Estimating the cost-reduction impact of the Heat Network Investment Project on future heat networks

January 2018

Carbon Trust prepared this report based on an impartial analysis of primary and secondary sources. Carbon Trust is an organisation of independent experts with the mission to accelerate the move to a sustainable, low carbon economy. We operate at a world-wide level and we have offices in London, Beijing, Johannesburg and Mexico City.

Tom Jennings
Director, Policy & Innovation
tom.jennings@carbontrust.com

Andrew Johnson
Senior Manager, Policy & Innovation
andrew.johnson@carbontrust.com

Daniel Marten
Associate, Policy & Innovation
daniel.marten@carbontrust.com

Tanja Groth
Decentralised Energy Manager, Programmes
tanja.groth@carbontrust.com

Acknowledgements

The authors would like to thank the following people for their contribution to this study:

Joe Cranston-Turner (BEIS)
Rob Lloyd (BEIS)
Anne Pentecost (BEIS)

Gautier Jacob (EDF Energy Services)
Medi Rampal (EDF Energy Services)
Lars Fabricius (SAV Systems)
Jan Hansen (SAV Systems)
Marcus Postings (Danfoss UK)
Birger Laursen (Danish District Heating Association)
Stella Faber (Business Sweden)
Kerstin Sernhed (University of Lund)
Morten Jordt Duedahl (Danish Board of District Heating)
Christopher Hill (Logstor UK)
Mike Cooke (Vital Energi)
Stephen Hayes (Nottingham City Council)
Toby Heysham (Pinnacle Power)
Ben Watts (Engie)
Alex Buckman (Energy Technologies Institute)

Emma Ashcroft (Carbon Trust)
Guy Henley (Carbon Trust)
Laura Glover (Carbon Trust)

Table of Contents

1 Executive summary

Heat plays a critical role in the UK energy system. Depending on energy efficiency and demand reduction measures, heat is expected to constitute 19-44% of energy demand through to 2050[1]. There is significant potential for heat networks to reduce CO_2 emissions and offer cost reductions for meeting this heat demand. The government's Heat Network Investment Project (HNIP) is intended to stimulate the heat network industry in the UK.

This study examines the potential cost reduction impacts the HNIP may unlock for the deployment of district heat networks in the UK to 2025 and beyond. Two types of impact have been identified: direct and indirect. Direct impacts are the most concrete estimate for the cost reduction impact of the HNIP and are estimated at £90-370 million cumulatively by 2050.

1.1 Direct impacts

Cost reductions attributable to the HNIP are assumed to only relate to learning-by-doing. This is because the HNIP is primarily a programme to support the deployment of heat networks in the UK, rather than research and development (R&D) in heat networks. The impact of the HNIP is directly related to how much deployment it supports, as learning-by-doing occurs through deployment.

Firstly we estimate overall learning-by-doing from deployment of heat networks in the UK to 2050. To achieve this we make use of the Heat TINA model[2]. Based on TINA deployment levels, the cumulative discounted learning-by-doing cost reductions for UK heat networks total £5.1 billion by 2050, a 7.2% reduction in costs compared with deployment without any learning-by-doing cost reductions.

Secondly we estimate the proportion of learning-by-doing directly attributable to the HNIP. This is determined by the HNIP's share of incremental heat network deployment. The HNIP-supported deployment has been modelled as 0.8-3.3 GW[3], giving a range of potential cost savings based on these deployment scenarios. Direct cost reductions expected by 2025 and 2050 are shown in Table 1.

The HNIP is modelled as supporting 19-75% of total heat network projects installed between the modelled years 2021-2025 and therefore accounts for 19-75% of learning-by-doing capital expense (CAPEX) cost reductions in these years only.

From 2021 onwards the HNIP also accounts for learning-by-doing operating expense (OPEX) cost reductions, which are again proportional to the HNIP's share of incremental deployment. As deployment increases, the HNIP accounts for a declining share of learning–by-doing OPEX cost savings, as the HNIP-supported projects account for a steadily smaller share of cumulative deployment.

Table 1 Direct impacts

HNIP-supported deployment to 2050	Value chain component	2025 (GBP million)	2050 (GBP million)
Lower (0.8 GW)	CAPEX	80	80
	OPEX	<10	10

---

[1] Low Carbon Innovation Co-ordination Group (2016). Heat Technology Needs Innovation Assessment (TINA).

[2] The Heat TINA model is a techno-economic model originally developed for the Low Carbon Innovation Coordination Group in 2012 for the purpose of estimating the cost saving potential of innovation in low carbon heat technologies to 2050.

[3] Based on discussions with BEIS on the possible impact of the HNIP.

	Total	**80**	**90**
Upper (3.3 GW)	CAPEX	310	310
	OPEX	<10	60
	Total	**320**	**370**

1.2 Indirect impacts

In addition to the cost reduction impact directly related to deployment supported by the HNIP, there are further indirect cost reduction impacts. These indirect impacts have been constructed using 'what-if' analysis; that is, making assumptions about possible impacts without direct primary evidence (albeit assumptions bound by the modelling used). These indirect impacts should be considered less concrete than the direct impacts for this reason.

1.2.1 Indirect impacts – Cost reduction via learning-by-doing from accelerated deployment

In the Heat TINA model, cost reduction is split into cost reductions from learning-by-R&D and cost reductions from learning-by-doing. The split between learning-by-R&D and learning-by-doing is determined, at the level of individual value chain components, by the maturity-level of the technology used. The maturity level in turn is related to how much deployment has occurred.

It can be argued that because of the HNIP, deployment of heat networks occurs earlier than would otherwise be the case. Cost reduction driven by learning-by-doing therefore occurs earlier and accounts for a higher share of total cost reduction than would otherwise be the case for the industry as a whole – not just the projects directly supported by the HNIP.

To estimate this impact, two different technology maturity scenarios have been calculated: altering maturity profiles by five years and then by ten years. Accelerating the deployment pathway under these assumptions can increase cost savings from learning-by-doing by £80-160 million cumulatively to 2025 and by £310-620 million cumulatively to 2050.

1.2.2 Indirect impacts – Cost reduction via lower cost of capital

The HNIP is also likely to impact district heat network costs by lowering the cost of capital. By supporting deployment at scale, the HNIP could achieve a more general de-risking of the market for the private sector, leading to a potential step change in financing costs. The effect could potentially be very large as it would lower finance costs across all heat network projects.

Quantifying this impact is extremely difficult. Our findings therefore are based on a 'what if' style analysis assuming a 3-6%-point change in the cost of capital while varying assumptions about the current cost of capital and what share of the downward shift is attributable to HNIP. A recent (2017) BEIS conference, aimed at heat networks investors in the UK, identified the current cost of capital that is most appropriate to attract third party investors ranges from 9-12%. Using these assumptions, we estimate that the reduction in cost of capital in 2050 ranges from £70 million (with a 9% current cost of capital) to £800 million (with a 12% current cost of capital)

Both of these indirect impacts, relating to the acceleration in overall deployment caused by HNIP and the lower cost of finance that HNIP helps bring into the market, are quantified in Table 2.

Table 2 Indirect impacts

Type of impact	Description	2025 (GBP million)	2050 (GBP million)

Indirect, cost reductions	Learning-by-doing cost reductions from HNIP accelerating deployment pathway	c.80-160	c.310-620
	Structural reduction in financing costs	c.10-210	c.70-800

1.2.3 Indirect impacts – Additional deployment

Another indirect impact of the HNIP is the potential to increase the volume of heat network projects being undertaken, on top of the projects directly supported by the HNIP. By providing a critical mass of demand at a crucial point in the development of heat networks in the UK, other networks will be deployed that would otherwise not have been. This is an impact on deployment, not cost reduction.

Again, quantifying this impact is extremely difficult. Our findings are based on a ‘what if’ style analysis. We have assumed the maximum additional deployment that could be achieved is the difference between the Heat TINA deployment profile on the one hand and the baseline of demand provided by BEIS plus the deployment supported directly by HNIP on the other. However, it is very unlikely that all this deployment could be unlocked by HNIP alone; other policy and regulatory initiatives and market changes will likely be needed to realise the full Heat TINA deployment profile.

Therefore, the ‘what if’ analysis shows how much additional investment can be attributed to HNIP by varying the share of additional deployment due to the presence of HNIP outside the directly supported projects; results are shown in in Table 3, where varying this share from 5-30% shows impacts ranging from £2,220-£13,290 million in 2050.

Table 3 Indirect impacts: increased deployment

Type of impact	Description	2025 (GBP million)	2050 (GBP million)
Indirect, increase in deployment	Value of additional deployment	c.290-1,720 (5-30%)	c.2,220-13,290 (5-30%)

1.3 Comparisons with other cost reduction estimates

The Danish market has shown a 13% cost reduction from 2013-2016[4]. Based on publicly available data it is difficult to analyse the drivers for this cost reduction and whether, for example, the differences are driven more by the highest cost networks moving closer to the lowest costs, or whether there has been a genuine reduction of costs across the board.

Separately, AECOM (2017)[5] examined capital cost reductions in district heating infrastructure with an aggregate 38% reduction identified. Focusing just on capital costs, this compares with 9% in our analysis. The 38% reduction is, however, from all sources including learning-by-R&D.

BEIS (2016)[6] conducted a cost-benefit analysis (CBA) for the pilot phase of the HNIP. The learning-by-doing and economies of scale effects calculated gave a cost reduction of 3.6% for the HNIP Pilot phase, relative to the counterfactual scenario of no cost reduction.

---

[4] Danish Energy Regulatory Authority, District Heating Statistics 2013-2016.

[5] AECOM, ETI (2017). Reducing the capital cost of district heat network infrastructure.

[6] BEIS (2016) Heat Networks Investment Project Consultation Government Response

These comparisons of potential cost reductions show results in this report are potentially conservative. However, raw comparisons of headline cost reductions should be made cautiously as each study includes different cost reduction factors. Sources of potential cost reductions which our study does not model include: cost savings from learning-by-R&D, higher efficiency of operations leading to fuel cost savings, energy system benefits and potential cost savings from quality improvements.

2 Introduction

2.1 The importance of heat networks for meeting the UK's low carbon targets

Heat plays a critical role in the UK energy system. Nearly half of the energy we use in the UK is used for heating of one sort or another[7], with heat demand for buildings modelled to reach approximately 150-500TWh in 2050[8], a 20% increase from 2012 levels. Depending on energy efficiency and demand reduction measures, heat is expected to constitute between 19-44% of energy demand through to 2050[9].

Heat demand is highly 'peaky' compared with other energy end uses in the UK, with much higher demand for heat during the coldest months of the year and during specific times of day. This high variability in demand across timescales of hours and seasons is a fundamental characteristic of heat delivery in the UK, with important implications for the technologies that can meet heat demand cost effectively.

There are limited low carbon technology options for meeting the aforementioned heat needs and all of these technologies face major challenges. There is significant potential for heat networks to reduce CO_2 emissions and offer cost reductions, by enabling the use of low carbon heat, such as waste heat from power stations and large scale heat pumps. District heat networks can be served by and enable the use of a wide range of heat sources supporting the wider decarbonisation transition of the UK's energy system, as well as providing increased security of energy supply.

2.2 The government's response

The 2015 Comprehensive Spending Review announced the intention to launch the Heat Networks Investment Project (HNIP) with a budget of £320 million. On 17th October 2016, the pilot phase of HNIP was formally launched with a budget of £39 million, initially targeting local authority-led heat networks. The main HNIP scheme will launch in 2018, offering funding to March 2021 to both public and private sector bidders.

This policy intervention is a critical step in supporting the transition to a low carbon heat infrastructure, particularly in light of the historically patchy development of heat networks in the UK.

2.3 Establishing additionality

Our analysis aims at understanding HNIP's potential cost reduction impact. As outlined in HM Treasury's Magenta Book[10], the estimation of the counterfactual constitutes a key determinant of the extent to which any intervention's impacts are additional:

> "The key characteristic of a good impact evaluation is that it recognises that most outcomes are affected by a range of factors, not just the policy. To test the extent to which the policy was responsible for the change, it is necessary to estimate – usually on the basis of (often quite technical) statistical analysis of quantitative data – what would have happened in the absence of the policy. This is known as the counterfactual."

The key objective of HNIP is to deliver the components of a sustainable heat network market, supporting growth in the market by providing financing for the most risky stages of heat network projects. While additionality can be defined at each stage of development of heat network projects,

---

[7] DECC (2013). The Future of Heating – Meeting the Challenge

[8] Low Carbon Innovation Co-ordination Group (2016). Heat Technology Needs Innovation Assessment (TINA)

[9] Ibid

[10] HM Treasury (2011). The Magenta Book – Guidance for Evaluation

our analysis of the counterfactual for HNIP focuses on the capacity of heat network projects which would not achieve construction (or would not have been extended) without HNIP.

We assume that the screening process in place for HNIP funding allocation identifies projects which satisfy the assumption of additionality and will reflect funding allocation in the main scheme. We then combine the resulting number of additional projects with measures capturing their cost reduction, thus arriving at an estimate of the net aggregate initial impact of HNIP.

2.4 Benefits not modelled

Some aspects of heat networks and the HNIP in particular have not been included in modelled benefits for this study.

Energy system benefits such as the potential for a heat network to provide flexibility to the wider energy system by acting as a thermal store have not been included. Understanding these benefits and in particular the connection between heating and electricity systems, e.g. how flexibility in the heating system could create benefits for the electricity system, is not currently well understood or extensively modelled. These benefits are potential sources of revenue as well as cost reductions for heat networks. Revenue generation of heat networks is not considered in this study.

Quality improvements in heat networks are a key objective of the HNIP. Criteria for supported schemes are likely to favour higher quality and better-designed networks that help facilitate some of the cost reductions outlined in this report, e.g. connections to existing networks. Theoretically this could provide additional cost reductions beyond what has been considered so far, or realise cost reductions at a faster rate. Interviewees were, however, unsure about the quality impact of HNIP and whether it would be positive or negative for the sector overall as higher-quality networks supported by HNIP may be offset by lower-quality networks outside the programme.

There are two further reasons these quality benefits have been excluded from our analysis. Firstly, precisely what criteria BEIS may ultimately design for the HNIP project have not yet been published. Secondly, the aggregate cost reduction is capped by a long-term relationship between deployment and cost reduction. This ‘macro’ curve includes all sources of cost reduction and smooths the rate of cost reduction. By adding additional cost reductions from the bottom up, the long term relationship is implicitly being questioned and the cap is no longer a cap.

This exclusion of quality impacts includes any other micro-level assumptions regarding the type of heat network supported by HNIP, i.e. HNIP supported projects are assumed to be representative heat networks, rather than defined by characteristics that set them apart from the population of heat networks, for example primary networks rather than secondary networks.

2.5 Objectives for the study

The objectives of the study as laid out in the invitation-to-tender document issued by BEIS are to:

1. Review and summarise the potential for cost reductions for UK heat networks (including heat source), and assess the proportion of these that could reasonably be delivered by HNIP deployment with associated uncertainties.
2. Estimate the ensuing cost savings for England and Wales heat networks deployment in the 2020s and beyond (if feasible) arising from HNIP derived cost reductions with associated uncertainties.
3. Indicate what alternative market interventions, if any, would be needed to deliver the cost reductions that are unlikely to be delivered by HNIP (this is discussed in Annex A1).
4. Summarise the historic evidence for cost reductions through deployment of heat networks markets in other countries and assess the extent to which that informs the likely impact of HNIP deployment in the UK.

3 Overview of approach

Our approach to this short study has relied primarily on pre-existing sources and material to arrive at an estimate of the cost reduction impact of HNIP. We have conducted a literature review, interviewed experts and adapted and built models before drafting the analysis into this report.

3.1 Simplifying assumptions made in the tender response

Given the time constraints and the potential complexity of estimating the cost reduction impact of the HNIP, we have made three simplifying assumptions regarding the direct impact of the HNIP.

Cost reductions attributable to the HNIP will only relate to learning-by-doing

Conceptually we divide all cost reductions between R&D/innovation and learning-by-doing (including economies of scale). To the extent that the HNIP does lead to some R&D cost reductions, this assumption will lead to an underestimate of the impact of the HNIP.

Ruling out cost reductions by R&D from the analysis is reasonable. While some of the eligibility criteria of the HNIP are likely to be designed to encourage more innovative heat networks than what the market alone might deliver, it is not an R&D programme. The HNIP is primarily designed to facilitate the deployment of heat networks to support the development of the UK heat network market.

Ruling out cost reductions from R&D is more appropriate for analysing the impact of the HNIP on cost reductions until 2025. Any new R&D and innovations spurred by the HNIP specifically are unlikely to enter the market in large volumes until after 2025, at the earliest. However, by 2050 R&D cost reductions would be expected to have manifested, meaning the impact of this assumption is more important for the 2050 estimate.

The meta-driver for learning-by-doing is deployment

This assumption is almost axiomatic – few if any learning-by-doing cost reductions could be realised without deployment (the ‘doing’) or the planning that future deployment would stimulate. We assume deployment is both the construction of physical assets and the expenditure of financial resources directly related to deployment e.g. going through planning processes.

This assumption is important for being able to connect estimates of deployment supported by the HNIP with estimates of learning-by-doing cost reductions supported by the HNIP.

The share of learning-by-doing cost reduction in the UK will correspond directly to the proportion of UK deployment accounted for by the HNIP

This assumption builds on the previous one to create a specific relationship between deployment and learning-by-doing cost reductions. We assume a directly proportional relationship between cost reduction and the share of incremental deployment accounted for by the HNIP to 2050.

This assumption would likely lead to an underestimate of the impact of the HNIP as this direct relationship between cost reduction and deployment likely only applies in narrow terms to the direct impact of the HNIP only. In the long run, the true relationship between deployment and cost reductions would likely show earlier deployment (which the HNIP supported networks will be) driving proportionally higher cost reductions than later deployment as the overall cost reduction learning curve demonstrates diminishing returns to scale. The cost of capital for heat network projects is likely to come down, providing a substantial additional indirect impact and the confidence given to the market by the HNIP deployment will likely lead to the deployment of projects that would otherwise not have occurred, again providing further indirect impact.

3.2 Literature research

Our review of literature has focused on understanding drivers of learning-by-doing and economies of scale cost reductions from both UK and international sources. Heat network cost reduction data in the literature are scarce as is any discussion of cost reduction. The most important papers for this study have been those that include discussion of future cost reduction drivers. These are:

- AECOM (2009). The Potential and Costs of UK District Heating Networks. A report to the Department of Energy and Climate Change
- AECOM (2015). Assessment of the Costs, Performance and Characteristics of UK Heat Networks
- AECOM (2016). Heat Infrastructure Development Project
- AECOM, ETI (2017). Reducing the capital cost of district heat network infrastructure
- Bank for International Settlements Working Papers (2014). Understanding the challenges for infrastructure finance
- Danish Energy Regulatory Authority, District Heating Statistics 2013-2016.
- Element Energy (2015). Research on district heating and local approaches to heat decarbonisation - A study for the Committee on Climate Change
- Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR
- Low Carbon Innovation Co-ordination Group (2016). Heat Technology Innovation Needs Assessment (TINA) refresh

A full list of literature reviewed can be found in the Reference section of this paper.

3.3 Expert interviews

In order to fill in the gaps in the literature we have conducted 12 expert interviews across 14 interviewees. Interviewees were selected to represent a range of expertise within the heat networks industry and can broadly be categorised into international experts or UK industry players. This selection allows for a balance between high level policy outlooks (mostly from Danish/Swedish experts, who have experience from more developed heat network markets) as well as practical insights from the ground (from UK industry stakeholders). Table 4 shows a list with more details on the selected interviewees.

Table 4 List of selected interviewees

Category	Interviewee	Organisation	Role	Interview date
International experts	Morten Duedahl	Danish Board of District Heating	Business Development Manager	August 29th
	Stella Faber	Business Sweden	Consultant - Heating Networks	August 31st
	Birger Lauersen	Danish District Heating Association	Manager of International Affairs	September 11th
UK expert	Alex Buckman	Energy Technologies	Strategy Analyst	September 26th

Category	Interviewee	Organisation	Role	Interview date
		Institute		
UK industry player manufacturer	Christopher Hill	Logstor UK	Managing Director	August 23rd
UK industry player utility	Gautier Jacob & Medi Rampal	EDF Energy	CEO & Business Development Manager	September 15th
UK industry player utility	Ben Watts	Engie	Managing Director	September 15th
UK industry player manufacturer	Marcus Postings	Danfoss UK	General Manager UK & Ireland	September 11th
UK industry player developer	Lars Fabricius & Silas Flytkjaer	SAV Systems	Managing Director & Project Manager	September 11th
UK industry player developer & utility	Mike Cooke	Vital Energi	Regional Director	September 12th
UK Industry player developer	Toby Heysham	Pinnacle Power	Managing Director	September 22nd
UK Industry player operator	Stephen Hayes	Nottingham City Government	Senior Programmer Analyst	September 12th

The interviews were carried out with three objectives in mind:

1. Gather qualitative/quantitative evidence of where the learning-by-doing cost reductions in UK heat networks will come from to 2025 and 2050.
2. Group thoughts regarding whether the HNIP could potentially have an impact on the quality of the heat networks installed.
3. Identify additional market incentives that should be implemented in the UK to drive deployment.

Interviews were scheduled throughout the length of the study, usually lasting for roughly 30 minutes and conducted by two Carbon Trust staff. Further details on the specific interview questions asked can be found in Annex A2. To respect the confidentiality of information provided by our interviewees, no finding in this study will be attributed to a specific single interview.

The interview process continued to reinforce one of the main constraints identified previously, which is the lack of robust quantitative evidence for cost reduction outlooks in the heat network industry. When asked about potential reasons for this knowledge gap, interviewees mentioned the fact that heat networks are complex projects which usually involve multiple diverse stakeholders, working together for several years. This implies that cost data and trends are shared across stakeholders for long periods of time, but have not been tracked consistently. Additionally, some interviewees consider this information to be commercially sensitive.

In an international context, the evolution of heat networks in the Scandinavian markets has happened over decades, being considered part of the wider energy strategy, thus costs were important, but not the main motivation, therefore these have not been analysed or published (with the exception of the Danish case).

Regarding UK specific datasets, the industry is still relatively young and the data from the existing projects has not been made available. As the UK market has evolved over the past decades, a UK industry player attested to having seen a 10-15% drop in bid prices in the UK over the last three and a half years, however, these claims could not be substantiated.

With regards to future cost reductions, multiple interviewers agreed that by 2050 prices in the UK should be comparable to those in the Scandinavian markets and the high level estimate given for this cost reduction ranged from 20-30%[11,12]. This estimate comes from anecdotal perception of Scandinavian consultants active in the UK.

Nonetheless, the interviews served their main purpose as they 1) allowed the identification of cost 'hot spots', 2) acted as a sounding board for preliminary outputs of the cost modelling exercise and 3) provided further qualitative indication of where the key cost reduction possibilities lie.

---

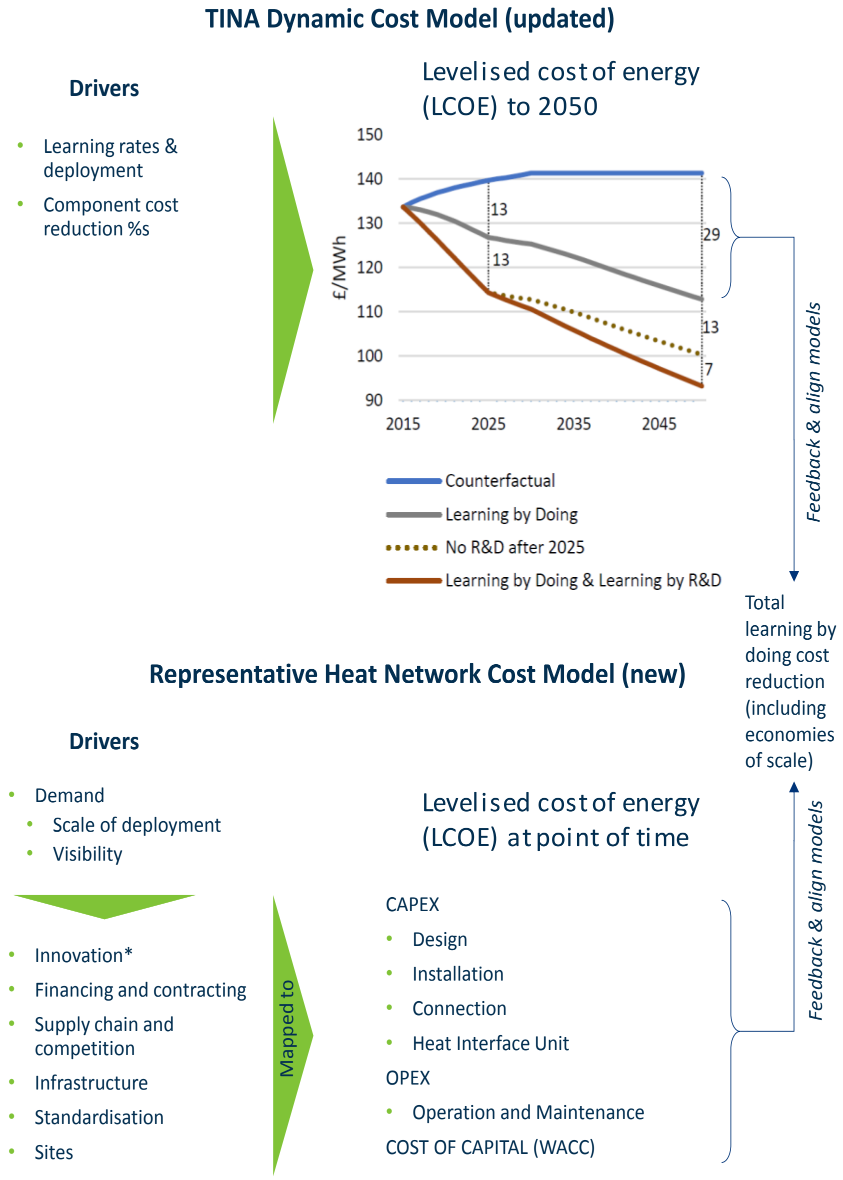
[11] Discussed in three expert interviews

[12] Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR.

4 High-level description of modelling and analysis of HNIP impact

Our overarching framework is based on two models: an updated TINA Dynamic Cost Model[13] (updated and agreed by the Low Carbon Innovation Co-ordination Group in March 2016) and a new representative heat network cost model. Figure 1 below shows a high level summary of this framework, which is explained in this section.

Figure 1 Overarching analytical framework



*The HNIP cost reduction analysis does not include innovation

---

[13] Low Carbon Innovation Co-ordination Group (2016). Heat Technology Needs Innovation Assessment (TINA) refresh. Accessed October 2017 http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/heat/

4.1 TINA dynamic cost model

The overall cost reduction potential for heat networks was examined in the UK for both counterfactual and cost reduction scenarios using the 2016 refresh of the Heat TINA as the starting point.

The Heat TINA is one of several TINA documents focused on cost reduction opportunities in the UK through R&D for the purpose of meeting the UK's 2050 low carbon targets at least cost. The Heat TINA aimed to identify and value the key innovation needs of heat technologies (heat pumps, heat networks and heat storage) to inform the prioritisation of public sector investment in low carbon innovation.

The TINA model is a techno-economic model that estimates the deployment costs for given levels of deployment of low carbon technologies to 2050 with and without cost reduction. The impacts of cost reduction from learning-by-R&D are derived from literature and expert interviews. The impact of cost reductions from learning-by-doing are derived by assumption in certain ratios to the amount of learning-by-R&D (explained further below).

The deployment scenarios used in the Heat TINA modelling are taken from a separate model – ETI's Energy System Modelling Environment (ESME). ESME scenarios assume carbon targets are met in a cost-optimal way, based on technical costs and constraints only i.e. no consideration is given to regulatory changes necessary to realise the projected level of deployment.

The Heat TINA model analyses the potential role of low carbon heat technologies in the UK's energy system, and among its outputs, the model estimates the value to the UK economy from cutting the costs of the technology through innovation. This analysis included a high-level aggregate estimate of cost reductions from learning-by-doing.

For this study, the analysis has been updated, as appropriate, following the literature review and interviews with expert stakeholders. The result is an overall cost reduction curve for heat networks in the 2020s and beyond.

According to the TINA approach, we will divide the cost reduction curve into a learning-by-R&D component and a learning-by-doing component. The learning-by-doing component includes the effect of economies of scale.

Within the Heat TINA, heat networks were assumed to be entirely based on excess heat captured from 'energy from waste generation'. Cost reduction opportunities related to the generation component of heat networks were not included in the analysis related to heat networks. Clearly, the HNIP will also impact cost reductions in generation, therefore we estimate this impact using separate data.

The actual mix of heat generation technologies deployed across the UK varies across a range of technologies, with gas-based combined heat and power (CHP) anecdotally being the most prevalent. Information provided by BEIS suggested the following categorises of technology should be considered for the purposes of the modelling analysis in this study: Gas CHP; Energy from Waste; Biomass boilers; Geothermal CHP; Gas boiler; and Water source heat pump. These have been included in the updated modelling.

4.2 Representative heat network cost model

The representative heat network cost model takes the top down constraints from the Heat TINA and applies them across the different components of the heat network: CAPEX – design; CAPEX – generation; CAPEX – equipment; CAPEX – installation; OPEX; and Weighted Average Capital Cost (WACC). The impact was based from literature where available and tested with interviewees.

The final output presents cost reductions in both percentage changes and in absolute GBP (appropriately discounted) relative to the counterfactual scenario – broken down into each value chain component.

5 Cost reduction drivers

5.1 Methodological approach

In order to identify cost reductions through learning-by-doing in heat networks in the UK, four main activities were undertaken:

1. Data on heat networks from the Danish Energy Regulatory Authority have been analysed to understand cost reductions in heat networks over time.
2. UK and international literature on the cost of heat networks and cost reduction potential has been reviewed (see References section for details).
3. Expert interviews: 12 expert interviews have been conducted.
4. Based from 1-3 above, a model of the cost impacts for a representative heat network in the UK to 2050 has been constructed.

5.2 Overview of data from Danish heat networks

The Danish Energy Regulatory Authority (DERA) has oversight of 570 active heat networks; of which 407 deliver heat to households. Every year since 2013 DERA has published an overview of cost and performance data for these networks. All heat networks are required, by regulation, to submit financial data to the Danish Regulatory Energy Authority on an annual basis. In 2016, heat networks delivered heat to 1.7 million households in Denmark, equivalent to approximately 64% of all domestic heating.

The total revenue earned by heat networks in Denmark from household heat sales for the financial year 2015/16 sum to £2.1 billion (16.8 billion DKK). The average price faced by each household for a statistically averaged house consuming 18.1 MWh range from £578 to £3,974 annually in 2016.

The majority of heat networks (81%) charge between £1,250 and £2,500 annually with an unweighted average of £1,732. Danish heat networks date back to the 1970s and it was not possible to determine an age distribution from publically available data.

5.3 How applicable are these findings to a UK context?

5.3.1 Limitations in comparability

Denmark is a much more mature market for district heating than the UK. As a result, the rate of growth of heat networks in the UK is currently much faster compared with Denmark, based on a much smaller base.

The most current publicly available DERA data used is available for four years (2013-2016). A more meaningful comparison would be obtained by being able to compare current costs and developments in the UK with a similar point in the development of heat networks in the Denmark (e.g. the 1970s).

Perhaps as a result of the different stages of development or perhaps because of market features particular to each country the scale of networks is less comparable. For example, a ‘small’ network in Denmark can supply as much as 20 GWh heat per annum.

The fuel mix used in the two countries is also different with for example the UK likely to use a higher proportion of natural gas.

5.3.2 Some other UK drivers

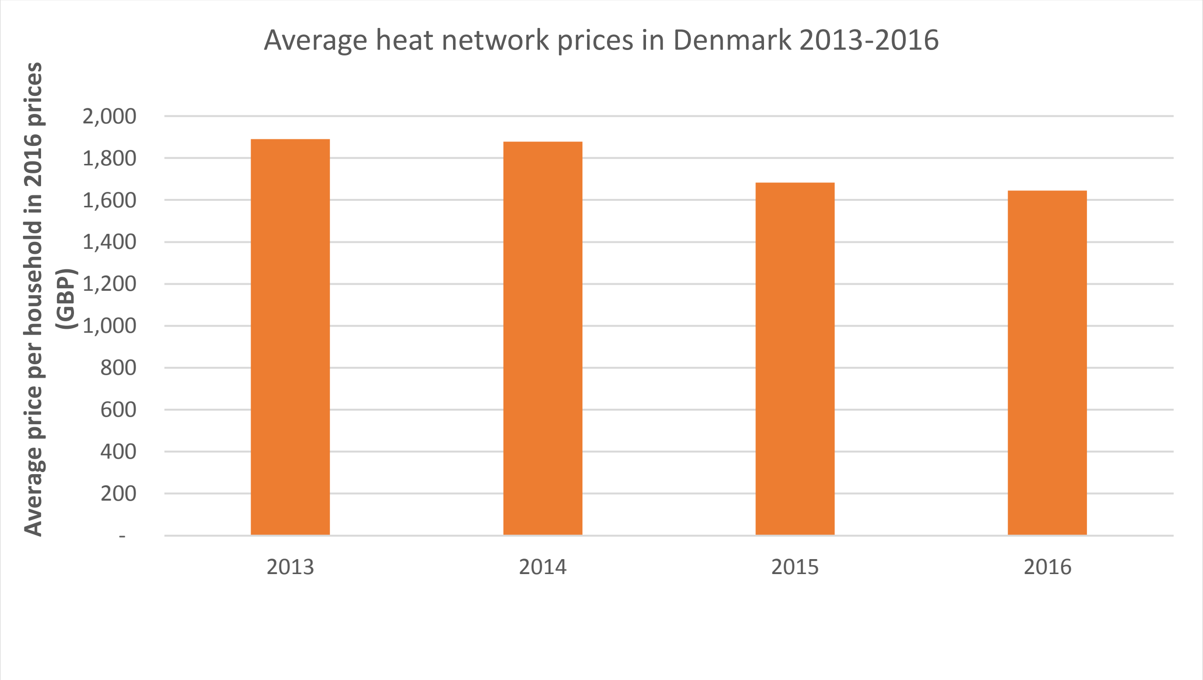
In the UK a low gas price has made it more difficult to establish the cost-effectiveness of district heat networks relative to the counterfactual of individual gas boilers. As such, there is a much greater focus on the cost reduction potential within heat networks as a means of making them a competitive option. The economics of heat networks in the UK is assisted by the potential to achieve higher linear heat densities in urban areas in the UK compared with Denmark.

Notwithstanding these limitations, costs are still decreasing in Denmark and there is some relatability of this to the UK market. According to a subject matter expert heat demand met by heat networks continues to grow by approximately 1% annually in Denmark. It is encouraging that even in a mature market like Denmark, cost reductions are still feasible and some of the major relationships between heat network cost and for example size of network, fuel used, ownership type, and location may have relevance. In terms of directly comparing costs we cannot, however, conclude that these findings are directly applicable to the UK.

5.4 Data from Danish heat networks

Figure 2 shows the overall costs of Danish heat networks for the four years where data are publicly available based on the 'average price per representative household' annual cost to a statistically averaged house consuming 18.1 MWh. Regulation in Denmark prevents district heat networks from turning a profit, therefore the price reported should in theory be equal to cost.

Figure 2: Average heat network prices in Denmark 2013-2016



DERA had a series of hypotheses on what could be explaining cost reductions based on an R-squared analysis of the first year of data (2013):

1. **Size of network:** efficiencies related to scale, such as larger purchasing agreements or lower relative administration costs.
2. **Fuel consumed:** cost reductions resulting from prices of different fuel types.
3. **Ownership type:** possible differences in the efficiencies of municipal vs privately owned networks.

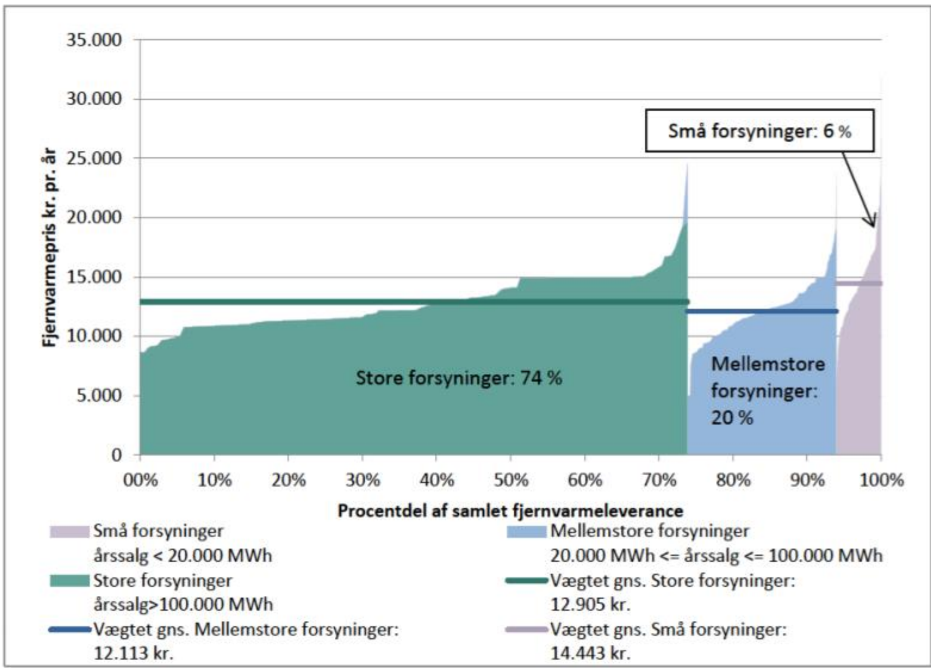
4. **Location of network:** difference in costs arising from rural, town/suburban and urban areas.

Longitudinal analysis of the four years of data (2013-2016) has proved less than conclusive for these factors.

Figure 3 shows the prices for Danish heat networks by size of network. The y-axis provides the annual cost (in DKK) to a statistically averaged house consuming 18.1 MWh. Heat networks are split into three size categories: Small with an annual heat supply of less than 20 GWh ('store forsyninger', green shaded area); medium with an annual heat supply between 20 – 100 GWh ('mellemstore forsyninger', blue shaded area); and large with an annual heat supply above 100 GWh ('små forsyninger', purple shaded area).

In 2016 medium-sized networks had the lowest weighted average costs of £1,514, followed by large networks with £1,613 and small networks with £1,805. Small networks, however, have exhibited the greatest reduction in costs. Small networks are disproportionally more expensive as they are frequently located in remote rural areas or locked into expensive natural gas supply contracts.

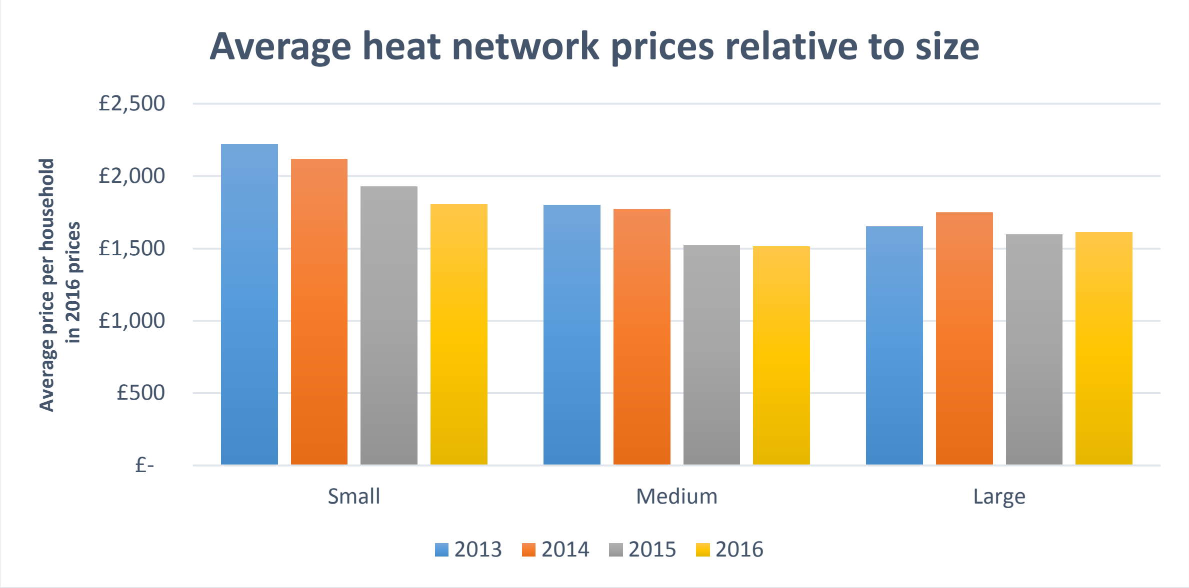
Figure 3: Danish heat network prices in 2016 by size of network



Source: Danish Energy Regulatory Authority, 2016 district heating price statistics

Figure 4 shows how the prices for each size category of heat network in Denmark have changed over the four years 2013-2016.

Figure 4: Evolution of average heat network prices in Denmark relative to size 2013-2016

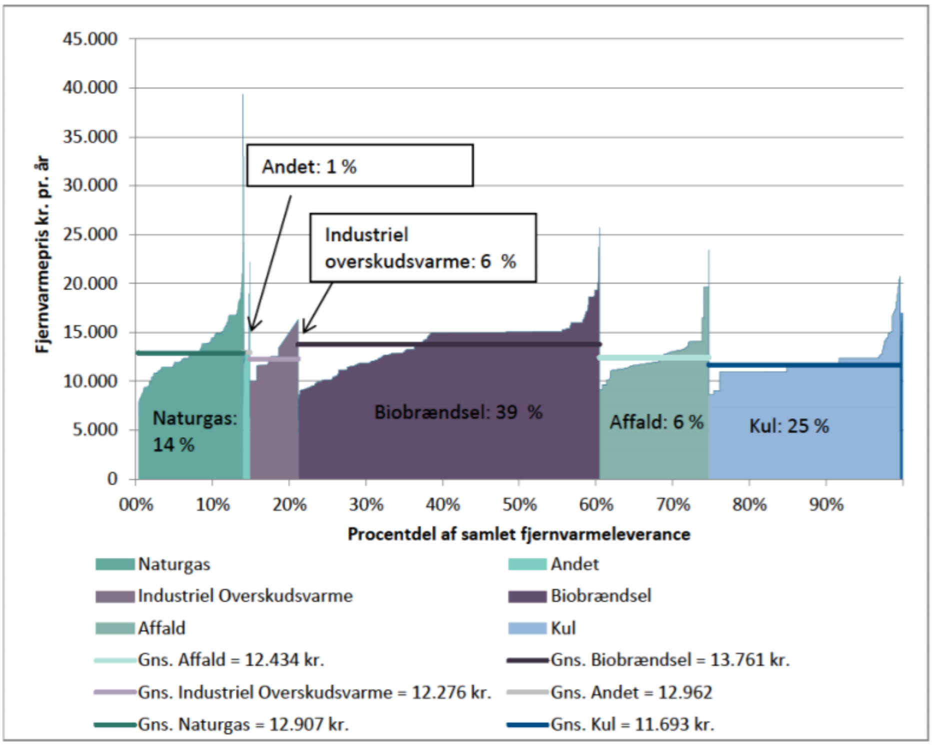


Source: Danish Energy Regulatory Authority, 2013 - 2016 district heating price statistics

The period 2013-2016 has seen a reduction in the average price per network, which has been attributed particularly to falling fuel prices across the main generation technologies deployed in Denmark (see below).

Heat network supply is split across six **primary** fuel categories; natural gas (14%), other (1%), industrial waste heat (6%), biomass (39%), energy from waste (6%) and coal (25%). Figure 5 shows that in 2016 coal had the cheapest weighted average cost at £1,462 while biomass was the most expensive at £1,720.

Figure 5: Danish heat network prices in 2016 by fuel consumed in network



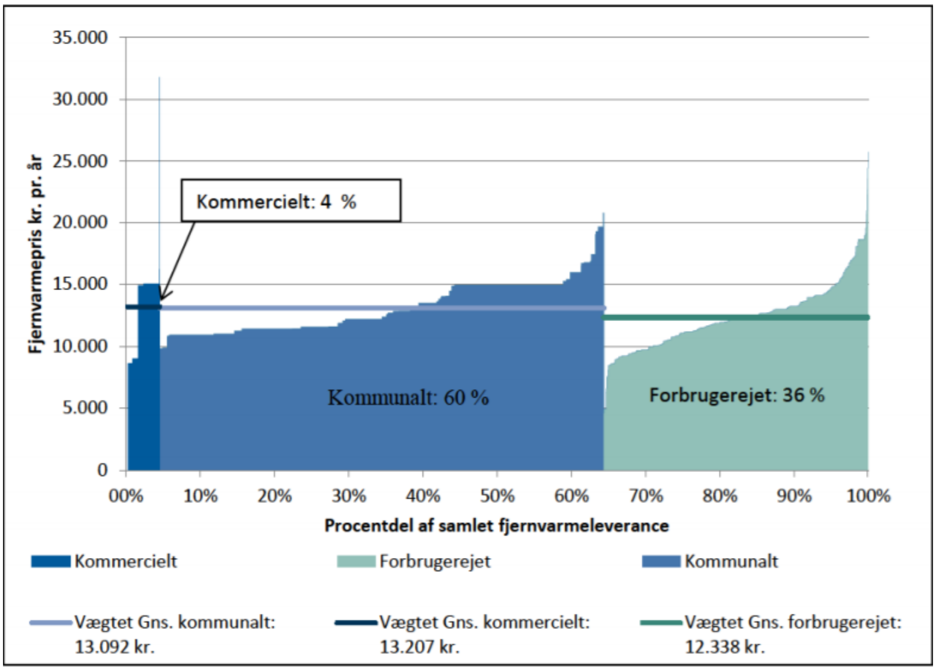
Source: Danish Energy Regulatory Authority, 2016 district heating price statistics

As with the cut by size, the variation within each fuel category is again significantly greater than the variation between fuel categories. Cost differences within fuel categories can depend on purchasing power (e.g. economies of scale), age of the network (contributing to generation and distribution efficiencies) and regional location of the network.

There are broadly three ownership categories for Danish district heating networks – private (Kommercielt) 4%, municipal (kommunalt) 60% and community-owned (forbrugerejet) 36%. A regression analysis conducted by DERA in 2013 indicated that community-owned schemes are cheaper than private and municipally-owned schemes. Private sector owned networks are on average more expensive than municipal and community networks.

Figure 6 shows prices by ownership category for 2016. Again, the variation within each ownership category is significantly greater than the variation between categories.

Figure 6: Danish heat network prices in 2016 by ownership type

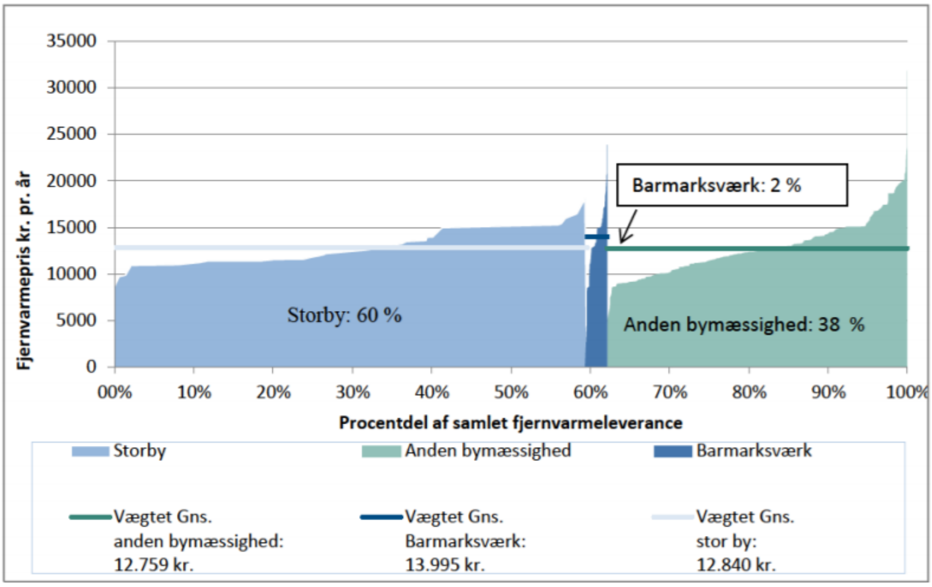


Source: Danish Energy Regulatory Authority, 2016 district heating price statistics

There are broadly three geographical regions for network locations: urban (Storby), rural (Barmarksvaerk), and town/suburban (Anden bymaessighed). As a proportion of total heat delivered, urban heat networks represent the majority of networks at 60%, followed by town/suburban networks at 38% and rural networks at 2%.

Figure 7 shows heat network prices by location of network for 2016. Weighted average costs suggest that town/suburban networks are marginally cheaper at an annual cost of £1,595, followed by urban networks at £1,605 and rural networks at £1,749. Variations within the categories are significantly higher for rural and town/suburban networks.

Figure 7: Danish heat network prices in 2016 by location of network



Source: Danish Energy Regulatory Authority, 2016 district heating price statistics

5.5 Conclusions from Danish data

The data indicates that costs have decreased in Denmark by an average of 13% between 2013 and 2016. Cost reductions are much smaller in large networks (2%) compared with small and medium networks (19% and 16% respectively).

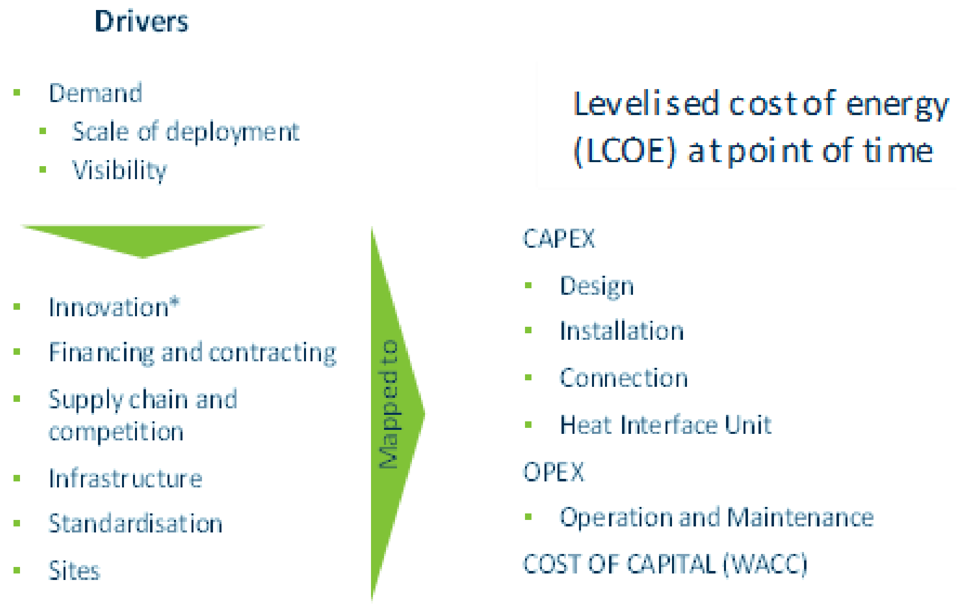
The original hypotheses of four drivers on cost (scale, fuel type, ownership and location) show a weak relationship with cost reduction in the time series. In particular the data suggests that there is not a statistically significant relationship between individual network scale (amount of heat delivered by a given network) and cost to the customer. There is much more variation within categories than between them.

This suggests that there are a large number of drivers affecting cost, which can manifest in a variety of combinations, making it difficult to establish broadly applicable findings.

6 A possible framework for learning-by-doing cost drivers

Error! Not a valid bookmark self-reference. sets out a possible framework for cost reduction in district heat networks. In the top left of the diagram, demand is depicted as the meta-driver that manifests through multiple sub-drivers. This is because demand – a viable market manifested through actual deployment or visibility of likely deployment – is crucial for encouraging both public and private actors to invest time and resources in bringing down costs.

Figure 8: Cost drivers in district heat networks



*The HNIP cost reduction analysis does not include innovation

Demand drivers are also an alternative way of viewing the role of economies of scale. Rather than seeing economies of scale as a separate individual driver for realising cost reduction, economies of scale are in fact created by higher demand which manifests in particular ways through each of the sub-drivers listed on the left hand side of **Error! Not a valid bookmark self-reference.** sets out a possible framework for cost reduction in district heat networks. In the top left of the diagram, demand is depicted as the meta-driver that manifests through multiple sub-drivers. This is because demand – a viable market manifested through actual deployment or visibility of likely deployment – is crucial for encouraging both public and private actors to invest time and resources in bringing down costs.

Figure 8. For example, higher demand justifies more complex/bespoke financing (with a lower risk premium); higher demand can, potentially, justify building or expanding factories closer to end markets; and higher demand justifies investing in enabling infrastructure to bring down overall costs.

6.1 Where will cost reductions come from?

The availability of reliable cost reduction data for heat networks in the UK is very limited. However, information gathered from literature and interviews has allowed for the identification of multiple cost reduction opportunities, categorised under five of the main *drivers* of cost reduction listed in the bottom left of **Error! Not a valid bookmark self-reference.** sets out a possible framework for cost reduction in district heat networks. In the top left of the diagram, demand is depicted as the meta-driver that manifests through multiple sub-drivers. This is because demand – a viable market manifested through actual deployment or visibility of likely deployment – is crucial for encouraging both public and private actors to invest time and resources in bringing down costs.

Figure 8: Financing and contracting; supply chain and competition; infrastructure; standardisation; and sites. Table 5 sets out what is included in each of these categories.

This qualitative assessment of cost reduction opportunities allows for a heat mapping exercise (shown at the end of this section), which will give a flavour of the main cost reduction opportunities in the heat networks value chain.

Table 5: Description of each of the main drivers of learning-by-doing cost reduction

Driver	Description
Financing and contracting	Access to financial capital and processes related to the formulation of administrative, purchasing, planning and legal agreements
Supply chain and competition	Elements pertaining to the existence of a competitive supply chain of industry stakeholders and the multiplying effects of increased competition
Infrastructure	Built environment elements which facilitate the operation of heat networks
Standardisation	Benefits as heat networks begin to mature and systems, processes and designs become standardised
Sites	Better understanding and exploitation of the individual complexities of heat network sites

Based on the results from our analysis, the following sections outline the main cost reduction opportunities under each driver. The following analysis is not supposed to be an exhaustive list of all possible cost reduction opportunities, but rather an outline of where the largest cost reductions can potentially come from. Unless referenced, the statements have come from one of the interviews with subject matter experts.

6.1.1 Financing and contracting

Specific opportunities for cost reduction under financing and contracting that have been identified include:

1. Greater confidence in the level and growth of demand, or the pipeline of potential bankable projects, will reduce the obstacle of access to capital in general and project financing in particular[14].

   "Currently, large engineering companies see a tremendous risk (…in district heating projects) due to uncertainty. To cover the risk they increase the price."

2. Opportunities to contract/bid more effectively by involving key stakeholders from an early stage. The process of bidding can be costly, especially for smaller companies. Tendering processes can be lengthy and projects are often re-designed after the tendering process, which can add further to delays potentially increasing the cost of the network.

   "Currently some energy companies struggle to get a competitive number of companies bidding for supply and installation of pipes, as well as the civil engineering side."

3. There has been some anecdotal evidence from the UK suggesting there is a lack of competition at the bid stage. Making the bid process simpler, potentially, will encourage a higher number of bidders, which will develop expertise on the process, decreasing costs.

4. As systems grow and become interconnected, there are opportunities for sharing administration costs across various projects within a wider defined area[15].

---

[14] Bank for International Settlements Working Papers (2014). Understanding the challenges for infrastructure finance

[15] Element Energy (2015). Research on district heating and local approaches to heat decarbonisation - A study for the Committee on Climate Change

5. Heat network operators can reduce costs by optimising fuel-purchasing agreements/contracts between the heat network administrator and suppliers[16].

6.1.2 Supply chain and competition

Specific opportunities for cost reduction under supply chain and competition that have been identified include:

1. Increasing competition in the civil engineering industry will lower pipe network installation costs. As competition increases, existing UK engineering companies will establish specialised departments and up-skill civil engineers to compete more effectively for market share. New companies will be encouraged to enter the sector if the opportunity is perceived as attractive. As they gain experience, costs will go down.

   "Control of civils cost will be a major driving force in driving the costs of UK district heating projects down."

2. Some supply chain stakeholders, such as pipe manufacturers and providers of retail or customer interfaces, are not commonly found in the UK. Increases in competition amongst suppliers will drive down costs slightly. For example, most pipes for district heating projects are imported from Europe. These delivery costs are significant given the fact that there are no manufacturers or efficient supply chains in the UK. District heating pipes are, however, already very competitively priced relative to other European countries.

3. Heat network developers' design costs will reduce through competition. If manufacturers work with contracting companies from the bidding stage and manufacturers are involved in the design from an early stage, the costs can go down by 10-15%.

6.1.3 Infrastructure

Specific opportunities for cost reduction under infrastructure that have been identified include:

1. Understanding of the infrastructure that will be served by the heat network, including co-ordination with building energy efficiency action plans to ensure the heating needs of buildings match the design of heat networks[17].

2. Improvements in infrastructure that allow improved access to fuel sources for the heat network (energy from waste/waste heat sources), lowering costs.

3. As heats networks grow and become more complex, with adequate planning, there is the opportunity to connect networks, delivering cost reductions through economies of scale.

   "In Denmark, interconnection of different district heating networks across municipalities has allowed for efficiencies and administrative cost reductions."

6.1.4 Standardisation

Specific opportunities for cost reduction under standardisation that have been identified include:

1. Standardisation of design: Stakeholders highlighted that both the plant and central infrastructure tend to be significantly oversized in the UK, leading to higher capital costs than necessary[18].

2. Standardisation of procurement processes will drive down costs across the value chain.

---

[16] AECOM, ETI (2017). Reducing the capital cost of district heat network infrastructure

[17] AECOM (2015). Assessment of the Costs, Performance and Characteristic of UK Heat Networks

[18] AECOM (2015). Assessment of the Costs, Performance and Characteristic of UK Heat Networks

6.1.5 Sites

1. As more projects are deployed in a variety of sites, there will be more clarity about the cost of developing heat network projects in greenfield, brownfield/suburban and city centre sites. This would allow for better planning, forecasting and design, which will drive down costs.

   "When companies dig, they have no clue what lies underground, which delays projects, which leads to delays and unanticipated costs."

2. Better and more systematic planning incorporating site-specific concerns, e.g. underground elements, in the development of heat maps and energy master-plans[19].

6.2 Summary of cost reduction sources

Each individual cost reduction opportunity identified in the previous section has been mapped against the heat network value chain. This has led to an identification of the 'cost reduction hotspots' for heating networks. Table 6 shows this matrix.

Table 6: Learning-by-doing cost reduction drivers and value chain component matrix

	Design	**CAPEX – Generation**	**CAPEX – Equipment**	**CAPEX – Installation**	**OPEX**	**WACC**
Financing & contracting				✓✓	✓	✓
Supply chain & competition	✓✓		✓	✓✓		
Infrastructure	✓				✓	
Standardisation	✓	✓		✓	✓	✓
Sites	✓			✓✓		✓

This framework allocates all the individual cost reduction initiatives mentioned by the interviewees and found in the literature review into our five key drivers. This exercise is not meant to outline all the cost saving opportunities potentially available, but the initiatives with the highest cost reduction potential. From a driver perspective (the rows in **Error! Reference source not found.**) the main drivers which are going to catalyse learning by doing cost savings are supply chain & competition, financing and contracting, and sites.

The matrix shown in Table 6 translates how each driver impacts on the individual elements of the heat network value chain. This was done by assigning each of the individual cost reduction opportunities on each driver to an individual cost element (represented by the individual tick marks

---

[19] Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR

in Table 6). A simple heat mapping exercise was done to assign green and amber categories depending on the number of drivers affecting the cost categories.

The columns in **Error! Reference source not found.** show that the cost categories with highest potential for cost reduction are CAPEX – installation, design, OPEX and WACC. Almost all of the interviewees agreed on the fact that the area with the highest cost reduction potential is the installation of the heat networks, which includes the physical laying down of the pipes, as well as the interface with heat user (which represent a large proportion of overall costs).

It is worth noting that the cost categories with the highest potential identified here do not perfectly match the cost saving potential that have been modelled as part of this project. The main reason for this is because the learning-by-doing cost savings by value chain component are constrained by the updated assumptions from the TINA modelling. It was not possible to update the TINA given the qualitative assessment cannot provide any new, reliable figures. This is, however, a useful heat mapping exercise to assess where industry experts predict reductions will come from.

7 Comparisons with other cost reduction estimates

Before going into our approach for deriving an aggregate cost reduction figure for HNIP, we give some context on aggregate cost reduction from other sources.

The Danish market has shown 13% cost reductions from 2013-2016[20]. Looking further afield, a paper from the IPPR (2017)[21] estimated UK costs are currently 20% higher than Scandinavian costs. Although not explicitly referenced, this estimate is broadly informally accepted in the UK heat network community and also is similar to what three interviewees disclosed, that costs in the UK are 30% higher than those in Sweden.

AECOM[22] has a forthcoming study for the ETI examining capital cost reductions in district heating with an aggregate cost reduction of 38% identified (including learning by R&D). The estimated direct learning-by-doing cost reductions modelled as part of this project suggest a cost reduction in the range of 7.2%, which may appear conservative relative to other sources listed above.

These cost differences cannot readily be attributed to learning-by-R&D as they are a comparison of current costs and not future potential innovations. This means a proportion of these differences could likely be captured by learning-by-doing. It is unlikely that all of the cost differences with Scandinavia will be eliminated through learning-by-doing, for example some factors could relate to inherent factors specific to Scandinavia. Examples identified by interviewees include lower costs of land and better quality data on existing underground utility infrastructure.

Overall it can be seen that our estimates are likely conservative, albeit with the cautions regarding making comparisons with estimates derived in different ways duly noted.

---

[20] Danish Energy Regulatory Authority, District Heating Statistics 2013-2016.

[21] Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR.

[22] AECOM, ETI (2017). Reducing the capital cost of district heat network infrastructure.

8 Modelling assumptions and results

The starting point for modelling deployment, costs and cost reduction assumptions is the refreshed Heat TINA analysis published in March 2016[23], described in Section 4. Building on this, the cost reduction model for a representative heat network uses updated estimates, where possible, provided through recently published literature, industry interviews, and the BEIS heat team to refine and update the initial assumptions to better fit with the current state of the UK heat market.

8.1 Changes to core assumptions

This section provides an overview of the changes to the core assumptions between the Heat TINA and the updated modelling. This includes a description of the underlying methodology for estimating the fraction of cost reduction which can be attributed to learning-by-doing and secondly, how the fraction of cost reduction directly and indirectly attributable to the HNIP is calculated. Next we provide the results of the modelling.

The Heat TINA provides a meta-analysis of the impact of innovation on cost reductions across the wider UK heat sector, with one component being heat networks. Cost assumptions were collected from the best available industry data. Deployment scenarios were generated from the ESME model and the cost reduction potential to 2050 was collated across multiple drivers through industry stakeholder interviews.

The representative heat network model essentially uses the TINA's deployment profile and where applicable, assumptions regarding cost reductions, but complements these with updates to reflect the latest available sources of information. The intention is to take the aggregate picture painted by the TINA and based on a sensible depiction of a representative heat network, describe what this means for overall cost reduction for a given network and cost reduction per value component. Table 7 provides an overview of the values and sources.

Table 7: Original and updated heat network modelling assumptions

Assumption vector	Original source of assumptions	Source of updated assumptions
Baseline deployment pathway	Custom runs of ESME 2015	ESME 2015/BEIS 2017
Heat network capital costs (excluding generation)	Element Energy 2015 for the Committee on Climate Change	AECOM 2017 for the Energy Technology Institute
Generation costs	Not included as part of the costs of the heat network in the Heat TINA – assumed to be energy from waste (EfW)	Danish Energy Agency Technology Data 2017[24]
Financing costs – WACC	Assumption of 10%	BEIS Heat Investment Conference September 2017

---

[23] Low Carbon Innovation Co-ordination Group (2016). Heat Technology Needs Innovation Assessment (TINA) refresh. Accessed October 2017 http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/heat/

[24] A full list of generation costs is included in Annex A3.

8.1.1 Deployment pathways

The deployment pathways used in the Heat TINA come from customized runs of ETI's ESME model. The medium deployment scenario modelled in ESME assumes a total deployment of heat network capacity of 46.7GW by 2050, from a 2015 baseline of 2.9GW. The 46.7GW translates into 65TWh of heat generation in 2050. This is comparable to total heat generation estimates provided from other sources. For example the Committee on Climate Change (2015) suggests deployment could range between 39.3-80.5 TWh. Note that the ESME optimised scenario assumes carbon targets are met in a cost-optimal way, based on technical costs only, i.e. no consideration is given to regulatory changes necessary to realise this level of deployment.

8.1.2 Heat network capital costs (excluding generation)

In the Heat TINA these costs include all capital elements of a heat network outside of generation. The pipe infrastructure and particularly the civil engineering costs associated with pipe infrastructure are a major component of this. The 2017 publication *Reducing the capital cost of district heat network infrastructure*, authored by AECOM, provides an updated proportional split of these network components relative to what was used in the Heat TINA but not an estimate of the cost of installed capacity.

Cost per unit of installed capacity will vary significantly from network to network, as there are different costs per square metre of pipe depending on the size and layout (straight versus corners), the type of ground (soft versus hard dig, greenfield versus brownfield etc) and the costs associated with traffic management on roads and intersections with rail and canals. As such it is difficult to estimate an average value for heat network capital costs which will accurately reflect costs in the future.

For simplicity, we have chosen to continue to use the value from the Heat TINA, but note that this is likely to be a conservative estimate, as many of the cheapest 'low hanging fruit' networks will have been built first with more expensive ones being built in future. Similarly, some interviewees indicated a structural difference in the location of heat networks supported by the HNIP - most of these were deemed town centre schemes which will be more expensive than their greenfield counterparts.

8.1.3 Generation costs

The Heat TINA assumed all heat in heat networks would be delivered from Energy from Waste (EfW) generation, with heat fuel costs set as a fraction (20%) of the electricity price pathway. The HNIP pilot assumes a mix of generation types, including EfW, which reflects existing knowledge of the market (including anecdotal evidence) and data from applications to the pilot HNIP scheme. Accordingly, generation costs have been updated to include a representative mix of gas CHP, EfW, biomass boilers, geothermal CHP, gas boilers, and water source heat pumps. The costs for these technologies have been sourced from the Danish Energy Agency website – full details are listed in Annex A3.

8.1.4 Fuel costs

Although the new model accounts for the mix of generation technologies, we assume fuel costs are constant. It is unlikely that learning-by-doing would have a significant impact on the cost of fuel itself - the main exception to this would be where smaller systems group together to purchase fuel contracts at better terms than they would otherwise have access to. As the majority of UK heat networks are likely to be owned either by public sector, who already purchase fuel in bulk to service their buildings, or by large energy industry operators (e.g. Engie, Eon, EDF Energy Services) an additional economies of scale effect on fuel costs is likely to be minimal, if it applies. Note the assumption that there are no learning-by-doing cost reductions from fuel costs is a departure from what was assumed in the TINA.

Fuel cost efficiencies can be achieved through better system design which can be affected by learning-by-doing. However, such efficiency improvements through better design will already have been captured (at least partially) through cost reductions in development, CAPEX, and especially OPEX and therefore additional reductions have not been modelled for fuel costs. To some extent this is likely to make our results conservative.

8.1.5 Financing costs

Estimates captured at a recent Heat Network Investment conference hosted by BEIS suggest current hurdle rates of 9-12% (this captures 50% of respondents across a mix of private and public sector respondents, sample size 42). From this sample 36% favoured 6-9% and 14% preferred 12+% (all in real terms).

Assuming that the private sector has a preference for higher hurdle rates than the public sector and given that the HNIP is aimed at unlocking third party private sector financing, a 12% WACC is assumed for our modelling as a reflection of combined private and public sector hurdle rates. Financing costs in the heat industry are likely to increase initially and then fall over the medium-to-longer term.

8.2 Cost reduction attributable to learning-by-doing

The Heat TINA follows Jamasb (2007) [25] in describing cost reduction as having a 'learning curve' relationship with deployment. Cost reductions are divided between learning-by-doing and learning-by-R&D at set ratios that depend on technology maturity (which in turn depends to a greater or lesser extent on deployment). Table 8 shows these ratios. This provides a method of differentiating between learning-by-R&D and learning-by-doing against total innovation across different stages in market development.

Table 8: Ratios of learning-by-R&D to learning-by-doing by technology maturity level

Technology maturity	Ratio of Learning by R&D to Learning-by-doing	Share of Learning by R&D out of total innovation impact
Emerging	6.00	86%
Emerging-evolving	3.75	79%
Evolving	1.50	60%
Evolving-mature	0.90	47%
Mature	0.30	23%

Source: Jamasb, T (2007), "Technical Change Theory and Learning Curves: Patterns of Progress in Electricity Generation Technologies", *Energy Journal*, Vol 28

Being able to attribute the share of cost reductions between learning-by-R&D and learning-by-doing is key in estimating the impact of learnings-by-doing on total cost reductions; a prerequisite to being able to determine the HNIP's impact on cost reductions in the heat sector. As described earlier in this document, the HNIP is unlikely to have a direct impact on cost reductions achieved through R&D in the sector and the focus in this analysis is therefore directed to learning-by-doing.

---

[25] Jamasb, T (2007). "Technical Change Theory and Learning Curves: Patterns of Progress in Electricity Generation Technologies", *Energy Journal*, Vol 28.

Different elements of heat network systems are at different levels of technological maturity. The Heat TINA allows for these to evolve over time as shown in Table 9.

Table 9: Technology maturity of heat network value chain components to 2050 as used in the Heat TINA

Innovation of heat networks	2016-2020*	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Connection to heat user (pipework)	Mature	Mature	Mature	Mature	Mature	Mature	Mature
Interface with heat user (heat interface units)	Emerging	Evolving	Evolving	Evolving	Evolving-mature	Evolving-mature	Evolving-mature
Controls (monitoring equipment for the network)	Emerging	Evolving	Evolving	Evolving	Evolving-mature	Evolving-mature	Evolving-mature
Design	Emerging	Evolving	Evolving	Evolving	Evolving-mature	Evolving-mature	Evolving-mature
Installation (civils)	Emerging	Evolving	Evolving	Evolving	Evolving-mature	Evolving-mature	Evolving-mature
O&M	Evolving	Evolving-mature	Evolving-mature	Mature	Mature	Mature	Mature
Fuel	n/a	n/a	n/a	n/a	n/a	n/a	n/a

**Given the lack of deployment of heat networks prior to 2021 in the ESME scenario, it is assumed that the technology maturity categorisation for 2016-2020 is not applicable to the central estimates provided in the modelling.*

As noted previously, generation technologies for heat networks are not considered outside of an energy-from-waste plant. BEIS identified six generation technologies that were of particular interest to this study: Gas CHP, Energy from Waste, Biomass boilers, Geothermal CHP, Gas boiler and Water Source Heat Pump. There were no readily available UK-specific estimates for cost reduction potential of these generation technologies, so data from the Danish Energy Agency's Technology Data for Energy Plants[26] was used as a proxy to estimate potential cost reductions over time. This approach ignores both the technology maturation classification and the share attributable to learning-by-doing versus learning-by-R&D and as such, should be considered a proxy only.

8.3 Attributing cost reductions to HNIP

Cost reductions are applied to incremental capacity supported by the HNIP. Learning-by-doing cost reductions for OPEX are applied over the lifetime of the asset (which runs past 2050). These are calculated in each year as the proportion of total OPEX learning-by-doing cost savings corresponding to the proportion of incremental installed capacity accounted for by the HNIP. Learning-by-doing cost reductions on design and CAPEX installation and capital equipment apply only in the years when projects specifically supported by the HNIP are installed.

---

[26] Taken from the Danish Energy Agency website, accessed 14th September 2017, https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger

In addition to the direct cost reduction impacts that can be directly attributed to the HNIP, there are further indirect impacts which can be estimated using ‘what-if’ analysis. The indirect impacts relate to the acceleration of learning-by-doing caused by the HNIP and a lowering of the cost of finance – both cost reduction impacts. A third indirect impact relates to the value of additional deployment unlocked by the HNIP.

8.4 Direct impacts via learning-by-doing cost reductions from the HNIP deployment

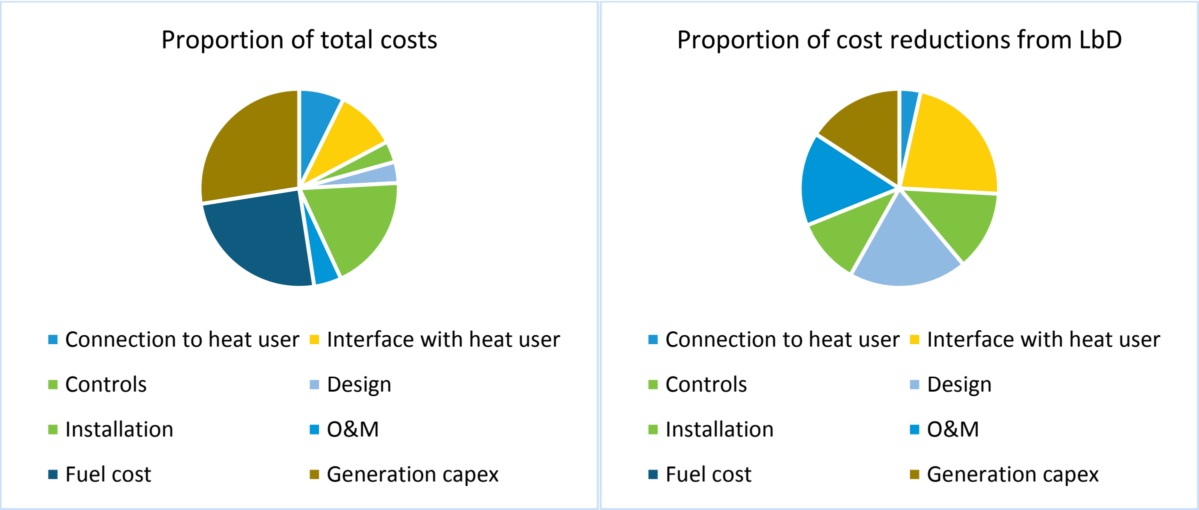
Based on updated Heat TINA deployment scenarios outlined above, cumulative discounted learning-by-doing cost reductions will total £5.1 billion by 2050, which represents a 7.2% reduction in costs. Table 10 provides the breakdown of different cost categories, the proportion of total costs for each value chain component, total costs and percentage savings from learning-by-doing against total costs by value chain component.

Table 10: Learning-by-doing impacts on costs by value chain component

	% of total costs	Total cost w/o LbD (GBP million)	Total cost w/ LbD (GBP million)	Aggregate LbD cost savings (GBP million)	% of savings
Connection to heat user	7%	5,150	5,030	120	2.2%
Interface with heat user	10%	6,960	5,900	1,060	15.2%
Controls	3%	2,420	2,200	220	9.0%
Design	3%	2,420	2,100	330	13.5%
Installation	19%	13,320	12,320	1,000	7.5%
O&M	4%	3,140	2,770	370	11.8%
Fuel cost	25%	17,500	17,500	-	0.0%
Generation capex	28%	19,320	17,340	1,980	10.2%
TOTAL		**70,230**	**65,170**	**5,070**	**7.2%**

Figure 9 compares the breakdown of costs by value chain component with the breakdown of cost reductions from learning-by-doing value chain component.

Figure 9: Proportion of total costs and cost reductions from learning-by-doing by value chain component



The HNIP-supported deployment has been modelled as an upper and lower boundary, based on discussions with BEIS on the possible impact of the HNIP.

Total capacity deployed under the upper boundary is 3.3 GW out of total deployment of 46.7 GW by 2050 while the lower boundary is 0.8 GW, corresponding to between 1.7-7% of total deployment up to 2050 under the scenarios used. The estimated cost reductions for these scenarios can be seen in **Error! Reference source not found.**:

Table 11: Estimated direct impact of the HNIP on cost reduction

HNIP-supported deployment	Direct impact analysis	2025 (GBP million)	2050 (GBP million)
Lower (0.8 GW)	CAPEX	80	80
	OPEX	<10	10
	Total	**80**	**90**
Upper (3.3 GW)	CAPEX	310	310
	OPEX	<10	60
	Total	**320**	**370**

During its modelled implementation (2021-2025), HNIP is modelled as supporting 19-75% of the total deployment (using the Heat TINA deployment profile) and therefore accounts for 19-75% of learning-by-doing CAPEX cost reductions. Beyond 2025, HNIP accounts for learning-by-doing OPEX cost reductions, proportional to its share of cumulative incremental deployment (which reduces over times as deployment continues to increase after the HNIP has finished). Hence it accounts for a decreasing share of learning-by-doing to 2050. Table 12 breaks down the cost reduction impact of the HNIP by value chain component[27].

Table 12: Learning-by-doing direct cost reduction impact from the HNIP by value chain component to 2025 and 2050

	Learning-by-doing cost reductions 2025			Learning-by-doing cost reductions 2050		
Value chain component	% savings	Low HNIP (GBP million)	High HNIP (GBP million)	% savings	Low HNIP (GBP million)	High HNIP (GBP million)
Connection to heat user	1.9%	3	12	2.2%	3	12
Interface with heat user	6.9%	14	58	15.2%	14	58
Controls	5.8%	4	17	9.0%	4	17
Design	9.5%	7	28	13.5%	7	28
Installation	5.1%	20	82	7.5%	20	82
O&M	6.6%	2	7	11.8%	14	57
Fuel cost	0.0%	-	-	0.0%	-	-

---

[27] Given the smaller quantities involved the figures in Table 12 are rounded to the nearest £1 million GBP rather than the nearest £10 million GBP as in other tables.

Generation capex	4.9%	28	115	10.2%	28	115
TOTAL	**4.4%**	**79**	**320**	**7.2%**	**91**	**369**

8.5 Indirect impacts – via learning-by-doing cost reductions from an accelerated deployment pathway

Deployment of the HNIP drives most of the learning-by-doing cost reductions over the period 2020-2025. In the absence of the HNIP, deployment would be significantly lower, which in turn would delay learning-by-doing cost reduction impacts across the industry.

The impact to the industry of the earlier HNIP deployment is an accelerated learning-by-doing impact on cost reduction across all incremental deployment across the sector. Learning-by-doing will deliver a higher proportion of total cost reduction in a scenario where the HNIP is implemented compared with a scenario where it is not implemented.

To estimate this accelerated learning-by-doing impact, the technology maturation classification in Table 9**Error! Reference source not found.** can be modified to alter the timing of technology maturity evolution for each value chain component – with faster maturation leading to a larger role for learning-by-doing in total cost reduction. This is illustrated in Table 13.

Table 13: Technology maturity classifications from original Heat TINA and updated to reflect accelerated learning-by-doing

	Updated model		**Assumption regarding delayed deployment**	
Innovation of heat networks	2016-2020	2021-2025	2016-2020	2021-2025
Connection to heat user (pipework)	Mature	Mature	Mature	Mature
Interface with heat user (heat interface units)	Evolving	Evolving	Emerging	Emerging
Controls (monitoring equipment for the network)	Evolving	Evolving	Emerging	Emerging
Design	Evolving	Evolving	Emerging	Emerging
Installation (civils)	Evolving	Evolving	Emerging	Emerging
O&M	Evolving-mature	Evolving-mature	Evolving	Evolving
Fuel	n/a	n/a	n/a	n/a

Applying different technology maturity profiles results in different learning-by-doing cost reductions. Table 14 illustrates the additional cost reduction impact from the HNIP deployment.

Table 14: Indirect impact of the HNIP on learning-by-doing cost savings through accelerating technology maturation

Impact of accelerated cost reduction impact	2025 (GBP million)	2050 (GBP million)
Total learning-by-doing (with the HNIP deployment)	440	5,070
Delayed maturity profile by 2020	360	4,760
5y acceleration cost reduction savings from HNIP	**80**	**310**
Delayed maturity profile by 2025	280	4,450
10y acceleration cost reduction savings from HNIP	**160**	**620**

Accelerating the cost reduction deployment pathway increases learning-by-doing savings by up to £160 million by 2025 and up to £620 million by 2050.

8.6 Indirect impacts from a structural reduction in financing costs

Greater deployment of heat networks will lead to investors becoming more comfortable with the risks and returns offered by heat networks and consequently lead to a reduction in WACC as risk premiums fall and more investors become interested in the market. The existence of this effect was supported by interview responses and anecdotal evidence. Modelling the size of this change in WACC accurately and what share of this can be attributed to the HNIP is highly uncertain and is therefore modelled on a 'what if' basis.

By assuming a step change reduction in the required rate of return as a result of deployment, it is possible to assess the potential indirect impact on financing costs in the industry. These are reductions in the cost of finance, not CAPEX or OPEX. With financing costs of 12%, 9% and 6% for all incremental capacity added up to 2050 results in the total costs of financing shown in Table 15.

Table 15: Discounted costs of financing heat network deployment to 2050

Discounted costs of financing – high (12%)	*(GBP millions)*	**£5,320**
Discounted costs of financing – medium (9%)	*(GBP millions)*	**£3,990**
Discounted costs of financing – low (6%)	*(GBP millions)*	**£2,660**

A step change could involve moving from a required return of investment of 12% to 9% or from 12% to 6%. Table 16 looks at these impacts and then shows a 'what if' share attributable to the HNIP. Clearly HNIP is only a fraction of total deployment likely between now and 2050 – nonetheless the impact on finance costs could be considerable, given its role in the development of the industry.

Table 16: What if analysis of the indirect impact of the HNIP on a structural shift in financing costs for heat networks to 2050

Share attributable to HNIP	WACC decreases by 3% (shift from 12%- 9%)		WACC decreases by 6% (shift from 12%- 6%)	
	HNIP impact on WACC	(GBP million)	HNIP impact on WACC	(GBP million)
5%	0.2% pts	70	0.3% pts	130
10%	0.3% pts	130	0.6% pts	270

15%	0.5% pts	200	0.9% pts	400
20%	0.6% pts	270	1.2% pts	530
25%	0.8% pts	330	1.5% pts	670
30%	0.9% pts	400	1.8% pts	800

It is possible that the HNIP could indirectly impact the costs of financing the UK heat network industry up to 2050 to a value of £70-£800 million. The size of the range evidences the fact that these potential savings are uncertain, and have been shown to give an indication of what these savings could be.

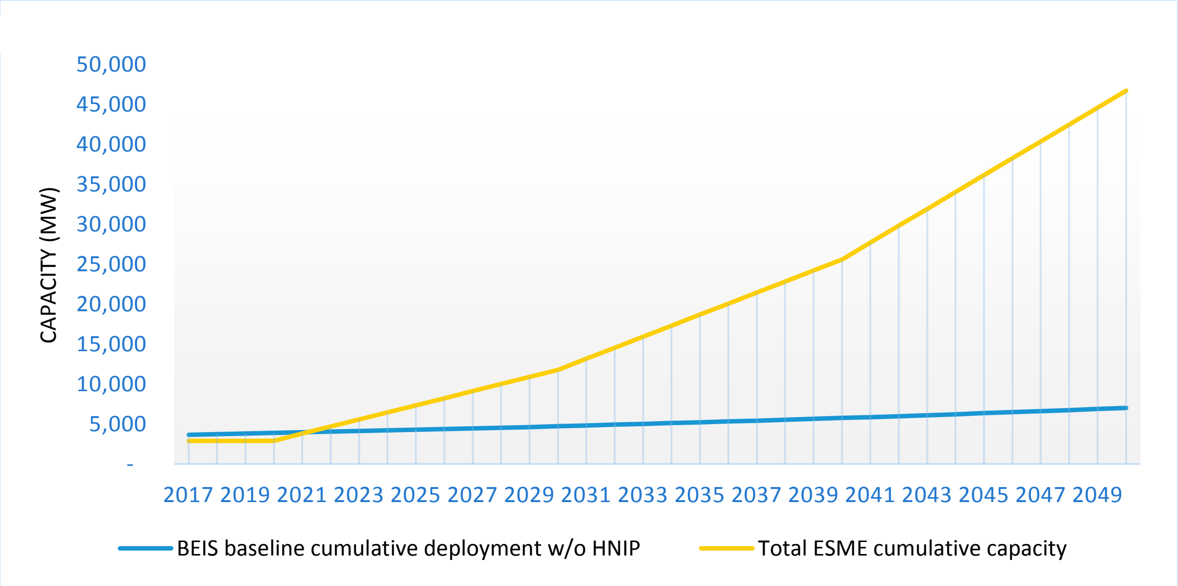
8.7 Indirect impacts from an increase in deployment

In addition to unlocking a step change in the costs of finance from heat networks, it is probable that the HNIP would unlock additional deployment of heat networks in the industry, either through the step change in financing cost of heat networks or through the additional deployment supported by the HNIP overcoming known or unknown market barriers impeding the growth of the market. Interviewees mentioned the confidence-building in the market that would be achieved by the HNIP ‘going first’ and demonstrating feasibility.

By providing a critical mass of demand at a crucial point in the development of heat networks in the UK, other networks will be deployed that would otherwise not have been. The benefit here is not a cost reduction but the investment value of the networks themselves, i.e. without HNIP they will not be constructed.

We have modelled the incremental deployment available to be unlocked by the HNIP as ranging from a low of the BEIS baseline plus the HNIP-supported deployment to a high of the TINA medium deployment scenario. This is the gap between the two profiles illustrated in **Error! Reference source not found.**. It is unlikely, however, that all the difference in deployment shown could be unlocked by the HNIP as other policy and regulatory initiatives and market changes will likely be needed to realise the full Heat TINA deployment profile.

Figure 10: Deployment profiles in BEIS baseline and modelled scenarios



Given the amount of uncertainty, a ‘what-if’ analysis has been used to estimate the potential impact of HNIP on unlocking additional market capacity. The incremental additional deployment above the BEIS baseline (excluding financing costs) has been multiplied by a potential share of additional deployment unlocked by the HNIP. The results are shown in Table 17. Even if the HNIP unlocks only 5% additional deployment, the impact by 2025 is up to £0.3 billion and by 2050 is up to £13.2 billion.

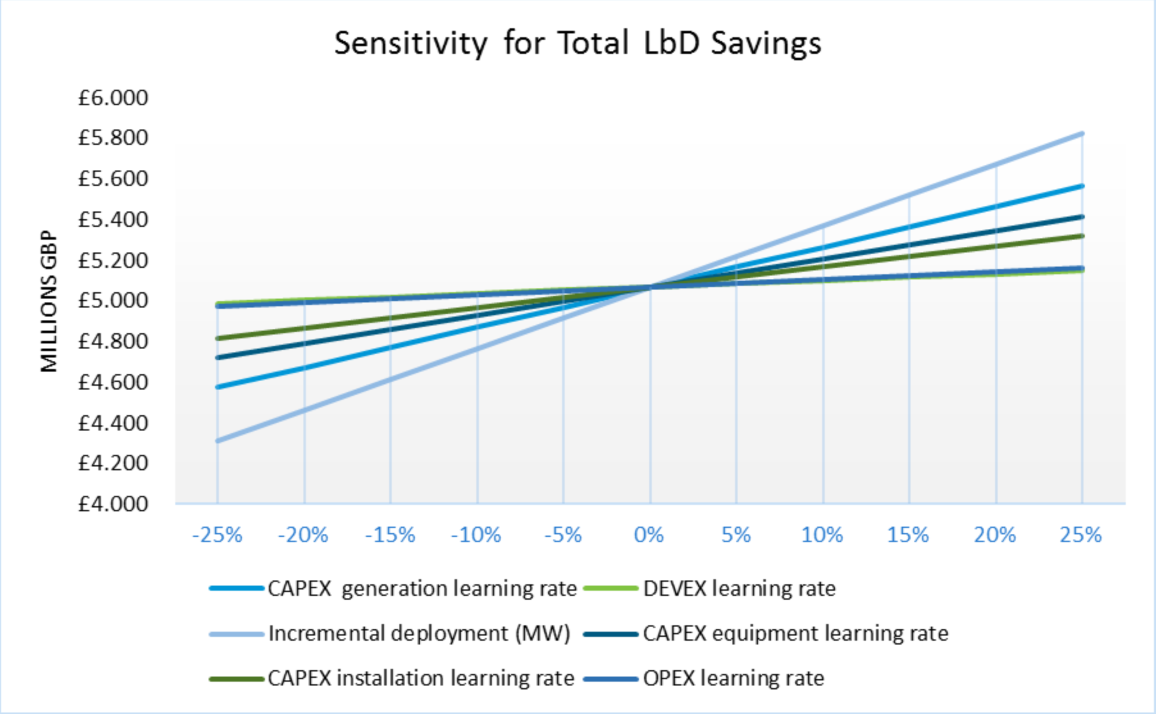
Table 17: What if analysis of the indirect impact of the HNIP in unlocking additional deployment to 2050

What-if analysis of indirect impact (deployment)	Additional deployment attributable to HNIP to 2025 (GBP million)	Additional deployment attributable to HNIP to 2050 (GBP million)
5%	290	2,220
10%	570	4,430
15%	860	6,650
20%	1,150	8,860
25%	1,440	11,080
30%	1,720	13,290

8.8 Sensitivity Analysis

The impact of deployment and learning rates on total learning-by-doing savings have differing impacts on the total learning-by-doing savings achieved up to 2050. An increase and decrease of 25% of the value of key independent variables and their impact on total learning-by-doing savings up to 2050 is illustrated in Figure 11. The key independent variables are CAPEX generation learning rate, development expense (DEVEX) learning rate, incremental deployment, CAPEX equipment learning rate, CAPEX installation learning rate, and OPEX learning rate. Learning rates are the rates at which costs reduce.

Figure 11: Sensitivity analysis of total-learning-by-doing cost savings to 2050



The variables with the largest deviation from a horizontal line are those which have the greatest impact on the learning-by-doing savings. Figure 11 illustrates that the learning-by-doing impact is the most sensitive to changes in incremental deployment, followed by the changes to the learning rates to the three variables on CAPEX; generation, other equipment and installation costs.

9 Conclusion

This study has examined the potential cost reduction impacts the HNIP may unlock for the deployment of district heat networks in the UK to 2025 and beyond. This report has identified four potential types of cost reduction impacts the HNIP may have on heat networks: one direct and three indirect. The direct impact analysis has used the TINA heat model and the representative heat network cost model to run various scenarios to assess the extent of cost reduction opportunities from the HNIP. The indirect impact analysis has been undertaken using a 'what-if' analysis and therefore results are less concrete than the direct impacts.

The direct impact arises from learning-by-doing cost reductions from the HNIP deployment and could measure up to a 4.4% cost reduction by 2025 and 7.2% by 2050. From Table 12, a breakdown of this cost reduction shows the largest cost savings by 2025 will come from design (9.5%), interface with heat user (6.9%), O&M (6.6%) and controls (5.8%). Additionally, cost reductions could sum up to £370m by 2050 though £320 million (86%) of these will be realised by 2025. These cost reduction percentages appear conservative relative to similar studies which have attempted to estimate potential cost savings from the heating networks market. One of the reasons for this is explained by the fact that our analysis is constrained by the top level cost saving assumptions from the Heat TINA model. Other reasons include the fact that most studies include both learning-by-doing and learning-by-research-and-development or other contextual factors particular to their geographical location. More comprehensive analysis is required to understand these differences.

The indirect impacts of the HNIP could be much larger than the direct impact, based on the analysis undertaken. Greater learning-by-doing cost reductions industry-wide from an accelerated heat network deployment pathway could sum to £620m by 2050.

The second indirect impact is that of a reduced cost of capital for future heat networks as HNIP deployment de-risks the market for the private sector, leading to a step-change in financing costs. In the modelling, this has an estimated impact of up to £800m by 2050 (depending on assumptions regarding the change of cost of capital and how much of this change can be attributed to the HNIP).

The third indirect impact relates to additional deployment (further to the networks directly supported). It is unlikely the HNIP could completely bridge the gap between the Heat TINA heat network deployment profile and BEIS's baseline heat network deployment assumptions. Other policy and regulatory initiatives and market changes will likely be needed to realise the full Heat TINA deployment profile. Nevertheless, additional deployment attributable to the HNIP could sum to £13,290m by 2050 (if the higher assumption of 30% additional deployment being attributable to the HNIP holds).

References

1. AECOM (2009). The Potential and Costs of UK District Heating Networks. A report to the Department of Energy and Climate Change
2. AECOM (2015). Assessment of the Costs, Performance and Characteristic of UK Heat Networks
3. AECOM (2016). Heat Infrastructure Development Project
4. AECOM, ETI (2017). Reducing the capital cost of district heat network infrastructure.
5. Bank for International Settlements Working Papers (2014). Understanding the challenges for infrastructure finance
6. BEIS (2016) Heat Networks Investment Project Consultation Government Response
7. Bush R. E., Bale C. S. E., Taylor P. G. (2016). Energy Policy, Realising local government visions for developing district heating: Experiences from a learning country
8. Carbon Trust (2017) Financial Aggregators for Distributed Generation Stage 1 Report, Using UK Heat Network Industry as a Pilot study
9. ChangeWorks and CSE (2017) Different Rules for Different Fuels: Exploring Consumer Protection in the District Heating Market
10. Danish Energy Regulatory Authority, District Heating Statistics 2013-2016.
11. Element Energy (2015). Research on district heating and local approaches to heat decarbonisation - A study for the Committee on Climate Change
12. Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR
13. Euroheat (2015). Country by country Statistics Overview
14. Hawkey, D., (2013) District Heat Policy Options in the UK: Workshop report, Edinburgh
15. HM Government. (2017) The Clean Growth Strategy
16. Hawkey, D., (2014). District Heating and Regulation in Scotland: Workshop report, Edinburgh
17. Heat Networks Demonstration Competition, Small Business Research Incentive
18. IRENA (2017) Renewable Energy in District Heating and Cooling
19. Low Carbon Innovation Co-ordination Group (2016). Heat Technology Needs Innovation Assessment (TINA) refresh. Accessed October 2017 http://www.lowcarboninnovation.co.uk/working_together/technology_focus_areas/heat/
20. Nordic Council of Ministers (2017) Nordic heating and cooling
21. Sven Werner (2017). Energy, International review of district heating and cooling
22. UK Energy Research Centre (2016). Best practice in heat decarbonisation policy
23. UKERC (2016) Technology and Policy Assessment, Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply
24. Webb J., Tingey M., and Hawkey D., (2013). Next Steps in Financing District Energy: Workshop report, Edinburgh

Annex

A1: Alternative interventions to incentivise uptake of heat networks

Throughout the development of this project, particularly through the interview sessions and the literature review, numerous insights were found relating to possible interventions to further drive deployment in the UK. Though this was not the focus of this project and this section is not meant to be exhaustive, we provide the main observations from our qualitative research which could drive deployment and help unlock further cost savings by learning-by-doing for UK heat networks. To be clear these are not recommendations for policy action but rather a record of observations.

Possible actions at a national level:

To unlock the potential investment opportunity within heat networks and to enable private stakeholders and local authorities to deliver these schemes effectively, national action will be required to address many of the barriers currently present in the market. National activity could focus on promoting the following:

- Strengthening costumer protection through regulation: a clear framework for price regulation and length of contracts[28].
- Dedicated heat zones within which various policies, including public body connections to district heating networks, planning policy to encourage the use of local heat sources, and the removal of incentives for competing heating technologies are all aligned[29].
- Providing alternative financing options (alternatives for disbursing scheme funding beyond grants, such as loans, equity investments or guarantees), this will enable funding to stretch further, and will allow other stakeholders to partner on subsidised projects[30].
- Increasing potential revenue streams (reduce unit price of heat): Carbon pricing, renewable/CHP heat incentives all increase the IRR of heat network projects, helping more schemes clear necessary hurdle rates for investment[31].
- Publication of HNIP-supported projects' details to greater disseminate information on the risks and costs for heat networks of all sizes to the wider market.

Possible actions at a regional level

Challenges in securing new customers to sign up to existing heat networks creates uncertainty regarding the viability of future networks. Even where local authorities can provide anchor-load heat demand developers still need a lot of private connections to foster the type of city-wide connections that maximise the efficiency of a potential network. Complementing national activity, regional-level activity led by cities or local authorities is also needed. Relevant activity could focus on promoting the following:

- Altering planning regulations/creating incentives to require or encourage developers to connect to existing district heating networks, this will guarantee clients in the future and de-risk projects. Currently new builds do not have an obligation to connect.
- Creating bespoke city-level procurement bodies for district heat[32].

---

[28] UKERC (2016) Technology and Policy Assessment, Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply

[29] Ibid

[30] Emden J, Aldridge J and Orme B (2017). Piping hot: The opportunity for heat networks in a new industrial strategy, IPPR.

[31] AECOM (2009). The Potential and Costs of UK District Heating Networks. A report to the Department of Energy and Climate Change

- Identifying gaps in the supply chain: local authorities will need to ensure that there is an appropriate supply chain of industry stakeholders in place[33].
- Allow district heating installers the same permissions to dig up roads as gas/electric installers, which will reduce installation costs associated with planning permissions and delays.

---

[32] ChangeWorks and CSE (2017) Different Rules for Different Fuels: Exploring Consumer Protection in the District Heating Market

[33] Ibid

A2: Interview Questions:

Introductions: Carbon Trust + Interviewee (5 minutes)

Description of project (5 mins):

We are working for the Department for Business, Energy and Industrial Strategy, on a project titled 'Estimating the cost-reduction impact of the Heat Network Investment Project on future heat networks'

We are trying to estimate the impact of the £320 million stimulus programme, the Heat Network Investment Project, on the overall UK heat network industry, particularly in terms of unlocking cost reductions on installation costs and equipment costs.

Main objective of this conversation is to is to verify assumptions around potential cost reductions, through to 2050, by having conversations with expert industry stakeholders

Insights from the interviews are going to be confidential. We will be transparent about the names of the experts interviewed, but we will not attribute particular findings to a single person or organisation

Main questions: Questions can have different emphasis depending on the background of the expert

1) Do you think there is potential for cost reductions in heat networks through to 2050?
2) What % reductions in overall cost do you see by 2025, and by 2050?
3) Present to interviewees cost reduction estimates (based on the 2016 Heat TINA and new data collected from the Danish Energy Agency) and allow them to comment on its accuracy
4) Present them our main cost reduction drivers (to be emailed beforehand) or value chain components, and ask them to rank them in terms of cost reduction opportunities. Regardless of the breakdown, conversation should focus on what is driving or causing the cost reduction.
5) Cost-reduction drivers: Innovation, Financing and contracting, Supply chain and competition, Infrastructure, Standardisation, Sites
6) Value chain components: Design, CAPEX Generation, CAPEX Equipment, CAPEX Installation, OPEX
7) If interviewees prefer, they may comment in terms of heat network value chain components (taken from the Heat TINA: Connection heat user; interface with heat user; controls; design; installation, operations and maintenance).
8) Ask for any data sources that interviewees have seen with this information. Any case studies.
9) What other levers are needed in order to increase the deployment of heat networks (i.e. regulation, policies, etc.) What will drive deployment faster
10) Do you think a project like HNIP (£320M) is going to have any impact on the quality of the heat networks that will be deployed?
11) Why do you think there has been little or no research publicized on cost reductions for heat networks? Why has there not been research from Swedish, Danish or British case studies?

A3: Generation costs for different technologies

Carbon Trust Model for the HNIP Cost Reduction project

The following tables show the investment costs per unit broken down by CAPEX and OPEX for the generation technologies assumed to be supported by the HNIP. These are used for the cost data in our modelling as the Heat TINA had assumed all heat generation came from energy from waste. All data taken from the Danish Energy Agency website, accessed 14th September 2017 https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger. All prices are in 2015 terms.

Natural gas CHP: Source: technology_data_for_energy_plants_-_aug_2016._update_june_2017

Technology	**06 Spark ignition engine, natural gas**									
	2015	**2020**	**2030**	**2050**	**Uncertainty (2020)**		**Uncertainty (2050)**		**Note**	**Ref**
Financial data					**Lower**	**Upper**	**Lower**	**Upper**		
Nominal investment (M€/MW)	1	0.95	0.9	0.85	0.9	1.1	0.8	1.1		3, 5, 11
- of which equipment	0.65	0.6	0.55	0.55	N.A	N.A	N.A	N.A	H	3, 5
- of which installation	0.35	0.35	0.35	0.3	N.A	N.A	N.A	N.A	H	3, 5
Fixed O&M (€/MW/year)	10000	9750	9300	8500	7000	20000	6000	15000	F	5
Variable O&M (€/MWh)	5.4	5.4	5.1	4.9	4	12	4	10	F	3, 5, 11

Waste to energy, district heating: Source: h_datablade_for_fjernvarmeproduktion_0

Technology	**Waste to energy, district heating**					
	2015	**2020**	**2030**	**2050**	**Note**	**Ref**
Financial data						
Specific investment (M€/MW)	1.2	1.1	1.1		B	1
Fixed O&M (€/MW/year)	54000	53000	53000		B	1
Variable O&M (€/MWh)	5.6	5.4	5.4		B	1
Regulation ability						
Minimum load (% of full load)	75	75	75			1

Wood pellet boiler: Source: h_datablade_for_fjernvarmeproduktion_0

Technology	**District heating boiler, wood-pellets**					
	2015	**2020**	**2030**	**2050**	**Note**	**Ref**
Financial data						
Nominal investment (M€ per MJ/s)	0.25 - 0.55	0.25 - 0.55	0.25 - 0.55			1
Total O&M (€/MWh)	2.7	2.7	2.7			1

Nominal investment (M€ per MJ/s)	0.4	0.4	0.4

Geothermal CHP: Source: h_datablade_for_fjernvarmeproduktion_0

Technology	**Geothermal heat-only plant with steam-driven absorption heat pump, Denmark**					
	2015	**2020**	**2030**	**2050**	**Note**	**Ref**
Financial data						
Specific investment (M€ per MJ/s geothermal heat)	1.8	1.8	1.8			1
O&M excl. electricity consumption (€/year per MJ/s geothermal heat)	47000	47000	47000			1

Gas Boiler: Source: technology_data_for_energy_plants_-_aug_2016._update_june_2017

Technology	**44 District heating boiler, natural gas fired**									
	2015	**2020**	**2030**	**2050**	**Uncertainty (2020)**		**Uncertainty (2050)**		**Note**	**Ref**
Financial data					**Lower**	**Upper**	**Lower**	**Upper**		
Nominal investment (M€ per MJ/s)	0.06	0.06	0.05	0.05	0.035	0.25	0.035	0.25	J	2, 3
- of which equipment	0.04	0.04	0.03	0.03	0.025	0.15	0.025	0.15		2, 3
- of which installation	0.02	0.02	0.02	0.02	0.01	0.1	0,01	0.1		2, 3
Fixed O&M (€/MJ/s/year)	2000	1950	1900	1700	1000	2500	1000	2500	F	
Variable O&M (€/MWh)	1.1	1.1	1.0	1.1	0.6	2.1	0.6	2.2		
- of which is electricity costs (€/MWh)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	L	
- of which is other O&M costs (€/MWh)	1.0	1.0	0.9	0.9	0.5	2.0	0.5	2.0		8, 9

Water source heat pumps: Source: technology_data_for_energy_plants_-_aug_2016._update_june_2017

Technology	**40 Absorption heat pumps - district heating**									
	2015	**2020**	**2030**	**2050**	**Uncertainty (2020)**		**Uncertainty (2050)**		**Note**	**Ref**
Energy/technical data					**Lower**	**Upper**	**Lower**	**Upper**		
Financial data										
Nominal investment (M€ per MW_{heat} excluding drive energy)	0.6	0.56	0.51	0.46	0.4	0.8	0.4	0.8	A	3
- of which equipment (%)	50	50	50	50	30	70	30	70		3
- of which installation (%)	50	50	50	50	30	70	30	70		3
Fixed O&M (€/MW_{heat}/year)	2000	2000	2000	2000	1000	3000	1000	3000		3
Variable O&M (€/MWh_{heat})	0.9	1.0	1.3	1.9	1.0	2.5	1.9	5.3		
- of which is electricity costs (€/MWh_{heat})	0.6	0.7	1.0	1.7	0.7	2.1	1.7	5.0	E	
- of which is other O&M costs (€/MWh_{heat})	0.30	0.28	0.25	0.23	0.30	0.40	0.20	0.30		3