energy technologies institute

AN ETI INSIGHTS REPORT

DISTRICT HEAT NETWORKS IN THE UK
POTENTIAL, BARRIERS AND OPPORTUNITIES

Delivered by

CATAPULT Energy Systems

Contents

future networks

District heating has the potential to play a much larger role in the UK energy system, but it needs to evolve to deliver more and larger schemes.

Capital costs are the main barrier to district heat network adoption.

An ETI project has developed eight route maps that could reduce the capital cost infrastructure of heat networks by 30-40%.

DISTRICT HEAT NETWORKS IN THE UK:

Potential, Barriers and Opportunities.

Use of heat in the UK accounts for around half of all energy use and around 1/3 of carbon emissions.

CO_2

Today, there is less certainty of district heat networks revenue when compared to other investment opportunities.

Improving current practice incrementally by 'learning by doing' and innovation are the primary ways to reduce cost in the deployment of infrastructure networks.

Nearly half of heat demand could be met by heat networks.

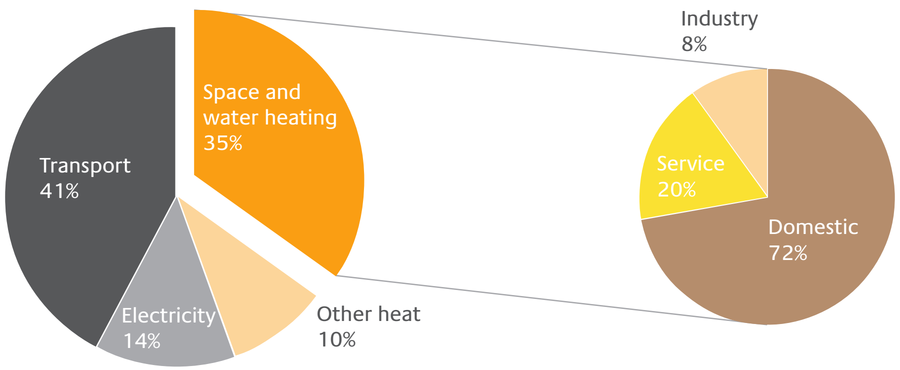
UK central and devolved governments need to provide frameworks to support:

- Demonstration
- Knowledge transfer
- Skills development in the sector.

INTRODUCTION

The end use of heat in homes, offices, shops, other buildings and industry in the UK accounts for around half of the end use of energy and around one-third of carbon emissions [1]. Space and water heating in buildings account for 35% of end energy use. Space heating needs vary from year to year, largely due to weather.

Figure 1
Energy Consumption by End Use – Modified from DUKES 2017



Given the scale of heat use and waste heat production across the UK, how heat is provided in a future low carbon UK energy system is a critical question. Choices about heating impact on every part of the energy system, from primary energy production, through network infrastructure, to the equipment installed in millions of buildings to provide thermal comfort and hot water. This has therefore been one of the central issues in the work of the Energy Technologies Institute (ETI), whether considering whole systems, energy storage, network transitions, consumers using heat in buildings or building fabric upgrades.

It is widely recognised that the investability of heat networks can be improved through policy changes that enable heat networks to be considered strategically, reducing the cost of capital [2]. However, recognising that the potential benefits of district heating would become available as an option for larger areas in local decarbonisation plans if the network capital costs could be reduced, ETI commissioned a project to examine the opportunities to do this in a UK context: The Heat Infrastructure Development (HID) Project.

This insight builds upon the findings of the HID project to contextualise how reducing costs of heat network infrastructure can address both stakeholder needs and competitiveness within a whole energy system approach to tackling the heating challenge.

The aim of this work is to provide an evidence-based assessment of the innovations most likely to drive down the capital costs of district heating, thereby leading to increased Government confidence in developing policies and governance to reduce the cost of capital for heat networks to levels enjoyed in other countries, and in the UK by other energy networks.

WHY HEAT NETWORKS?

> "The heat system that will emerge is still not totally clean. The cost effectiveness of decarbonisation predominantly through electricity or through a combination of hydrogen and bio-methane is still up for debate, but whatever you do you end up with 17- 24 per cent district heating. What really matters with that number is we are talking about a step change, going from an on the edge infrastructure to something that is central to government ambition to decarbonising the UK economy and to decarbonising heat in cities."

Dan Osgood, Director, Department for Business, Energy and Industrial Strategy, ADE Heat 2017

The carbon emissions attributed to heat can be reduced by minimising demand and decarbonising supply.

Reducing demand

Very deep energy efficiency retrofits to homes to reduce demand are technically feasible but could be comparable in cost to rebuilding the entire housing stock (in excess of £2t). Implementing the easy wins, such as easy-to-treat cavity walls, before tackling cost effective but harder-to-treat cavity walls and ensuring that standards are increased, will be two of the lowest regret options that could be implemented early in the energy transition. Reducing demand through more extensively retrofitting existing buildings to be more efficient will play an important part in the future energy system but should be targeted appropriately to avoid unnecessary cost.

Decarbonising supply

The options to deliver the required decarbonisation of supply for heating are:

- Electrification of heat – using resistive heating, air, ground and water source heat pumps.
- Hydrogen – repurposing the gas distribution system to run on hydrogen as opposed to natural gas.
- District Heat Networks – development of large scale district heating networks.

It's unlikely that a single 'winning option' will emerge to serve all types of buildings in all areas. Each has its benefits and barriers which are dependent upon many factors, such as local resource, consumer preferences, the availability of investment and existing infrastructure capacity.

Heat networks can be a very attractive and cost-competitive way of providing space and water heating in homes, shops, offices and other commercial buildings in dense urban areas.

In some European cities they are a major way of providing heat into these kinds of buildings [3], [4], [5], [6]. The three large integrated networks described in the references each serve between 0.5M to 1M people and the businesses located around their homes. Every town in Germany with a population of more than 80,000 residents has at least one heat network. Large heat networks developed across Europe partly as a result of history and culture and partly in response to fossil fuel price shocks in the 1970s.

The UK by contrast was until recently the world's largest market for gas boilers, until it was overtaken by China. Poor experiences with badly designed and operated civic district heating schemes and the availability of North Sea gas at the point where central heating was rapidly penetrating the UK market, effectively blocked the growth of heat networks much beyond private land. Without access to regulated monopoly capital and effective oversight of consumer protection, heat networks struggled to compete with gas networks.

On the other hand, heat networks provide half of UK heating within large institutional estates such as hospitals and universities, due to their more favourable economics when these barriers do not apply.

Gas boilers are an excellent heating solution (apart from NO_x emissions [7]) and the lack of penetration of heat networks was not seen as a strategic issue for the UK until:

- We became a significant net importer of natural gas, exposing us to the potential for the kind of shocks that drove other countries to provide policy support for heat networks.
- And looking forward, UK decarbonisation targets inevitably require reductions in the use of gas for heating, that cannot be achieved by fabric efficiency improvements alone.

In the short-term there are significant opportunities for low cost carbon emissions reductions by installing heat networks powered by gas CHP. As these develop, they can provide a market for heat from waste (CHP plants) and waste industrial and commercial heat. In the longer term, the energy centres will need to be replaced with low carbon heat sources such as marine heat-pumps (extracting heat from rivers, lakes and the sea), large scale ground-source heat pumps, and very large scale industrial heat sources such as thermal power stations and large industrial plant.

Low carbon thermal sources such as CCS plants and nuclear power plants are especially attractive sources of low cost heat at scale, when located within 100km of a large city (or cities).

In addition to the potential direct efficiency and cost advantages of district heating, when compared to other low carbon heating sources, there are other important benefits:

Installing a gas CHP district heating network today produces immediate cost-effective carbon savings and then enables a transition to low carbon sources, without further work within individual buildings or having to dig up the roads again. District heating does not require peak electricity supply to be decarbonised to deliver these savings.

Floor space savings from storing heat elsewhere in the network can be very considerable when compared to the stores that will need to be installed in homes with heat-pumps – perhaps as high as £10,000 of additional value for an inner-city flat that avoids a hot water tank installation[1].

The visual amenity and noise pollution impacts of the external heat exchangers and fans for air source heat pumps are avoided.

Creating a market for low grade heat enables local businesses to invest in waste heat recovery in a way that boosts the local economy and reduces the risk from exposure to uncertain and fluctuating electricity prices.

Retaining some of the existing energy centres long-term will provide peak power capacity at very low cost. Gas engines can provide both heat and electricity efficiently and can contribute to the avoidance of the need to build significant central capacity of gas turbines to meet peak electricity demands. Retaining some gas boilers avoids the need to retain them in individual buildings.

A higher proportion of the final installed costs of the low carbon heating systems may be retained in the UK economy than with other low carbon heating systems.

1. Estimated from ONS data on price per floor area www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/housepriceshowmuchdoesonesquaremetrecostinyourarea/2017-10-11

The cost advantages of district heating lead to an increase in its uptake in all of the many thousands of future energy pathways that ETI has produced using its Energy System Modelling Environment (ESME) tool – a national planning capability [8]. Heat networks currently provide around 2% of UK space and water heating [9]. The cost optimum level of heat networks by 2050 can range from 5-7% up to over 40%, depending on many factors, including the costs of all the competing low carbon heating technologies, the cost and performance of building fabric retrofits and the relative costs of electricity, heat, hydrogen and bio-methane, as well as the implied marginal 'cost of carbon'.

This wide range of potential uptakes can be thought of as a very powerful case for heat networks in many city centres. There is also a good case for them to spread out across much of the urban area. Work by the Energy Systems Catapult (ESC) for the ETI on local area energy planning in co-operation with the councils of Bridgend, Bury and Newcastle has confirmed that heat networks are attractive in appropriate areas[2].

To meet our carbon targets in the most cost-efficient way, we must understand how to develop the UK Heat Network industry capability to deliver large-scale heat networks to existing areas within cities, towns and large, dense villages. There is significant opportunity with approximately 56% of building heat demand located in only 4% of the GB geographical area; the vast majority of which could be connected to heat networks economically, based upon ETI analysis [10].

Other programmes in this area

Most work on the development of district heat networks and their proposition for contributing towards UK carbon reduction has been led by Government programmes.

The main Heat Networks Investment Project (HNIP) funding scheme aims to launch at the end of 2018 supporting up to 200 District Heat Networks (DHN) related projects with £320m funding by 2021.

The Heat Network Delivery Unit has provided 203 grants to 139 local authorities over six funding rounds amounting to near £14m to support early stage development of district heat network schemes - typically feasibility studies and masterplanning.

The heat network Small Business Research Initiative competition funded 9 innovation projects totalling near £6m in 2014 to improve the performance of DHNs.

The ETI has published a series of reports on UK Networks Transitions Challenges, one of which focuses on heat networks and the potential roles they could play.

The Competition and Markets Authority has launched a Market Study into heat networks, to be run throughout 2018. This work will focus on barriers to heat network implementation in the areas of information transparency, concerns around monopoly of supply and outcomes for heat network customers.

The Department for Energy and Climate Change (DECC)/The Department for Business Energy and Industrial Strategy (BEIS) have also commissioned several reports in relevant areas, such as the 'Research into barriers to deployment of district heating networks' report [11], and 'The Potential and Costs of District Heating Networks' [12].

2. 2018 Local area energy planning Newcastle City Council - Evidence Base, 2018 Local area energy planning Bridgend County Borough Council - Evidence Base, 2018 Local area energy planning Bury Council - Evidence Base

Within industry, there is growing support through industry associations and professional bodies, with several technical guides and standards produced around identifying opportunities and barriers to heat networks:

- The Association for Decentralised Energy (ADE) has recently published two important reports: 'Market Report: Heat Networks in the UK', summarising the current state of play in the UK heat network market [9], and 'Shared Warmth: A heat network market that benefits customers, investors and the environment', addressing the need for a regulatory framework to reduce risk to investors and customers [2].
- The Energy Research Partnership has published their 'Transition to low-carbon heat' project, looking at options to decarbonise heating [13]. Heat networks, alongside other options are evaluated from both top-down and bottom-up aspects.
- Changeworks and the Joseph Rowntree Foundation have produced a report to identify the drivers behind DHN development by social housing providers and whether they are meeting stakeholder requirements [14]. This report complements these existing activities by addressing the role of cost reductions from a whole systems perspective; accounting for techno-economic factors alongside the requirements of a complex range of stakeholders.

WHAT ARE THE BARRIERS TO THE WIDER DEPLOYMENT OF HEAT NETWORKS?

A key challenge to heat networks – as with other new methods of heat provision – is the requirement to meet the needs of all stakeholders within development, operation, procurement and use. Figure 2 illustrates the complexity of the stakeholder landscape for heat networks in the UK. Although some organisations can operate across investor, developer and operator, currently they are not able to offer a fully integrated team. Therefore, the landscape is fragmented with diverse capabilities, objectives and requirements; currently, the market in the UK is too immature to be able to satisfy all of these.

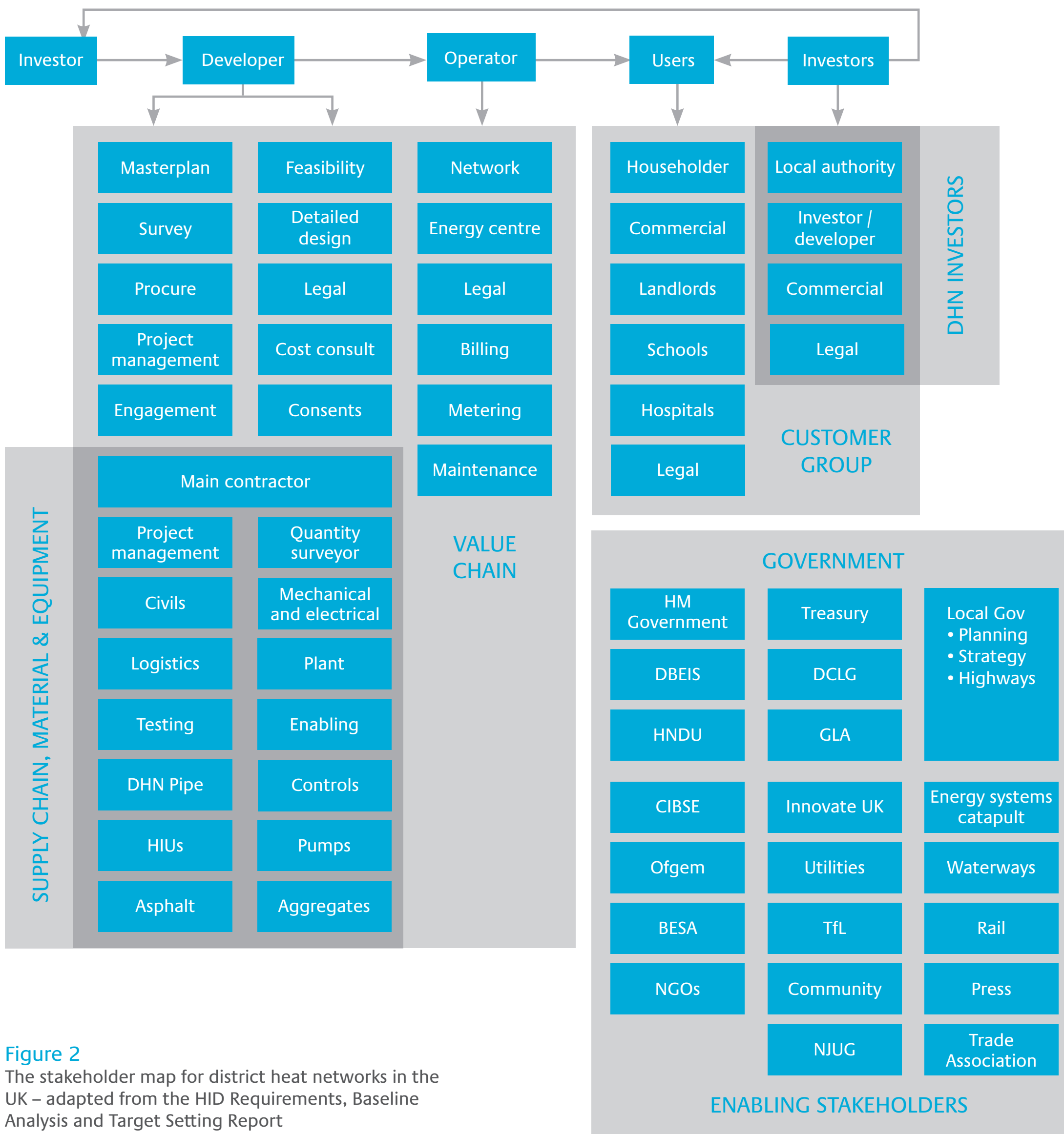


Figure 2
The stakeholder map for district heat networks in the UK – adapted from the HID Requirements, Baseline Analysis and Target Setting Report

Each group of stakeholders has a different relationship with DHNs:

- **Investors** are able to choose where to invest. The perception of DHN attractiveness amongst investors needs to exceed that of alternative investment options. Decisions are based upon certainty of profit.
- **Users** also have some choice, albeit not as directly. Individual users are unlikely to have a direct choice between hydrogen and district heating, but they would likely be represented during public consultations; such as at local area heat strategy meetings. Any negative perception of performance will also then influence other areas in the decision to implement DHNs or not.
- **The Value Chain** is motivated by the generation of profit, needing a market to sell into, whilst the quality/cost of the offerings may contribute towards the development of the market.
- **Enabling stakeholders** can support, enable or block development of DHNs. DHNs need to be able to align with the requirements of these bodies to gain their buy-in.

Each group has distinct requirements that DHNs need to meet or exceed if the number of networks is to grow; barriers to deployment exist where this is not currently the case. The following four sections summarise the findings from the ETI's analyses for each of the stakeholder groups.

Investors

Investors encompass several types of organisation: local authorities, social landlords, network and property developers, cooperatives, third party investors, the Green Investment Bank and Her Majesty's Government via BEIS.

The specific requirements vary for different types of investor within three common themes:

- Certainty of capital expenditure (capex), revenue, project programme and operating costs. These are seen to be less certain for DHNs when compared to other investment classes.
- Simplicity on agreeing timescales, legal and commercial terms with developers and end users.
- Internal Rate of Return (IRR)/Return on Investment is a requirement that varies in size between stakeholders; it may be low for a strategic local authority project (≈3%) or much higher (≈18%) for a third-party investor.

Based on current practices, there are better ways to get more certain returns on investment and DHNs have a history of underperformance against design, resulting in higher operational expenditure (opex) and capex and consequent lower investment returns; this is compounded by a shortage of technical resource capable and experienced in delivering high quality heat networks. Investors are currently financing approximately 15% of a scheme's capital cost at risk before project contracts are signed and will often need to cross subsidise the cost of the heat network from the broader development funding to justify the high capital cost; an option that is likely not to be available when retrofitting heat networks within existing urban areas.

In order to address these barriers:

- The value proposition to investors should be more attractive than alternatives;
- Capital cost should be minimised – without increasing opex;
- Certainty of cost should be increased to reduce risk of investment.

Users

As a group of stakeholders, users represent four separate categories: owner-occupier, private landlords, social landlords and tenants. Even within this group, a broad and diverse set of factors exist that are likely to influence DHN uptake. Key themes include:

- **Cost, which is a requirement for all users, albeit different users consider costs in different ways [15]. For example:**
  - Social landlords see capex as the key issue;
  - Private landlords are more focussed on payback period;
  - Owner/occupiers tend to prioritise running costs over capital costs;
  - Tenants will not accept higher running costs, since they will not see capital costs, and they desire stable and fair usage costs.
- **Any new heat source (e.g. DHNs) needs to match or exceed the performance of gas combination boilers for the provision of comfort, hot water and associated experiences within the home**
- **Bills and maintenance costs are important to all users**
- **The switch to a new heat provision system needs to be straightforward and the user needs to be able to transact with confidence**
- **Timing of installation should suit the user, especially when their existing system is not at end of life.**

Many current heat networks are not meeting some or all of these requirements. If individuals were presented with the opportunity to connect to a DHN, most would see no compelling reason to do so: a DECC study found that only 31% of participants in their research were aware that district heating existed. However, even if the option was provided, overheating, poor hot water performance, the current practice of a long-term tie-in to a monopoly district heat provider and a large variation in monthly costs results in a poor proposition for new users.

Based upon our analysis, the underlying drivers to encourage users to convert to a DHN are:

- **Reduced costs – compared to current and alternative options;**
- **Additional benefits – improved performance (actual or perceived);**
- **Reduced sacrifices – easier transactions, fewer failures.**

User needs

The ETI Smart Systems and Heat Programme included a project called Consumer Response and Behaviour (CRaB), through which the needs and behaviours of consumers with relation to heat could be quantified. The study included a quantitative survey of 2,313 households, which took place in January and February 2014. A quota sampling approach was followed in order to generate a nationally representative sample of British households, with quotas set on tenure, property type and the presence of children.

In 2015, 29% of greenhouse gas emissions by end use were attributed to residential gas combustion, with the majority of this used to heat the home or deliver hot water. The incumbent fuel sources for heat are well-established energy vectors in the UK system, users are generally used to them, even if they are not necessarily always happy with their performance. Among the many problems identified, for the 98% of respondents in the CRaB study who were not using a district heat network for their space heating, between 20% and 56% were not always warm enough. However, within a DECC report investigating homeowners' willingness to take up more efficient energy systems, the vast majority would not consider changing to any alternative – 80% of those on-gas grid and 91% of off-gas grid homeowners. This is an example of householder inertia, a concept that stretches beyond heating systems, to energy provider and efficiency measures.

The CRaB study found that fewer people on district heating reported problems getting warm on a winter's day than those with gas central heating. However, the sample was small (c. 50 homes), and there are also reports of problems with district heating, like overheating, opening windows to cool down, unfair pricing [14] [16], unresponsive suppliers, inconvenience caused by maintenance and fixing problems in one home causing problems elsewhere on the system [17].

New systems are generally able to address these issues but in order to encourage the wider take-up of district heating, the implementation needs to be of a high standard and the benefits need to be communicated to potential customers more widely.

The ability of heating systems to provide comfort within the home is of paramount importance to consumers. From 3000 consumers in a recent ETI study[3], the indication was that the majority had a preference towards comfort over cost, as shown in Figure 3. Together with results from the HID project, the implication is that from an energy consumer's perspective, the performance of the heat network is a priority over cost, but for a well performing system the running costs are more important than the capital costs seen up front (e.g. their Heat Interface Unit). However, the capital costs of the entire network are likely to be recovered from the consumers through their running costs.

Keeping my home at a comfortable temperature is always more important than saving money on my energy bills

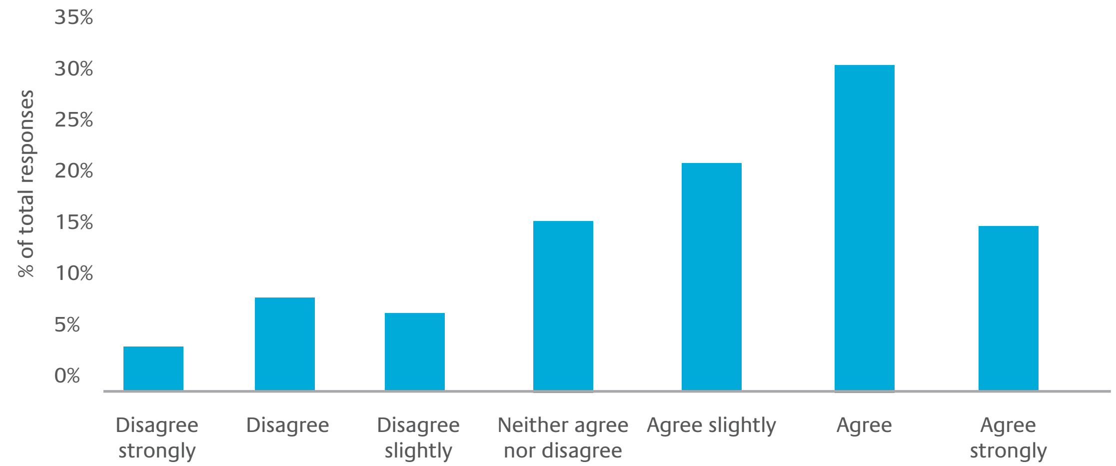


Figure 3
Keeping my home at a comfortable temperature is always more important than saving money on my energy bills - sample size 3000

When relating this analysis to new district heating networks, it must be remembered that district heating is not common in the UK and not well-understood. If, as the market expands, more people have bad experiences of underperformance, resulting in a generally negative perception compared to other technologies in the public eye, then this may well shift the factors that influence choice of a new heating system. Therefore, to reduce the risk of a backlash against the technology, the performance of district heating should not be compromised in pursuit of reduced costs.

3. The Consumer Segmentation project builds on the preliminary segmentation developed in the Consumer Response & Behaviour Project and the Consumer Insights Project to identify how consumers buy and use energy and upgrade their boilers

Value chain

Although there are some exceptions, commercial businesses form the majority of the DHN value chain, resulting in profit and growth-led business plans, aiming to maximise one or both of sales volume and margins. Many of the barriers to DHN deployment within the value chain are due to uncertainty of demand and lack of competition. These barriers include:

- The capital cost of elements within the physical system and supply chain is seen as disproportionate compared to alternative methods of low carbon heat provision
- The complexity of engagement within the supply chain attracts multiple layers of margin, adding cost
- DHN systems are currently bespoke with a high risk of over-engineering and less opportunity to benefit from learning curve effects
- Linear contracting prevents collaboration
- The variable performance and quality of current installations results in costs for testing and commissioning to inspect quality
- Landlords and developers are often not able to translate their requirements into a clear DHN specification, which is difficult for the value chain to work with and results in increased prices to minimise risk of re-work.

The value chain needs to strike a balance between encouraging competition to drive improvements in cost and performance whilst standardising to enable common systems and scale, which will also improve cost.

Enabling stakeholders

This group represents both Government and organisations that can support and enable the development of the heat network industry.

- For central government, the key requirement is to have a self-sustaining, viable, open market heat supply through DHNs with minimal legislative involvement. Additional requirements include generating economic activity, addressing fuel poverty, and minimising the costs to the UK as a whole of meeting 2050 carbon targets.
- Local government require clarity over DHNs, their costs and their wider implications on the local community.

Conclusion

The analysis carried out within the ETI's projects has shown that the stakeholder landscape for heat networks is very complex and requires targeted change in different sectors to overcome existing barriers and meet stakeholder requirements.

The largest barrier to the sustained implementation of large scale heat networks at the current time is access to regulated monopoly capital and effective oversight of consumer protection. Without this, reducing the capital cost of district heating would enable it to become an option for larger areas in decarbonisation plans. Consequent deployment of district heating would strengthen the case for government to develop policies to reduce the cost of capital to levels available to other energy networks.

Consumer protection will need to be considered as part of any policy and governance changes. Experience in other countries shows that consumers can be satisfied by heat supplied through a pipe.

The historic bad experiences in the UK with town heating schemes from the middle of the last century are an example of what can happen with any energy supply if consumer interests are not taken seriously.

The capital cost of district heat networks is either a direct barrier or a contributory factor to a barrier for every stakeholder group. When reducing capital cost, there are several other considerations that need to be considered; including opex, certainty of outcomes, impact on performance and attractiveness to users and investors.

The ETI's Heat Infrastructure Development (HID) project focussed on reducing the capital cost of heat network infrastructure through innovation. There is significant room for 'learning by doing' savings to bring current practice up to best practice and then incrementally improving best practice. However, to supplement this, the HID project aimed to show that further cost savings could be achieved beyond current best practice. The rest of this report will focus on the development and impact of these capital cost savings.

REDUCING CAPITAL COST

In dense urban areas, the current cost structures of different heating methods in houses (on a levelised regulated network basis) are shown in Figure 4. This highlights the importance of the cost of network piping within the overall cost of district heating.

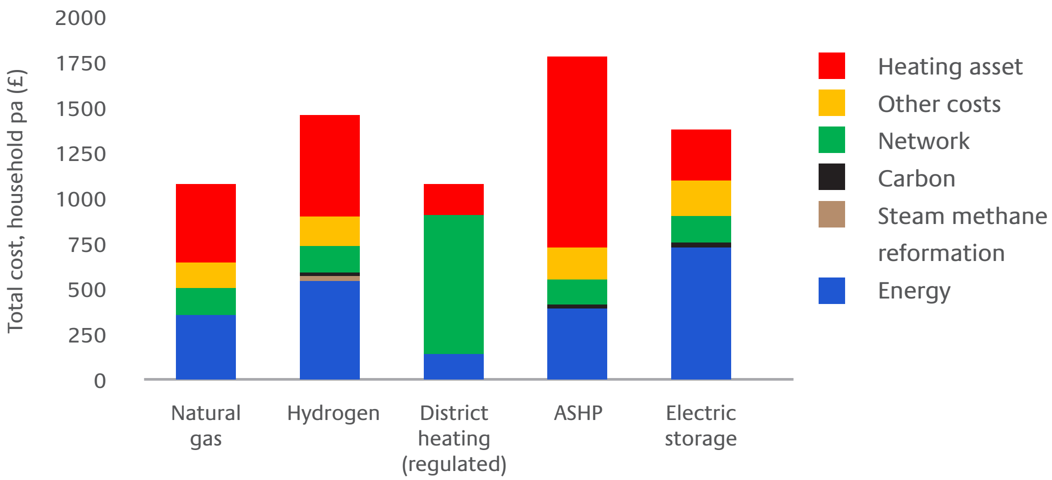


Figure 4
Comparison of the total costs of heating with natural gas in 2014 (2014 prices) - taken from analysis delivered to the ETI by Robert Sansom Consulting – The Potential Role of Hydrogen for Domestic Heating[4]

The HID project included the development of a bottom up heat network cost model which represents all the spectrum of urban and semi-urban typologies that heat networks are most suitable to be deployed in. When looking at overall heat network system costs[5], Figure 5 shows that the majority of costs are found in the network infrastructure itself, with the development and energy centre cost forming the remainder. Within the network costs, there are several high cost areas, namely the pipework, its installation and connection to the buildings.

Total heat network cost distribution

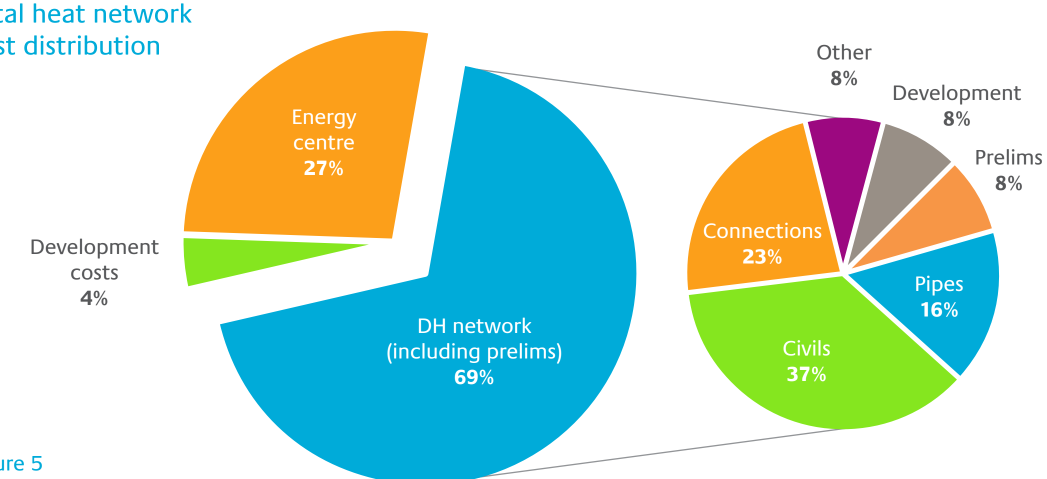


Figure 5
Cost components of heat networks

4. Carbon prices used are the central scenario in DECC's short-term traded sector carbon values, 2013 [20]
5. In this case, we are referring to all costs associated with the deployment of a heat network, from the energy centre, through to installation of internal equipment within buildings.

- **Pipes** includes the purchase and installation of all pipes, insulation and joints;
- **Civils** includes the work of digging and reinstating trenches;
- **Connections** includes the Hydraulic Interface Units (HIUs) and connections within buildings to the HIU;
- **Development** includes the design and legal costs accrued before a contractor is appointed;
- **Prelims** are costs associated with running a construction project, including site office, safety etc.;
- **Other** is any other costs, here mainly around data systems, water treatment and one-off items like rail crossings.

Analysing cost at the component level (as in Figure 6) shows that 11 specific components and activities form 80% of heat network deployment costs in the UK (per the shaded area in Figure 6). By focussing innovation on these areas, the likelihood of developing significant step changes in capital cost of heat networks is significantly improved. The HID project used this analysis and evaluated innovations against a best practice baseline to identify ways in which capital cost of heat network infrastructure could be reduced without negatively impacting operational cost or any other stakeholder requirements.

Pareto analysis of the HID project baseline heat network

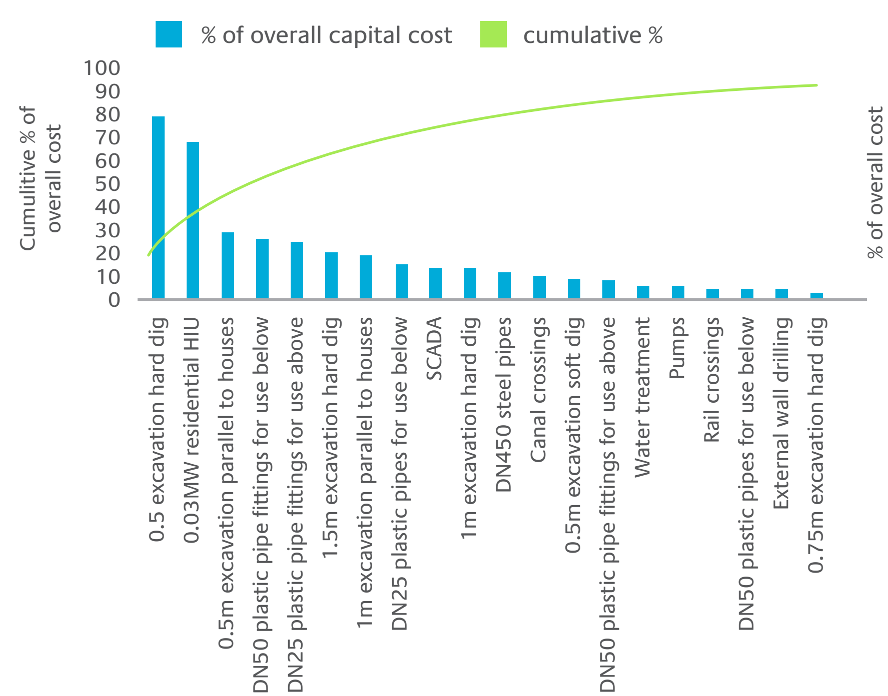


Figure 6
Contribution of individual components to the capital cost of infrastructure within a baseline heat network - Heat Infrastructure Development project

Innovative solutions to reduce capital cost

When taken independently of external influencing factors, the two primary ways to reduce cost in the deployment of infrastructure networks are to improve current practice incrementally through learning by doing and reduce cost through innovation. The former will help several stakeholder groups to improve certainty on outcomes and perception of risk, whilst the latter will more likely impact directly upon capital cost. Both are important to help drive down costs of heat networks. The HID project aimed to focus on identifying innovations.

Figure 7 shows the approach taken within the HID project. Work carried out in Stage One contributed to the generation of 96 potential innovative solutions warranting further examination. As shown in Figure 8, these 96 ideas were reduced to the most promising 13 which were evaluated quantitatively (for cost) and qualitatively (for all other barriers) to identify those that would likely make the biggest impact on UK heat network infrastructure capital cost reduction. 11 were chosen and combined to form eight route maps that describe the means by which these innovations can be taken through to commercial deployment.

Figure 9 summarises each of the route maps identified. Much more detailed information on these can be found in the 'Reducing the capital cost of district heat network infrastructure' summary report[6] alongside the more detailed reports developed during the project.

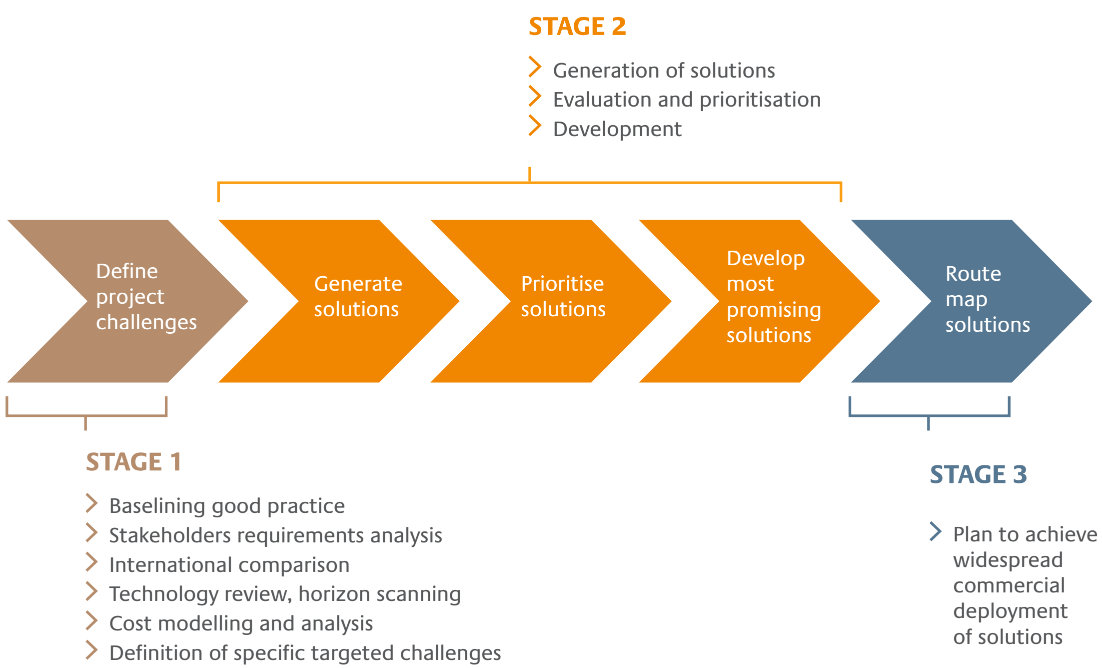


Figure 7
The three stages of the ETI Heat Infrastructure Development Project

6. Find this report at: www.eti.co.uk/programmes/energy-storage-distribution/heat-infrastructure-development

96 potential solutions identified and assessed

13 most impactful solutions selected	8 route maps created
1. Knowledge, management, research and training	A. Knowledge, management, research and training
2. Low flow rate design	B. Low flow rate design
3. District heating wall	C. Radical routes
4. Loft space / cellar route	C. Radical routes
5. Trenchless technologies	D. Trenchless technologies
6. Improved front end design and planning	E. Improved front end design and planning
7. Pipe crossings	
8. Share civils engineering costs	F. Shared civils engineering costs
9. Direct HIU system and existing DHW storage	G. Direct HIU system and existing DHW storage
10. HIU (1) design for manufacture and assembly	H. HIU optimisation
11. HIU (2) further simplification & value engineering at scale	H. HIU optimisation
12. HIU (3) value engineered direct HIU & DHW storage	H. HIU optimisation
13. Internal connections	

Figure 8
How the 8 route maps were chosen

Knowledge Management Research and Training

Establish a District Heating Knowledge Centre to share learning and increase the impact of all other innovations. This knowledge centre both disseminates current best practice and outputs of other innovations. One place to bring together a wide group of stakeholders.

Low Flow Rate Design

Develop tools to help increase accuracy of heat demand estimates and maximise difference between temperatures entering and leaving the building.

Keep existing radiators, develop a new TRV and software tools to promote quick installation. Use smart meter data to improve peak demand estimate.

Radical Routes

Reduce costs of civil engineering by running distribution pipes along the buildings themselves; in the eaves or on the front.

Most effective in terraced housing but can be implemented cost effectively in semi-detached areas.

Trenchless Technologies

Drill tunnels underneath the surface, removing the need for trenching. The technology itself exists but key products need development to make more cost effective.

Developing more flexible pipe and the capability to carry out connections remotely will improve cost savings.

Improved Front End Design and Planning

Demonstrate and quantify the positive impact of improved design work and surveying. Undertake detailed survey and design work early, focussing on the activities that realise the greatest cost savings. Adapt alternative contract frameworks to minimise pricing of risk.

Shared Civil Engineering Costs

Share costs of civil engineering between utilities working in the same region. Solution includes:

- Aligned planning cycles
- Develop a Streetworks Partnership
- Joint ventures between DH and Utility companies

Direct Heat Interface Unit System and Existing Hot Water Storage

Demonstrate the potential cost savings of replacing indirect with direct HIUs whilst making use of existing hot water tanks.

Includes some product development to alleviate perceived risks to consumer.

Heat Interface Unit Optimisation

Innovate to reduce the cost of HIUs for retrofit schemes from approximately £1500 to £200 through:

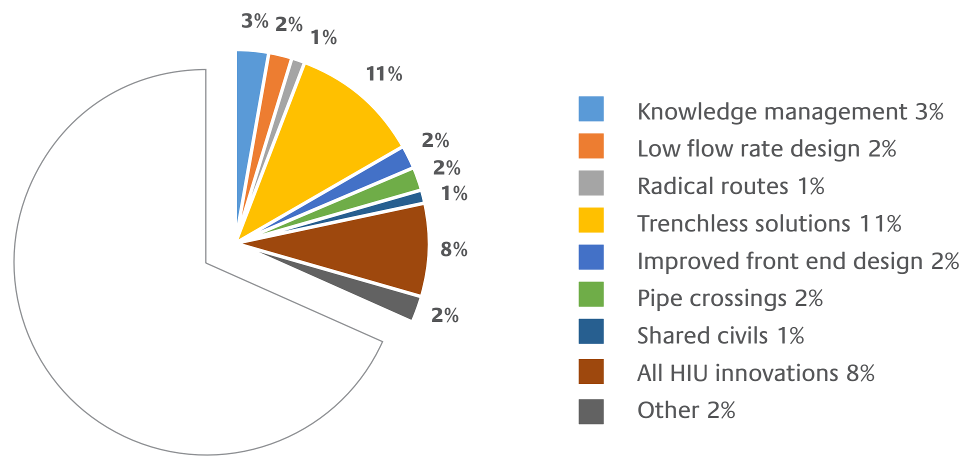
- Simplification and design for manufacture
- Value Engineering
- Optimisation of system solution

Figure 9
Innovation Route Maps identified within the ETI Heat Infrastructure Development project

In a similar way to overall heat delivery methods, these solutions are often more appropriate to certain geographic areas than others. For example, an area with a high number of connections per metre of distribution pipe (such as terraced houses) will benefit more from Heat Interface Unit (HIU) cost reductions than a semi-rural area. By contrast, reductions in trenching costs will have a larger impact on less urban areas which typically have larger distances between connections; making heat networks more cost competitive in these areas – increasing their potential market.

Figure 10 shows the capital cost impact that the different innovations identified in the route maps would have on total heat network infrastructure cost within different areas[7].

% cost reductions from each innovation on total network cost



% Cost Reductions from each innovation on different urban areas

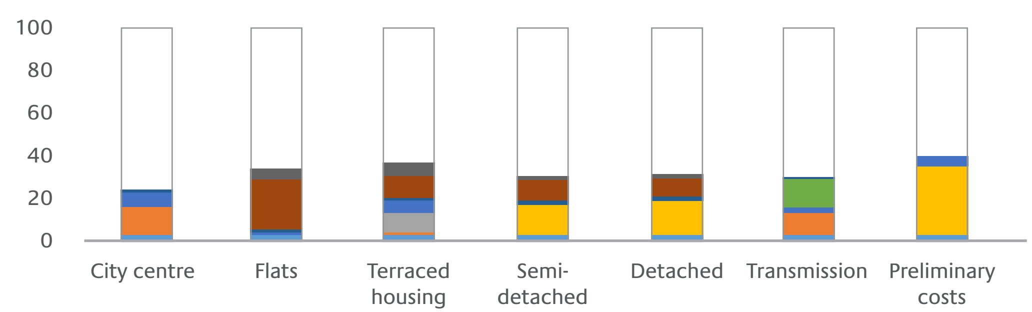


Figure 10
Impacts of Innovations on Heat Network Cost

7. For more information on cost ranges, refer to the summary report: 'Reducing the capital cost of district heat network infrastructure' available from www.eti.co.uk [17]

Each of the solutions and associated route maps require a set of activities to be completed before the innovations identified in the route maps can be deployed at scale. These activities are set out in more detail within the summary report [18] and the route maps report[8] but generally contain three initial activities:

RESEARCH

All solutions require some form of research; this could include market research, technical studies or the development of value propositions.

SOLUTION DEVELOPMENT

Most solutions need either product or market development. This could include prototyping, software development or contractual framework creation, for example.

DEMONSTRATION

Most solutions require funding to overcome commercial barriers and risks associated with demonstrating the benefits of a novel solution. After demonstration, confidence should be high enough to incorporate solutions into normal practice.

For example, Figure 11 below illustrates the activities proposed within the Direct HIU System and Existing Domestic Hot Water (DHW) Storage route map, which focusses on deploying direct heat network connections in homes with existing hot water tanks; including research, development and demonstration.

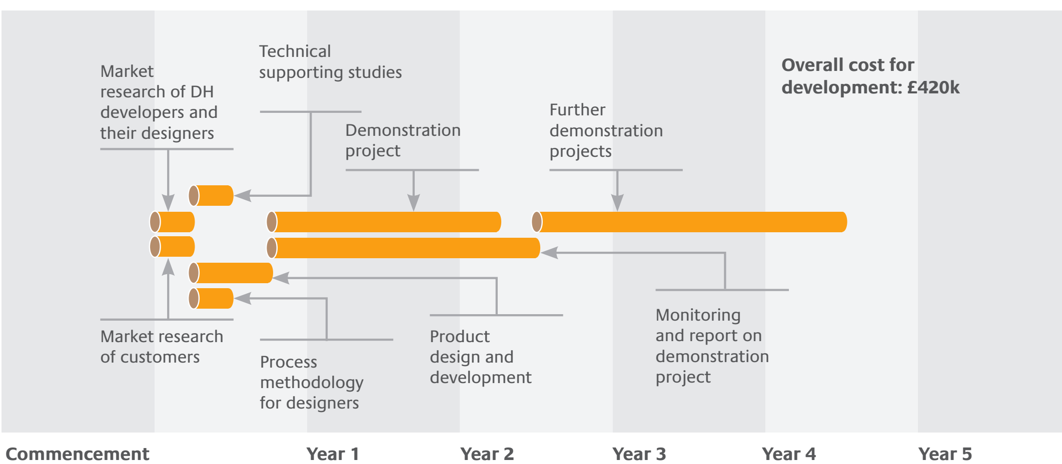


Figure 11
Example illustration for the Direct Heat Interface Unit System and Existing Hot Water Storage route map

By successfully implementing these route maps, the capital cost and associated barriers to the deployment of heat networks can be substantially reduced. The next section explores their impact on the system-wide competitiveness of heat networks.

8. 'Solution Route Maps Report' available from www.eti.co.uk

The impact of cost reductions on the competitiveness of heat networks

The potential capital cost reductions within heat networks would be less important if the size of the potential market didn't improve as a result. The size of market will, in part, depend on how cost-competitive district heat networks become when compared with alternative heat provision methods: The Government would be less likely to support a less cost-effective option, whilst investors on a per project basis would likely choose the option that had a better return on investment.

Although many other contextual factors contribute to the selection of a particular method of heat provision for different areas, their cost competitiveness within a low carbon energy system can be investigated using the ETI's whole energy system model, ESME. By applying the cost reductions identified in the HID project to the appropriate typologies and technologies represented in ESME, their impact on whole energy system design can be investigated[9].

What is ESME?

ESME was created by the ETI as a whole energy systems design tool. It includes all the major flows of energy: electricity generation, fuel production, heating and energy use in buildings, energy use in industry, and transportation of people and freight.

The central approach taken in ESME is one of policy-neutral cost optimisation. The ESME optimisation finds the least-cost energy system designs which meet stipulated sustainability and security targets, whilst taking account of technology operation, peaks in energy demand and UK geography. The aim of the model is to examine the underlying cost and engineering challenges of designing energy systems. Therefore taxes, subsidies and other policies which affect the price of technologies or fuels are absent.

ESME is a Monte Carlo model which considers the uncertainty in this problem, particularly the uncertainty in future energy prices and the future cost and performance of energy technologies. This functionality allows the user to explore system-level responses to user-specified uncertainty in the future values of key assumptions.

9. In the following section district heating is competing against gas boilers, heat pumps, oil boilers, biomass boilers and resistive heating on a techno-economic basis

Using the ESME model, the impact of applying the innovations identified in the HID project route maps on likely heat network deployment in the most appropriate areas can be assessed (see Figure 12).

Comparing % space heat provision in 2050 after reducing DH Capex

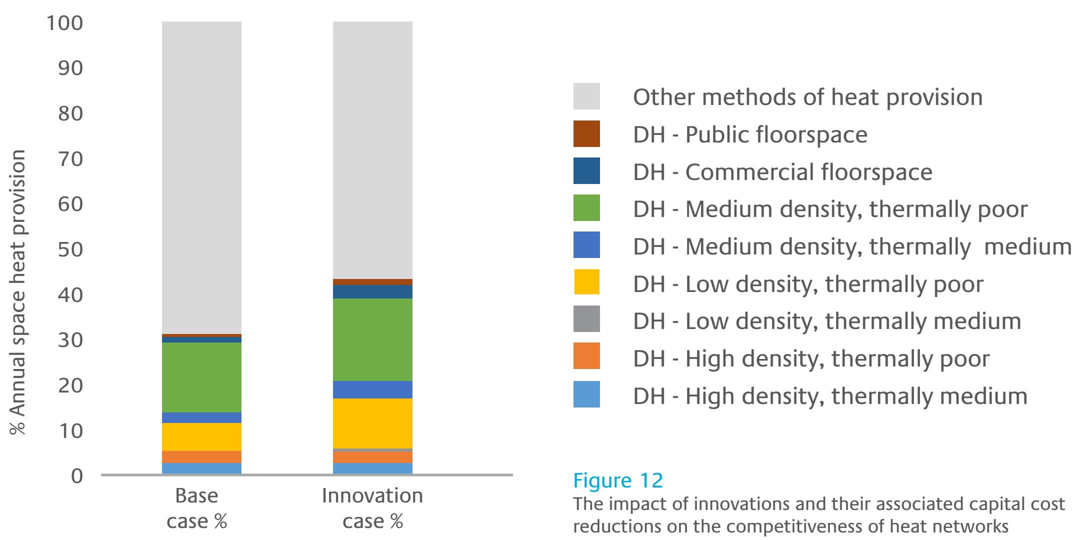


Figure 12
The impact of innovations and their associated capital cost reductions on the competitiveness of heat networks

A significant increase in the uptake of District Heating for the provision of heat would result, increasing from 31% of UK heat provision in the base case, to 43% in 2050[10]. The majority of this increase relates to using DH in areas of less efficient low and medium density housing, and corresponds to equivalent reductions in the installation of deep energy efficiency retrofit packages, as shown in Figure 13. Each of these deep energy efficiency retrofit packages displaced by DHN relate to a 20-30% energy saving resulting from wall insulation, loft insulation, floor edge insulation, draught stripping, single room heat recovery, Thermostatic Radiator Valvess and zoned controls; estimated to cost up to £26k. The cost of heat delivered through heat networks is typically relatively low compared to that of other methods. The results reflect this and imply that as the competitiveness of heat networks increase, the amount of deep energy efficiency retrofit that we need to implement reduces. In total, there would be close to 2 million less retrofits in all building types. This is not suggesting simple and economic efficiency measures should be avoided (such as double glazing and draught proofing) but that more expensive whole house energy efficiency retrofits have less benefit when district heating is implemented more widely.

10. This chart shows the results for the base case and innovation case using Monte Carlo analysis to show the average system design from a range of runs accounting for uncertainties.

Number of energy efficiency retrofits

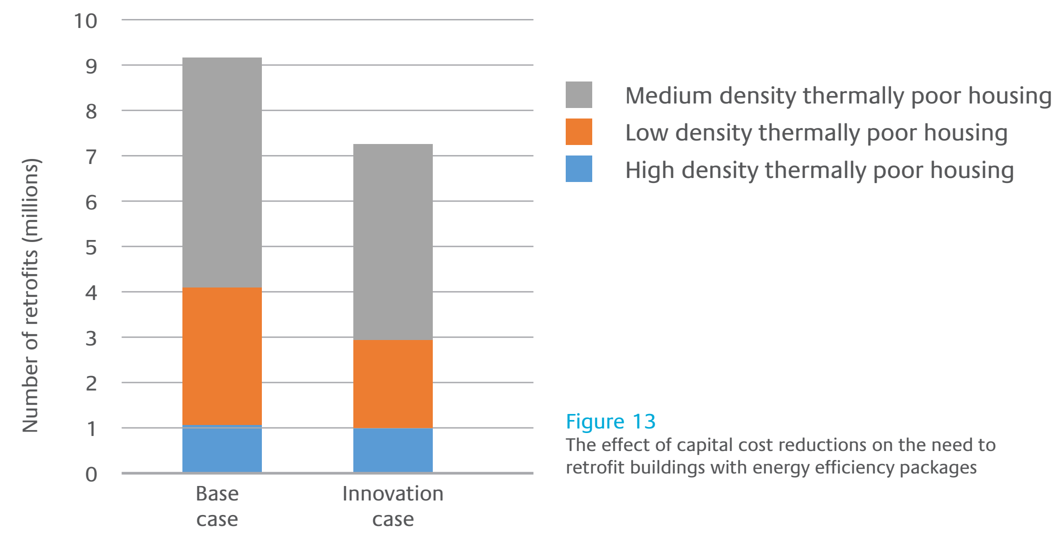


Figure 13
The effect of capital cost reductions on the need to retrofit buildings with energy efficiency packages

Number of domestic properties connected to district heating in 2050 (millions)

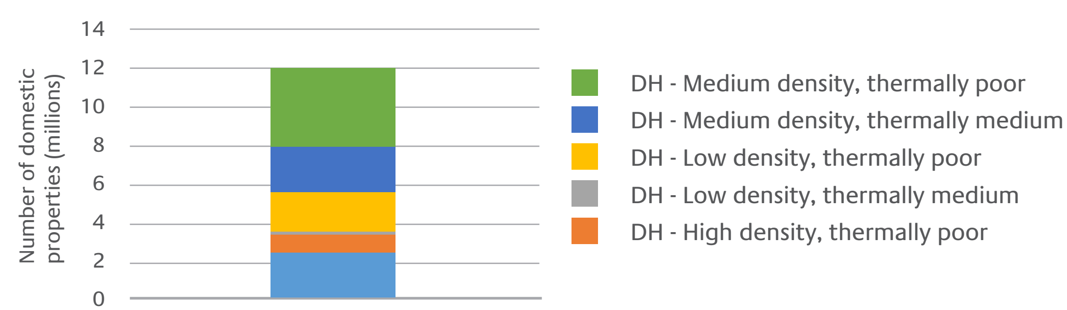


Figure 14
The number of heat network connected domestic properties in 2050 implied as part of a lowest cost energy system transition pathway should the HID project route maps be implemented

By recognising that heat networks are more suitable for some areas and types of buildings than others, there is a risk that a disparity in energy supply costs may develop between those who have heat networks and those who do not. Market structures should be considered to address this risk. One such option could be to focus on the provision of comfort as a service rather than by the amount of energy consumed. By providing comfort as a service, there is more onus on the energy provider to implement strategic energy efficiency improvements – e.g. energy suppliers would be more actively engaged in ensuring energy efficiency within those homes that use higher cost energy sources for their heating.

High and medium density connections are around five times more numerous than low density homes; this would imply that there would be a higher number of connections per length of network installed and therefore that innovations focussing on reducing the cost of heat interface units may have a higher impact than others when applied to a whole energy system design. Figure 15 shows how the percentage of space heating provided by DH would change when implementing innovations in different areas using the ESME whole system analysis tool. The following were tested:

- HIUs Innovations – only cost reductions to HIUs are implemented;
- Non-domestic innovations – only cost reductions on commercial and public floor space are implemented;
- All but HIU innovations – cost reductions from all but HIU innovations are implemented;
- All innovations – all cost reductions are implemented.

Whole system space heating impacts by focussing on different innovations

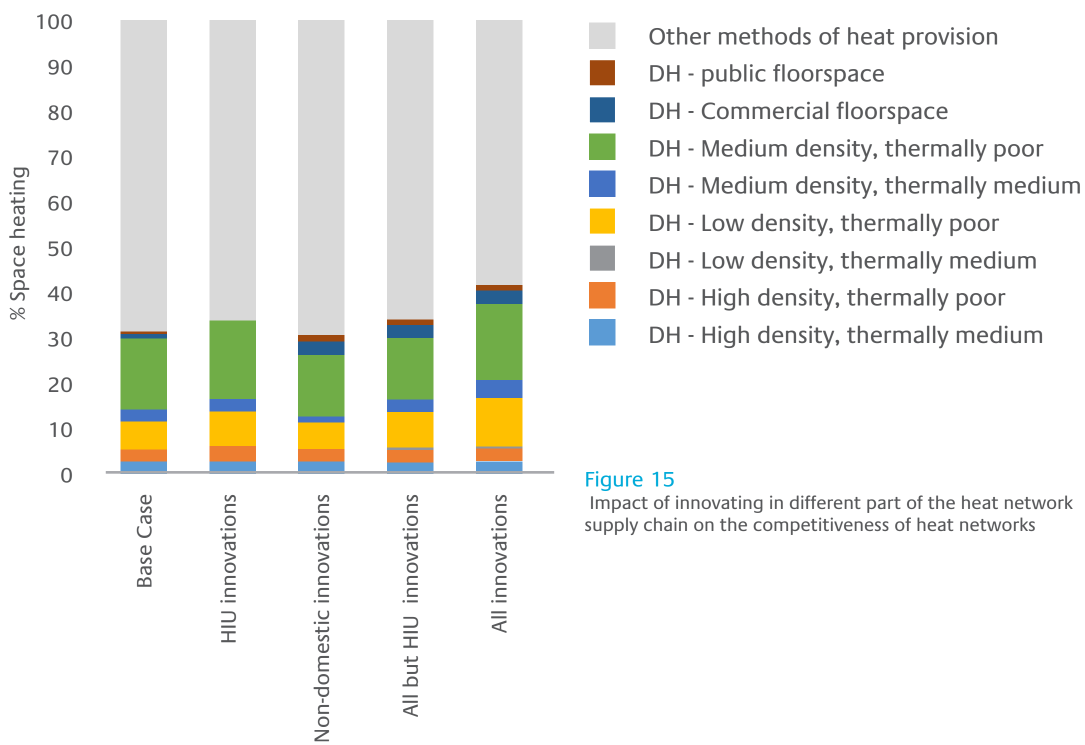


Figure 15
Impact of innovating in different part of the heat network supply chain on the competitiveness of heat networks

Figure 15 shows that regardless of the innovation scenario run, the areas in which heat networks are suitable remain consistent. Even without the new innovations, there are opportunities for industry to develop heat networks, with the innovations mostly expanding existing markets rather than creating new ones – the exception being that non-domestic innovations would help establish heat networks as a techno-economically effective option within public and commercial areas.

Key insights that can be drawn from this are:

- The high heat density within medium and high-density building stock means that these areas do not need the capital cost reductions to be techno-economically competitive.
- The HID capital cost reductions could increase the range of areas within which heat networks are competitive.
- Within this 2050 scenario, the cost reductions to HIUs make the largest contribution to the increased competitiveness of heat networks, as they have the highest impact in areas with a higher connection density.
- The HIU and non-HIU innovations contribute equally to the competitiveness within low density, thermally poor housing.
- Low density, thermally medium density housing stock is still a little bit too expensive for these capex reductions to have an impact; they are likely to be more cost effectively heated using alternative approaches.

The deployment of these heat networks may not be evenly spread throughout the urbanised areas of the UK, as their suitability will depend upon local sources of heat and the type of housing stock.

Although agnostic to energy source, heat networks would be harder to justify in areas where extensive capital cost would need to be spent in order to provide the heat. There are several options for provision of low carbon heat: for example, heat offtake from power stations, heat pumps with a decarbonised electricity supply and many niche opportunities using local resources, such as geothermal. The location of these technologies will be context and resource dependent; therefore, the areas most suitable for heat networks will also be those that limit the required length of transmission of heat from the energy centre.

CONCLUSION

The heat network sector in the UK is currently small but has the potential to play a vital role in the future of heat delivery. Nearly half of heat demand could be met by heat networks. From a whole energy systems perspective, heat networks should play a much larger part in our heat delivery system in 2050, especially in less efficient and higher density buildings. However, from the perspective of the wide variety of stakeholders today, there are many requirements that must be satisfied to improve the attractiveness of DHN, not all of which are met by the offerings currently available. A key one of these is capital cost. By targeting innovation in the sector at high cost areas, not only would capital cost and investment barriers be reduced, but in the longer term the size of the market would likely expand due to increased competitiveness with other methods of heat delivery.

Either way, to deliver a low-cost energy system that meets the 2050 emissions targets, heat networks can only fulfil their potential if the sector is mobilised quickly. As with most challenges associated with the energy transition, the scale of change needed is very large; with hundreds of thousands of connections needed per year. To stand a chance of achieving these numbers, the skills base in the UK needs to be coordinated and supported to increase capacity rapidly, ensuring that best practice is both achieved and incrementally improved through innovation and learning.

Heat networks can deliver comfort to homes at lower cost than alternative technologies when designed and operated well. They have been shown to have positive impacts on social inequality and are tried and tested in other European markets. However, public perception is crucial to the success with the end consumers having a potentially powerful collective voice if performance standards are not met. Several organisations in the sector are leading improvements and advocating quality developments but to deliver the full potential of heat networks and develop the market responsibly, with a clear offering to all stakeholders, coordination and collaboration is crucial.

To enable innovations to reduce capital costs within heat network infrastructure, UK Central and devolved Governments need to provide frameworks that support demonstration, knowledge transfer and skill development in the sector. Elevating heat networks to be included as infrastructure within the Infrastructure and Project Authority[11] will give impetus for stakeholders to innovate; it would demonstrate that the Government recognises that the need for and scale of our heat network development is a major infrastructure project.

There are key actions for all stakeholders relating to heat networks:

- Professional and Trade bodies should align with common standards and present a clear message to their members and markets that DHNs have an important role to play for the UK Energy System
- Local Authorities to continue to support heat networks and allow provision for demonstration of innovations
- The DHN design community to engage, collaborate and develop common solutions; overcoming the concern that standard solutions will reduce their fees for bespoke design.

11. www.gov.uk/government/organisations/infrastructure-and-projects-authority

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About the author

Dr Alex Buckman joined the ETI in 2016 and was the technical lead on the Heat Infrastructure Development Project. He completed his PhD in Mechanical Engineering at the University of Sheffield where he also gained his Master's Degree in Mechanical Engineering. He moved as part of the transfer of the ETI's strategic analysis capability to the Energy Systems Catapult at the end of 2017 where he is presently - Practice Manager, Networks and Energy Storage.

Further Future Networks reading from the ETI

- Enabling Efficient Networks for Low Carbon Futures. https://www.eti.co.uk/library/enabling-efficient-networks-for-low-carbon-futures
- UK Networks Transition Challenges – A Systems View. https://www.eti.co.uk/insights/uk-network-transition-challenges-a-system-view
- UK Networks Transition Challenges - Electricity. https://www.eti.co.uk/insights/uk-network-transition-challenges-electricity
- UK Networks Transition Challenges - Gas. https://www.eti.co.uk/insights/uk-network-transition-challenges-gas
- UK Networks Transition Challenges - Heat https://www.eti.co.uk/insights/network-transition-challenges-heat
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Energy Technologies Institute
Charnwood Building
Holywell Way
Loughborough
LE11 3AQ

01509 202020
www.eti.co.uk
info@eti.co.uk
@the_ETI