based company. • Strategic approach: researched the UK market carefully before choosing to invest. Sees the UK as an underdeveloped market with considerable growth potential. • The availability of GHNF (and other supporting policy) is seen as evidence that the UK market is serious about heat networks (meaning that investors' strategic growth aspirations are more likely to be achievable).	Supportive policy environment, market opportunities, a demand for investable opportunities.	We are looking for low-carbon investment opportunities that are attractive to our investment community. The UK market has huge potential, but heat networks are complex, and challenging to develop. However, the UK has developed an increasingly supportive policy environment, and we have some confidence in the long-term direction of policy travel.	Investment fund manager investing at scale with a view to growing a portfolio of heat network assets over the long term.

		• Institutional investors (pension funds) are a significant investor. Such funds are associated with strong Environmental, Social, Governance (ESG) requirements. • Policy and ESG drivers mean that they are only interested in low-carbon heat network. • Interested in securing and developing heat network opportunities that offer significant growth (network expansion) potential over time.			
E1a: Investor attracted by supportive policy environment and the associated market opportunities.	New variant	Investment fund manager manages one or more funds focused on low-carbon energy infrastructure. Key contexts: • Established infrastructure investor. • Experienced heat network investor (UK and international experience). • Has previously invested in UK heat network projects, nearly all of which have received some form of government support. • Expect to hold onto heat network assets for several years. Institutional investors (pension funds) are a significant investor. Such funds are associated with strong	Supportive policy environment coupled with a demand for investable opportunities.	We are looking for low-carbon investment opportunities that are attractive to our investment community. The UK market has huge potential, but heat networks are complex, and challenging to develop. However, the UK has developed an increasingly	Investment fund manager actively looking at opportunities to invest in GHNF supported low-carbon heat network projects.

		ESG (Environmental, Social and Governance) requirements[1]. • Policy and ESG drivers mean that they are only interested in low-carbon heat network. • Has not invested in heat network recently owing to a lack of visible opportunities. • GHNF and other policy support mechanisms related to heat networks (e.g. zoning) are seen as evidence of government support for heat network developments in general (i.e. it is not just about one offs). • Is currently talking to some GHNF supported projects and may invest in the future. • Potential heat network investments have to align with the fund's Investment cycle.		supportive policy environment, and we have some confidence in the long-term direction of policy travel.	
E2: The award of GHNF support to a project increases investor confidence in it.	Refined	Investment fund manager manages one or more funds focused on low-carbon energy infrastructure. Key contexts: • Investors view heat network developments as complex and challenging (particularly in	Expert support (including paid for commercialisation studies), and a rigorous approval process, overseen by an expert external,	For this investment fund we have a relatively low tolerance for risk. Schemes which are awarded GHNF capital	Investors see GHNF support as reducing the risk of prospective investments in such schemes.

[1] ESG investing focuses on companies that follow positive environmental, social, and governance principles.

		the initial development stage) and therefore risky. Likely context: • Investor may undertake additional investment appraisal work in addition to GHNF funded activity.	agency (Triple Point).	grant support will have been subject to considerable scrutiny and this gives us confidence that the project has a genuine chance of being successful.	
E3: GHNF capital grant support is essential in ensuring a viable business case	Refined	Investment fund manager manages one or more funds focused on low-carbon energy infrastructure. Key contexts • In the absence of GHNF grant aid investors would consider the supported projects to be un-investable. • Investors have alternative opportunities, heat networks need to compete with other forms of project, including projects in other geographies.	GHNF capital grant support.	We are interested in investing in heat networks but for most low-carbon projects capital support funding is essential, and it is unlikely we would be investing in heat networks in the UK without it.	Investors, with an interest in heat networks, are looking for, or already investing in GHNF supported projects.

Annex 3: Qualitative Comparative Analysis

Introduction

QCA is a case-based method that enables evaluators to systematically compare cases, identifying key factors which are responsible for the results of an intervention. For the evaluation of the GHNF, this analysis was applied to 14 project 'cases', in order to identify patterns and provide insight into the conditions within a project context that enabler or hinder it in staying on track in its project delivery.

Conditions

Based on evaluation theories and emerging evidence from interviews, a set of potentially influential causal conditions were identified, as listed in the table below. For each of the 14 cases analysed, the presence or absence of each condition was graded on a scale of 0 (completely absent) to 1 (completely present) with data derived from a range of sources, listed below.

Table 11: QCA proposed causal conditions

Condition	Description	Data Source
Large Network (LN)	Size of the network, as coded by Triple Point in the GHNF pipeline document	GHNF Pipeline Dataset
Existing Network (EN)	Whether the network is existing or new	GHNF Application Dataset
Straightforward Heat (SH)	Whether the heat source is assessed to be more novel or less novel	GHNF Assessment Dataset
Own Heat (OH)	Whether the project's heat source relies on a third-party organisation, or is produced by the project	GHNF Application Data
Previous Experience (PE)	Whether the project team has existing prior experience	Evaluation Project Survey
Quality Feasibility (QF)	Extent to which the work completed prior to the GHNF was of a good quality	Evaluation Project Survey
Internal Support (IS)	Perceived strength of internal support for the project	Evaluation Project Survey
Straightforward Governance (SG)	Whether respondents consider the governance arrangements of their organisation to be straightforward	Evaluation Project Survey

Condition	Description	Data Source
High Turnover (HT)	Extent to which the project team has changed over the project lifetime	Evaluation Project Survey
Available Suppliers (AS)	Whether the project has been able to access good quality suppliers	Evaluation Project Survey

The outcome measure used for the QCA was the extent to which a project was considered on track, with those on track indicated by a (1) and those deemed as being off track by a (0). Individual project RAG ratings from the Triple Point team on progress were used as the data source, given their overarching view on whether a project is, or is not, on track. This insight was translated into fuzzy-set data to be analysed using fsQCA software. The full dataset with conditions and outcomes is included in Table 12 below.

Table 12: GHNF QCA Dataset

Case	LN	EN	SH	OH	PE	QF	IS	SG	HT	AS	Outcome
1	0	0	1	1	1	1	1	0.7	0.7	1	*1*
2	1	1	1	1	1	1	0.7	0.5	0.5	1	*1*
3	1	0	1	0	1	1	1	0.5	0.7	0.7	*0.5*
4	1	0	1	0	1	0.5	1	0.8	0.8	1	*0.5*
5	1	0	1	1	1	1	1	1	0.7	1	*1*
6	0	1	1	1	1	0.5	1	0.2	0.7	0.3	*0.5*
7	0	0	1	1	1	1	1	0.5	0.3	1	*0.5*
8	1	0	0.6	1	0	0.5	0.7	0.0	0.3	0	*0*
9	0	1	1	1	1	1	0.7	0.5	0.7	1	*1*
10	1	0	1	1	1	1	1	1	0.8	1	*1*
11	1	0	1	0	1	0.5	1	0.2	0.5	0	*0.5*
12	1	0	1	0	1	0.5	1	0.3	0.2	0.3	*0.5*
13	1	0	0.4	0	1	1	1	0.2	0.8	0.7	*0.5*
14	1	0	1	0	1	1	0.3	0.3	0.7	0.7	*0*

Findings

Truth Table Analysis

Analysis of the QCA truth table indicates the conditions that, when in combination, lead to the outcome. For the GHNF dataset, two pathways were identified that, when each condition is present/absent, the project will be able to stay on track. These pathways are shown in Table 13 below. The presence of a condition in the pathway is indicated by a bullet symbol (●) and the absence by a Tilde symbol (~). QCA convention indicates that a consistency score of greater than 0.8 suggests that pathways are sufficient to lead to outcomes, and as such, all other pathways that may have led to outcomes have been removed. The raw coverage score indicates the empirical instances of each pathway within the GHNF dataset.

The results highlight that, where a project used a more straightforward heat source and was producing their own heat, had prior experience and had conducted a high-quality feasibility study work, and had strong internal support and straightforward governance procedures, and had access to suppliers, they are likely to be able to progress their project as planned. Much less observed in the data was a pathway where the project did not produce its own heat and used a non-simple heat source, as well as had complex governance. In this case, where the project had previous experience, quality feasibility, internal support and access to suppliers, they were likely to stay on track.

Table 13: QCA Sufficient Conditions Analysis

Path	SH	OH	PE	QF	IS	SG	AS	Consistency	Coverage
1	●	●	●	●	●	●	●	1	0.517647
2	~	~	●	●	●	~	●	0.833333	0.0588235

Necessary Condition Analysis

QCA also allows for analysis of the conditions which are necessary to be present / absent to achieve a desired outcome. This type of analysis was applied to the GHNF dataset. Convention in the literature suggests that a consistency score of greater than 0.9 indicates that a condition is necessary. Therefore, as highlighted in Table 14 below, four conditions are identified as being necessary for projects to remain ‘on track, namely: (1) That the heat source for the network is straightforward; (2) That the organisation leading the project has previous experience; (3) The feasibility work completed prior to the GHNF portion of the project is of a high quality; and (4) There is strong internal support within the organisation for the project. A fifth condition, the availability of supply chain contractors had a high consistency score of over 0.89, indicating its high importance (if not quite at the threshold of a necessary condition).

Table 14: QCA Necessary Condition Analysis

Condition	Consistency	Coverage
Large Network	0.647059	0.550000
Existing Network	0.294118	0.83333
Straightforward Heat	**0.988235**	**0.646154**
Own Heat	0.705882	0.750000
Previous Experience	**1.000000**	**0.653856**
Quality Feasibility	**1.000000**	**0.739130**
Internal Support	**0.929412**	**0.637097**
Straightforward Governance	0.717647	0.910448
High Turnover	0.752941	0.761905
Available Suppliers	0.894118	0.783505

Limitations

Funded projects are heterogeneous, and the different conditions impact different projects differently. For example, one project may struggle to commercialise a novel heat source technology, whilst another, may not encounter issues. This means finding pathways of sufficient conditions that meet threshold consistency is challenging, which therefore limits the findings.

Additionally, those not responding to the GHNF participant survey were excluded from the analysis due to a lack of data. It may be the case that projects which are experiencing the most challenge in progressing their project were also those who did not respond to the survey, meaning the dataset analysed for QCA may be biased in favour of projects that have been able to successfully progress.

It is also the case, particularly for survey responses, that subjective judgements are made on the factors such as the quality of previous work, the level of internal support, or the straightforward nature of governance. Other data points are based on more objective measures, such as network size, whether it is existing, or whether it is producing its own heat.

Annex 4: Media Analysis

Introduction

Media monitoring forms part of the overall GHNF Impact Evaluation, assessing levels of awareness, and so informing assessment of the extent to which there has been dissemination and promotion of the programme and funded projects. The media analysis also comprised some sentiment analysis to assess the nature of coverage.

The primary focus of the media monitoring was to address IEQ7 - *What effect is GHNF Main Scheme having on consumer awareness, attitudes and behaviour towards heat networks and transitions to sustainable heating, and what are the mechanisms involved?*[2] *Are there any specific groups of consumers for whom the intervention worked better / worse*? Some data from the media monitoring might also be used to answer impact evaluation questions and evidence / assess the theory of change.

The metrics we aimed to observe through the media monitoring analysis were as follows (key metric in bold):

- **Increase in mentions of heat networks (in general) and green heat networks (specifically) over time, compared to pre-GHNF.**
- An increase in media reports regarding UK organisations that have (a) strategies specifically centred on heat networks and green heat networks; (b) incorporated green heat networks into their operations, including participation in the heat network supply chain.
- Evidence of the dissemination of GHNF findings, including events, webinars, newsletters, case studies, etc., by funded projects and their partners, as well as by sector bodies within the UK and potentially internationally.
- The extent of public announcements pertaining to funding for heat networks, whether originating from governmental or private sector sources.

Findings

This chapter presents a summary of key insights derived from our analysis.

Summary of findings

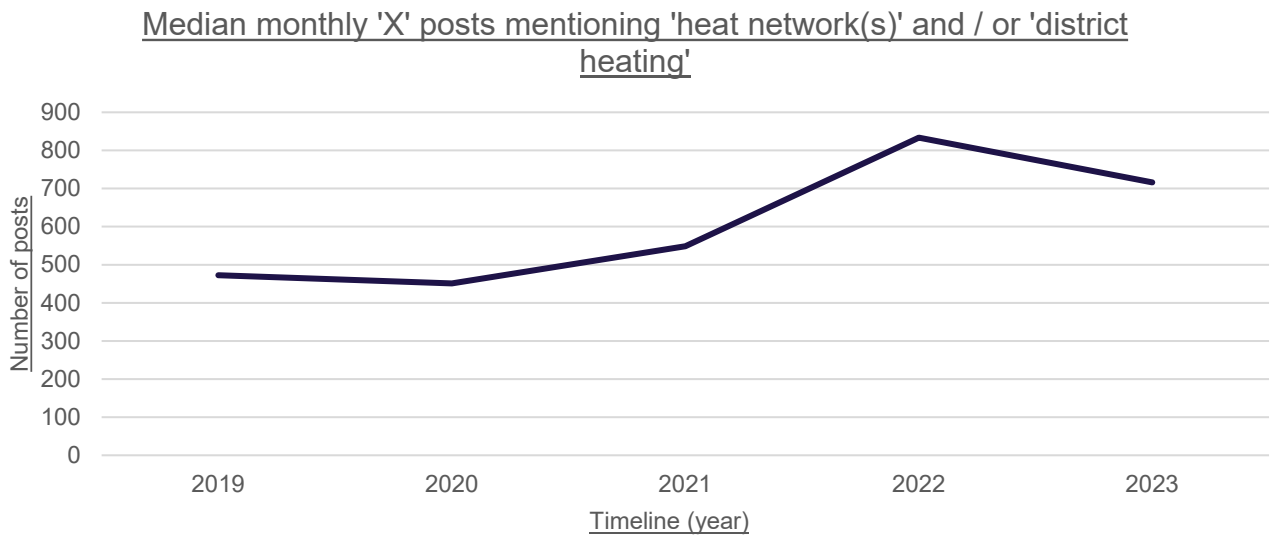
Both web scraping and media monitoring provide insights into the impact of the GHNF on consumer awareness, attitudes, and behaviour.

Figure 1 shows the median number of monthly ‘X’[3] posts referencing "heat network(s)" and/or "district heating" for each respective year. There was an increase from 2020 to 2022, but a

[2] Due to constraints in time and resources, our opportunity to explore the final part of IEQ7 was limited.
[3] Formerly known as Twitter

decrease was observed in 2023. The chart suggests varying levels of interest in heat networks over the period explored, but there is a broad increase overall.

Figure 1: Median monthly ‘X’ posts referencing 'heat network(s)' and / or 'district heating' (2019-2023)



Examining the trends in Non-'X' media references to “heat network”, “district heating” and “green heat network” over the examined period reveals an upward trend in the annual total number of publications over the years. The annual total number of publications for each respective year was as follows: 2019 (35), 2020 (55), 2021 (55), 2022 (63), and 2023 (83).

While representing only a small portion of the scraped heat network and district heating publications (4% of the total), the frequency of ‘X’ posts that mention the term "green heat network(s)" show a fluctuating trend in media coverage and discussions surrounding green heat networks over the years of interest. The number of posts mentioning the term 'green heat network(s)' increased over the years as follows: 2019 (4), 2020 (37), 2021 (64), 2022 (80), but saw a decrease in 2023 (71). While there was a notable increase in 2020 of 825%, 2022 recorded the highest number of posts (80).

The timing of peaks in 'X' posts mentioning 'green heat network(s)' appears to align with significant government announcements and GHNF milestones. Manual exploration of these articles indicates that they are primarily from industry bodies and industry media, reflecting government GHNF funding announcements and GHNF milestones. Notably:

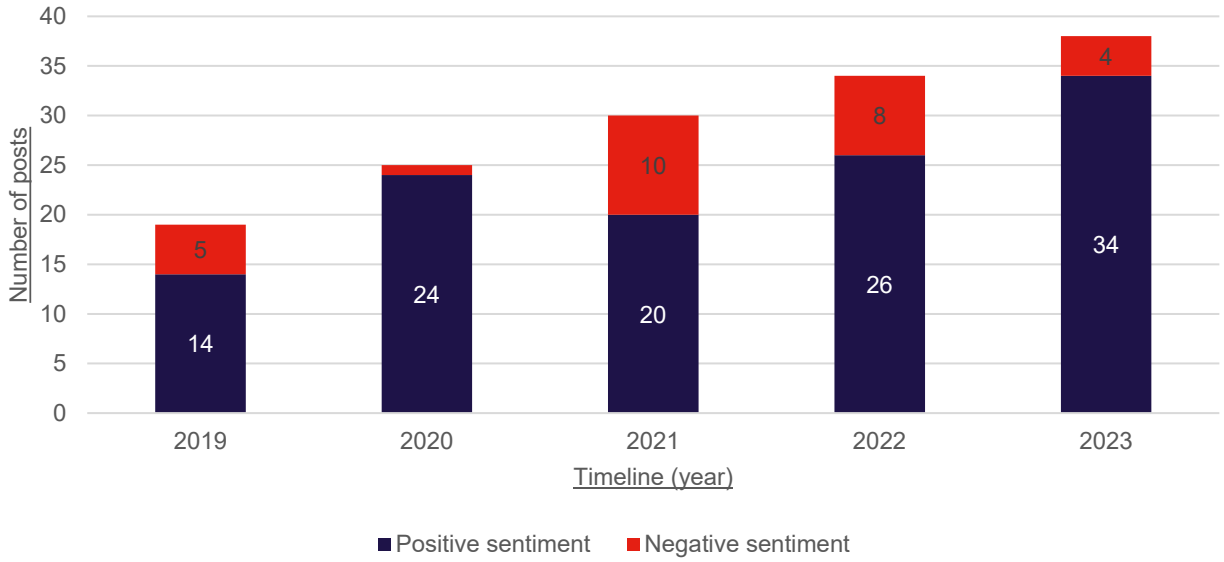
- In September 2021, coinciding with the government's announcement of the GHNF (£270 million commitment), there were 51 posts.
- March 2022 saw 52 posts, coinciding with the official launch of the GHNF.
- The peak in May 2023 (31 posts) corresponded to the announcement by Triple Point Heat Networks Investment Management that £91 million funding had been secured for seven low-carbon heat networks under the GHNF. This alignment suggests government GHNF announcements may have a strong influence on media discourse and public awareness on green heat networks.

Although the overall number of posts referencing 'green heat network(s)' have remained low, in-depth analysis of ‘X’ accounts participating in discussions about green heat networks indicates an increase in the total number of posters (both new and repeat) over the years 2020 to 2022 - 26 in 2020, 53 in 2021, 55 in 2022. However, there was a slight dip in 2023, with 51

posters. Across 2021-23, the percentage of first-time posters for each year (as a % of all those posting) was 92% (2021), 80% (2022), and 84% (2023).

Sentiment analysis of the 146 ‘X’ posts referring to 'heat network consumers' shows an interesting trend across the 2019-23 period. Figure 2 shows the count of 'X' posts referring to 'heat network consumers’, categorised as positive, neutral, or negative sentiment, for each respective year. The proportion of ‘positive’ posts increased from 74% in 2019 to 96% in 2020, followed by a dip to 67% in 2021. This was followed by an increase to 76% in 2022 and a further increase to 89% in 2023.

Figure 2: Sentiment analysis of ‘X’ posts referring to 'heat network consumers’ over time (2019-2023)



An exploration of social media posts analysed indicates a number of mechanisms likely influencing consumer attitudes. Table 15 highlights factors that appear to be particularly contributing to positive and negative sentiment regarding heat networks, offering an overview of key themes derived from ‘X’ posts.

Table 15: Factors influencing sentiment toward heat networks

Positive sentiment	Negative sentiment
Government funding initiatives such as GHNF awards, signalling support for and investment in heat networks.	Limited options, in terms of service providers, available to heat network consumers
The approval of regulatory measures related to consumer protections and rights is seen as a positive step.	The absence of a dedicated consumer advocate to address common issues like billing errors and standing charges.
Appreciation of heat networks contribution to affordability and environmental targets.	The lack of regulations to support consumer choices and ensure protection against substantial price raises.

Increased positive sentiment in 2022, after the dip in positivity in 2021, overlaps with the passage of the Energy Bill in July 2022[4], which created a market framework for the heat network sector. The Bill covered market regulation, regulator appointment, developer rights, and insolvency measures; it also limited heat network energy prices while appointing dispute resolution bodies. These provisions may have contributed to improved consumer perceptions.

While publications referencing 'green heat network(s)' have a predominantly positive sentiment across the years, much of this positivity is driven by announcements of the GHNF by the government and echoed by industry media or stakeholders in the heat networks industry, such as 'Manufacturers of Equipment for Heat Networks Association' or the 'Federation of Master Builders'. Consequently, these publications tend not to be effusive/express strong perspectives. Although potentially limited by the defined parameters of our analysis, there seems to be limited discussion on green heat networks beyond government announcements and industry media coverage.

Additionally, the influence of alternative mechanisms potentially responsible for influencing consumer awareness and attitudes towards heat networks seemed negligible. Examinations of published articles did not provide clear evidence of either organisations having strategies focused on heat networks or the dissemination of GHNF findings being impactful drivers of changing attitudes towards heat networks.

Lastly, the manual examinations of a set of articles relating to different stakeholder groups provides some preliminary indications that over the past five years heat network interventions have worked better for industry groups than for heat network consumers. Some of the latter have cited issues around lack of heat network regulation and high energy costs. This is shown in Table 16.

Table 16: Summary of manual review of articles

Stakeholder group	Summary of article coverage
Heat network consumers	The absence of regulatory measures has in some cases negatively affected the perceptions of consumers subject to higher energy costs.
Stakeholders interested in exploring and understanding heat network technologies	There is growing engagement with heat networks however understandings of the technology and its potential remains nascent.
Industry bodies which support the implementation of green heat network initiatives	Industry bodies are largely receptive to recent heat network initiatives and often benefit from the funding initiatives organised by government.

4 https://assets.publishing.service.gov.uk/media/64147d57e90e07769ca60929/Policy_Statement_Heat_Network_Market_Framework.pdf

Annex 5: Literature and Context Review

Introduction

This literature and context review, undertaken by ACE Research (ACE-R), is intended to contextualise the evaluation and help scope the project as a whole and inform the Theory of Change (ToC). The aim is to deepen our understanding of the delivery framework within which the Green Heat Network Fund (GHNF) operates to ensure that the nature of GHNF's delivery performance is fully understood. It will help to position the GHNF's intended impacts in the context of prevailing policies. It will also provide an anchor for the assumptions presented within the ToC. In the main, the review draws on DESNZ and government publications, strategy documents and commissioned research.

This review was initially carried out in August 2022 at the beginning of the evaluation. It has then been updated in July 2023 to reflect policy and market developments. In February 2024 the content was reviewed to ensure it remained fit for purpose and it will be updated throughout the lifespan of the evaluation. It should be noted that the review was developed prior to the July 2024 general election and change of government, and any discussion of current and future policy direction should be understood in this context.

Agreed Research Questions

The Department for Energy Security and Net Zero (DESNZ),[5] ACE-R and RSM have agreed on the following Research Questions (RQs) and sub-research questions for the literature/context review. The RQs provide a framework within which relevant evidence can be captured and reported.

RQ1: Overview of existing UK Heat Networks (current and planned; size etc.)

- What is the state of the current heat network market?
- What are the characteristics of existing heat networks? (size, location etc.)
- Who is developing and delivering projects?
- What is the split between the public and private sector?
- What is the current makeup of the supply chain?
- What are the routes to market?
- What finance is available?
- What are the gaps in the market?

RQ2: What role can capital schemes such as GHNF play in promoting heat networks in the UK? (informed by case studies in England, Scotland and globally)

[5] DESNZ is the Department currently responsible for the GHNF. Prior to a recent government re-organisation, the responsible Department was known as the Department for Business, Energy and Industrial Strategy (BEIS). BEIS is used in this document when referring to publications issued prior to the name change

- What can we learn from previous capital schemes (e.g. HNIP and more broadly in England, Scotland and globally) to inform and explain GHNF?
- What is the role and adequacy of time-limited central government capital expenditure in mitigating barriers to heat network development?
- What is the role and adequacy of time-limited central government capital expenditure in supporting the broader benefits to heat network development?

RQ3: What previous, current, or planned policies and programmes (local, regional, national) have paved the way for, or could increase/decrease the impact of, GHNF?

- Heat network policy – zoning, waste heat, and market regulation
- Heat pump policy
- Levelling up and fuel poverty policy
- Public sector spending
- Governance
- Other contextual factors

RQ4: Who are the key actors involved in the development of heat networks?

RQ5: What are the awareness, attitudes, behaviours and needs when it comes to the transition to low-carbon heat network solutions?

- Consumers
- Supply chains (and the wider market)
- Energy investors
- Sponsors
- ESCos
- Aggregate users/customers (e.g., developers)
- Projects (applicants/ non applicants).

Methodology

Documents were selected for review in this study as follows:

- Documents proposed by DESNZ and/or RSM that were known to be relevant to GHNF.
- Documents proposed by ACE Research from previous work on heat networks are thought likely to be relevant to GHNF.
- Any additional documentation deemed relevant to address the research questions since the first iteration of the GHNF literature and context review.

The documents included: publicly accessible industry reports on UK and international heat network markets; related DESNZ (former BEIS) reports, consultation documents and scheme evaluations; and a range of other relevant industry, public sector, and academic publications.

A total of 73 documents were reviewed. The literature was coded according to relevance to each research question / sub-questions using *Atlas.ti*. The coded text was then reviewed and synthesised into the findings reported here.

Key Findings

Key findings from the literature review are summarised by research question below. The fully referenced detailed findings are included in the subsequent 'main body' of the review.

RQ1: Overview of existing UK heat networks

To date, communal networks have dominated the heat network market. Hence, most buildings on networks are residential and the majority of heat networks are small, communal systems.

Heat networks today are primarily located in the densest urban areas, although work on novel heat sources, such as the Coal Authority's work on heat from disused mines and Mullan's report on more general use of deep geothermal heat, could broaden the locations seen as suitable for heat networks.

Current heat networks are primarily fuelled by gas. However, there is potential for a range of low-carbon fuels, with particular interest in using waste heat.

The market for heat networks is growing slowly but steadily. Heat networks have the potential to play a significantly expanded role in a decarbonised heat system, but several challenges have not yet been overcome. These include, but may not be limited to, investor risk and a lack of skilled supply chains. As detailed policy on zoning and regulation is currently under development, there may also be further short-term risks created by this period of flux in the policy environment, such as the treatment of existing network operators within future zones.

RQ2: The role of capital schemes such as GHNF in promoting heat networks in the UK

Time-limited government capital expenditure can help overcome financial barriers to the development of specific heat networks.

Government capital expenditure can support supply chain development, but if the timeframe for time-limited funds is too short, this is unlikely to be the case.

If developer capacity is limited (e.g. in the case of local authorities), capital funding may need to be accompanied by capacity building. Careful programme design in this respect can help promote a self-sustaining market's development.

RQ3: The impact of other policies and programmes on GHNF

There are a number of policies and programmes that may influence the effectiveness of GHNF. The literature describes these but does not offer insight into how they might interact with the GHNF. Key policy areas of interest are regulation, local area energy planning and heat

network zoning; use of waste heat and electrification of heat using heat pumps, and any consequent impacts from the latter as a result of the high level of grid constraint currently being seen on the distribution networks.

RQ4: Key actors involved in the development of heat networks

The literature does not provide a comprehensive stakeholder map for the heat network sector. The research team have therefore taken learnings from the Literature and Context Review and added additional stakeholders to the wider project's stakeholder mapping exercise. The following categories and sub-groups have been mapped:

- Projects and sponsors - those that have applied for GHNF funding and non-applicants.
- Aggregate users – including developers who build at scale and campus-based schemes.
- Consumers – the users of a service, in this case heat.
- Supply chains (and the wider market) – organisations that deliver heat network projects.
- Energy investors – those that invest in heat network projects.
- Waste heat suppliers – those organisations that supply waste heat to heat networks.
- Policy – those with influence, but not directly involved with heat network project stakeholders.

RQ5: Awareness, attitudes, behaviours, and needs

Consumers

The results of the most recent DESNZ Public Attitudes Tracker, as of Spring 2023, suggest that 14% of those surveyed had never heard of low-carbon heating systems, 56% knew a little or hardly anything, whilst only 30% felt that they knew a lot or a fair amount.

Some research has found that consumers state a preference for gas heating systems over low-carbon alternatives. While the evidence wasn't explicit to the reason why, the research team felt that this is due to the familiarity of gas heating systems. Consumers also noted that they were more likely to welcome new technologies if they resulted in enhanced home heating experiences.

Consumers connected to heat networks are at least as satisfied with their heating systems as those who are not connected (74% compared to 72%). Where there is dissatisfaction, it is driven by concerns about billing accuracy, perceptions of overpricing, levels of control and service interruptions. There is strong support amongst heat network consumers for increased regulation to protect consumers' interests.

Consumer needs linked to low-carbon heating included:

- The need to have increased awareness of the technology options available to them.

- The potential for consumer choice, paired with the provision of expert advice on the best options for a given consumer.
- An overall positive experience from using the heating system.

Supply chain

There is generally a good level of awareness of heat networks within the supply chain, but certain actors e.g. equipment and component suppliers, may have limited exposure to the full details of heat networks.

Positive relationships between consumers, regulators and the supply chain support the sector's growth. Government and industry have been working to create positive relationships to facilitate the growth of the sector, reflected by the creation of the Heat Network Industry Council (HeatNIC).

Building professionals are reluctant to advise clients on technologies that they have little or no direct experience with. Given that consumers need expert advice, it will be necessary for these professionals to understand the full range of low-carbon heating options and, therefore, recommend the most appropriate options to their clients.

Energy investors

There was nothing specific in the literature on energy investors' awareness of heat networks as an opportunity. However, the number of public and private sector investors already involved in the heat network market suggests that there is a reasonable degree of awareness.

Financial viability and financial risk are two key determinants of an investor's attitude to a project. Heat networks have relatively long payback periods and hence need to be seen as low risk. Demand assurance is one way to provide low risk, as is strong local policy commitment to heat networks.

Scheme size can be an issue: investors prefer to invest at scale (above £20-£25 million) which is larger than typical investments in individual heat networks. The landscape for private investment is continuously evolving and there are now several major investment firms partnered with heat network ESCOs. This includes firms such as DIF Capital, Asper and Gren, and the UK Infrastructure Bank (UKIB)[6].

Sponsors and projects

Sponsors and active participants in heat network projects are, by definition, aware of heat networks. They demonstrate strong support and shared enthusiasm for heat networks but are concerned about connecting privately owned buildings to networks.

The literature on the behaviour of these stakeholders focused on how they view their customer protection responsibilities. Public sector sponsors tended to see their responsibilities as being

[6] Now the National Wealth Fund (NWF).

linked to their role as landlord / property manager. Private sector sponsors considered that their responsibilities were defined by the contractual arrangements they had with their clients.

These stakeholders, like others in the supply chains, need increased capacity and capability to deliver heat networks. Specifically, the heat network sector lacks senior project management and engineering capacities, while local authorities have skills gaps in the technical, project management, commercial and data management skills.

Energy Service Companies (ESCos)

No research was identified for this stakeholder segment.

Aggregate users/customers (e.g., developers)

No research was identified for this stakeholder segment.

Findings by Research Question

RQ1: Overview of existing UK heat networks

RQ1a What is the state of the current heat network market?

For the purposes of GHNF[7], a heat network is defined as a network of pipes that, by distributing a liquid or a gas, enables the transfer of thermal energy for the purpose of supplying heating, cooling or hot water to at least one building or persons in that building (and includes any appliance the main purpose of which is to heat or cool the liquid or gas). There are three sub-categories of heat networks:

- District heat network: A heat network by means of which heating, cooling or hot water is supplied to two or more buildings or persons in those buildings is a district heat network.
- Communal heat network: A heat network by means of which heating, cooling or hot water is supplied only to a single building divided into separate premises or persons in those premises.
- Campus heat network: A heat network by means of which heating, cooling or hot water is supplied to buildings within a campus where the owner of the connected buildings (taking at least 80% of the heat supplied by the network) and network owner are either the same or are related parties, for example a university, prison or hospital site.

The current state of play

In 2018, the UK district heating market was valued by an industry study at EUR 138.4 million (BSRIA, 2019). The same study reported growth in the market over the previous five years. Key stakeholders interviewed for the evaluation of HNIP at a similar time also reported slow but steady growth (BEIS, 2018b).

[7] Department for Energy Security and Net Zero (2024) Green Heat Network Fund. Available at: Green Heat Network (GHNF): Round 10 application guidance

The market is largely arranged around a growing group of large organisations that are referred to as multiple-function companies (MFCs). There are also a number of smaller schemes with private property developers and single-site public schemes (BEIS, 2018b). Most of the very big schemes are built and operated by large companies such as Hemiko, E.ON, SSE, Metropolitan, Equans, Vital and Vattenfall. Industry representatives suggest that they tend to be newer, more efficient, and better maintained than the smaller networks (BEIS, 2018b).

Heat networks account for only a small proportion of UK heat demand (~3%). As a result, historically their locations were unrecorded, and their operation unregulated. In 2014, the voluntary Heat Network (Metering and Billing) Regulations were introduced which allowed operators to submit notifications of a heat network and the installation of meters. However, few operators submitted data under the voluntary scheme. These regulations became mandatory in September 2022. This has increased the amount of data collected and provides insight to government and the heat network sector on the location and profile of heat networks.

The lack of independent regulation of the heat network market to date means there have been no comprehensive sector-specific protections for heat network consumers, unlike for consumers of other utilities such as gas, electricity, and water. There has been some self-regulation of the market through Heat Trust, a voluntary consumer protection body which allows operators to act as if they were regulated (Heat Trust, 2022).

Government consulted on how to implement regulation for the sector in the 'Heat Network Market Framework' consultation in 2020 (BEIS, 2020d). Primary legislation has been drafted which appoints Ofgem as the heat networks regulator, the energy Ombudsman for complaints and Citizens Advice for consumer advice in Great Britain. This mirrors regulation for gas and electricity. Secondary legislation is currently being reviewed after the consultation was closed in November 2023, having collected views on consumer protection requirements around pricing, quality of service, transparency of information, consumers in vulnerable circumstances, the scope of the rules, and how they should be phased in[8]. This will bring heat network regulation to par with the electricity and gas markets, improve technical standards, improve consumer protection standards and price transparency and improve market information. The heat networks industry overwhelmingly supports these measures because they provide market confidence for investors who are vital to funding large heat network projects.

Future expectations for the sector

Heat networks offer one of the biggest growth potentials for energy networks in Europe, with an investment potential of between £60 billion and £80 billion by 2050 (BEIS, 2022a).

They are expected to play a significantly increased role in a decarbonised system, as they can use a range of low and zero-carbon heat sources, including heat pumps, waste heat and hydrogen (BEIS, 2021d). The Climate Change Committee estimates that 18-20% of UK homes could be heated via heat networks in 2050 (CCC, 2020).

[8] https://www.gov.uk/government/consultations/heat-networks-regulation-consumer-protection

Heat networks growth may have limits linked to geography and to the type of customer. Although heat networks can technically work anywhere, their cost-efficiency is affected by urban density, willingness to connect, available heat sources and whether the alternative is low-carbon or not. Work by Element Energy, for example, suggests that "*heat networks will be cost-effective only in densely populated areas, where capital-intensive distribution infrastructure is justified by a high volume of heat sales*" (Element Energy & E4tech, 2019). This thinking is developing further through the Government's work on the Heat Network Zoning Transformation Programme. Pilots in specific areas helped develop a National Zoning Model which will identify areas in England best suited to decarbonise through heat networks (BEIS, 2022). Following on from this, the ongoing Advanced Zoning Programme aims to have at least 10 heat network zones under construction by December 2026.

Upcoming secondary legislation is expected to establish the process for designating areas as heat network zones (DESNZ, 2023b). Heat network zones will be areas where heat networks are expected to provide the lowest cost low carbon heating technology, for example, where there are appropriate heat demands close to viable sources of low-carbon heat (BEIS, 2021j). Research supporting the development of heat network zoning proposals included asking domestic, commercial and public sector stakeholders what types of buildings/customers would most likely connect to a heat network. Out of 64 respondents, 24 thought that public sector buildings and social housing would most likely connect, 12 respondents thought private non-domestic establishments would be most likely to connect, 12 thought domestic consumers, 5 thought large heat users, and 4 thought energy efficient developments were most likely. Please note, that it is not clear what level of heat network knowledge these stakeholders had (BEIS, 2022h).

Future innovations also include the potential for heat networks to provide city-scale cooling. Research conducted by Prof. Martin Freer at Energy Capital highlights the increasing demand for air conditioning units and the role of heat networks in providing city-wide cooling solutions (Energy Capital, 2017).

Market drivers for a growing heat network sector

Drivers that may support the market for heat networks include the net zero carbon target, an increased focus on energy security, heat network zoning, and improved regulation of the sector:

- **Net Zero**: Heat networks can offer a low-carbon solution for heating buildings, as discussed above (BEIS, 2021j). As the ban on gas boilers in new build homes is planned to come into effect in 2025, more housing construction will mean more heat network connections (Ministry of Housing, Communities and Local Government, 2019).
- **Energy security**: Low-carbon heat networks can help to diversify the fuels used in heat supply and hence improve energy security (BSRIA, 2019).
- **Affordability**: Heat networks can offer consumers affordable services (ADE, 2018).
- **Heat Network Zoning**: Heat network zones will see the identification and designation of areas where heat networks can provide the lowest cost low carbon solution, for example

where there are appropriate heat demands close to viable sources of low-carbon heat (BEIS, 2021j). New homes, public buildings, existing communal heat networks and commercial buildings within the zones may be required to connect to the network (BEIS, 2022h). The ability to require buildings to connect to a heat network is essential to providing demand assurance[9] and would further de-risk investor decisions. This policy is likely to come into effect in 2025 (BEIS, 2022h).

- **Improved regulation**: the recent and imminently expected legislation to improve consumer protection for heat networks, mentioned above, together with the now mandatory metering and billing regulations, will provide more certainty in the market and hence reduce risk for investors (ADE, 2018).

Challenges for a growing heat network sector

Challenges that may constrain the growth of the heat network sector include: the cost of deploying heat networks; investor perception of risks; a lack of skilled workers leading to supply chain delays, a lack of competition stunting the market and uncertainties linked to the use of hydrogen.

- **Cost:** The high investment costs associated with heat networks may mean they are only economic in areas of high heat demand. A study by Imperial College London found nationwide deployment of district heating to be a higher cost pathway to decarbonisation than individual property heating alternatives, such as gas boilers and heat pumps (Imperial College, 2018). However, the study noted that around 40% of heat demand is in urban areas, which are more likely to have the high density of heat demand needed to give heat network developers sufficient demand assurance to make the business case viable. Recent research supported and published by UKRI suggests that, for UK city-regions, the levelised cost of heat networks could be 40% lower than for individual heat pumps (UKRI, 2022).

  The cost of electricity compared to gas also presents a significant challenge for the heat network sector. At the moment, there are stark discrepancies in electricity and gas prices, with gas currently being cheaper than electricity due to levies placed on electricity. At the time of writing, the government is currently committed to rebalancing these prices by the end of 2023/2024 (DESNZ, 2023c). This rebalancing will create a transparent short-term price signal that is crucial in encouraging both households and businesses to adopt lower-carbon and more energy-efficient technologies such as heat pumps (DESNZ, 2023c).

- **Investor risk:** The financial environment for heat networks is challenging because of a high risk to return ratio. Risks include low demand and delays to construction. Several investors interviewed during the HNIP evaluation (BEIS, 2018b) noted that heat networks compete with existing gas infrastructure, which can result in greater financial viability for gas installations. Most investors also noted that they prefer investments of above £20-25 million, which is many times larger than the investment required for typical single heat networks.

- **Skills:** A lack of knowledge and skills is a significant and emerging challenge in the heat network market. This was identified in the HNIP evaluation (BEIS, 2018b). A BEIS-funded review of Heat Network Skills (BEIS, 2020a) concluded that current skills gaps will become

[9] Demand assurance is the certainty for heat network developers (the assurance) that in a given area they will definitely be able to connect to the large heat users (the demand).

more acute as the sector grows and therefore the sector may not deliver the infrastructure to supply the 18% of heat demand foreseen by the CCC. The review also noted that there are more immediate impacts of skills shortages, including low-quality outputs and delays in delivery, which could have knock-on impacts on consumer and investor confidence.

Another challenge is the lack of skilled workers in construction and other related trades who are involved in work that may happen alongside the development of the heat network itself, including improving the energy efficiency in the buildings supplied by the network and installing the heat supply technologies for the network. However, the scale of the problem in the wider retrofit sector is hard to quantify as there is no publicly available data on the number of qualified heat pump installers, retrofit coordinators, energy efficiency installers and assessors (CCC, 2020).

New roles are likely to be created where shortages may appear in the future, as the sector scales and is regulated. An example of this is the role of the technical standards assessor, which is likely to play an important part in the Heat Network Technical Assurance Scheme[10]. Planned zoning regulations when implemented will see local authorities become zoning coordinators. Given this is a new role, there may be skills shortages for local authority officers.

- **Competition**: The Competition and Markets Authority (CMA) conducted a study into the heat network market and found that heat network providers face little competitive pressure to offer reasonable prices, reliable supply and high quality of service (CMA, 2018). A lack of competition in the market can mean heat networks are expensive to develop. This can prevent heat networks from being a cost-effective heating option in comparison to the low cost of gas installations (BEIS, 2018b). There may be scope for alternative business models that allow supply of heat through the heat distribution infrastructure by several competing suppliers. Alternatively, the Danish zoning methodology puts significant obligations on all parts of the network to offer the cheapest possible heat. There is also the potential for 'de-zoning' if networks are not offering cheap heat.
- **Hydrogen**: Hydrogen is a potential low-carbon energy source to replace the use of natural gas in heat networks. However, according to DESNZ, “there is little evidence on how hydrogen could be used in heat networks, whether combined heat and power conversions would be possible, and to what extent the current market for hydrogen-fuelled systems could grow in future” (BEIS, 2018). This is a potential gap in the market and further research is needed for heat networks to tap into a low-carbon fuel type.

RQ1b: What are the characteristics of existing heat networks?

Existing heat networks vary in the energy services they provide, where they are located, what fuels they use and the types of buildings they serve.

Generations of heat networks

- **First- and second-generation** networks were mostly used before the 1970s and piped steam or pressurised hot water (>100°C), with high heat losses. Very few still exist.

[10] The Heat Network Technical Assurance Scheme (HNTAS) aims to benefit end consumers, developers, house builders, and investors by de-risking the transition to the Future Homes Standard and removing performance risk.

- **Third-generation networks** emerged in the 1970s and use pressurised hot water (70-100°C). Most existing UK heat networks use third-generation technology.
- **Fourth-generation** networks operate at lower temperatures of around 40–60°C (a hot shower is around 40°C). They are better able to use low-carbon heat sources and result in less heat being wasted in pipes. Older networks may be retrofitted with fourth-generation technology, though the energy efficiency of connected buildings often needs improving to do so (see below).
- **Fifth-generation heat and cooling networks** (or 'ambient loop systems') seek to eliminate pipe heat loss by using water in the network at or close to ambient ground temperature, reducing or eliminating the need for pipe insulation. Each dwelling on the network uses its own heat pump (to raise the temperature of water in the network to that required to provide heating). The same heat pump can be used in reverse to put heat back into the network, cooling the building. Fifth-generation networks are designed to connect multiple low-carbon heat sources with a mixture of residential and commercial properties (which have differing patterns of heat and cooling demand) to share these loads efficiently.

Please note that data on the number of heat networks within each category for the UK is not available.

Energy Service Provision

Heat networks meet 3% of the UK's heat demand (BEIS, 2022h). Rough estimates indicate that there are around 14,000 heat networks in the UK which provide 75,645 buildings and 476,951 individual customers (including domestic, commercial and public sector customers) with heating and/ or cooling (BEIS, 2018a). A large proportion (70%) of networks provides space heating and hot water. A much smaller proportion (8%) provide heating, hot water and cooling. Even less provide cooling only (just 141 networks) (BEIS, 2018a).

Location

The location of existing heat networks reflects the fact that it is easier to assure heat demand in densely populated areas with significant anchor loads. There are higher numbers of heat networks in more densely populated areas, in particular around London, Manchester, Belfast, Birmingham, Newcastle, and Sheffield (BEIS, 2018a). London has the highest number of district heat networks (20% of the UK total) whilst the North West has the lowest (8% of the total) (BEIS, 2018a).

Yorkshire and The Humber has the highest regional heat network heating and hot water capacity, at 6.0 GW, out of a total 19 GW installed capacity across the UK (BEIS, 2018a).

London has the highest level of heat and hot water generation and supply from heat networks, at 3.7 TWh and 2.8 TWh respectively. It also has the highest installed capacity, generation, and supply for cooling (BEIS, 2021e) (BEIS, 2018a).

Fuel Sources

Most current heat networks are powered by Combined Heat and Power (CHP) units, which use a large engine that spins an alternator or turbine to generate electricity. The excess heat from this process is then captured and used to heat buildings.

Gas is the dominant fuel source for heat networks. It is used by 90% of networks, sometimes in combination with other fuels. Electricity is used to fuel 5% of heat networks, and bioenergy and waste 2%, with a combination of other sources making up the remainder (BEIS, 2021e). However, there has been an increase in the use of heat pumps as the primary heating technology in heat networks: for example, a third of successful HNIP schemes use heat pumps (Triple Point, 2022). The BEIS Heat Pump Ready Consultation (BEIS, 2021j) notes that there are several schemes using a single heat pump to provide communal heating, and that systems based on 'shared ground loops' can be an attractive solution in many buildings.

BEIS's international heat networks market frameworks review found "a mixed picture on historical decarbonisation [of heat networks], with very little evidence of there being one or two approaches that work better than others". Different approaches across the globe were linked to local circumstances, including existing natural resources, crises with energy prices and waste (BEIS, 2020).

Some environmental heat sources, such as mine water, are increasingly being used in heat networks. The Coal Authority estimates that there are 23,000 abandoned deep coal mines around the UK, above which sit one-quarter of the UK's homes and businesses. These mines have filled with water and are naturally warmed (to 12–20°C) by sub-surface geological processes. Heat pumps can be used to extract some of this zero-carbon heat, which can then be used to heat fresh water to provide low-carbon heating and hot water for use in domestic and commercial buildings via heat networks (NELEP, 2021). If all of the 42 schemes in the Coal Authority's pipeline were to be built, this would generate projected carbon savings of 90,500 tonnes per annum. The idea of using deep geothermal heat more broadly is put forward in a recent report from Dr Kieran Mullan MP (Mullan, 2023). This estimates that there is the potential for the production of 15,000 GWh energy per year by 2050.

Building types

Most buildings on heat networks are residential (80%) and most final customers are residential (92%) (BEIS, 2018a). Out of the residential connections, 91% are to a flat or maisonette with only 5% to a terraced/semi-detached/end-of-terrace house and 2% to detached properties. The size of the properties connecting tend to be small: 52% of connections are to single-person households compared to only 3% of connections from a household with 5 people or more (BEIS, 2022d). However, both BEIS and Scottish Government have suggested that in future they expect the majority of connections to be from non-domestic buildings (BEIS, 2021e) (Scottish Government, 2022).

A BEIS survey found that around two-thirds of surveyed customers supplied by a heat network were renting their property from a housing association or a local authority. Only 20% of all heat network customers lived in private accommodation that they owned (65% of all households are

owner-occupiers). The remaining 11% of heat network customers were renting privately-owned accommodation (BEIS, 2017a).

Table 17: Summary of heat network headline data

Area	Finding
Heat demand:	Current: 3% of UK heat demand Ambition:18% of UK heat demand by 2050
Number of Heat Networks:	Total: 14,000: • 12,000 operate as communal networks (85.8%) • 2,000 operate as district scale systems (14.2%)
Regional profile:	Highest: London (20% of the UK total) Lowest: North West (8% of the UK total)
Number of buildings serviced:	75,645
Number of customers:	476,951
Customer profile:	80% residential: • 52% of connections are to single-person households, whilst only 3% of connections are to households with 5 people or more. • Two-thirds of surveyed customers supplied by a heat network were renting their property from a housing association or a local authority, whilst only 20% of all surveyed heat network customers live in private properties.
Proportion of networks providing:	Space heating and hot water: 70% Space heating, hot water and cooling: 8% Cooling: ~1%
Fuel source for heat networks:	Gas: 90%: Electricity: 5% Bioenergy and waste: 2% Other: 3%
Market value:	€138.4m
Investment potential:	Between £60 billion and £80 billion by 2050

RQ1c: Who is developing and delivering projects?

In the UK, heat network developments typically fall into one of four types (IPPR, 2017):

1. **Local authority-led schemes** including the connection of schools, leisure centres, other public buildings and both private and social housing.

2. **Private sector developments** on new housing schemes, which may also include blocks of flats or commercial developments.

3. **Stand-alone campus networks** serving hospital sites or universities.

4. **Schemes in individual social housing blocks** built in the 1960s and 1970s.

Developers to date have primarily been local authorities, ESCos, property developers, waste heat developers or community organisations. See RQ4 for more details. However, this is likely to change as heat network zoning is introduced. Whilst the detailed policy regarding zoning is still under development, the zoning coordinator will hold the power to make mandatory connections, meaning they are more likely to make up a higher percentage of heat network development and delivery (BEIS, 2022h). The routes to market within zones remain unclear. They may include existing routes such as concessions where local authorities and ESCos have a specific agreement on who has the right to operate a heat network and for how long, or there may also include new approaches to competition within zones. More details on routes to the market, below on RQ1f.

Published in May 2023, the GHNF has awarded £91 million across the country (Triple Point, 2023). Those who have been awarded the funds have included energy companies, such as WhyEast London Energy (owned and operated by Equans) and 1Energy. The recipients also included various councils, such as Cornwall Council, Kirklees Council, and the East Riding of Yorkshire Council. Other recipients include universities such as Reading.

RQ1d: What is the split between public and private sector?

BEIS Experimental statistics on heat networks (BEIS, 2018a) states that there are 60,832 residential building connections, which makes up the majority of the connections. The data suggests that there are 754 connections to public buildings, but it does not suggest how many are private, only providing the breakdown of each building type.

Table 18: Summary of number of heat network connections per building type in UK

Type of Buildings (UK)	Number of connections
Residential	60,832
Commercial	5,550
Retail	492
Light Industrial	182
Industrial	41
Education	6,627
Public	754
Other	1,167

Total	**75,645**

According to BSRIA analysis, 60% of new connections are to private networks. The remaining 40% are to public networks, however, the literature does not specify the time frame this refers to (BSRIA, 2019).

RQ1e: What is the current makeup of the supply chain?

Each heat network development can include a large number of supply chain actors, such as consultants, designers, building contractors and operating companies. This leads to a supply chain that is very fragmented (BSRIA, 2019).

As part of this review (and the wider evaluation project), the research team mapped the stakeholders involved in heat networks, including those actors from the supply chain. Please see RQ4 below for the results from this task.

RQ1f: What are the routes to the market?

The Financing Heat Networks in the UK guidebook (Grant Thornton, 2018) sets out four broad categories of 'Delivery Models' used to develop heat networks. All the models take similar approaches to the development and operation of a heat network, but in each case the motivations of the lead organisation(s) may impact some elements of the approach.

The first category is **a private sector led delivery model**: This is where a private sector company is responsible for the design, financing, building, ownership and operation of the heat network. These are the elements that are most likely to be different in a private sector led scheme because of the motivations of the lead organisation (Grant Thornton, 2018).

The second is **public-private shared leadership**: This is where Local Authority and at least one private sector company share the risks and returns. The roles that define a project as public-private led are likely to be Governance and Funding or anchor customer with these elements being the motivating factor (Grant Thornton, 2018).

The third category is **a public sector led delivery model**: This is where the Local Authority is responsible for designing, financing, building, owning and operating heat networks (Grant Thornton, 2018). The roles that define a project as public sector led are likely to be Governance, Funding and Asset ownership.

The fourth category is a **Community Company (CoCo) led delivery model**: This is where a community body has a leading role in the business of supplying heat (Grant Thornton, 2018). The roles that define a project as Community-led are likely to be Customer, Governance and Sale of Heat with these elements being the motivating factor.

GHNF funding can support organisations in the public, private and third sectors (individuals, households and sole traders are excluded) and hence could support any of the above delivery models. The HNIP Pilot did not allow applications from private sector organisations, something for which it was criticised (BEIS, 2018b), although they were eligible for the HNIP main scheme. The inclusion of the private sector in GHNF could result in an increase in private sector-led schemes.

RQ1g: What finance is available?

Stages of heat network development

To understand the financing options available to support heat networks, it is important to consider the stages of heat network development. This is because different sources of funding are available for different stages. This is illustrated in the literature in the Financing Heat Networks in the UK Guidebook (Grant Thornton, 2018). The GHNF funds the commercialisation and delivery stages of heat network development, funding commercialisation and construction of new low- and zero-carbon heat networks, along with the retrofitting and expansion of existing ones.

Types of borrowing

There are various types of borrowing available to different actors to finance heat networks. For example, Local Authorities have access to Prudential Borrowing from the Public Works Loan Board (PWLB), which is non-project specific and effectively becomes 'internal reserves' once obtained. This funding can be used in-house or lent to an ESCo (Grant Thornton, 2018).

Public and private sector entities have access to Corporate Borrowing from banks – this is also non-project specific and effectively becomes 'internal reserves' once obtained. An organisation's 'relationship bank' may be the first port of call for such funding (Grant Thornton, 2018).

There is also the option of borrowing from the UK Infrastructure Bank (now the National Wealth Fund, NWF) which is a British state-owned investment bank. It is intended to help with the UK Government's plan to reach net-zero carbon by 2050 and to support economic growth in regional and local sectors across the United Kingdom (The UK Infrastructure Bank, 2022).

To do this, the UK Infrastructure Bank is providing £22 billion of infrastructure finance according to their strategic plan (The UK Infrastructure Bank, 2022). Investment is spread over five sectors; however, the spread is not equal. Clean energy is expected to be the largest sector in their portfolio, as it is important to the UK's net zero and energy security ambitions. There will also be significant investing across the transport and digital sectors. Lastly, water and waste will likely be the smallest sectors in their portfolio given its fewer investment opportunities.

UKIB has recently collaborated with Bristol, Greater Manchester, and West Yorkshire to develop a new advisory function for local authorities across the UK. The partnership has launched three pilot projects that aim to address the challenges of achieving net zero emissions and promoting local growth. These projects will focus on electrifying buses, developing mass transit systems, and creating low-carbon energy infrastructure. Bristol City Council will also work with the Bank on their City Leap initiative, which aims to build £1bn of net zero infrastructure, including strategic heat networks, over the next 20 years (The UK Infrastructure Bank, 2022).

DESNZ Heat Investment Vehicle (BHIVE)

BHIVE, established by DESNZ in 2020, was set up to allow public sector heat network owners/developers in England and Wales to procure funding and funding-related services for

their heat network projects from a range of potential funders. It was referred to as a dynamic purchasing system (DPS) for heat networks. It aimed to support the market to be economically attractive to investors and to deliver and sustain jobs (BEIS, 2020). BHIVE was available to all Public Sector Bodies in England and Wales ("Contracting Authorities"). The Department extended BHIVE for 2 years and it closed on 31st March 2025 (BEIS, 2020). The funding categories available under BHIVE were divided into two Lots: Lot 1: Equity Finance, Lot 2: Asset Finance.

BHIVE aimed to provide:

- Accessibility for Contracting Authorities to access Funding providers
- Increase standardisation to reduce costs and timescales of further due diligence
- Flexibility due to the diverse range of skills and
- Value for money as contracting authorities can access the most economically advantageous terms for their project.

There were 14 suppliers onboarded as of May 2023 for Lot 1 such as Downing LLP, E.ON UK Infrastructure Services Limited, Greencoat Capital LLP and SMBC Leasing (UK) Limited. For lot 2 there are 4 suppliers consisting of PEAC (UK) Limited, SMBC Leasing (UK) Limited, Triple Point Lease Partners and TP Leasing Limited (Triple Point , 2023).

Heat Network Delivery Unit

To address the capacity and capability challenges that local authorities identified as barriers to heat network deployment in the UK, the government set up the Heat Network Delivery Unit (HNDU) in 2013 (BEIS, 2020b).

HNDU provides support to local authorities in England and Wales through the early stages of heat network development, focusing on heat mapping; energy master planning; techno-economic feasibility and detailed project development (GOVUK, 2017) . HNDU has also provided grant funding to local authorities, running 11 funding rounds and awarding £25.6 million for over 280 schemes across over 173 local authorities areas (GOVUK, 2017).

Literature on which of these early stages of heat network development received funding was not readily available. However, as HNDU supports the development of heat networks and GHNF supports the commercialisation and construction (BEIS, 2022b), this suggests that GHNF compliments the work done by HNDU to support the entirety of the stages of heat network development thus stimulating the increased deployment of heat networks at scale.

Public Sector Decarbonisation Scheme[11]

In July 2020, the UK government announced a £3 billion Covid-19 green recovery plan. This included £1 billon to decarbonise public sector buildings – the Public Sector Decarbonisation Scheme (PSDS) (Salix, 2022). The scheme provides up to 100% grant funding for the capital

[11] Note, in June 2025 the Government announced that it would not commit further investment for the Public Sector Decarbonisation Scheme beyond currently awarded projects: https://www.salixfinance.co.uk/news/public-sector-decarbonisation-scheme

costs of energy efficiency and heat decarbonisation projects within public sector non-domestic buildings. There have been three phases of funding as part of the scheme so far. Initially conceived as a five-year scheme, the latest spending review has now extended this to 10 years, with the total level of funding remaining broadly the same.

Phase 1 of the Public Sector Decarbonisation Scheme was allocated £1 billion of funding, Phase 2 was allocated £75 million, and Phase 3 will provide £1.425 billion split into multiple application windows (DESNZ, 2023d). Phase 3a provided £553 million and closed to applications in November 2021. Phase 3b is currently underway and will provide up to £635 million of funding over 2022/2023 to 2024/2025. Phase 3c is expected to open to applications in autumn 2023. Applications for grants are managed and processed by Salix Finance Ltd (Salix).

PSDS does not provide support to heat networks as such, only to heat off takers in the form of energy efficiency measures. However, the literature associated with PSDS does not specify how much of this funding is being invested in this way.

Salix loans

Salix enables public sector organisations across England, Scotland, Wales and Northern Ireland to take a lead in tackling climate change by increasing their energy efficiency. Salix provides 100% interest-free capital for the public sector to reduce their energy costs by enabling the installation of modern, energy-efficient technologies and replacing dated, inefficient technologies.

To date, Salix has funded over 14,400 projects with 1,460 public sector bodies, valued at £462.9 million (Salix, 2022). This has saved the public sector over £116 million annually and £1.7 billion over the projects' lifetime. In the future, this will reduce public sector carbon dioxide emissions by 613,793 tonnes annually and over 8.6 million tonnes over the lifetime of the projects. The literature does not specify exactly how much of this funding is dedicated to heat networks.

Heat Networks Investment Project (HNIP)

HNIP provided £320 million in grants and loans to the public and private sectors in England and Wales, for the commercialisation and construction of heat networks serving two or more buildings. A pilot in 2016 preceded the HNIP main scheme, which ran from January 2019 until February 2022 (BEIS, 2018c), when it was replaced by the GHNF.

Green Heat Network Fund Transition Scheme

Before the GHNF main scheme opened there was the GHNF Transition Scheme. This £10 million capital grant scheme, open to public, private and third sector bodies in England, opened to applications in July 2021 (BEIS, 2021b). The aim of the GHNF Transition Scheme was to focus on commercialisation funding only to enable a pipeline of low—zero carbon (LZC) heat network projects to be ready to apply for construction funding from the GHNF main scheme when it opened.

Green Heat Network Fund (GHNF)

Following on from the transition scheme, the main GHNF scheme was made available and took the form of a three-year capital grant fund worth £288m (BEIS, 2022b). In 2023, capital support for the scheme has been extended to 2028 with additional funding provided (DESNZ, 2023c). It is open to public, private and third sector bodies in England and provides support for both the commercialisation and construction of new low and zero-carbon heat networks, as well as the retrofit and expansion of existing heat networks.

The scheme funds up to 50% of a project's combined commercialisation and construction costs, with an upper limit of £1m for commercialisation[12].

The GHNF seeks to incentivise heat network market transition to low-carbon heat sources via targeted financial support that will help stimulate the increased deployment of low-carbon technologies at scale. Its objectives are to:

- Achieve carbon savings and decreases in carbon intensity of heat supplied.
- Increase the total amount of low-carbon heat utilisation in heat networks (both retrofitted and new heat networks).
- Contribute towards market transformation across the investment landscape and supply chain (increasing capability and capacity) that will better prepare the heat network sector for further decarbonisation (BEIS, 2022c).

Heat Network Efficiency Scheme

The HNES Demonstrator was a £4.175m grant scheme with the aim of providing financial support to improve the efficiency of existing heat networks. DESNZ (2023e) has recently launched a multi-year HNES Main Scheme in 2023/24 (Year 1) which will continue into 2024/2025 (Year 2). This is a £32 million grant scheme split into revenue grant funding (up to £2 million across 2023/2024 and 2024/2025) and capital grant funding (up to £30 million across 2023/2024 and 2024/2025).

The primary objectives of the scheme are to:

- Achieve fuel and carbon savings in existing projects.
- Improve customer outcomes in existing projects.
- Increase the transparency and visibility of heat network performance.

Applicants to the Demonstrator scheme can apply for either revenue or capital grant funding. Revenue funding is to procure third party support to identify causes of sub-optimal performance and recommend improvements. Capital funding is to fund installation of measures to improve efficiency and address sub-optimal outcomes. The GHNF compliments the work of HNES by continuing to provide funding to the retrofit and expansion of existing heat networks.

[12] Please note that this limit can be exceeded, if the need is well evidenced, recommended for investment by Triple Point heat network assessors.

RQ1h: What are the gaps in the market?

The research team considered those consumers not being served in the heat network market, both now and in the future. Existing homes are less well served than other buildings, in terms of drivers for connection to heat networks. Heat network zoning policy, introduced as part of the Energy Security Bill, will provide additional powers to speed up the rollout of heat networks, the policy will require a new build domestic, large non-domestic, and public buildings to connect to heat networks**Invalid source specified.**. There will be no requirement however for existing domestic buildings within zones to connect, even though such buildings could provide high heat demand for a heat network and could be better served by a heat network than by other low-carbon heat options. This may result in some potential domestic customers not being served by the local heat networks that are developed. It may also result in some heat networks not being developed, where the mandated connections do not provide sufficient demand assurance.

RQ2: What role can capital schemes such as GHNF play in promoting heat networks in the UK?

This section looks at the role and adequacy of time limited central government capital expenditure in mitigating barriers to heat network development, drawing on examples from previous schemes.

Time-limited government capital support has played a key role in overcoming difficulties in securing and providing funding for the initial deployment networks and the cost of connecting customers to networks (BEIS, 2018b) (Imperial College, 2018). For example, HNIP applicants stressed that, due to the high upfront costs, the schemes would have been financially unviable without the capital support of the programme or, more specifically, without the support to move into commercialisation and construction phases (BEIS, 2018b). This initial injection of capital and increased deployment of heat networks can further bring down deployment and operating costs due to greater standardisation and a more competitive market. Similar to HNIP, the GHNF provides support to overcome the initial upfront capital costs of low-carbon technology deployment and also aims to bring down the operating costs in the long term and work towards creating a self-sustaining market (BEIS, 2022c).

As noted previously, heat networks offer one of the biggest growth potentials for energy networks in Europe, with the potential of between £60 billion and £80 billion investment by 2050 and the creation of 30,000 jobs (BEIS, 2022a). Therefore, programmes offering capital funding to support infrastructure investment, can also support the growth and development of supply chains and project sponsors (e.g. councils and the wider public sector). However, when government investment is time-limited, this can create uncertain long-term demand for the industry and can lead to supply chain reluctance to invest in upskilling (North East Local Enterprise Partnership, 2021).

This issue has informed the design of the GHNF, which continues from HNIP and aims to create longevity of demand and certainty for market expansion. The aim of the capital investment in heat networks is to develop a self-sustaining market, no longer reliant on capital schemes. The idea is that this will be achieved by: stimulating greater creativity in heat network

design; increasing interest from consultants and technologists; instilling greater supply chain confidence to invest in skills, expertise and marketing; reducing costs, and creating a large scale public sector market (BEIS, 2018b).

The need for supply chain skills development extends beyond the people directly involved in the construction and operation of heat networks. A 2013 government report on the barriers to the deployment of heat networks noted that “training of local authority procurement staff and part funding for legal advisors would help to avoid schemes stalling at the procurement stage " (Department of Energy and Climate Change, 2013). This is important because the local authority will play a significant role in the designation of zones. However, it may be mitigated somewhat depending on the choices made within the detailed policy development for zoning; including the routes to market to be used in zones, the extent to which local authorities procure heat networks in all zones and the extent to which the zoning pilots effectively accelerate heat network development in some areas ahead of others. Scotland’s Local Heat and Energy Efficiency Strategies (LHEES) aim to establish local authority area-wide plans and priorities for systematically improving the energy efficiency of buildings and decarbonising heat. The evaluation of Scottish government’s pilot of LHEES highlights the lack of local authority resources, expertise, and the reliance on consultants to deliver the scheme (Scottish Government, 2022). The evaluation recommends that a dedicated officer is employed within councils to deliver such schemes, which could be a useful insight when addressing how zoning will be resourced. GHNF recognises a lack of skills and knowledge as a barrier to heat network deployment and therefore aims to address this issue by building the skills and the knowledge to operate heat networks through its fund (BEIS, 2022c).

If a programme has a focus on capacity building to ensure impact beyond the scheme being supported, programme design is important. For example, the Pioneer Cities project was launched by the UK government in 2013 to address key barriers that local authorities encounter during the early stages of heat network development. The programme allowed funding recipients to use some of the money to hire consultants to produce feasibility studies (Ambrose, Eadson, & Pinder, 2016). This will have helped overcome a barrier to the implementation of the specific heat network concerned but may not always have resulted in improved capacity within the local authority to increase the likelihood of future successful scheme development (Ambrose, Eadson, & Pinder, 2016). The evaluation of Phase 3 of Scotland’s Local Heat and Energy Efficiency Strategy (LHEES) pilots found that hiring external consultants led to very varied results in terms of local authority capacity building (Scottish Government, 2022).

Similarly, a key lesson learned from HNIP was a concern about whether the scheme was supporting capacity building to the fullest extent that it could. The GHNF includes a requirement for Market Transformation Commitments (MTC). MTCs are used to ensure the project is aligned with the Governments ambitions to Build Back Better by creating reliable and resilient energy systems, growing local supply chains, addressing skills gaps and investing in research and development. All applications to GHNF will be required to sign up to these commitments (BEIS, 2021b).

RQ3: The impact of specific policies and programmes on GHNF

As noted above, this review was initially carried out in August 2022 at the beginning of the evaluation. It has then been updated in July 2023 to reflect policy and market developments. In February 2024 the content was reviewed to ensure it remained fit for purpose and it will be updated throughout the lifespan of the evaluation. It should be noted that the review was developed prior to the July 2024 general election and change of government, and any discussion of current and future policy direction should be understood in this context.

The GHNF provides capital support for the development of low or zero carbon heat networks. Therefore, any other policy action that increases demand for heat networks or reduces the cost of their development / the cost of low or zero carbon heat supply technologies may increase the effectiveness of GHNF. Conversely, any policies that might delay or stall heat network development plans may reduce interest in the GHNF. This section summarises policies and programmes that may have impacts on GHNF. There is no evidence in the literature that directly addresses the question of whether or not they will actually have an impact.

Market regulation

In late 2021, the Government announced that Ofgem would be appointed as heat networks regulator for Great Britain. This means that Ofgem is responsible for enforcing consumer protection rules, regulating both supply and operation functions for heat networks, monitoring compliance and acting where necessary (Energy Saving Trust, 2022). With regulation, so comes the support from Citizen's Advice and the energy ombudsman.

Updates to regulations in 2020 enabled heat network developers to become licensed to be statutory undertakers (BEIS, 2020c). Statutory undertaker rights allow developers to carry out complex construction involving disruption of roads when installing pipework. Members of the industry have mentioned to DESNZ that they would like to see tight scrutiny of the licenses awarded, ensuring that only financially viable operators are approved (BEIS, 2022h).

While the heat network market is not yet regulated, the UK Government supports the idea that the market must be supported by regulation, consumer protections, and standards to secure a faster roll out of low-carbon heat networks (BEIS, 2020c). There is also wide support in the industry for consumer protection measures, especially for consumers who are required to connect (including owners of non-domestic buildings). In a recent BEIS consultation on Heat Network Zoning, 76% of respondents were in favour of this (BEIS, 2022h). The Energy Bill Relief Scheme (EBRS) and Energy Bills Discount Scheme (EBDS) established new regulatory requirements on heat networks. For example, the Energy Bills Discount Scheme Regulations and Energy Bills Discount Scheme Pass-through Requirement have introduced requirements for heat networks, such as the requirement that they must declare themselves, and if the heat supplier has benefited from EBRS or EBDS, they must communicate this to their consumers and pass that benefit on to heat network consumers in a just and reasonable way (DESNZ, 2023).

In 2022, BEIS announced that they wanted to develop standardised quality assurance processes that will provide demonstration of compliance to relevant standards and plausible

performance data for heat networks. This will establish compliance with mandated standards, improve data about heat network performance, and improve accountability for parties involved in heat network design, build, operation, and maintenance (BEIS, 2022h). Work has begun to identify the appropriate governance frameworks, technical requirements, and procedures necessary to achieve the objectives of the program. Good progress has already been made in designing and establishing a scheme that can offer reliable assurance of heat network quality and performance, while also demonstrating adherence to technical standards (CIBSE Journal, 2023).

Waste heat

Gas is the fuel that currently powers 90% of heat networks but the planned low-carbon future for heat networks involves heat pumps and waste heat recovery (BEIS, 2018). Waste heat is a potentially abundant and low-cost source of low-carbon heat for use in heat networks. Around 310TWh/yr of potentially usable waste heat is generated around the country and waste heat is regarded as an essential component of future energy scenarios (BEIS, 2021i). DESNZ has indicated its intention to pursue decarbonisation of heat networks using waste heat, where possible, and to build and extend heat networks across the UK that recycle heat produced in industrial processes (BEIS, 2017).

Heat Pumps

Heat pumps will also play a major role in heat decarbonisation and the Government's intention is to grow the heat pump market to 600,000 installations a year by 2028 (BEIS, 2021j). The Boiler Upgrade Scheme (BEIS, 2022e) offers financial support to encourage heat pump (and biomass boiler) installation in homes in any location in England and Wales.

The Heat Pump Ready Programme is designed to increase heat pump uptake in both domestic and non-domestic buildings but is not seeking to deploy heat pumps in areas which are suitable for heat networks (BEIS, 2021j).

GHNF, the Public Sector Decarbonisation Scheme and the Social Housing Decarbonisation Fund, include support for ground-source heat pumps, which can work in tandem with heat networks (BEIS, 2021j). In addition, the government consulted on the Market-based mechanism for low-carbon heat in 2021. This consultation sought views on proposals to introduce a market-based mechanism to support the development of the UK market for low-carbon electric heat pumps. Having considered the responses, the government intends to proceed with developing plans to introduce a market-based mechanism for low-carbon heat (BEIS, 2023).

Levelling up policy and fuel poverty

In February 2022, the Government published the Levelling Up United Kingdom white paper (DLUHC, 2022). The document collects a history and analysis of the causes behind economic and social disparities across the UK and discusses Government plans to address and mitigate these disparities.

The Levelling Up white paper sets out the Government's aim to deliver against targets across 12 focus areas, including: Living Standards, Research and Development, Skills and Housing. None of the focus areas are directly linked to energy, heat decarbonisation or heat networks although investment in these three areas could contribute towards progress in the focus areas listed.

Government is also committed to tackling fuel poverty. A recent policy paper emphasised the commitment to ensure households in fuel poverty "have access to sustainable, low-carbon warmth as we transition to net-zero" (BEIS, 2021i).

As part of this strategy, government wants to continue investing in domestic and non-domestic energy efficiency measures through existing programmes such as the Home Upgrade Grant, Energy Company Obligation (ECO), and Green Homes Grant Local Authority Delivery. It is also improving regulatory obligations and standards through policies such as Future Homes Standard and Decent Homes Standard (BEIS, 2021i).

Heat Network Zoning

Recent developments in heat network and broader energy governance that could affect GHNF are the forthcoming introduction of heat network zoning and the increasing support for Local Area Energy Planning.

Heat network zoning refers to the process of identifying and designating areas as "heat network zones", within which heat networks are expected to be the lowest cost, low-carbon solution for decarbonising heat (BEIS, 2022h) (DESNZ, 2023b). The Energy Act 2023, which received Royal Assent in October 2023, enables the Government to implement heat network zoning through secondary legislation. DESNZ consulted on further policy detail from December 2023 to February 2024, in advance of secondary legislation expected in 2025/2026. Following the Heat Networks Zoning Pilot[13], DESNZ is also running the ongoing Advanced Zoning Programme, which aims to have at least 10 heat network zones under construction by December 2026.

It is generally accepted that decarbonisation needs to have a regional focus on heat and a 'one-size fits all' approach is not the optimal way to achieve net zero (National Grid ESO, 2022). Heat network zoning is intended to complement GHNF by ensuring heat networks are deployed where they are most appropriate (BEIS, 2022h).

DESNZ believes that heat network zoning will help drive demand and grow the market by requiring certain buildings to connect to a heat network within a zone (BEIS, 2021d). Within heat network zones, large non-domestic buildings, new buildings and existing buildings which are already heated via communal systems could be required to connect to a heat network within a given timeframe (BEIS, 2021d; DESNZ, 2023b). This should act to reduce investor perceptions of risk and hence increase the private finance available for heat networks (BEIS, 2020d).

[13] Heat Networks Zoning Pilot - GOV.UK

Local authorities will need the powers to identify and designate the best suitable areas for low-carbon, cost-effective heat networks (BEIS, 2021d). Designating heat network zones is a major role in the future of the heat network market, and local authorities are relatively new stakeholders in this sector. The way they operate can be very different to the private sector and the overall impact of their increased participation on the market is not known.

Local Area Energy Planning

There is increasing interest in Local Area Energy Planning[14], which is a data driven and whole energy system, evidence-based approach that sets out to identify the most effective route for a local area to contribute towards meeting both local and national net zero targets. The Scottish Government has piloted the development of LHEES and has now placed a statutory duty on Scottish local authorities to produce local energy plans (Scottish Gov, 2022). LAEP in other parts of the UK is being promoted and supported by a number of organisations including the Energy Systems Catapult (Energy Systems Catapult, 2022) and the Centre for Sustainable Energy (CSE, 2020). Ofgem is also considering the institutional structure needed to best manage local energy systems (Ofgem, 2022).

RQ4: Who are the key actors involved in the development of heat networks?

There are a range of stakeholders identified within the literature analysed by the research team, but this list was far from exhaustive. There is not a single source that comprehensively lists or maps stakeholders across the heat network sector.

Therefore, the research team have taken learnings from the literature and added additional stakeholders from the wider project's stakeholder mapping exercise.

The project team created a database of relevant stakeholder groups using examples from the UK by sharing data from existing literature, industry knowledge from the consortium leading the GHNF evaluation and DESNZ own data and knowledge.

The following categories and sub-groups have been mapped:

- Projects and sponsors – including those that have applied for government funding and non-applicants
- Aggregate users – including developers who build at scale and campus-based schemes
- Consumers – the users of a service, in this case heat
- Supply chains (and the wider market) – organisations that deliver heat network projects
- Energy investors – those that invest in heat network projects
- Waste heat suppliers – those organisations that supply waste heat to heat networks
- Policy – those with influence, but not directly involved with heat network project stakeholders.

Details of stakeholders across these groups have been expanded below.

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Please note that this section of the report links to research question 1e (What is the current makeup of the supply chain?).

Projects and sponsors

There are a range of stakeholders that are directly involved in heat network projects, including both those involved in GHNF projects (applicants) and those that are not (non-applicants). These organisations take an active role in developing heat networks.

From the public sector:

- Local government
  - *e.g. councils*
- Public sector – public bodies
  - *e.g. campus schemes (universities and hospitals), city centre schemes (municipalities)*
- Registered Socials Landlords (RSLs)
  - *e.g. The Guinness Partnership, Optivo*

From the private sector:

- Developers of new buildings
  - *e.g. Taylor Wimpey, Crest and Barratt*
- Owners of heat sources
  - *e.g. those who own and operate heat sources – industrial energy, data centres, Energy from Waste sites.*

In addition, Energy Service Companies (ESCos) are also part of this stakeholder segment and can include a mix of private and public sector organisations in a variety of commercial structures (Grant Thornton, 2018). Examples include *Vital Energi, Pinnacle, Veolia, EQUANS, Metropolitan, 1Energy.*

Sponsors of heat networks are expected to change dramatically as heat network zoning and regulation is introduced. Firstly, the introduction of Statutory Undertaker Rights through heat network regulation will allow private heat network operators rights akin to other forms of infrastructure with respect to crossing roads, railways etc (BEIS, 2020c). This may lead to more private-only, larger heat networks being developed where previously the developer would have needed to partner with the local authority in a joint venture to benefit from such rights. Further, the routes to market that will be used in zones are not currently clear but are likely to be diverse. The local authority will be strongly involved in the designation of the zone and in at least some cases, will act as the zoning coordinator, mandating the public sector estate and larger private buildings in the area to connect to the heat network. In other cases, a different body, such as central government, may act as zoning coordinator (BEIS, 2020c). In different areas, the local authority may want to be actively involved in the delivery of the network or may be less involved. It is likely that there will be a range of competition and procurement approaches used to reflect these different circumstances.

Aggregate users

There are a range of stakeholders that aggregate consumers as part of heat network development including domestic and non-domestic building developers, and heat developers (who develop heat sources).

Consumers

Consumers are defined as users of a service, including heat. This can include domestic consumers, but also non-domestic users, from both the public and private sectors.

Consumers can be split down into more specific groups, as detailed below.

Non-domestic

There are a range of non-domestic "consumers of heat" relating to heat networks, including those in both new and existing buildings:

- Public sector stakeholders, including those from:
    - The national government estate, including:
        - *Ministry of Defence (MoD), Department of Justice (DOJ), The National Health Service (NHS), Police and Fire Services.*
    - The regional government estate, including offices.
    - The local government estate, involving both single tier councils (Metropolitan, Unitary and London Boroughs) and two-tier councils (County and District councils), and including offices, leisure centres, schools and libraries.
        - *Examples include: Woking Borough Council, Westminster City Council, West Sussex County Council*
    - Higher education estates, including universities and colleges.
        - *Examples include: University of Dundee, University of Warwick, University of Edinburgh, Bloomsbury Heat and Power Consortium*

- Commercial sector stakeholders, including those from industrial sectors, agriculture, private education (including academy schools), private healthcare, utilities and waste, transport, culture and leisure, and commercial buildings)
    - *E.g. the London Stadium*

Note that in addition to being heat users, some of these consumers may also be heat providers, delivering waste heat to heat network projects.

Domestic

There are a range of domestic stakeholders, including:

- New build domestic building stakeholders:
    - Private developers
    - Social housing new build developments are led by a range of stakeholders including local government, as well as Registered Social Landlords (RSLs)

    - (Note that residents are not in situ and therefore not classified as stakeholders).
- Existing domestic building stakeholders, including those in individual tenures:
    - Private owner-occupier sector residents
    - Private rented sector (PRS) residents and landlords
    - Social rented residents and Registered Social Landlords (RSLs) (including those owned by local government and Arms-Length Management Organisations (ALMO)).

Supply chains and wider market

There are a range of organisations in the supply chain and wider markets that are involved in the delivery of heat network projects.

Manufacturing is outside the scope of the evaluation project and therefore these stakeholders have not been included here.

Professional services

There are a range of professional services stakeholders that work across various stages of heat network delivery, including:

- Legal consultants
    - *(e.g. Gowling WLG (UK) LLP, Bevan Britton, Heat Network Associates Ltd, Lux Nova)*
- Technical consultants
    - *(e.g. AECOM, Arup, Atkins, Buro Happold, Eneteq, Fairheat, Now Then Energy Ltd, Phil Jones, Mabbett and Associates Ltd, WSP, Hoare Lee, Ramboll)*
- Feasibility consultants
    - *(e.g. Arup, d3associates, Enica, Fairheat, FVB District Energy UK Ltd, Mabbett and Associates Ltd, WSP)*
- Project design and development consultants (including the management of sub-contractors)
    - *(e.g. Arup, Breathe Energy, d3associates, Enica, Fairheat, FVB District Energy UK Ltd, Hodkinson Consultancy, Mabbett and Associates Ltd, Reheat (Renewable Technologies) Limited, WSP, SAV, Altecnic, Cenergist, CSE, Arcadis)*
- Legal and financial consultants, including contracting and procurement functions
    - *(e.g. d3associates, Enica, Teno Energy)*

Survey companies

There are a range of organisations working in surveying roles as part of heat network development. This includes quantity and ground surveyors, for example *Dachol Services Ltd (quantity surveyors).*

DBOM contractors

There are a range of Design, Build, Operate and Maintain (DBOM) stakeholders involved in the development and delivery of heat networks. This includes contractors offering bundled DBOM services and those that offer specific services including:

- Design and Build (D&B) contractors.
- Operate and Maintain (O&M) contractors
- Metering and Billing (M&B) contractors.

Example companies include:

- Package (offers DBOM):
  - *Pinnacle Power, SSE, Vital Energi, Engie Cofely, SSE, British Gas, SW Energy, Veolia, Vital, E.ON, MITIE. Skanska, and NG Bailey.*
- Unbundled (offers specific services):
  - *Switch2 Energy Ltd, Reheat (Renewable Technologies) Limited, Fairheat, Birdsall, Insite, Sycous, FVB District Energy UK Ltd.*

Construction professionals

There are a range of organisations that include heat networks into their developments. This includes both domestic and non-domestic developers. Examples include *Taylor Wimpey, Crest and Barratt.*

Equipment and component suppliers

There are a range of equipment and component supplier stakeholders, including:

- Control systems
  - *(e.g. Danfoss, Micc Group)*
- Heat exchangers:
  - Domestic
    - *(e.g. Danfoss, Essco, SAV Systems, Thermal Integration Ltd.*
  - Non-domestic
    - *(e.g. Danfoss, Essco, SAV Systems, Thermal Integration Ltd., SWEP, Alfa Laval, Kelvion (GEA), UK Heat Exchangers)*
- Home Interface Units (HIUs) and Meters and Billing Systems
  - *(e.g. SAV Systems, Altecnic, Vital, Evinox, Thermal Integration, Bosch, Mitsubishi, McCallum Water Heating, Logstor, IsoPlus, Switch 2)*
- Pipe systems
  - *(e.g. CPV, Isoplus, Logstor, Powerpipe, Aquatherm, REHAU, Uponor, Brugg, Flexenergy).*
- Heat pumps (air/ground/water)
  - *(e.g. Genius Energy Lab Limited, Kensa, LC Energy, SAV Systems, Star Refrigeration)*
- Boilers (including biomass) and engines
- Electrical contractors

Installation, operation, and maintenance contractors

There are a range of installation, operation, and maintenance contractors, including:

- Civil engineers
  - *(e.g. CPC Civils, Jackson Civils)*
- Mechanical engineers
  - *(e.g. JGD District Heating, PPSL District Heating, Eneteq, Valmech, Proven Project Construction, Kensa Contracting)*

Energy investors

There are a range of stakeholders that invest in heat network projects, including:

- Private sector investors
  - *1energy*
  - *(e.g. Amber Infrastructure Limited (Fund: IPP Investments Limited Partnership)*
  - *Amber Infrastructure Limited (Fund: The Mayor of London's Energy Efficiency Fund LP)*
  - *Amber Infrastructure Limited (Single Entity)*
  - *Ancala Partners LLP*
  - *Asper and Gren*
  - *Asper Investment Management Ltd*
  - *Dalmore Capital Limited*
  - *DIF Capital Partners*
  - *Downing LLP*
  - *E.ON UK Infrastructure Services Limited*
  - *Equitix Holdings Limited*
  - *Fortum Power and Heat Oy*
  - *GLIL*
  - *Green Finance Institute (GFI)*
  - *Green Investment Group*
  - *Greencoat Capital LLP*
  - *Gravis*
  - *Hartree Partners*
  - *Ingenious*
  - *Iona Capital*
  - *Kyotherm*
  - *Neovela Group*
  - *Octopus Investments*
  - *PEAC (UK) Limited*
  - *Hemiko (former Pinnacle Power Limited (Fund: PP Esco DivisionCo Ltd))*
  - *Hemiko (former Pinnacle Power Limited (Fund: PP ESCO HOLDCO LTD))*
  - *SMBC Leasing (UK) Limited*
  - *Sustainable Development Capital LLP*
  - *Temporis Capital Limited*
  - *TP Leasing Limited*

    - *Triple Point Energy Efficiency Infrastructure Company Plc*
    - *Triple Point Investment Management LLP*
- Public sector investors
    - *(e.g. Public Works Loan Board, Pension Infrastructure Platform (PIP), UK Infrastructure Bank, Salix, Central Government, the Mayor of London).*

Waste heat suppliers

There are a range of stakeholders that are providers of waste heat that is used in heat networks. This includes suppliers and contractors in the following areas:

- Recovered waste heat from industrial processes and data centres (e.g. industrial sites (including those with carbon capture and storage systems, and hydrogen) and power stations, supermarkets, data centres, Transport for London).
- Energy from Waste (EfW).
    - *(e.g. Waste authorities, Altcom, CeraPhi Energy, Hydracrat (geothermal drilling contractor), Eden Geothermal, EGS Energy, Geothermal Engineering Ltd (Developer/Operator), GEAA, GT Energy, Hotspur Geothermal, Marriott Drilling Group, TownRock Energy, Merlin Energy Resources, Geolorn, Storengy, Geoscience).*
- Power generators, including biomass technologies.
    - *(e.g. Engie, Aberdeen Heat and Power, Veolia)*
- Wastewater heat sources from utility companies, mine-water and deep geothermal drilling projects.
    - *(e.g. Canals and Rivers Trust, Coal Authority, Altcom, CeraPhi Energy, Hydracrat (geothermal drilling contractor), Eden Geothermal, EGS Energy, Geothermal Engineering Ltd (Developer/Operator), GEAA, GT Energy, Hotspur Geothermal, Marriott Drilling Group, TownRock Energy, Merlin Energy Resources, Geolorn, Storengy, Geoscience).*
- Biomass
    - *(e.g. Compte-r, LC Energy (biomass and heat pump supplier), Myriad Heat and Power Products Ltd, Reheat Limited).*

Policy and wider stakeholders

There are a range of stakeholders that have influence but are not directly involved with heat network project stakeholders. This includes:

- UK government:
    - Department for Energy Security and Net Zero (DESNZ)
    - Triple Point
    - Department for Levelling up Housing and Communities (DLUHC)[15]
    - Department for Environment, Food and Rural Affairs (Defra)
    - Cabinet Office
    - HM Treasury

[15] Now Ministry of Housing, Communities and Local Government (MHCLG)

    - Department for Transport
    - Salix
- Devolved administrations:
    - Welsh Government
    - Scottish Government
    - Northern Ireland Assembly
- Regulators and system operators:
    - Office of Gas and Electricity Markets (Ofgem)
    - Water Services Regulation Authority (Ofwat)
    - Distribution Network Operators (DNO)
- Regional and local level government:
    - Regional and local government, including Combined Authorities and individual councils
    - Local Enterprise Partnerships (LEPs)
    - DESNZ Energy Hubs
    - Local Government Association (LGA)
- Training providers
    - *(e.g. Vital Energi Training Academy).*
- Other stakeholders including:
    - The Heat Network Industry Council (HNIC)
    - Trade associations
        - *(e.g. heat network trade associations, including the Association for Decentralised Energy (ADE) and the UK District Energy Association (UKDEA), heat pump trade associations, including the Ground Source Heat Pump Association (GSHPA), Heat Pump Association (HPA) and the Heat Pump Federation (HPF), renewables trade associations including Association for Renewable Energy and Clean Technology (REA) and Scottish Renewables)*
    - Heat Trust
    - The Heat Network

RQ5: What are the awareness, attitudes, behaviours and needs when it comes to the transition to low-carbon heat network solutions?

The research team have explored the following stakeholder groups in the sections below:

- Consumers
- Supply chains
- Energy investors
- Projects and sponsors
- Energy Service Companies (ESCos)
- Aggregate users

RQ5a: Consumers

Much of the literature identified is focused on domestic consumers but insights on non-domestic consumers are included throughout where possible.

Awareness

In 2019, six Parliamentary select committees called for a citizens' assembly to help understand the public's preferences on how the UK should mitigate and adapt to climate change. The UK Climate Assembly brought together members of the public to discuss how the UK can reach net zero by 2050. In addition to learning about climate change and the potential solutions in the UK to address it, delegates were convened to discuss key issues and then made recommendations. The UK Climate Assembly report (Climate Assembly UK, 2020) reported on Assembly participants' attitudes to heat decarbonisation technologies. The report illustrates that, when presented with explanations of technologies, the general public understood the pros and cons of different options for decarbonising heat in homes, including heat networks, but also heat pumps and hydrogen.

The 2022 BEIS Public Attitudes Tracker (BEIS, 2022f) explored consumer awareness and knowledge of low-carbon heating systems. Following an introduction explaining the ways that the UK's building stock will need to change to meet net zero, 87% of respondents said that they had a good awareness of low-carbon systems (with 31% of respondents saying that they knew a lot or a fair amount). From the total number of respondents, 13% had never heard of low-carbon heating systems before (BEIS, 2022f).

In addition, the public attitudes tracker (BEIS, 2022f) also explored awareness levels by gender, age, and education level.

- The results showed only a small gender difference in overall knowledge. However, men were much more likely to report that they knew at least a fair amount about the need to change to low-carbon heating systems than women (39% of men versus 22% of women).
- In terms of age, the older respondents (those aged 55 and over) had a higher level of knowledge (36%) compared to those aged 25 to 54 (28%) and those under the age or 25 (22%).
- Meanwhile knowledge was much higher for those educated to degree level (44%) compared to those with a lower qualification (26%) or with no qualifications (18%).

Looking specifically at consumers' awareness of heat networks, this is growing, but slowly. BEIS's December 2020 Quarterly Public Attitudes Tracker (BEIS, 2021f) indicated that less than a third of respondents (28%) had heard of heat networks. More recent social research for BEIS into heat network zoning policy (BEIS, 2022g) (but notably a different study) found that around 30% of respondents had previously heard of heat networks.

Attitudes

In 2018, Energy Systems Catapult reported findings from a trial in advanced home energy management systems in 30 homes (Energy Systems Catapult, 2018). The research concluded that "*90% of consumers would prefer gas central heating to lower carbon alternatives*". While this headline finding could be viewed negatively, the study was very small, and the researchers

concluded that consumers cared more about their experiences in the home than how services were delivered. Study participants liked the concept "*of buying services, like a warm home, rather than kWh of fuel and a boiler*" and they were more likely to welcome new technologies if they resulted in enhanced home heating experiences. The research team considered that progress in the transition to low-carbon heating would be "*faster and simpler if consumers found low-carbon heating designs more appealing*". For example, this involved fixing widespread problems like damp, mould, draughts and overheating (which were issues reported by two thirds of households involved in the study) or helping consumers to get more value from the energy they use. This could have important implications for the design of successful heat network offerings to consumers.

The UK Climate Assembly report also includes commentary on delegates' views on heat networks (Climate Assembly UK, 2020). Typically, delegates focussed on domestic buildings. Some advantages of heat networks were outlined by delegates:

- The fact that heat networks are ready for deployment now
- The use of low-carbon heat sources, such as the use of waste heat
- The sense of taking communal action and joint cooperation with multi-user systems
- Maintenance is conducted centrally and not in individual homes (although some delegates had raised concerns over maintenance and repair (see below).

On the other hand, the following potential issues or limitations were identified:

- A large but unspecified number of delegates considered that heat networks were not suitable everywhere, noting that they were more likely to be found in cities and urban areas, with high densities of buildings, and therefore not available for the majority of UK homes.
- There was an expectation that there would be high levels of disruption in retrofitting heat networks in existing buildings compared to new buildings.
- Some delegates [number not defined] suggested that deployment could be cheaper and easier in flats, but in individual homes heat network deployment would be too disruptive and expensive.
- There were also concerns on:
    - The level of individual controls for consumers within buildings
    - The monopoly status of networks with consumers unable to switch to alternative systems
    - Maintenance and repair issues
    - The potential need for additional systems, such as immersion heaters.

Despite the relatively low awareness about heat networks mentioned previously, the experience of actual heat network consumers seems to be positive. The literature offers some insight into heat network consumer satisfaction with their heating and hot water service.

BEIS's Heat Networks Consumer Survey (BEIS, 2017a) found that heat network consumers were as satisfied (74%) with their heating system as non-heat network consumers (72%). Some dissatisfaction was expressed relating to billing, perceptions of over-pricing, levels of control and service interruptions (which are explored further below in 'consumer needs'). The survey also found strong support for increased regulation to protect consumers' interests due to the natural monopoly nature of heat networks.

More recent data from the Heat Networks Consumer and Operator Survey (BEIS, 2022d) found that the proportion of heat network consumers satisfied with their heating remained the same as in 2017, (74%) but the percentage of non-heat network consumers who were satisfied with their heating system had fallen slightly (from 72% to 67%). The survey also looked at how satisfaction differed between communal and district networks, across different operators and with age of property. It found that:

- Consumers on district networks were twice as likely to be dissatisfied (19%) as consumers on communal networks (10%),
- Consumers on schemes led by local councils were more likely to be dissatisfied (19%) than those on schemes run by private operators (13%) or an RSL (9%).
- Consumers on heat networks in newer properties (homes built after 2010) were more likely to be satisfied with their heating system (73%) than those in older properties (2000 – 2010,64%, and pre-2000, 62%).

In terms of the general public's views on heat networks, the BEIS's 2020 Quarterly Public Attitudes Tracker found that, following the provision of information on heat networks, almost two thirds (66%) of respondents would be likely to join a local heat network if given the opportunity (BEIS, 2021f).

More recent social research for BEIS into heat network zoning policy (BEIS, 2022g) found that 72% of respondents (including domestic consumers in public and private housing, but also public sector and commercial consumers) indicated that, following the provision of information on heat networks, participants would be likely to connect voluntarily to a heat network in a zoning area. This research indicates appetite amongst consumers in joining local heat networks. However, it should be noted that these two studies cannot be directly compared.

The enthusiasm for heat networks from the zoning social research stemmed from perceived direct benefits of connecting to a heat network, including lower heating bills (95%), implementation of cost-effective heat decarbonisation activities in their buildings (93%) and increased building comfort (86%). Respondents had concerns about performance and reliability and identified incentives and regulation as key to successful heat network zones.

This positive attitude to heat networks was recorded after research participants had received information on climate change, heat decarbonisation and heat networks. When presented with information on heat networks, participants from the study noted that they would want specific information about installation, including upfront costs, disruption and delivery timescales to make an informed decision. This suggests that the development of new heat networks will require extensive consumer engagement.

BEIS social research on heat network zoning identified that there is a limited evidence base of stakeholders' attitudes on heat network zoning specifically. This is principally because zoning is an emerging policy area. While there is some international research that introduces insights from European countries' use of zoning policies, these are set in a policy environment and amid social attitudes which may be different to those of the UK (BEIS, 2022g).

Finally, it is important to note that there is a need for transparency as part of this engagement, and also in the wider operation of heat networks. A BEIS study looking at international heat network markets noted consumer attitudes research from the Netherlands, Finland and the UK, which found that transparency was a key component of consumer satisfaction (BEIS, 2020d).

Research published by the North East LEP, focussing on the development of mine water energy, has examined attitudes at the development stage of mine-water fed heat networks. Expert stakeholders noted that where care is not taken to clearly communicate the potential risks and disruption associated with mine water heat networks, local resistance can increase.

> *"While early indications suggest that communities respond favourably to mine energy schemes in principle, this can change rapidly should schemes create significant disruption, or potential opponents of a scheme inflate community perceptions of risk"* (North East Local Enterprise Partnership, 2021).

Reliability, controllability and customer service were also important factors tied to positive consumer experiences to heat networks, suggesting that these are all needs that must be met as part of the customer experience. BEIS's Heat Networks Consumer Survey Report (BEIS, 2017a) identified several key consumer needs, which were not being fully satisfied by heat networks leading to reduced satisfaction:

- 37% of heat network consumers reported service interruptions in the previous 12 months, compared with 24% of non-heat network consumers, and 21% reported multiple interruptions over the same period.
- Almost 40% of heat network consumers had experienced overheating in the previous 12 months.
- Heat network customers who had complained about their heating were less likely to be satisfied with the complaints resolution process than non-heat network customers.

A later and expanded BEIS study - Qualitative Research with Consumers and Operators of Heat Networks - also found that the above issues (system reliability, controllability, and responsiveness and effectiveness of repairs and maintenance) impacted satisfaction scores (BEIS, 2018d). Periodic and planned interruptions were accepted by consumers: most consumers were satisfied with the frequency and handling of such interruptions and saw them as a necessary part of network maintenance. However, some heat network consumers reported frustration with unplanned outages, particularly where they felt their provider had not acted promptly to resolve an issue, where there was a lack of clarity on who was responsible for repairs, and where communications to consumers fell short in terms of billing or repairs updates.

Behaviours

Lack of control and resulting overheating were issues explored in BEIS's Heat Networks Consumer Survey Report (BEIS, 2017a). Headline findings included that:

- 39% of heat network consumers had experienced overheating in the previous 12 months (compared to 22% of non-heat network consumers)
- 13% of heat network consumers reported that their home was 'always' too warm (compared to 3% of non-heat network consumers)

As a result, heat network consumers were slightly more likely to report opening windows or using electric fans to deal with overheating.

The research also found that customer billing is unlikely to incentivise energy saving behaviours:

- Heat network consumers reported that they were "*less likely to receive any form of bill, account summary or statement*" in comparison with non-heat network consumers.
- Only 27% of respondents reported bills based on actual use, compared with over half (53%) of non-heat network consumers.
- A relatively large proportion of heat network customers (20%) were paying bills based on the overall building heat demand.
- A relatively large proportion (18%) paid a set price for their heat that didn't vary with actual consumption.

Needs

The literature included commentary on the need for locally relevant solutions, information and awareness of technology options, consumer choice, and support from industry to choose the best solution for their property.

Technology solutions need to be appropriate at the local level. Over 94% of UK Climate Assembly delegates agreed that local areas or regions should be able to choose the technologies best suited to their needs (Climate Assembly UK, 2020). This finding was mirrored in National Grid's most recent Future Energy Scenarios report (National Grid ESO, 2022).

The need for increased consumer awareness of technology options has been noted above. Consumers need sufficient information on technology options to choose what is right for their property. This will require a range of stakeholders to raise consumer awareness of low-carbon technologies, as well as supply chain support for consumers to select the best technology for buildings.

In its most recent Future Energy Scenarios report, National Grid outlined how the choices of consumers will have big impacts on how the UK will meet its net zero ambitions cost effectively (National Grid ESO, 2022). National Grid also acknowledge that consumers who are "willing

and enabled to engage with the energy system [are] crucial" and that consumers "need to be reliably informed" about the steps that they can take. National Grid call for "targeted campaigns, led by trusted bodies", "to provide consumers with the information they need to decarbonise and embrace new technology".

Research by the Energy Systems Catapult published in 2018, explored advanced energy management systems in a small number of domestic properties (Energy Systems Catapult, 2018). The report acknowledged that "consumers will need help to get high quality experiences from low-carbon heating solutions". Most consumers [proportion not defined] preferred "to be able to trust someone else to simplify" the complexities around low-carbon heating and participants were open to businesses playing a larger role in selecting the technologies to install in their properties.

Customer choice also featured in the literature regarding heat networks. The UK Climate Assembly report (Climate Assembly UK, 2020) highlighted that, while 80% of Climate Assembly participants agreed or strongly agreed that heat networks should be part of the pathway in reaching net zero targets, there was overwhelming emphasis on the need for consumer choice.

A report published by Citizens Advice also focussed on billing and over pricing issues (Citizens Advice, 2018). The research participants called for more information from their heat network operator so that they could understand their energy bill. In addition, the Citizens Advice report also highlighted that "many residents felt misinformed and lacked information when heating systems were installed on their estates or when moving onto a new estate". Once in the property, some residents felt that heat networks offered a lack of freedom in terms of fuel switching and seeking out cost saving opportunities from suppliers, leading to "a feeling of entrapment into a deal that perhaps they don't want or can't pay".

RQ5b: Supply chain

There are a range of stakeholders under this category, including: professional services consultants; survey companies; Design, Build, Operate and Maintain (DBOM) contractors; construction professionals; equipment and component suppliers, and installation, operation and maintenance contractors.

These stakeholders are an integral part of the supply chain and they can facilitate and support the transition to net zero and decarbonisation of buildings, but also may contribute to the barriers that slow down uptake of new technologies and practices.

As mentioned above, consumers seem to value being able to trust someone else to inform them and advise on decisions regarding their property, which puts emphasis on the role of the professionals involved in the supply chain.

Overall, there was relatively little research identified on this stakeholder segment.

Awareness

Although heat networks are classified as an immature but growing market there is good awareness of heat networks within the heating supply chain, as detailed in a previous DESNZ research study on skills (BEIS, 2020a). However, there was literature which indicated that some groups, such as equipment and component suppliers, may have limited understanding of the full details of a heat network system. BSRIA (Building Services Research and Information Association) market reports suggest that in the majority of cases, suppliers act "as subcontractors, and may have limited exposure to the project as a whole or to the client" (BSRIA, 2019). In addition, looking specifically at mine water heat network applications, a recent report by the North East LEP found that some industry stakeholder interviewees considered that there *"was insufficient awareness and acknowledgment of the actual potential risks associated with mine energy schemes".* It is understood that the Coal Authority is developing practitioner guidance (NELEP, 2021).

Attitudes

The team found no evidence describing current supply chain attitudes towards heat networks, but some evidence on how to develop positive supply chain attitudes.

BEIS's international heat networks market frameworks review (BEIS, 2020d) explores the relationships between consumers, regulators and industry across the globe and how these affect supply chain attitudes to heat networks. This found that positive relationships between these stakeholders supported the growth of the sector. For example, in the Netherlands, stakeholders described how positive relationships between regulators and the heat network industry has led to improved attitudes towards heat networks within the supply chain, which in turn has helped the resolution of complex issues and supported the growth of the sector. This was also the situation in Norway, where good industry and government relationships and a positive delivery track record sits in a context of "a light touch system of regulation" (BEIS, 2020d).

Such positive relationships have been developing between government and industry following the creation of the Heat Network Industry Council (HNIC) by the Association for Decentralised Energy (ADE) (The Association for Decentralised Energy, 2020). The council and its members have committed to creating jobs, accelerating network decarbonisation, delivering high-quality customer experiences and working with government to develop regulatory and policy frameworks to support the growth of the sector and its supply chains in the UK.

Behaviours

Market research from BSRIA details how DBOM contractors are deployed to provide specialist skills in most heat network projects. This is particularly true when the sponsor decides to take on a greater role in managing and running a network, resulting in contractors playing a more critical role (BSRIA, 2019).

As low-carbon technologies become mainstream, the supply chain may look to influence their clients and individual scheme specifications. However, a recent study found that building professionals may not share information on new, low-carbon technologies if they have little

experience with them or if they don't feel they are cost-effective for clients. Vocational professionals value their reputation and client satisfaction and if they do not feel a product is right for a client, they will not recommend it (Simpson, 2020). The study concluded that it is entirely possible that if middle actors (defined as individuals or organisations with influence, such as clerks of works, and technical advisers) don't see the value in low-carbon heat networks, neither will many of their customers. This seems to be corroborated by the research mentioned before showing that customers rely on being given information and help to choose.

As noted previously (in the consumer section of this RQ), Energy Systems Catapult research identified an opportunity for the low-carbon heating sector in supporting consumers with the specification of appropriate energy service solutions (Energy Systems Catapult, 2018). This could lead to more supply chain actors changing their business models in order to support consumers.

Needs

The main needs of the supply chain are focussed on capacity and capability (skills and expertise). Previous BEIS research has explored what additional skills are currently required in the heat network sector, and where the existing and future shortages are likely to be (BEIS, 2020a). The collaboration between HNIC and the government, wider progression on policy objectives and BEIS's broader Market Transformation programme are all supporting the industry to expand[16].

More recent research raises concern that the lack of expertise in the mine water heat sector in particular is constraining the deployment of heat networks from this waste heat source. "Specifically, there are concerns about technical consultants, scheme design engineers (borehole and pump system) and drilling contractors" (North East Local Enterprise Partnership, 2021).

RQ5c: Energy investors

Energy investors are an integral part of the market since the amount of investment required to meet heat network trajectories (estimated at £60-80 billion[17]) far outstrips the grant funding available from government.

> *"The Climate Change Committee projects that the UK need to invest £17.5 billion in heat networks by 2030. Whilst BEIS are still working through the analysis and timing of investment, it is anticipated that this scale of investment will need to continue through to 2040 if we are to decarbonise heating in the most cost-effective manner"* (BEIS, 2021h).

Investors can facilitate and support the transition to net zero and decarbonisation of buildings by financing new schemes. However, they can also present barriers, for example when they are not willing to invest in smaller schemes.

[16] Department for Energy Security and Net Zero (2024) Heat Networks. Available at: https://www.gov.uk/government/collections/heat-networks
[17] Heat Network Industry Council (2022). https://www.heatnic.uk/about-heat-networks-industry-council/

The landscape for private investment is continuously evolving and there are now several major investment firms partnered with heat network ESCOs. This includes firms such as DIF Capital, Asper and Gren, and the UK Infrastructure Bank[18]. For example, DIF Capital has committed to investing in Pinnacle Power[19], a leading UK district heating platform (DIF Capital, 2023). Asper has recently reached the final close of its UK sustainable district heating co-investment platform after making £220 million commitments from UK and global institutional investors. Asper will support investments in 1Energy, which is a platform focussed on developing, building, and operating sustainable city centre heat networks across the UK (Asper, 2023). A leading Northern European energy company, Gren, has also recently agreed to acquire 11 heat and power generation assets in the UK to support their expansion into the UK district heating market (Gren, 2023). Compared to models using balance sheet funding, the introduction of these investment firms may have an impact on how GHNF projects are structured commercially.

The UK Infrastructure Bank is also developing its portfolio in this area and have pledged £22 billion of infrastructure finance to tackle climate change and support regional and local economic growth across the UK (The UK Infrastructure Bank, 2022).

As noted above, the heat network sector has recently seen several new investors enter the market. Their entry may change the commercial models used in GHNF projects.

Awareness

There was nothing specific in the literature on energy investors' awareness of heat networks as an opportunity. However, the number of public and private sector investors already involved in the heat network market (see RQ4, above) suggests that there is a reasonable degree of awareness.

Attitudes

Investors may view alternatives to heat networks as more financially viable: the HNIP Evaluation states that several investors noted that *"heat networks compete with an existing gas infrastructure, which can render gas installation much more financially viable*" (BEIS, 2018b).

Longer repayment terms caused by lower financial viability may not be an issue in themselves, as the evaluation report for HNIP also reported that investors "*would accept long repayment terms and relatively low returns in principle, but that such investments would need to be low risk*".

However, the HNIP evaluation noted that investors considered heat network projects to have "a number of high-risk characteristics – particularly relating to demand risk (related to securing anchor load contracts) and construction risk (relating to time and cost over-runs during the construction phase)" (BEIS, 2018b). Research by IPPR came to similar conclusion on investor risk perceptions (IPPR, 2017).

[18] Now the National Wealth Fund (NWF)
[19] Now Hemiko

Behaviours

There was no research identified for this stakeholder segment in terms of behaviours. It would be useful to have access to investment figures of some companies or local authorities to see how behaviour is evolving.

Needs

Three specific investor needs are identified in the literature:

- A rate of return that is considered acceptable for the level of risk associated with the investment.
- Regulation that is considered proportionate.
- Investments at a level that is considered worthwhile.

As discussed above, heat networks may not provide as high a return as some competing investments. The gradual returns that tend to be generated from investments in heat infrastructure may not appeal to investors, particularly as they imply a need for long-term contracts between suppliers and heat users, which may not be attractive to consumers (Ambrose, Eadson, & Pinder, 2016).

There is commentary in the literature on how the risks to investors can be minimised. The ADE's task force recommendation on financial "*demand assurance*" essentially guarantees *"a return on investment in assets, even if those assets are not fully utilised, and would be provided against an approved strategic plan*" (ADE, 2018). Recent research from ClimateXChange highlights the importance of heat network zoning and the role of mandatory connections within policy frameworks in providing investment assurance (ClimateXChange, 2018).

BEIS research (BEIS, 2020d) found that *mandatory connection, as zoning will be, "is cited by many heat networks commentators as essential for investment confidence, and this is strongly backed up by feedback from stakeholders in British Columbia, Norway and Denmark*". However, strong policies to support heat networks at the local level, together with sufficient power of control over heat network development for local authorities, could be an acceptable alternative to mandatory connections for investors (e.g. in Germany and the Netherlands).

The research also found that regulation can hinder investment in some cases. In British Colombia, for example, schemes over $15 million are regulated using a regulatory model developed for large utilities with integrated networks, and investors viewed this as disproportionate and off-putting. The International Market review also highlighted that "*where there is a regulator, industry-regulator relationship and levels of trust is also clearly important for investor confidence*" (BEIS, 2020d).

The HNIP evaluation report notes a critical point around the size of investments. The report details how *"most investors highlighted a preference for investments of above £20-25m, many times larger than typical individual heat networks investment opportunities"* (BEIS, 2018a).

RQ5d: Sponsors and projects

Sponsors and other stakeholders directly involved in heat network development projects are important to driving growth in the market. This section of the report includes evidence focussed on those involved in publicly funded projects (applicants). Note that there was no evidence focused on non-applicants.

As noted previously, the sponsors of heat networks are expected to change dramatically as heat network zoning and regulation is introduced (BEIS, 2020c). Firstly, the introduction of Statutory Undertaker Rights through heat network regulation will allow private heat network operators rights akin to other forms of infrastructure with respect to crossing roads, railways etc. This may lead to more private-only, larger heat networks being developed where previously the developer would have needed to partner with the local authority in a joint venture to benefit from such rights. Further, the routes to market that will be used in zones are not currently clear but are likely to be diverse. This may include joint ventures or other commercial partnerships between local authorities and private developers. It may also involve the awarding of concessions. It could also involve newer approaches to competition and exclusivity within zones – for example, processes run by central government.

Awareness

This group are, by definition, well aware of heat networks. Note that this group is expanding, with a growing number of projects applying for support and funding from HNDU (250 projects), HNIP and GHNF in recent years. The transition of applications from gas powered schemes to low-carbon heating sources supports the idea that awareness of low-carbon heat networks is increasing. The introduction of zoning and market regulation is likely to further spread awareness.

Attitudes

Heat network sponsors, including local councils, social housing providers, higher education providers and the NHS were amongst the stakeholders who demonstrated strong support and shared enthusiasm for heat networks in recent research into heat networks zoning (BEIS, 2022g). They did however express some concerns about connecting privately owned buildings to networks:

> "*Both local government and public sector building owners expressed support for the designation of areas as heat network zones. They identified connecting new developments and social housing as more straightforward than connecting privately owned buildings, with concerns about the complex ownership arrangements, including international investors, in the private sector*" (BEIS, 2022g).

Behaviours

The literature focused on how sponsors – including owners and operators - behave towards their customers, in particular how they view their customer protection responsibilities.

Qualitative research with operators of heat networks for BEIS found that *"Most public sector providers interviewed described their responsibilities in relation to heat network users in ways that suggest these are enmeshed with their responsibilities as landlord/property manager to tenants and leaseholders. In public-led schemes (where the landlord is also the operator), the responsibility for maintenance and repairs was generally well understood by consumers"* (BEIS, 2018d).

This research also explored the roles and behaviours of owners and operators of heat networks in mitigating against *"the risks of poorly designed or installed schemes negatively impacting on the future cost efficiency, reliability and value for consumers".* To ensure that schemes are operating effectively and efficiently, the research highlighted the role of Building Management Systems and other monitoring options to monitor operational efficiency (BEIS, 2018d).

None of the providers interviewed as part of the same research *"recalled passing on the additional costs of inefficient performance to customers".* It was also noted by several public sector providers that were interviewed that they had not passed the costs of major refurbishment works onto consumers, noting that such repairs had been paid for from organisational reserves. Such behaviours from operators can support the delivery of affordable heating and hot water and reduce the risk of households being in fuel poverty.

Private providers who fed into the research also commented that their energy service company (ESCo) models had protected consumers *"against potentially high costs of underperformance*" (BEIS, 2018d). Note however that *"Private heat network operators suggest that their consumer protection responsibilities depend on the type of contractual arrangement that they have with developers and landlords. In many cases, consumers are unclear on divisions of responsibility, particularly between landlord/property manager and heat network provider"* (BEIS, 2018d). Therefore, ahead of market regulation being implemented in England, the nature of the contractual arrangement agreed will shape the behaviour of a heat network operator.

Needs

Like the supply chain stakeholder segment, the main needs of sponsors and project stakeholders are around capacity and capability (skills and expertise). Previous BEIS research has explored what skills are currently required by the heat network sector, and where the existing and future shortages are likely to be (BEIS, 2020a). Progression on policy objectives, and more specifically on resourcing levels within zoning policy, and DESNZ 's broader Market Transformation programme are all supporting this segment to expand (BEIS, 2021a).

The social research on zoning details how local governments will be key partners in overseeing the delivery of heat network zones. Findings from stakeholder workshops detailed how local authorities see themselves playing a strategic role in planning and overseeing heat network zoning. However, stakeholders raised concerns about "*insufficient capacity within the public sector to deliver against the scale of the challenge*" (BEIS, 2022g).

As noted above, skills and resourcing issues were explored in the Heat Network Skills Review (BEIS, 2020a) and were also noted in the Government's response to its recent zoning

consultation. "*We have noted the concerns of a skills gap within local government, including the technical, project management, commercial and data management skills required to fulfil the role of the zoning coordinator. We will ensure we engage with the relevant parties to inform our policy development going forward."* (BEIS, 2020c). These gaps need to be resolved, or the implementation of zoning and the GHNF will be negatively impacted.

RQ5e: ESCos

Overall, there was relatively little research identified on this stakeholder segment.

As noted in RQ1f and RQ4, there are a wide range of ESCo models, with a mix of private and public sector organisations in a variety of commercial structures and different drivers (Grant Thornton, 2018).

RQ5f: Aggregate users

There was no research identified for this stakeholder segment.

Implications for the wider GHNF evaluation project

Implications for the wider GHNF evaluation

This Literature and Context Review have been a key element of the scoping phase of the evaluation. This section details how findings from the review have been utilised in the evaluation planning phase and will be used on an ongoing basis.

The review has informed the ToC by deepening the evaluation team's understanding of the GHNF delivery context, positioning the fund's intended impacts in the context of prevailing policies and market factors, and providing an important anchor for the context sections and assumptions presented within the ToC.

It has also facilitated the identification of key groups likely to be affected by the GHNF and the key actors in each, which was the central information source drawn on for evaluation stakeholder mapping.

More specifically, the evidence has been used to shape, refine and add more nuanced lines of enquiry to the final evaluation questions for the Transition and Main scheme evaluations, both in shaping questions, and also through adding prompts for each evaluation question.

As well as shaping elements of the scoping stage in an overall sense, the literature and context review has uncovered a number of insights into the sector which should be picked up by the evaluation team and interrogated further. In turn this has enriched the development of context, mechanism and outcomes (CMOs) which form part of the evaluation of the GHNF Main Scheme.

Gaps in the literature

The research team have identified gaps in the literature which will be looked at during the follow up evaluation phases. The team will address these evidence gaps in future updates to the Literature and Context Review.

The research team were unable to find literature detailing the impact of Brexit on heat network supply chains and impacts on GHNF of increasing inflation and the energy price crisis. Other gaps and potential future research focus for specific RQs are detailed below.

RQ1: Overview of existing UK Heat Networks

- The literature does not provide a comprehensive list of the challenges that heat networks face. Clear gaps include demand assurance and the lack of a defined date for the phase-out of natural gas boilers.
- The most complete and accessible heat network data is from 2018 and therefore does not represent the current state of the heat network market.
- There is a lack of data on which stages of heat network development have received funding.

RQ2: What role can capital schemes such as GHNF play in promoting heat networks in the UK?

- There is a lack of empirical evidence on the role of capital schemes and the benefits they provide in overcoming barriers to heat network deployment.
- There is a lack of empirical evidence on the role and adequacy of time-limited central government capital expenditure in supporting the broader benefits to heat network development.

RQ3: What previous, current or planned policies and programmes (local, regional, national) have paved the way for, or could increase/decrease the impact of, GHNF?

- Zoning regulation could affect the GHNF but that the nature and magnitude of effects is something that we need to explore.

RQ4: Who are the key actors involved in the development of heat networks?

- There is no comprehensive map of current heat network stakeholders. This may also change over the time frame of the GHNF.

RQ5: What are the awareness, attitudes, behaviours and needs when it comes to the transition to low-carbon heat network solutions?

Consumers

- The literature is predominantly focused on domestic consumers. There is less evidence detailing the levels of awareness, attitudes, behaviours and needs of non-domestic consumers.

Supply chain

- Overall, there was relatively little research identified on this stakeholder segment.

Investors

- Overall, there was relatively little research identified on this stakeholder segment.
- In particular, the team will be looking for further evidence outlining optimum investment portfolio sizes and investor attitudes to long term policy certainty and market stability.
- The team could review any DESNZ and industry data on investment in heat networks compared to other technology solutions to see whether there are differences in investor behaviours, including between those who self-fund and those partnering with private capital.

Sponsors and projects

- If data is available in the future, the team would like to review the number and type of sponsors and projects applying for HNDU, HNIP and GHNF, and the changes in applications for gas powered schemes to those with low-carbon heating sources.

ESCos

- There was no research identified for this stakeholder segment.
- Future work could include an analysis of data (if readily available) of the number and structure of ESCos that have sponsored heat networks and whether this trend has changed recently.

Aggregate users

- There was no research identified for this stakeholder segment.

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