THE POTENTIAL AND COSTS OF DISTRICT HEATING NETWORKS

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A report to the
Department of Energy and Climate Change

April 2009

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EXECUTIVE SUMMARY

Introduction

Heat for homes, businesses and industrial processes accounts for around 49% of total energy demand and 47% of carbon emissions. The majority of households and non-domestic buildings have their own heating systems, with gas the predominant fuel source. Less than 0.5% of heat is from renewable sources.

The UK has adopted challenging carbon reduction targets and committed to renewable energy targets that will require a significant change in the energy mix by 2020. Significant policies, most notably the Renewables Obligation, are already in place to encourage additional renewable generation. If the UK is to deliver on its climate change targets, then there will need to be a substantive change in the efficiency of heat consumption and the associated production mix.

District heating – where the heat is produced centrally and hot water is piped to the buildings – has the potential to contribute to the achievement of these targets. It can improve the efficiency of energy use (especially where heat production involves exploiting combined heat and power (CHP) or waste heat from existing power stations) and has the flexibility to accommodate heat from a variety of sources, including biomass.

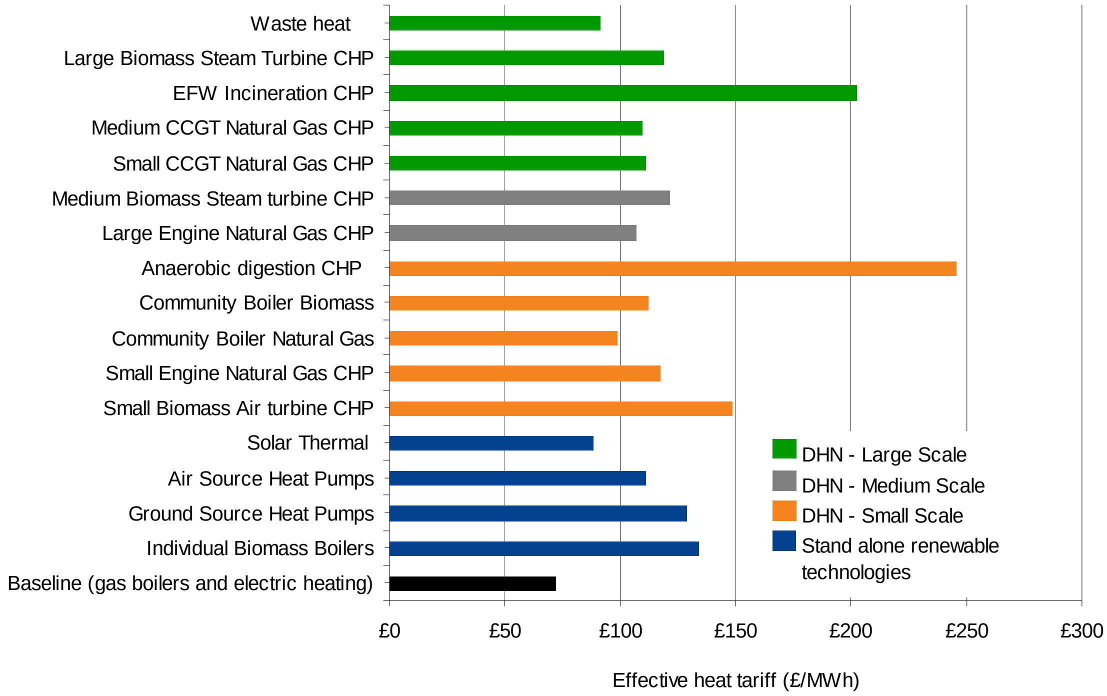
While district heating has been deployed in the UK since the 1950's, it has achieved only a low market penetration and currently provides less than 2% of UK heat demand. This is in stark contrast to the position in many other European countries; in Finland and Denmark, for example, district heating is the dominant heat source, accounting for 49% and 60% of total heat supply respectively. Even where district heating makes a lower overall contribution to heat supply, it is often a major source of heat in larger cities. For example, district heating is responsible for only 18% of total heat supply in Austria, but in Vienna it provides 36% of the city's heat supply, including over 270,000 domestic households and with plans to extend the system.

The aim of this study is to identify the potential costs and benefits of district heating, assess the technical potential in the UK and investigate the economic and non-economic barriers to further investment and deployment. The report is part of ongoing work by the Department of Energy and Climate Change (DECC) into the need for, and form of, policy options to support district heating schemes.

Comparative cost of district heating

The main explanation for the low penetration to date is the relatively high cost of providing heat through district heating in comparison with conventional gas or electric-based heating systems. This is illustrated in Figure 1 which compares the average cost of heat for a range of district heating options and stand-alone renewable heat technologies with gas and electric heating.

Figure 1 – Cost of heat provision by technology (current market conditions, £/MWh)



Notes: Waste heat is heat obtained at very low wholesale cost from power plants or industrial processes. Solar thermal heating applies to water-heating only.

The main driver of the higher cost of district heating is the network of hot water pipes. For example, under current cost assumptions, a heat network to supply 270,000 households (i.e. comparable with the Vienna scheme) would cost in the region of £1.5bn.

Nevertheless, there are some combinations of fuel sources and building types that can reduce the relative cost, for example, where the district heating scheme:

- uses waste heat from conveniently sited power stations, since the heat is essentially produced at a very low marginal cost;
- replaces electric heating systems; and
- supplies to commercial premises and high rise flats in high heat density areas.

Even in the current market and regulatory environment, we estimate that district heating could displace electric heating on economic grounds – but in only 70,000 dwellings and in some non-domestic buildings equating to 14% of the modelled commercial heat demand. Together, these add up to only 0.3% of national heat demand.

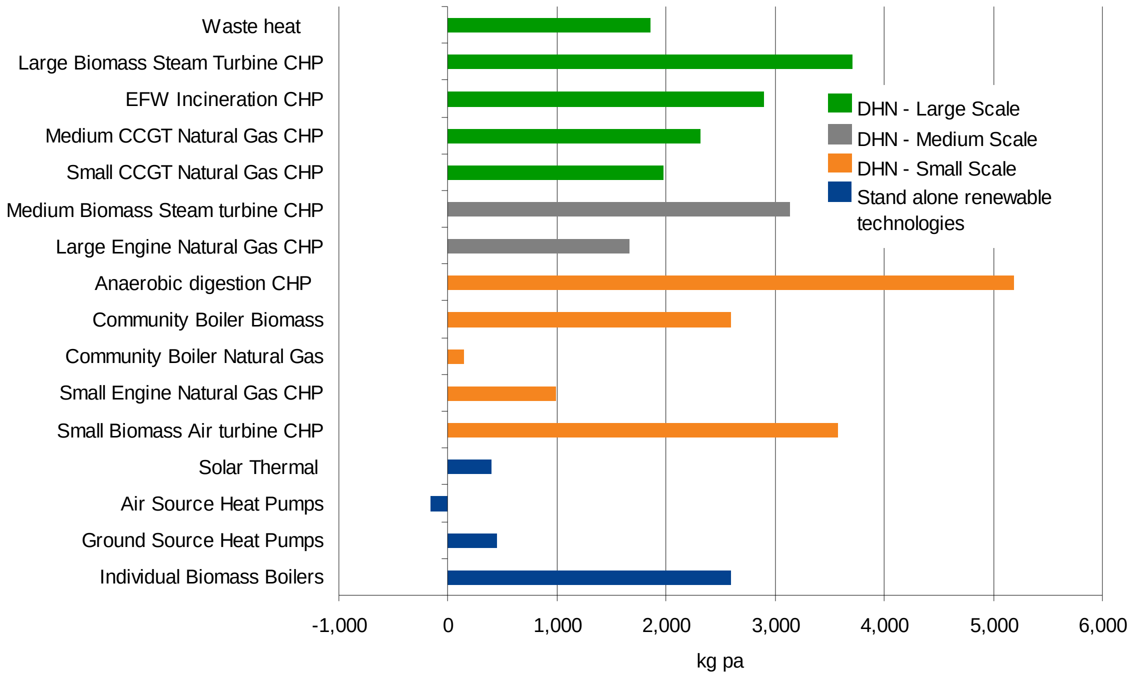
Unless there is a shift in the market or regulatory environment we conclude there will be no significant additional take-up of district heating for the existing building stock, particularly the domestic sector. Our conclusion applies irrespective of the source of heat for district heating, whether through gas boilers, low-carbon heat from gas-fired CHP or zero-carbon heat from biomass or waste.

This is not a problem that is exclusive to district heating. As Figure 1 shows, alternative sources of zero/low carbon heat (ground source heat pumps (GSHPs), air source heat pumps (ASHPs), solar thermal or individual biomass boilers) are also not currently commercial against conventional heating systems in built-up areas based on the assumptions used in this modelling.

Incorporating the value of carbon savings

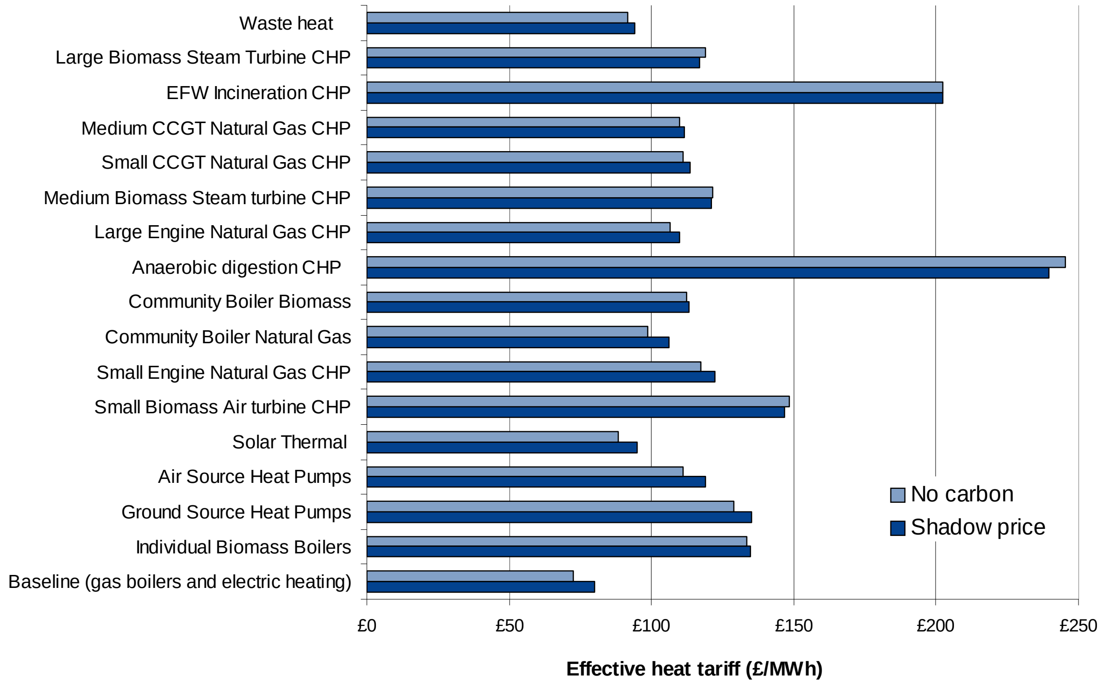
The main benefit of moving to district heating or renewable technologies is expected to be the carbon savings they can deliver. Figure 2 shows the potential annual savings achieved for a composite benchmark dwelling from each technology. For example, we calculate that a district heating network covering 250,000 households may save between 0.25 Mt CO_2 and 1.25 Mt CO_2 relative to conventional heating systems annually, dependent on the fuel used and the carbon intensity of centralised electricity production.

Figure 2 – Carbon savings compared to the composite benchmark dwelling



Under current policies, the benefit of these carbon savings is not fully rewarded, but even if they are fully valued at the government's shadow price of carbon the picture is virtually unchanged as illustrated in Figure 3.

Figure 3 – Impact of incorporating the shadow price of carbon

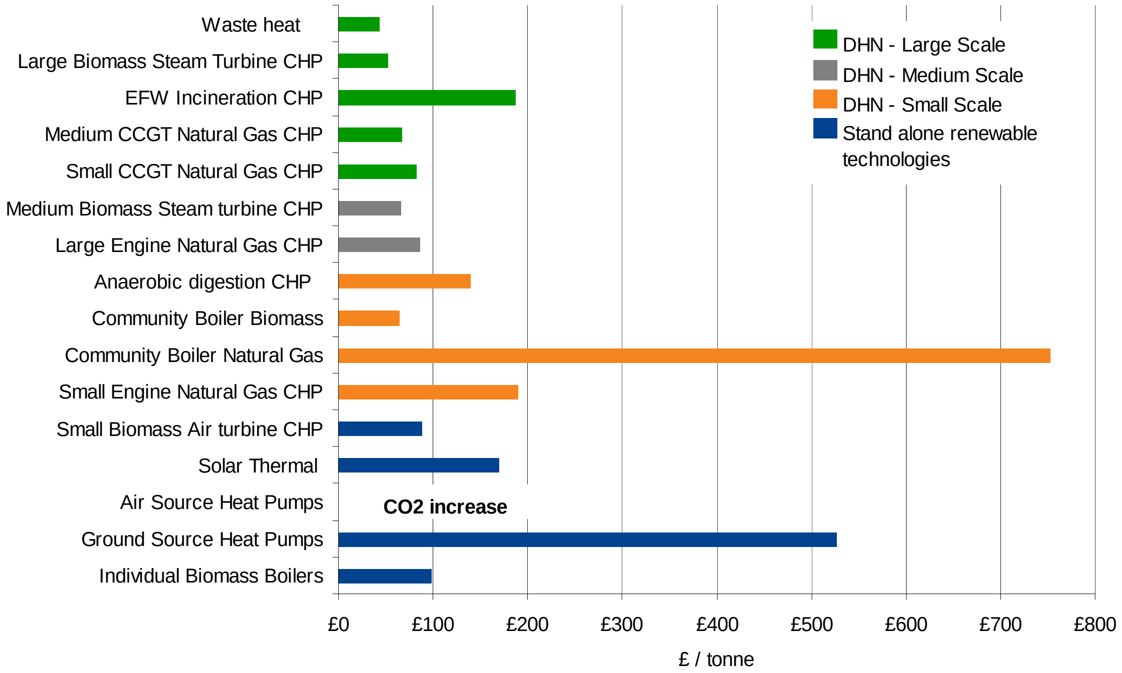


Comparison of district heating and renewable heat

Given the lack of commercial drivers, the question still arises as to whether it is more attractive to substitute conventional gas and electric heating either with district heating or with renewable heat technologies for conventional gas and electric heating.

Our analysis suggests that, where district heating networks can achieve a high penetration (in the region of 80%) in a built-up area, the carbon abatement costs of district heating options can be better than the most cost-effective stand-alone renewable technology, as shown in Figure 4.

Figure 4 – Implied carbon abatement cost (£/tCO_2)



Such carbon competitiveness may reduce if:

- DHNs are perceived to be riskier than other technologies – requiring a higher rate of return and a consequent higher heat tariff;
- penetration of the network is lower; or
- the carbon intensity of electricity provided from the national grid falls without a consequent increase in the price of electricity – which then may favour heat pumps.

Although the delivery of renewable energy targets is expected to reduce the average grid electricity carbon intensity in the future, our analysis shows that DHNs remain the preferred option for achieving carbon reduction in built-up areas unless electricity can be de-carbonised to a level below 0.15 kgCO_2/MWh (our analysis is based on 0.43 kgCO_2/MWh) and without raising its wholesale price above current levels (around £45/MWh).

This situation need not be an absolute choice between one technology or another. District heating options have the potential to exploit larger volumes of no/low-carbon heat in built-up areas where the stand-alone renewable options may be subject to restrictions on the availability of existing chimneys, roof space and ground, or on the combustion/processing of biomass and waste. Optimisation of the supply of no/low carbon heat to buildings might target the DHN options at the more densely built-up areas, with heat pumps and the limited resource of biomass utilised elsewhere.

Since our analysis suggests most district heating would be gas-based, at least in the short-term, stand alone renewable options are likely still to be needed to assist compliance with the 2020 renewable energy targets.

Barriers to DHN deployment

Investigation of the experience of DHNs in the UK and internationally has identified several barriers that adversely affect the commercial position of DHNs relative to conventional heating systems. These fall into three main areas:

- economic barriers;
- general institutional issues; and
- carbon price.

Economic barriers

The economic barriers to the deployment of DHNs result from the main characteristic of any DHN project – namely, the capital costs associated with the construction of plant, heat network and connections. This capital cost makes the cost of capital (or the required return) a core driver of the cost competitiveness of any scheme. Since the cost of capital reflects the risk of investing in the project, we can categorise the economic barriers as those that impact on project risk (actual or perceived) and project cost.

Project risk

We believe the main risk factors for developers and investors alike are:

- a perceived lack of experience and knowledge of district heating schemes in the UK;
- coordination problems associated with managing the simultaneous development of heat sources (or connections to existing sources), distribution networks and end-user connections;
- significant revenue variability because of a lack of understanding of tariffing options or the exposure to take-up risk if long-term contracts have not been agreed;
- concern over potential redundancy in the network in the longer-term if alternative technologies (e.g. heating from de-carbonised electricity) were to become more competitive;
- barriers to accessing risk and loan capital in view of the difficulty forecasting financial viability; and
- lack of familiarity with the concept of district heating amongst consumers and the public sector.

We also believe that developers/investors may perceive a lower risk for other technologies than DHNs, further widening the commercial gap.

Project costs

Some cost drivers are structural – for example, the mix of the housing stock in the UK increases the unit cost of building a network compared to, for example, Finland, where there is a higher proportion of flats and apartments, increasing the heat density and making the district heating network more cost effective.

However, there are several potential obstacles that are raising costs artificially. These include:

- lack of local expertise and an established supply chain – this may raise the cost of procurement (there is prima facie evidence that network development costs in the UK are higher than in markets with more established district heating systems). This reflects a lack of experience amongst civils contractors in the UK and hence a high risk premium being added to the cost;

- lack of standardisation in contract structures for district heating developers (though there is ongoing work in the industry to address this);
- competition against the sunk costs of existing networks;
- inability to access full revenues from CHP-based schemes because of the incentives in current distribution charging methodologies to pursue the 'private wires' approach;
- financing costs are raised as these factor in uncertainty over revenue risk; and
- significant additional marketing costs if sufficient volume commitments are to be achieved upfront.

Institutional issues

The example of those European countries which have successfully developed extensive DHNs strongly suggests that any drive to deploy low/no-carbon heat through district heating must be led by the public sector. Potential private sector investors in DHNs will be looking for underwriting of the identified project risks by the public sector and the natural public sector counterparties in urban areas are the local authorities that:

- wield relevant planning powers, including over new development; and
- own, or have close relationships with the owners of, the social housing and public buildings which are likely to form the core of developing schemes.

Our research has found that existing engagement by local authorities in the promotion of DHNs is variable for three main reasons:

- compared to education and health, energy is not a high priority for local authorities;
- the application or interpretation of building regulations and planning policies by local authorities (and developers) is not transparent or consistent; and
- local authorities are relatively inexperienced in this area.

These institutional issues reinforce the economic barriers identified above.

Carbon price

All low- or zero-carbon heat solutions are disadvantaged by the fact that the full cost of carbon (as given by the government's shadow price of carbon) is not reflected in the cost of conventional heating or electricity production. However, as already shown, the removal of this distortion would not materially alter the commercial position of DHNs or the stand-alone renewable alternatives.

Maximising national potential

The potential for district heating depends on the underlying policy and market environment – it can only displace existing heating if it can be made commercially competitive with the conventional heating systems. Our analysis has shown that the two main factors influencing the economic potential are:

- the upfront capital costs associated with installing a heat distribution network; and
- a high required rate of return (discount rate) by investors.

To a lesser extent, the current lack of full carbon cost reflectivity in heat costs also increases the differential with conventional gas and electric heating.

Using a community level model of national potential, we have assessed how the potential for district heating to displace conventional heating varies with these three factors. Our results are summarised in Table 2, in which we examine the potential against scenarios, defined in Table 1, that vary across the following dimensions:

- active policy regime – current policy environment or a 'pure' carbon pricing regime (where emissions are costed at the government's shadow price of carbon);
- technology discount rate – 10%, 6% or 3.5%;
- capital cost reduction – an assumed reduction in district heating network costs from current assumptions; and
- customer group – whether the district heating is offered to all consumers or targeted specifically at consumers with electric heating systems or in social housing.

Table 1 – Summary of scenario parameters

Scenario	Policy	Discount rate	CAPEX reduction	Customers
1	Current	10%	0	All
2	Current	10%	0	Electric heated
3	Current	6%	0	All
4	Current	6%	20%	All
5	Pure	6%	0	All
6	Pure	3.5%	0	Social housing
7	Pure	3.5%	0	All

Table 2 – Economic potential of district heating under alternative scenarios

Scenario	Connections		Share of UK heat demand (%)
	Domestic households (million)	Commercial space (million m2)	
1	-	-	-
2	0.07	11.4	0.3%
3	-	-	-
4	1.6	14.6	3.1%
5	0.3	11.4	0.6%
6	1.1 – 1.4	15.6 – 16.7	1.7 – 2.0%
7	3.3 – 7.9	15.6 – 26.3	5.8 – 13.9%

Our analysis suggests that the highest potential for displacing conventional heating by DHNs could be achieved if:

- district heating development is completely 'de-risked' (i.e. a societal discount rate of 3.5% applies); and
- the full shadow price of carbon is applied to the combustion of fossil fuels (in conventional gas heating as well as in electricity generation).

Results suggest that including the carbon price and applying the 'de-risked' cost of capital would increase the potential for DHNs to 3 – 8 million households and 15 – 26 million square metres of non-domestic floor space – together 6 – 14% of the nation's building heat demand.

For similar potential to be realised in the current policy environment substantial reductions in project discount rates and capital costs would be necessary. Our analysis suggests that a combination of a 6% discount rate and a 20% reduction in capital costs would increase district heating potential to an additional 3% of total UK heating demand. The 6% discount rate is comparable to historic returns from PFI schemes and regulated network businesses, and a 20% reduction in total CAPEX would be consistent with bringing installed heat mains costs down to continental European levels. Achieving 10% of UK heat demand would need radical cost efficiencies, in the order of 40% lower capital costs at a 6% discount rate, or 25% lower capital costs if discount rates could be lowered to 5%.

Overall we conclude that, in order to encourage greater deployment, a shift away from the current market and regulatory framework is needed.

Roll-out of DHNs in the UK

We now consider the pathways for developing DHNs in the UK. The case for developing district heating networks does not change significantly over time, and is fairly robust against differing scenarios of future fuel prices. In the longer–term, our analysis suggests that waste heat from power plants is the most economic heat source for district heating. This pre-supposes that the heat load is large enough and close enough to the power station for the transmission of waste heat not to be excessively expensive. This would, for example, be the case for a load of 200MW (equivalent to over 50,000 domestic customers) within 15km of the power station.

However, a more practical pathway towards larger scale DHNs is to start with smaller schemes on interim heat sources (e.g. gas-engine CHP) even though they are too small to connect to larger heat sources. We believe that there is no advantage in delaying any initiative to develop DHNs; indeed, rather the reverse. Initial development would naturally be focussed where DHNs are likely to be relatively more competitive against conventional heating systems – i.e. where:

- there is a relatively high heat load density – in particular, in city centres and the denser urban areas;
- waste heat from a power station is available close by;
- high rise flats and commercial buildings account for a high proportion of the mix of built forms; or
- a high proportion of the potential connections use electric heating.

In practical terms, it may be institutionally more effective to focus initially on social housing and public buildings.

Scenario analysis indicates that if project development is both de-risked and is subject to the shadow price of carbon, it could be economic to develop DHNs serving up to 1.4 million dwellings in social housing and up to 16.7 million square metres of floor-space in public buildings, or around 2% of total UK heat demand (see Table 2).

Potential solutions

Given the position that DHNs have relative to conventional heating technologies, we now turn to potential remedies. The main options appear to revolve around three elements:

- reducing the commercial risk of DHNs;
- reducing capital costs for DHN developers; and
- increasing the revenue streams for DHNs to compensate for higher costs.

Reduction of risk

Our focus on the reduction of risk is on creating an environment where the uptake risk is reduced. It therefore centres around measures to guarantee minimum (or anchor) loads for the development. Sensitivity analysis has shown that, where a guaranteed load of around 80% of the total network capacity can be secured up front through the provision of long-term contracts, etc, then this significantly reduces the risk of stranded assets from oversizing.

Guarantee of volume comes from creating the appropriate incentives on heat consumers to consider district heating as a viable option for their energy needs. In general, given the scale of a scheme, this will need to involve some coordination amongst potential users and is therefore best suited to the following three groups:

- new developments;
- local authorities/housing associations/public buildings; and
- large commercial buildings – though it should be noted here that this group of customers may currently have stronger incentives for developing low-risk stand-alone systems.

Whilst district heating will be best suited to these groups, the benefit will be greater still in areas with accessible waste heat, high demand and electrically heated dwellings.

Actions to consider here include:

- adjustments to planning and building regulations requiring developers of new buildings to consider DHNs along with other heating systems – the benefit of new buildings is that the DHN is not competing against an incumbent network with large sunk costs, but their problem is that heat load will be lower due to better underlying building efficiencies;
- requirements on local authority and government organisations to consider DHN – this may include an obligation or mandating; and
- full mandating of connection in designated district heating zones, along the lines of the policy pursued in Denmark.

An additional element that reduces the risk would be to alter the terms of payment to DHN providers. This may be achieved through guaranteed availability payments for network providers – similar to those provided for in PFI contracts.

Increasing local authority responsibility

We have already highlighted that successful schemes across Europe have generally had a strong public sector involvement and that, in the UK, this responsibility would most naturally sit with local authorities.

Of course local authorities will need to form relationships with other public bodies, with developers, with contractors and so on. Special-purpose vehicles might be established to implement schemes, depending on local circumstances. However, the ultimate drive for the development of district heating in their areas should lie with the local authorities.

Our analyses have shown, however, that we would not see an increase in deployment without decisive action from central government, in two areas:

- setting the policy framework within which the local authorities will operate;
- imposing the appropriate duties on, and providing the appropriate powers to, local authorities; and
- providing assistance and guidance to local authorities on matters such as identifying heat demand, planning for district heating development, organisational options for that development, appropriate commercial arrangements, and technical quality control.

This suggests the creation of a body within central government, or closely associated with it, to provide these services and act as a 'champion' for DHN development.

Reducing capital costs

To mitigate the high capital costs, we suggest the following possible policy responses:

- provision of capital grants or subsidies to potential developers – this may be achieved through deeming of potential revenues achievable through a renewable heat incentive as well as via specific capital grants; and
- availability of low cost borrowing facilities for the provision of the heat mains.

To the extent that capital costs are temporarily high and may fall to continental European levels over time, any capital grant scheme could be limited to support a small number of specific starter schemes, designed both to illustrate the feasibility of installing a major heat network, and to provide the catalyst for the cost reductions and development of a local supply chain.

Increasing potential revenue streams

The focus here is initially on the effective unit price of the heat (and power for CHP) provided by the developer. We deal with the variability in that revenue separately. Options here are generally not DHN specific, but include:

- comprehensive carbon pricing framework either through expansion of the existing regime or through carbon taxes;
- renewable heat incentives;
- CHP incentives or obligations; and
- revision to distribution charging arrangements that will enable CHP-based schemes to achieve the full value of their electricity output.

Unintended consequences of further district heating development

Further expansion of district heating will also raise other potential issues around cross-subsidies and consumer protection.

The modelling analysis chooses the least cost heat supply option given the assumed policy environment. However, since the costs of heating differ by technology, location and building type, the average required tariff will not necessarily ensure all customers are better off than with the conventional alternative. For example, research has shown that, in Denmark, around 8% of district heating customers are paying more than they would have if they had been supplied through an individual gas boiler and 2% are paying more than the comparable cost of oil-based heating.

To minimise this eventuality, some tariff differentiation may be required or an alternative form of compensation (perhaps through variable connection cost grants) may need to be considered.

If schemes are small, this differentiation may be straightforwardly captured in agreed contractual terms, but as schemes grow, then the number of customer types to be considered may also grow and a more formal regime may be required. Indeed, a more formal regime may be required irrespective of this issue, since the network provider becomes an effective monopoly heat supplier to the customer. An appropriate form of regulation may be to allow tariff changes relative to an index of alternative fuel costs, thereby maintaining the inter-fuel, or inter-technology, competition through which the district heating network was first chosen.

Summary and conclusions

District heating currently contributes only 2% to the UK's heat supply and our analysis suggests that this situation is unlikely to change materially under current market and policy arrangements.

High potential under correct circumstances

However, under appropriate conditions, district heating could feasibly provide up to 14% of the UK's building heat demand. To achieve this, the main economic barriers facing new projects – high risk and upfront capital costs – would have to be addressed.

Need to lower risk and capital cost

We believe, and international experience has shown, that the role of the public sector (and local authorities in particular) is crucial in enabling developers to construct low-risk district heating business models. Local authorities have the relevant planning powers and the ability to coordinate between developers and potential consumers given their network of relationships with controllers of large heat loads (e.g. social housing groups, NHS Trusts and public buildings).

Further initiatives from central government are needed to incentivise more active engagement across local authorities:

- establishing a clear policy framework within which the local authorities will operate;
- imposing the appropriate duties on, and providing the appropriate powers to, local authorities; and
- providing assistance and guidance to local authorities on district heating feasibility.

Such a role could be the responsibility of a body within central government, or closely associated with it, to act as a 'champion' for DHN development.

This framework would need to be supplemented in the medium-term by further measures to facilitate the development of a robust local supply chain for district heating network development. Comparison of UK and European costs has highlighted that estimated UK civils costs are more than double those in European countries with more established district heating businesses. Much of this difference has been attributed to lack of experience in laying district heating mains and hence high risk premia being applied by contractors.

To the extent that this is due to immaturity in the supply chain, a limited capital grants scheme, to support a small number of specific starter schemes, may be appropriate both to illustrate the feasibility of installing a major heat network, and to provide the catalyst for the cost reductions and development of a local supply chain.

Comparison with stand-alone renewable technologies

A further insight of the analysis is that even if zero/low-carbon technologies were to be fully rewarded for the carbon emission savings they offer relative to conventional systems they remain more costly. However, the study has shown that in built up areas, zero/low-carbon options involving DHNs are likely to offer lower carbon abatement costs than the other low carbon technologies, especially if they are able to access large heat loads enabling them to utilise low cost waste heat from large-scale power stations.

In consequence, should Government decide to intervene to support the development of stand-alone renewable heat in built-up areas, it would be inconsistent not to do so for the district heating options. A further implication of this is that stand-alone renewable heat technologies may be best suited for off gas-grid locations and areas of less-dense housing, where the heat mains costs start to rise substantially.

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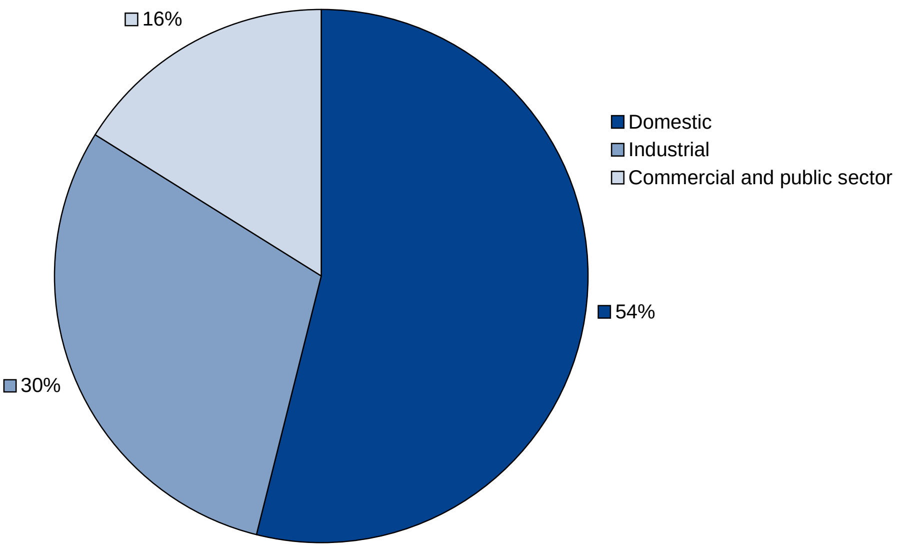
1. INTRODUCTION

1.1 Overview

Heat for homes, businesses, and industrial processes accounts for around 49% of total energy demand and over 40% of UK carbon emissions. Of a total UK demand for heat in the order of 900TWh, 70% is estimated to be used in dwellings and commercial and public buildings, with 30% used for industrial processes, as illustrated in Figure 5.

Figure 5 – Heat demand by sector, 2006

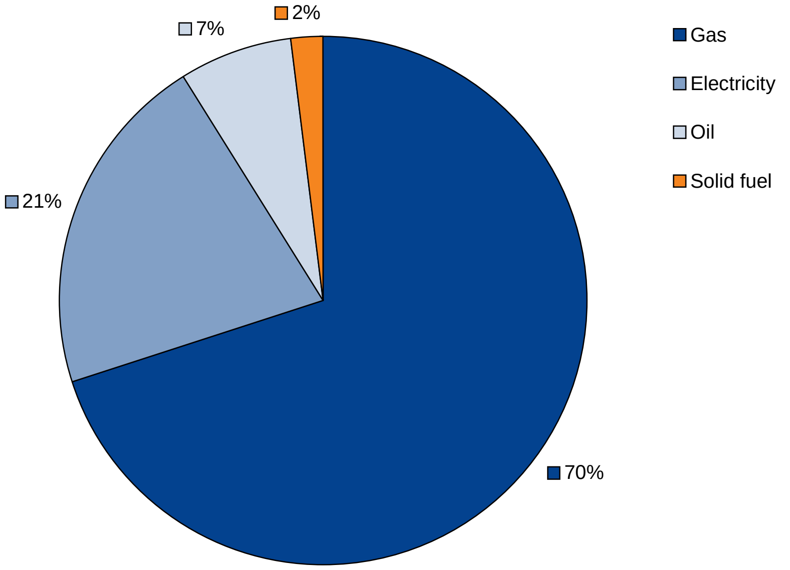


Source: BERR Energy trends 2007

As noted in the Renewable Energy Strategy, published in June 2008, the energy sources used for heating are carbon-intensive. Figure 6 shows that 70% of our heat demand is met by natural gas, the majority of the remainder being from oil and electricity[1]. Only 0.5% of heat is generated from renewable sources.

1 Electricity is itself still relatively carbon-intensive given the UK generation mix.

Figure 6 – Heat production by fuel source, 2006



Source: BERR Energy Trends 2007

The UK has adopted challenging carbon reduction and renewable energy targets for the medium- and long-term:

- 15% of final energy demand is to come from renewable sources by 2020, the UK's contribution to the European Union's 20% renewable energy target; and
- carbon emission reductions of up to 36% by 2020 and 80% by 2050, have been proposed by the Committee on Climate Change.

If the UK is to deliver on its climate change targets, then there will need to be a substantive change in the efficiency of heat consumption and the associated production mix – that is, we will need to find ways of reducing heat demand and decarbonising heat supply.

1.2 A role for district heating?

District heating – where the heat is produced centrally for an area and hot water is piped to the buildings – has the potential to contribute to the achievement of these targets. It can improve the efficiency of energy use (especially where heat production involves exploiting combined heat and power or waste heat from existing power stations) and, since it can accommodate heat from a variety of sources, can facilitate the development of biomass heat production to a larger market over time.

While district heating has been deployed in the UK since the 1950's[2], it has achieved only a low penetration. Though there are small schemes in cities such as Sheffield, Nottingham and London, district heating currently provides less than 2% of UK heat

2 The Pimlico scheme was built in the 1950s and used heat from Battersea power station to supply the new flats being constructed on the other side of the river. It is still in operation today.

demand. This is in stark contrast to the position in many other European countries. In Finland and Denmark, for example, district heating is the dominant heat source, accounting for 49% and 60% of total heat supply respectively. Even where district heating at a national level is less prevalent it is often a major source of heat in larger cities. For example, district heating is responsible for only 18% of total heat supply in Austria, but in Vienna it provides 36% of the city's heat supply, including around 270,000 domestic households with plans to extend coverage.

One explanation for the differences between Europe and the UK was the response to the oil price shocks of the 1970's. While the UK had a supply of relatively cheap indigenous North Sea gas, many European countries had no such supplies and so had no option but to look at increased energy efficiency measures such as district heating.

Over the last ten years, there have been several studies into the potential for district heating as a commercially viable replacement to conventional gas and electric heating in the existing domestic housing stock. Table 3 provides a summary of the conclusions from these reports, all of which indicate that district heating may be a cost-effective (or carbon-effective) heat solution for between 4m and 6m households. However, these conclusions are highly dependent on the return an investor may require from a scheme – they appear to show that district heating schemes can readily provide an internal rate of return of at least 6% real pre-tax, but very few were able to deliver 9% or more.

Table 3 – Summary of previous district heating potential studies

Source	TWh heat at >6% IRR	Nos of dwellings at >6% IRR	TWh heat at >9% IRR
DETR (1998-2002)	114	5.5m	19.4
Defra Oct 2007	150	6.5m	0.63
Environmental Change Institute		4.4m existing	

Source: Pöyry Energy Consulting and Faber Maunsell

1.3 Aim of the study

The dynamic nature of energy markets and policy-making mean that these assessments of potential may not be applicable given current policies. Furthermore, these studies focussed on the domestic sector, whereas the current development model for district heating networks is to focus initially on connecting larger commercial loads, new commercial and residential developments and then to extend the network into the existing domestic sector.

The aim of this study is to provide a more up to date view on the economic and technical potential for district heating in the UK's existing building stock, focussing on domestic, commercial and public sector buildings. The first stage of this is to identify the potential costs and benefits of district heating in isolation and in comparison with alternative technology options. The second stage is to investigate the economic and non-economic barriers to further investment and deployment. The third and final stage is to consider how alternative policy responses may address these barriers and increase the economic potential for district heating.

The quantitative analysis considers both the costs for an individual dwelling and those for a wider tranche of the community (reflecting different mixes of domestic and commercial built forms). As such, it can provide comparative cost assessments across technologies and simulate district heating take-up at a national level, as a commercial decision to invest in district heating schemes as opposed to other technologies.

This study is part of ongoing work by the Department of Energy and Climate Change (DECC) into the need for, and form of, policy options to support district heating schemes.

1.4 Structure of report

The report is structured as follows:

- chapter 2 outlines the technical and cost characteristics of alternative heating technologies, including individual gas or electric boilers, various district heating options and a range of renewable heat technologies;
- chapter 3 presents comparisons of the costs of using different heat technologies and the carbon savings that may be afforded through introducing district heating or renewable heat technologies;
- chapter 4 provides an overview of the main barriers to district heating deployment and the risks facing a potential private sector investor;
- chapter 5 quantifies the economic potential for district heating if these barriers can be removed within a simulation model of the national take-up of district heating systems;
- chapter 6 investigates potential policy responses to mitigate the barriers to enhanced economic potential of district heating; and
- chapter 7 summarises and presents some emerging conclusions.

More detailed information, background assumptions and summary results are contained in a series of annexes.

2. POTENTIAL HEAT TECHNOLOGIES – OVERVIEW OF CHARACTERISTICS

District heating is one of several heat technologies that may provide heat to domestic and commercial buildings. Any assessment of the potential for district heating must therefore consider the economic and environmental costs and benefits of district heating against these other technologies. This chapter first describes the principles of District Heating as a technology and then defines the range of options available for heating buildings that have been included in this study.[3]

These options are:

- individual gas and electric heating systems – since these technologies are used in the vast majority of domestic and commercial buildings, they are taken to be the baseline technologies against which both district heating and renewable technologies are assessed;
- the District Heating technologies – these are differentiated by fuel type, scale (small-scale, medium-scale and large-scale), and whether they produce only heat or heat and power; and
- alternative low carbon technologies – other options based on individual heating systems, including individual biomass boilers, ground and air source heat pumps and solar thermal water heating.

Since subsequent analysis will consider the development of these technologies over a period of time, the chapter concludes with a discussion on possible future trends in costs and performance of systems.

2.1 Principles of District Heating

Conventional heating systems in buildings rely on the provision of fuel to the building and the combustion of this fuel in the building to produce heat. In the UK, the main fuel is natural gas, with oil often used in households that are not connected to the gas grid[4]. By contrast, District Heating (DH) is a system where the heat is produced centrally for an area and hot water is piped to the buildings.

The concept is not new – the Pimlico scheme was built in the 1950s and used heat from Battersea power station to supply the new flats being constructed on the other side of the river. This scheme is still in operation today. Many schemes were built in the 1960s and 1970s. The justification then was an economic one – the central plant could use lower cost fuel such as coal or heavy fuel oil which could not be used conveniently if at all in individual dwellings especially in blocks of flats. The alternative was to use electric heating which has since proved expensive to run.

Elsewhere in Europe the justification for DHNs was the need to reduce imports of energy by improving energy efficiency, especially after the oil price rises in the 1970s. We are

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3 More detailed cost and operational assumptions for each technology can be found in 0.

4 There are around 5 million homes that are not connected to the gas grid. In the main analysis it is assumed that these homes would not be feasible to connect to a district heating network (due to prohibitively high costs) and therefore this portion of the UK building stock is not considered in the main analysis.

now in the position where both climate change and a desire to reduce energy imports especially of natural gas are major drivers for DHNs.

Many DH schemes were removed in the 1980s and 1990s but there has been a resurgence of interest as DHNs allow the production of low carbon heat through the use of Combined Heat and Power (CHP) or biomass boilers. Smaller-scale CHP units are typically reciprocating gas-engines of a scale of 100kWe to 5MWe which generate both electricity and heat. This system is much more efficient than the production of heat and power separately in boilers and central power stations with a potential for a 30% reduction in fuel utilisation. Larger CHP plant using Combined Cycle Gas Turbine technology up to power station scale can also be used to supply large DHNs. For example, a 200MWth plant would be able to supply heat to over 50,000 domestic consumers. The use of low carbon fuels such as biomass either for boilers or CHP will also enable significant CO_2 reductions.

The DHNs can be of widely varying scale and some cities have built up very large networks such as in Copenhagen, Helsinki and Berlin. In these cities heat is supplied from major power stations and waste to energy plants and the heat is transported over many km. The Copenhagen scheme extends 40km across the city.

The reason that DHNs can be cost-effective is that heat can be produced centrally at lower cost than in individual boilers using conventional fuels. The cost of heat at a CHP plant is low as the heat can be seen as ‘waste heat’ that would otherwise be dissipated to atmosphere. The cost of fuels supplied to individual dwellings is determined by both the fuel production cost and the distribution cost of this fuel. If the difference between heat production cost and heat selling price is high enough the DHN capital cost can be recovered over time. Operation and maintenance costs can also be in favour of the DHNs but this is normally a secondary benefit.

The heat distribution network normally consist of a pair of pipes, one carrying the flow water at temperatures of 90ºC to 120ºC and one the return water after the heat has been extracted at temperatures of 40ºC to 70ºC. The heat is transferred to conventional heating systems within the buildings either directly or indirectly through a heat exchanger which provides a separation of the two water based systems. These heat exchanger substations may be at an individual dwelling level or a block or street level or an area level. The heating system within the building is no different to other heating systems such as gas-fired boilers with the same level of control available. Heat can be metered as for other energy supplies although the heat meters are more expensive. The pipe systems developed for this market typically comprise an inner carrier pipe of steel, cross-linked polyethylene or polybutylene, an insulation of polyurethane foam or foamed polyethylene and an outer casing of high density polyethylene. These pipes are produced as a factory assembled pre-insulated pipe system and are covered by CEN standards. The pipes are buried in the ground and surrounded with a sand protection layer which avoids the need for concrete ducts thus reducing costs. The cost of the DHN comprises the ‘mechanical work’ – the supply of the pipes, the connection of the pipe lengths, the forming of branches and the installation of valves and the ‘civils work’ for the excavation of trenches, the backfilling and the resurfacing. Typically the mechanical and civils costs are of a similar magnitude.

2.2 Conventional baseline technologies

As we are comparing costs of a number of technologies the baseline needs to be established. We have assumed that this will consist of the current heating system together with the expected upgrade of the fabric of the property and the heating system that might occur over the period of the analysis.

For example, gas-fired boilers will be replaced with more efficient condensing boilers, insulation levels may improve in lofts and cavity walls encouraged by the CERT programme and it is important to take account of these trends in calculating the potential benefit of DHNs. We have assumed that the current mix of gas, electric, oil, LPG and coal heating will remain. Often there is a significant cost barrier for conversion to other fuels and most of the electric and oil heating is in off gas grid areas or, in the case of electric heating, in high rise blocks where gas has not been installed for safety reasons.

2.3 DHNs and associated heat production technologies

2.3.1 Building improvements

It is envisaged that as part of the DHN installation the building will be thermally upgraded to a level which produces the lowest life cycle cost. There are advantages in the design of the DHN if such an upgrade is introduced before the network is sized and constructed. In addition, it is likely that the DH company would be able to finance the insulation improvements as part of the DH connection package thus removing one of the barriers to the uptake of insulation measures.

2.3.2 Heating systems

Most housing is heated by gas-fired boilers supplying a wet radiator system and hot water storage cylinder although there are some warm-air systems. Either can be converted to district heating relatively easily. The issues to consider are the operating temperatures and pressures and whether a hydraulic separation between the dwelling heating system and the DHN is necessary. For this analysis we have assumed that the radiator circuit will be retained but separated from the DHN by a plate heat exchanger. A new secondary pump will be installed with control valves and heat meter on the primary side of the heat exchanger. This equipment will be pre-assembled as a packaged unit, termed a hydraulic interface unit (HIU). This is the worst case scenario and in some cases, particularly blocks of flats, a direct connection would lead to cost savings. We have also assumed that the HIU will contain a heat exchanger to produce instantaneous hot water in a similar manner to the combination type boiler. This has the advantage of producing lower primary return temperatures than can be achieved with a hot water cylinder. In some cases, retention of the hot water cylinder may be preferred and this would lead to lower costs than assumed in the economic model.

2.3.3 District heating network

A district heating network can be typically divided into three elements:

- **Local networks** consisting of heat mains in each street, probably buried beneath the road surface in most streets together with connecting pipes into each building;
- **District networks** which link the supply points of the local mains and which may also serve larger buildings only; and
- **Transmission networks** which link the district networks to a more remote energy source and frequently operate at higher pressures and temperatures.

These networks can conveniently be linked to three different scales of Combined Heat and Power plants which are likely to be the most frequently available source of low carbon heat (see below).

The costs of the local networks have been estimated based on developing designs for typical street layouts with blocks of flats, terraced houses and semi-detached houses.

The district network costs have been developed using a more generic model which links point loads together with the spacing of the point loads related to typical heat densities. The transmission main has been sized and costed assuming a heat demand capacity of 200MW and a distance from a remote source assumed to be 15km.

We have assumed in the analysis that the heat load will grow over time. The costs have therefore been split into two parts:

- the network capital cost which will have to be installed in a given area at the start of the development; and
- the connection cost for the local heat main and the HIU which would only be installed when the customer connects.

There are some possible design variations that could lead to significantly lower costs, e.g. installing pipes through roof spaces of terraces to avoid road excavation, installing the local mains through the back gardens, supplying a pair of semi-detached houses through a shared connection. All of these result in one property being supplied by a utility service passing through another. In order to allow for rights of access for maintenance and to prevent one person being able to cut-off the supply to a neighbour there would have to be legal covenants or wayleaves put in place. For the analysis we have assumed that roof mains are not feasible but that a shared connection for a pair of semi-detached houses would be allowable.

2.3.4 Heat production plants

Although there is clearly a continuum of possible scheme sizes, we have assumed three broad types of system represented by scaling factors of 5 to 10 between each. Schemes of intermediate size could be found by interpolation but there are significant break points in the type of heat production technologies that are cost effective at the different scales.

At the smallest scale, the local networks would be supplied from gas engines of 500kWe to 1MWe scale, supplying 500 to 3,000 dwellings typically (or similar scale of commercial buildings). This size is typically at the limit of pre-assembled CHP packages. Multiple units would be used to suit the scale of the scheme. Small-scale biomass CHP plants using the combustion/air-turbine, gasification or combustion/organic rankine cycle technologies could feature with this size scheme. A further option is the use of anaerobic digestion of waste to generate a biogas which can then be used as a fuel for a small gas-engine CHP system.

At a medium scale, both the district network and the local networks would be needed so that much larger gas engines of the order of 3 – 5MWe can be used and with multiple units supplying perhaps 3,000 to 15,000 dwellings. This would also be the scale where energy from waste plant and large-scale biomass CHP could supply the scheme, with a heat supply from such plants of around 10 – 30MW.

At a larger scale the transmission network would also be required to take heat from either Combined Cycle Gas Turbine (CCGT) CHP plants up to the scale of a conventional power station or very large waste to energy or biomass plants. The heat supply would probably be of the order of 60MW up to 200 MW or more.

Biomass boilers

Biomass could be used in boilers to supply heat to the DHN as an alternative to the CHP options discussed above. This is generally less effective in terms of CO_2 saving per unit of biomass than a biomass CHP plant but the option has been included for comparison purposes. This option is most likely to apply to smaller schemes where biomass CHP is more expensive and less proven.

Peak and standby boilers

In addition to the CHP plant there is a need for the provision of standby boilers to operate when the CHP plant is being maintained or if there is a fault on the heat network. On the smaller schemes these would be located with the CHP plant at the supply point of the local network. On larger schemes, the optimum location would again be at the supply point of the local network as this maintains a high level of security of supply in the event of network faults and reduces the heat supply capacity of the district network which can be sized only to deliver the CHP heat output.

Other equipment

Other equipment includes the DHN pumps, thermal store, controls for the system and electrical interface for the CHP plant.

The **Operating Costs** can be broken down into the following components:

- dwelling heating system and hydraulic interface unit maintenance – this is generally less than for an individual boiler system;
- heat meter reading, billing and debt collection, which would be a similar cost to other individual heating systems;
- DHN maintenance, mainly monitoring and inspections as the system should require minimal maintenance apart from water treatment;
- operating staff at the CHP plant;
- routine and abnormal maintenance of the CHP plant;
- fuel costs for the CHP or biomass boiler plant;
- fuel costs for the peak and standby boilers;
- electricity for pumping;
- electricity revenues from CHP generation; and
- other administration and business costs including insurances.

0 contains details of the cost and efficiency assumptions used in the analysis for each district heating technology.

2.4 Low and zero carbon counterfactual technologies for dwellings

For comparison with the DHNs the following alternative low carbon heat technologies have been analysed:

2.4.1 Solar thermal systems

These typically meet around 60% of the annual heating demand for domestic hot water. The solar panels need to be suitably oriented ideally on an unshaded south facing roof which will limit the numbers of properties that could be supplied in this way in a given area. They will be less suitable for blocks of flats where there is typically limited roof area and the cost of connecting the panels to each dwelling or the provision of a new centralised hot water system would be high. Solar thermal systems will reduce the amount of fuel or electricity used for hot water heating and have limited maintenance so there is an operating cost saving.

2.4.2 Ground source heat pumps

These systems extract heat from the ground via either horizontal coils or vertical pipes and use electrical energy to raise the temperature of the heat to a useful level. They only have a high efficiency where the heat is supplied at relatively low temperature e.g. with underfloor heating. This means that conversion costs can be high when converting from higher temperature radiator systems. The domestic hot water is not normally supplied from these systems. There needs to be sufficient ground available if horizontal pipes are used.

Although the amount of electrical energy required for the heat pump will typically be less than a third of the energy for a gas boiler, the costs of electricity is typically three times that of gas so there are unlikely to be significant operating cost savings when compared to gas boilers. For areas off the gas grid however there could be a saving if the alternative heating system is direct electric heating. There needs to be sufficient ground area available if horizontal coil collectors are used and so this type of system is not normally suitable for blocks of flats.

2.4.3 Air source heat pumps

These operate similarly to ground source heat pumps, but extract heat from the air rather than the ground. They either heat the internal air directly or via a water based radiator circuit. The time when most heat is needed is when the external air temperature is lowest but the low external air temperatures mean that the efficiency of the unit is also reduced at these times. These systems would not normally provide heat for the domestic hot water system. Operating cost savings are also small except in off gas grid locations where the incumbent fuels are more expensive.

2.4.4 Biomass boilers

Domestic scale biomass boilers using wood pellets are now available which could replace or supplement a fossil fuel boiler or electric heating system. These boilers are fully automated, however there would still be a need for some operation by the occupier to arrange fuel deliveries and ash collection. In urban areas there would be concerns over air quality. Both space heating and hot water demand could be supplied. At present biomass wood pellets are more expensive than natural gas and the boiler system is a relatively high cost. It may not be suitable for blocks of flats due to the difficulties of fuel storage and delivery.

2.4.5 Micro-CHP systems and fuel cells

These systems are designed for individual dwellings and have the advantage of obtaining the benefits of CHP without the cost of the heat network. At present however the Stirling engine type is relatively inefficient compared to larger CHP units and the CO_2 savings are therefore smaller. They are also not fully commercially available; the Carbon Trust have been sponsoring field trials. A more efficient unit for the future would be based on a fuel cell and it is expected that such products will be available in the market in the next few years. Due to the limited availability and lack of firm operating data and costs, micro-CHP systems have not been included in the analysis. Larger fuel cells can also be used with DHNs but again are not commercially proven at present and so have not been included in the comparisons.

0 contains details of the cost and efficiency assumptions used in the model for each alternative low-carbon technology.

2.5 Future Trends in Costs and Performance

One of the benefits in the use of gas-fired CHP and District Heating is that the technology is well-established and technically proven. As a result we would not expect major changes into the future with respect to costs or performance. However, there are a few areas where large-scale implementation of CHP and DHNs could lead to important changes which are discussed below.

2.5.1 Cost of District Heating Networks

Although the DHN technology is well established in Europe and there are large-scale manufacturing plants producing pre-insulated pipes we have identified a significant cost difference between the UK and continental markets. This appears to be related to the relatively high costs in the UK for excavating trenches, backfilling and reinstatement of road surfaces. The main reasons appears to be lack of experience in the UK with the technology, the need for relatively wide and deep trenches compared to other services and the pricing in of constructions risks which may be over estimated. It is also thought that traffic management costs are higher in the UK than elsewhere. It is possible that with the widespread introduction of DHNs costs would fall to reflect a reduction in the risk allowances that contractors will apply as these would be based on experience. There may be some savings in the pipe systems supply cost if there was a UK manufacturing plant. Comparisons with Helsinki prices indicate that there is the potential for a 50% reduction in price for DHNs compared to the current UK price level.

2.5.2 Routes for DHNs

If DHNs were to be the preferred route for delivery of low carbon heat to lower density housing then it would be worthwhile considering regulations to permit DHNs to be routed through one property to supply another, rather than to require a separate connection from a heat main in a public highway to the boundary of each property without passing through any other property.

An example would be the use of roof spaces in terraced houses to distribute heat rather than for the heat main to be buried in the road with individual branches to each house. This solution would result in much lower costs and lower heat losses. There are examples in the social housing sector where this method has been successfully applied even though some of the terraced houses have now been sold under the right to buy scheme.

A further option is to supply more than one house from a single connection to the road main with the heat supply entering one front garden and passing to the adjacent properties through the front gardens close to the house. This would be an obvious solution for semi-detached houses but could also be used for terraced houses. Costs would be reduced as there is only one branch connection to the road main and heat losses would also be reduced.

A number of existing services are installed this way e.g. common drainage and electrical connections, and covenants are provided in the property deeds to allow for access rights. Providing the same facility in regulations for DHNs as is available for other utility providers would be worthwhile investigating.

2.5.3 Small-scale biomass CHP

At present biomass is mostly used in power generation with a growing application in small-scale boiler systems. A more efficient use of this limited low carbon resource would be in CHP plants. Whereas the technology is well established at a larger scale there is still significant development potential for small-scale systems i.e. less than 5MWe capacity. If the smaller-scale biomass CHP technologies become technically proven and lower cost this could impact on the economic case for small-scale DHNs as the cost of heat could be very low, especially as there are financial incentives (ROCs) for the production of renewable electricity (which could justify the cost of the CHP plant itself) and a renewable heat incentive is likely to be introduced.

2.5.4 Fuel cells

Fuel cells represent a more efficient gas-fired CHP system but are also well suited to biogas or hydrogen rich syngas fuels. At present the high capital cost and limited lifetime are barriers but if these can be overcome this would benefit the small-scale DHNs.

2.5.5 Micro-CHP

If domestic scale CHP using fuel cells or other technologies are developed successfully and the efficiency is sufficiently high then these could deliver similar benefits to small-scale DHNs. The issues that arise will be mainly associated with matching of heat demand and electricity demand and the potential for significant amounts of exported electricity onto the local electricity distribution network. Such units are however likely to be dependent on the local natural gas supply whereas DHNs can be supplied with heat from a range of sources including renewable-fired CHP or biomass boilers. In addition DHNs have the potential benefit of diversity of supply resulting in a smaller CHP capacity for a given group of buildings.

3. POTENTIAL HEAT TECHNOLOGIES – COMPARISON OF PERFORMANCE

3.1 Introduction

The technologies introduced in the previous Chapter have different cost structures and environmental impacts. In this Chapter we compare the technologies across two dimensions:

- cost competitiveness – the implied cost of heating using each technology; and
- carbon emissions – the volume of carbon emitted in producing the heat.

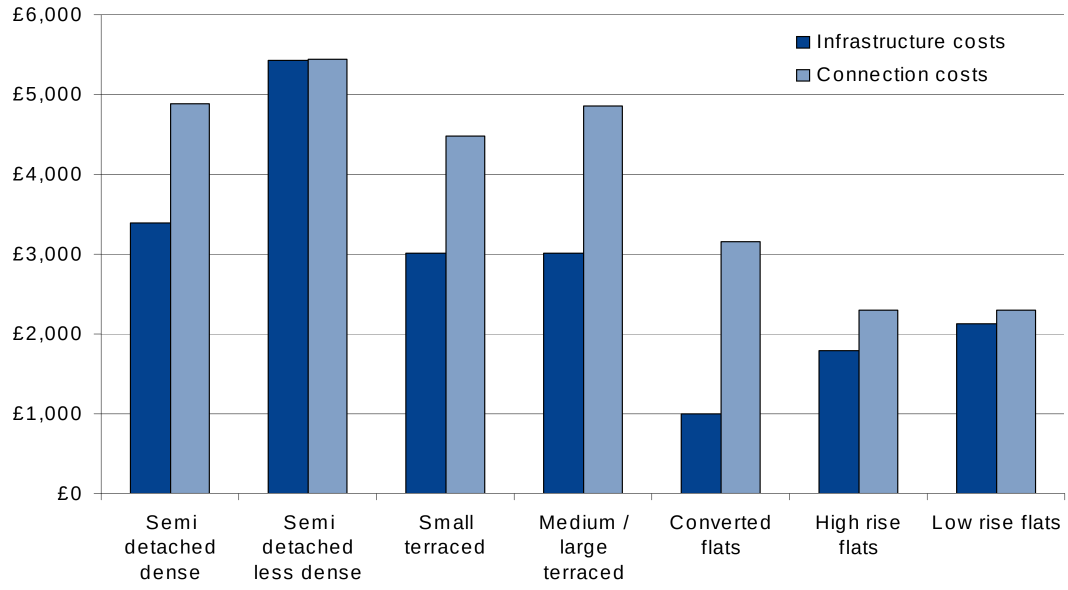
We then consider how performance on each is affected by changes in the underlying assumptions used.

The fact that district heating, by its very nature, is provided on a collective basis, makes a comparison with individual technologies difficult, since the heat network is likely to cover a variety of built forms for which the costs of connection differ. While the national take-up modelling will explicitly account for this factor, the initial comparisons are undertaken for a composite dwelling, reflective of the underlying mix of built forms and existing heat technologies. The composition of the current UK housing stock and the form of the composite dwelling is described before the comparative results are presented.

3.2 Overview of UK housing stock

The nature of the housing stock has a significant impact on the economic potential of district heating since the cost of connection varies materially across built forms (see Figure 7).

Figure 7 – District heating infrastructure and connection costs by built form



Source: Faber Maunsell and Pöyry Energy Consulting

As part of the study, a review of the UK housing stock was undertaken to ensure the analysis captured the key characteristics of the UK market. A detailed summary of this is provided in Annex A, but the main points are as follows:

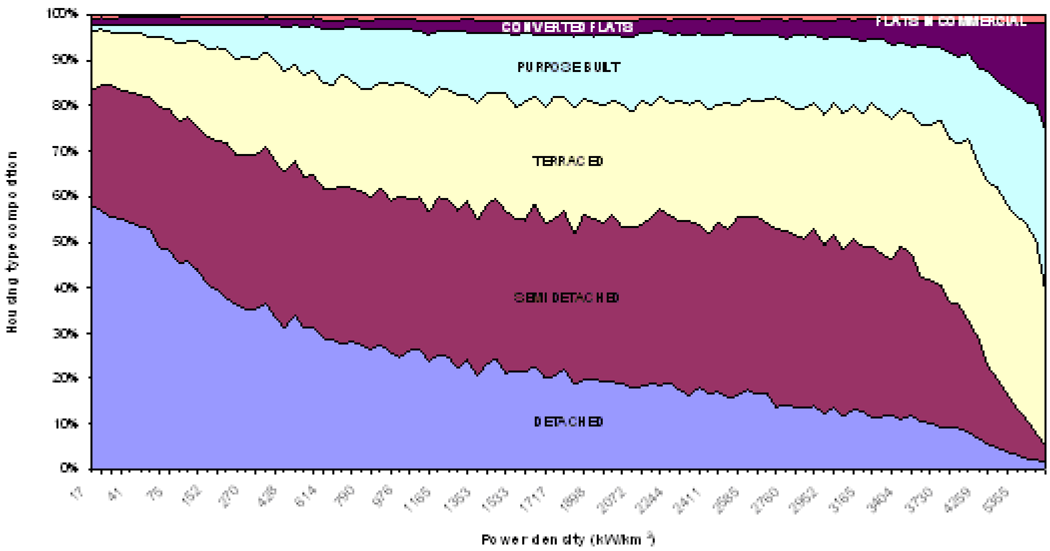
- terraced houses (of various sizes) and semi-detached houses are the two largest portions of the UK housing stock;
- areas that would be categorised as 'suburban residential' in the English House Condition Survey have the highest number of dwellings;

While a weighted average of the costs of providing heat to the mix of house types in the total UK housing stock could have been used in the subsequent comparisons, it was thought that this may distort the overall results. As can be seen from Figure 8, the mix of housing type varies with heat density.

As heat density falls, the number of semi-detached and detached houses becomes significant at the expense of terraced houses. Since the economics of district heating is likely to be improved with increasing heat density (as this lowers the capital cost per unit of heat demand), a composite dwelling was assumed to have the mix of house types that would be observed at or above 3000kW/km^{2}.

The proportion of heat demand for dwellings in this region is around 20%, which could be represented by 90% of the flats and about 20% of the terraces in the housing stock. We assume this mix as a basis for our cost calculation in the following sections, but our later projections of national take-up are based on actual built form shares for different areas.

Figure 8 – Housing types and heat density as percentage of total number of dwellings in each area



Source: Faber Maunsell and Pöyry Energy Consulting

3.3 Comparison of cost effectiveness

3.3.1 Calculating the effective heat tariff

To compare the cost effectiveness of different technologies, we have calculated an effective heat tariff for the composite dwelling. The effective heat tariff is the annualised tariff required to provide the project with a given rate of return over its lifetime, taking account of all capital and operating costs and non-heat revenue streams (including electricity sales, carbon credits and other current government support mechanisms where appropriate).

3.3.2 Base case assumptions

The effective heat tariff calculation includes assumptions on long-run fuel prices and trends in heat demand across time reflecting improvements in wall insulation, roof insulation, and glazing. Importantly, a commercial discount rate of 10% is assumed to apply to all technologies. Table 4 below outlines the key assumptions used in this analysis. More detail can be found in Annex E.

Table 4 – Base case assumptions for effective heat tariff calculation

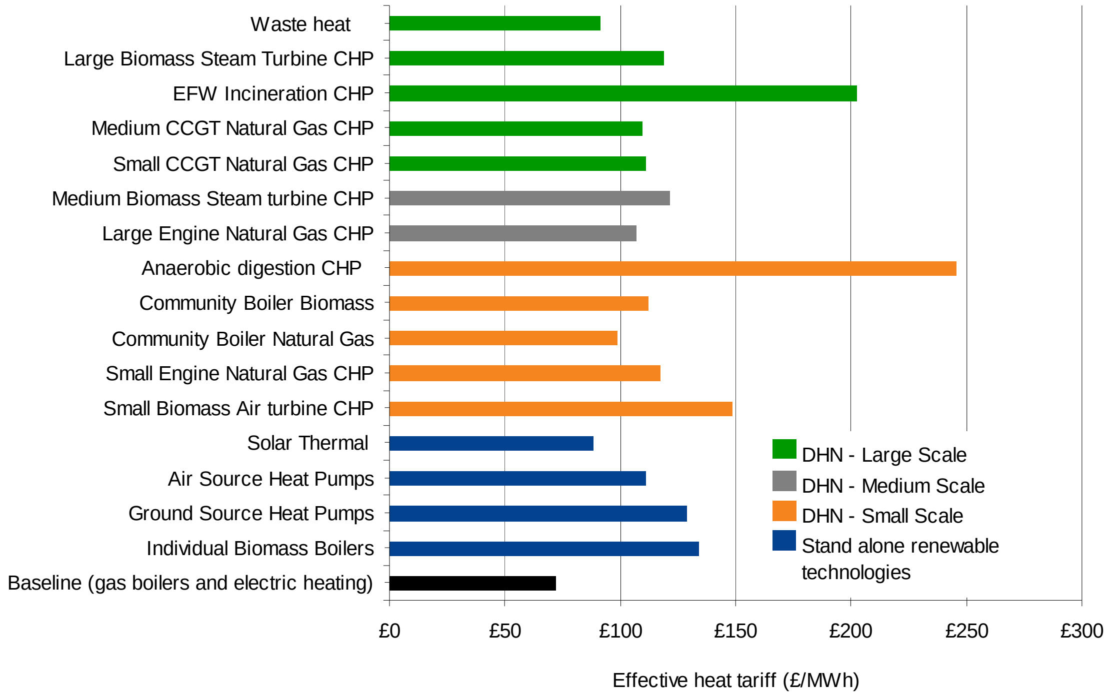
Variable	Assumption
Fuel Prices	DECC central scenarios
Electricity sale price	DECC central scenario
Uptake of scheme	100 per cent in year 1
Discount rate	10%
Sizing of scheme	Perfect foresight (optimal sizing)
Cost of carbon (in heat and fuel)	0
Electricity ROC price	0
Cost of heat / Heat tariff	Market based [determined in the model]
DH technical inputs	See 0
Counterfactual inputs	See 0
Grid electricity generation efficiency	45 per cent (based on gas)
Grid CO_2	Marginal gas

Source: Pöyry Energy Consulting and Faber Maunsell

The results based on these assumptions (presented for the composite dwelling[5]) are provided in Figure 9 below. As can be seen, under the assumptions outlined in Table 4, the baseline heating technologies are more cost effective than either the district heating options or the other low-carbon technologies. Though they are more expensive than the conventional baseline, the analysis also shows that, with the exception of energy from waste (EfW) and anaerobic digestion (AD) CHP, the district heating options can provide heat at comparable cost to the other low-carbon technologies.

5 Heat density of 3,000 kW / km2 and above.

Figure 9 – Effective heat tariff by DHN technology (base case assumptions)



Source: Pöyry Energy Consulting and Faber Maunsell

One of the main reasons for the high cost of the district heating options is that they require a significant upfront capital investment in the heat distribution network. For example, a network similar in size to that currently in place in Sheffield (approximately 70,000 dwellings) may cost in the order of £430 – £500 million to fully install and connect, whereas a scheme equivalent to that in Vienna (270,000) may cost between £1.5 and £1.8 billion. In the following sections we investigate how sensitive the cost effectiveness is to changes in key parameters. These include:

- the calculation of the conventional heating system heat tariff;
- 100% take-up of heat demand in first year;
- the discount rate applied to technologies; and
- extent of allowance for carbon costs or benefits; and the availability and level of alternative revenue streams.

3.3.3 Conventional heating system tariff calculations

There are two aspects of our basic analysis of the effective heat tariffs that may bias the relative attractiveness of different technologies:

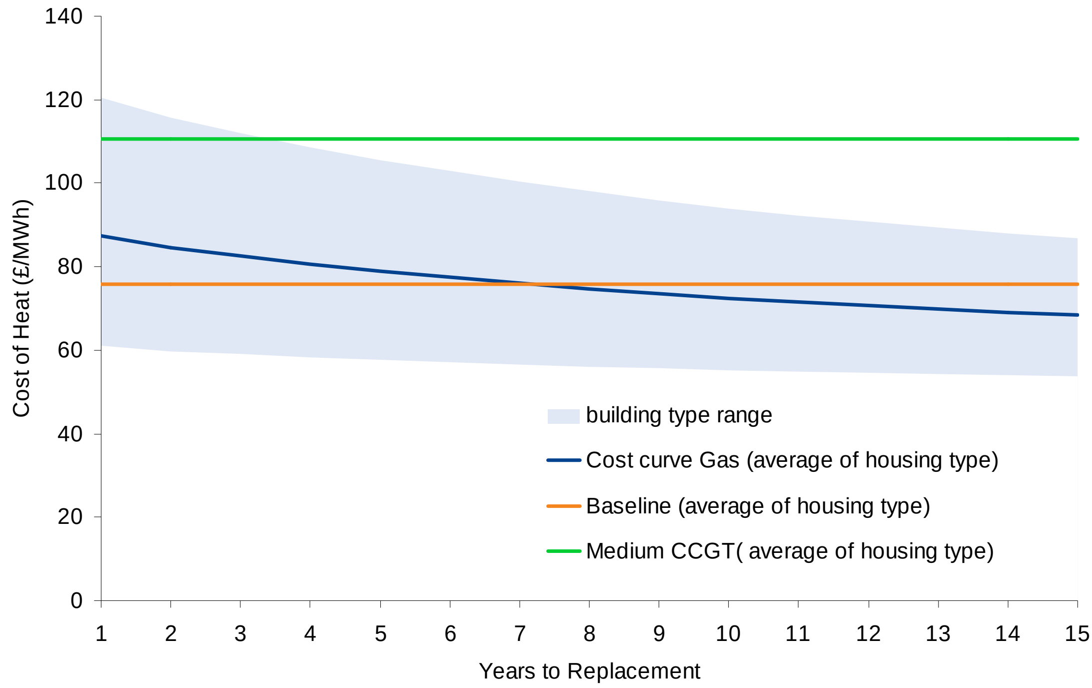
- the use of a composite dwelling – i.e. a weighted average of the different building types in the UK building stock – masks differences in the cost of using conventional heating between building types; and
- capital expenditure on conventional systems is assumed to be spread evenly over the assumed boiler lifetime but should take account of when replacement is actually required. If consumers have old systems that are near to replacement, then they will be anticipating a capital expenditure in the near future and this may go some way to mitigating the impact of investment in alternative heating technologies.

We have analysed both aspects of this in Figure 10.

If we assume that conventional CAPEX is incurred when the system is replaced, rather than spread evenly over its lifetime, the effective heat tariff for a conventional system for the composite dwelling is represented by the blue line, rather than the orange line. That is, the tariff for those customers whose boilers will need replacing in the next few years will be higher than that presented in Figure 9.

However, in comparison with a representative tariff for a CCGT CHP-based DHN technology, the conventional system still has a lower heat tariff.

Figure 10 – Varying treatment of conventional CAPEX



Source: Pöyry Energy Consulting and Faber Maunsell

The shaded area in Figure 10 shows the range of conventional heat tariffs for the individual housing types, from high rise flats which have the highest heat tariff down to pre 1919 Medium / large terrace properties that have the lowest heat tariff.

What this shows is that, although on average DH options are less cost effective than the conventional baseline, there are circumstances where district heating technologies are more cost effective than the conventional systems. It implies that, if developers are able to effectively target some house types in an area (high conventional heating cost buildings (typically flats with electric heating) and old systems), then there is a higher probability that a district heating scheme will be commercially viable. Nevertheless, this does require the house types to be concentrated in a small geographic area that the network can realistically serve.

3.3.4 Impact of the take up risk

As part of the base case assumptions set out in Table 4, the analysis has assumed that take up will be 100% in the first year and the network would be built with perfect foresight to match the demand. However, practically network development will take time and new connections will be added incrementally.

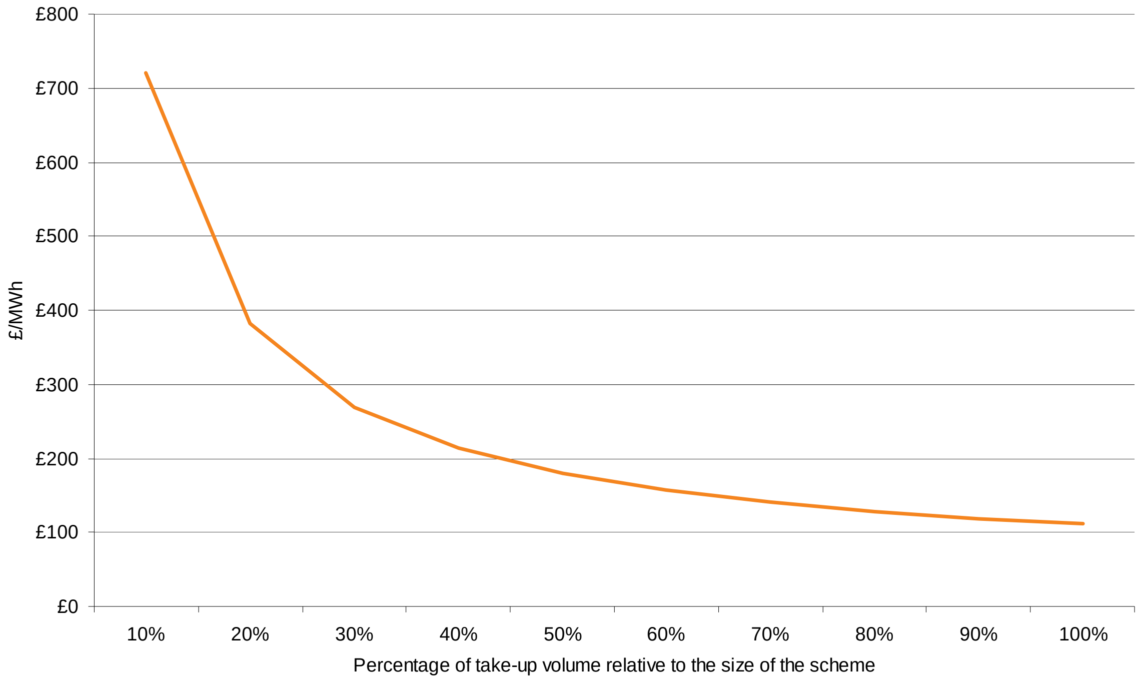
More importantly, it is often unlikely that 100% take-up will be achieved in any area without mandating of connection (as occurred in the zoned development in Denmark). With high upfront capital costs take up risk may have a major impact on cost effectiveness through two avenues:

- it delays revenue recovery in the early years if it takes time to connect; and
- it leads to stranding of the network if a scheme is over-sized to meet expected demand yet that demand is not realised.

Initial analysis indicated that the effective heat tariff is relatively insensitive to the profiling of take-up. This is because the model assumes that network development is also profiled as far as possible, minimising the mismatch between capital outlay and revenue recovery.

However, the impact of the second bullet is more material. To understand and quantify this risk we have assessed the impact on the effective heat tariff of capping the uptake of the schemes at various percentages of the size of the network built. The results shown in Figure 11 shows this impact on the effective heat tariff for a Medium CCGT CHP DHN system, but the pattern is similar across all technologies.

Figure 11 – Quantifying the take up risk



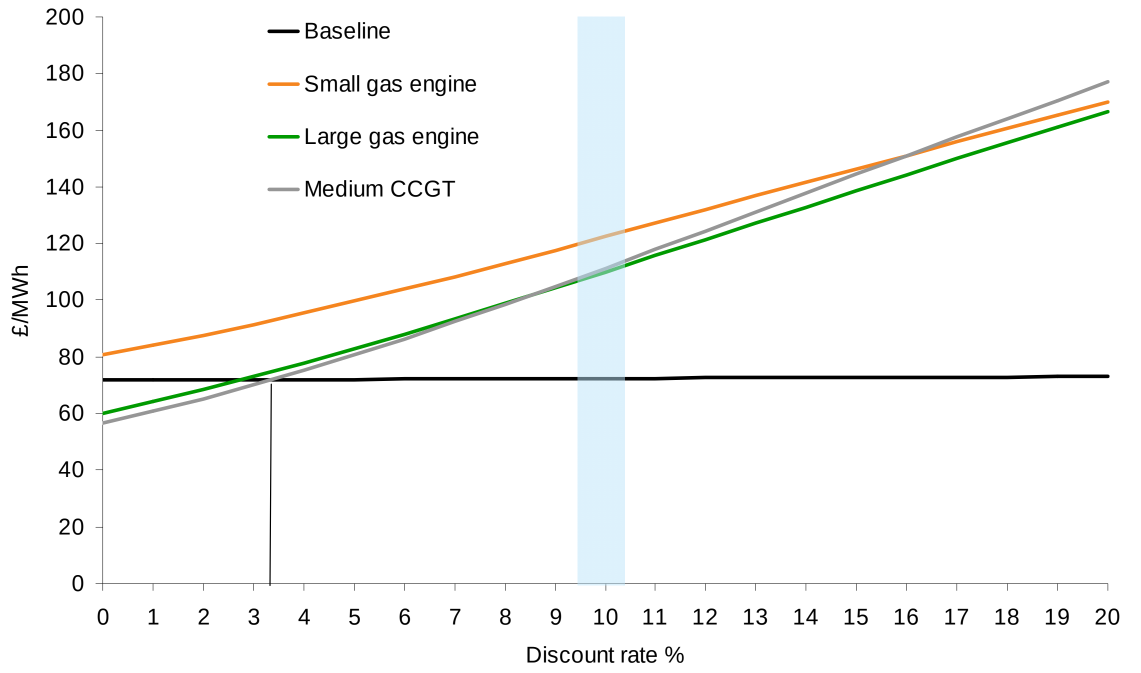
Source: Pöyry Energy Consulting and Faber Maunsell

As can be seen, the effective heat tariff increases sharply as the actual size of the scheme declines, since the fixed capital costs are spread over a much smaller heat load. Interestingly, the variation in effective heat tariff is limited above 80% take-up. This suggests that, in reality, a developer may be willing to over-size slightly, but will not invest speculatively in large-scale heat networks without guaranteed anchor loads. Consequently, in our later national potential modelling we have assumed that a district heating network will be sized on the basis of achieving an 80% take-up of maximum potential.

3.3.5 Discount rate impact

With high upfront capital costs, the discount rate also has a major influence on the effective heat tariff. Our base assumption is a 10% discount rate applied to all technologies. Figure 12 shows how the effective heat tariff for a selection of district heating technologies varies as the discount rate changes.

Figure 12 – Variation in the common discount rate



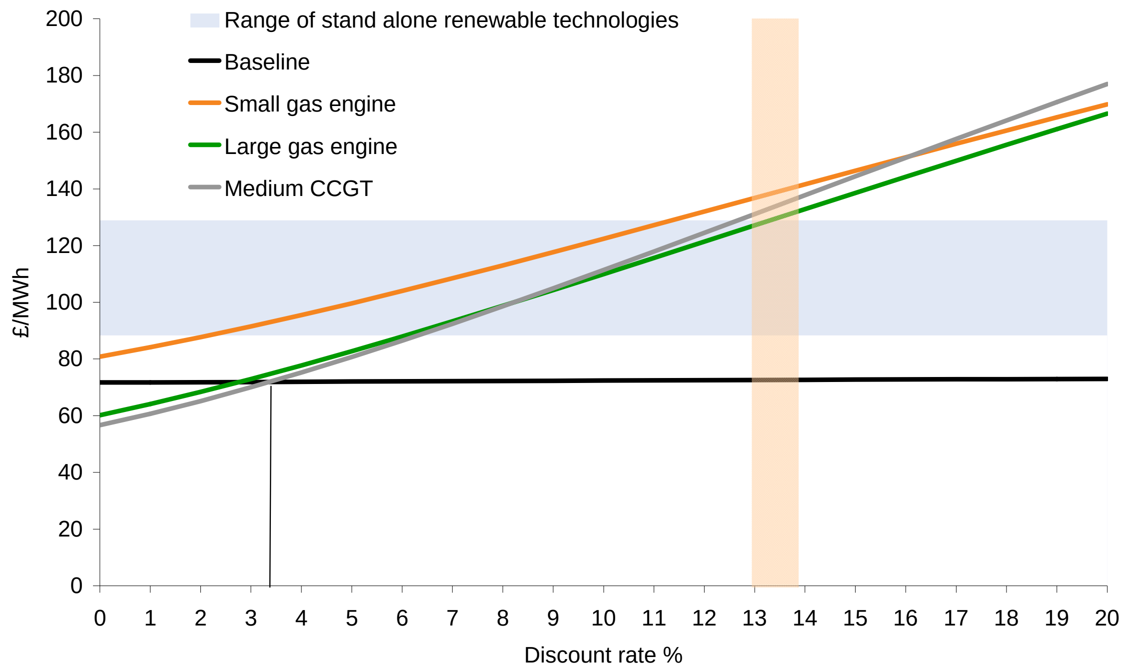
Source: Pöyry Energy Consulting and Faber Maunsell

All technologies require higher effective heat tariffs as the discount rate increases – the differences in the responsiveness to the discount rate related to the variations in the cost structures for the technologies chosen. In particular, the more capital intensive large- and medium-scale schemes (medium CCGT CHP and large gas engine CHP respectively) are more responsive to discount rate than the small gas engine CHP.

The shaded vertical line is at the base assumption 10% discount rate. As can be seen, at this level, the effective heat tariffs are well above those of the conventional alternative. More importantly for the technologies shown, they only achieve parity with the conventional baseline mix of individual gas boilers and electricity heating at discount rates of 3.5% or below. It should be noted, nevertheless, that, as is evident from Figure 10 above, the effective tariff for a given house type may be competitive at higher discount rates.

A further question is whether a global discount rate across all the technologies is appropriate. If investors perceive risk to differ across technologies then this will alter their required returns and change the effective heat tariffs. For example, it may be the case that the high upfront capital costs, the lack of experience of district heating within the UK and the need to coordinate across a large number of heat consumers/loads may raise the discount rate on DHNs relative to that on other technologies. Figure 13 considers this impact.

Figure 13 – Impact of a differential discount rate



Source: Pöyry Energy Consulting and Faber Maunsell

Figure 13 shows the three district heating schemes at the increasing discount rates compared against the range of counterfactual technologies at a fixed 10% discount rate. The results show that, if district heating schemes are perceived to be riskier than the stand-alone renewable technologies, a differential discount rate of 2% to 3% would make all stand-alone renewable technologies more cost-effective than district heating. Private sector perceptions of district heating investment in the UK are discussed in later chapters.

3.3.6 Summary of cost effectiveness

The analysis of cost effectiveness provides some important insights for new heat technologies:

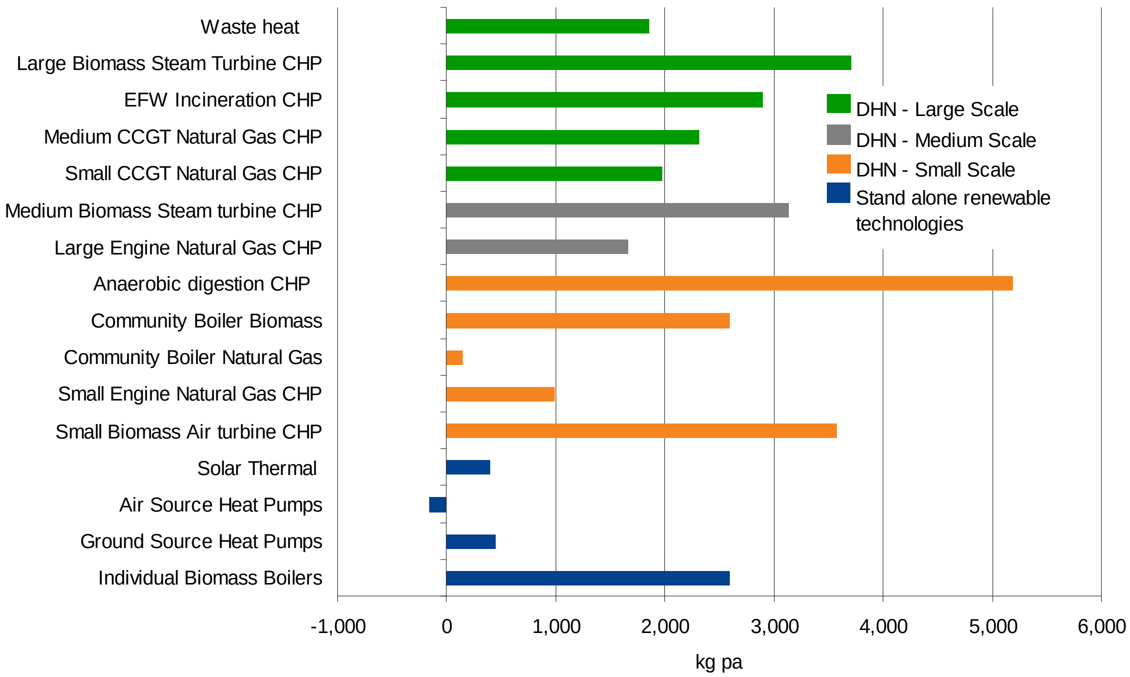
- the high capital costs of new technologies compared with the conventional gas and electric heating systems contribute to a lack of cost effectiveness as the required tariff to recover the initial outlay must be relatively high;
- the effectiveness is dependent on the house type and heating system type that will be replaced – new heating options are much more competitive with electrically heated flats than modern, gas-heated detached houses;
- district heating developers are unlikely to build networks that have capacity significantly above that for which they have a guaranteed offtake in the medium-term; and
- a lower discount rate reduces the effective heat tariff of the more capital intensive options, though it still struggles to be competitive with the conventional baseline.

3.4 Comparison of carbon emissions

So far we have only compared technologies on the basis of cost. However, it is also essential to consider the carbon impact of these technologies and the benefits this could bring in meeting the UK's CO_2 targets.

In pure carbon terms the district heating options can provide substantial carbon benefits relative to both the current baseline mix and the counterfactual technologies. These results for the carbon savings compared to the baseline are shown in Figure 14. These results are dependent on the implied carbon content of the electricity network, which we have assumed to be 43 t CO_2 /MWh[6].

Figure 14 – Carbon savings compared to the baseline



Source: Pöyry Energy Consulting and Faber Maunsell

Of the district heating options the community boiler natural gas is predicted to have the lowest impact on emission savings – this is due to DHN network thermal losses outweighing any efficiency gains which may be obtained at the centralised plant. However, as mentioned above the carbon savings from district heating are on average much greater than from the baseline and the counterfactuals. These savings include both improvements in the efficiency of heat production and the savings a CHP plant would have in terms of displacing stand-alone grid generation. Hence, CHP options are much more effective in reducing emissions than the stand-alone heat technologies.

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6 However, in reality this level will vary depending on the marginal source of generation (e.g. gas or coal fired generation). It is also expected that the carbon content of the electricity grid will decrease as the electricity grid is decarbonised with increased renewable generation and low carbon generation.

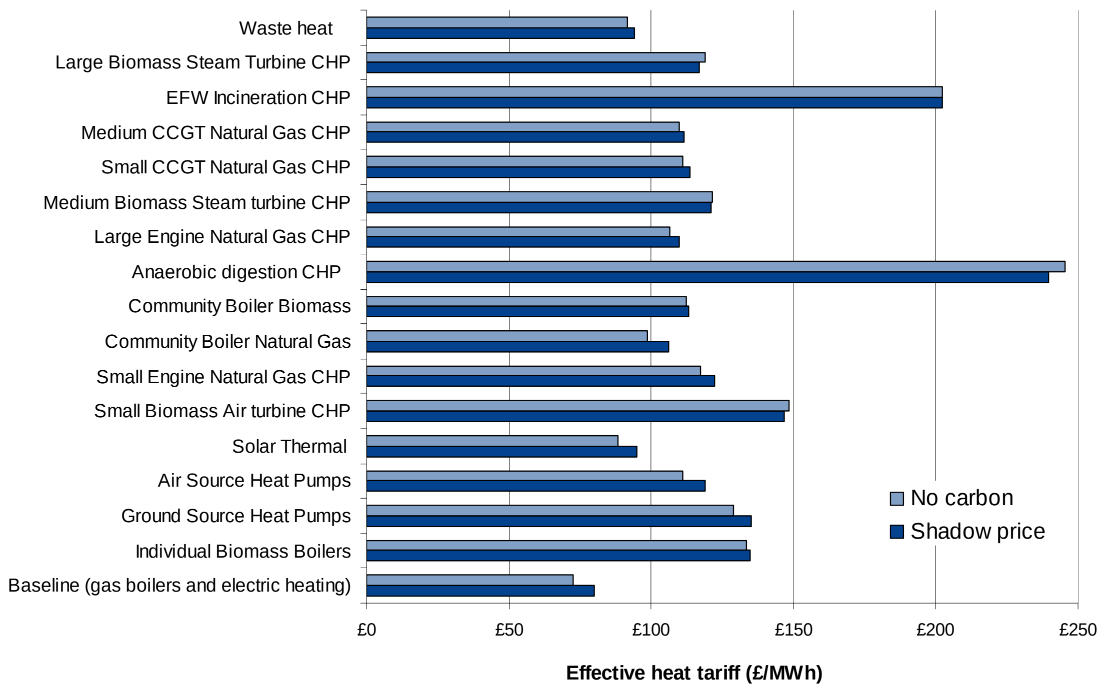
Of all the technologies only the Air Source Heat Pumps are predicted to increase emissions compared with baseline gas and electric heating mix. However, this is due to the CO_2 intensity of grid electricity combined with relatively low Co-efficient of Performance (COP) assumed for air source heat pumps. The COP assumptions for heat pumps are based on the UK Government Standard Assessment Procedure 2005 (SAP 2005) which sets standardised efficiencies for different technologies for use in Building Regulation compliance. The COP values used in this study include a SAP 2005 adjustment to allow for heating using the existing radiator systems rather than lower temperature underfloor systems. This study assumes for retrofit installations that it may be financially and technically challenging to change the heating system type from the existing radiator system to a new low temperature distribution system such as underfloor heating.

Over time we would expect the heat pumps to have more of a benefit as the average CO_2 intensity of the electricity grid decreases (see section 3.5). It is also important to note that in off-gas grid applications where the alternative fuels are higher carbon electricity or oil heating, the CO_2 saving from heat pump systems will be greater. These are generally areas where district heating will not be viable.

3.4.1 *Incorporating the shadow price of carbon*

Given the substantial carbon benefits of the district heating options it might be expected that by valuing the carbon and including this in the effective heat tariff calculation there would be a change in the effective heat tariff compared to the chart shown in Figure 9. However, Figure 15 shows that although valuing carbon at the government's shadow price of carbon does alter effective heat tariffs, the impact is small. This is likely to be in part because of the increasing efficiencies of the baseline gas boilers over time, together with the discounting of the value of carbon over the lifetime of the project.

Figure 15 – Incorporating the shadow price of carbon

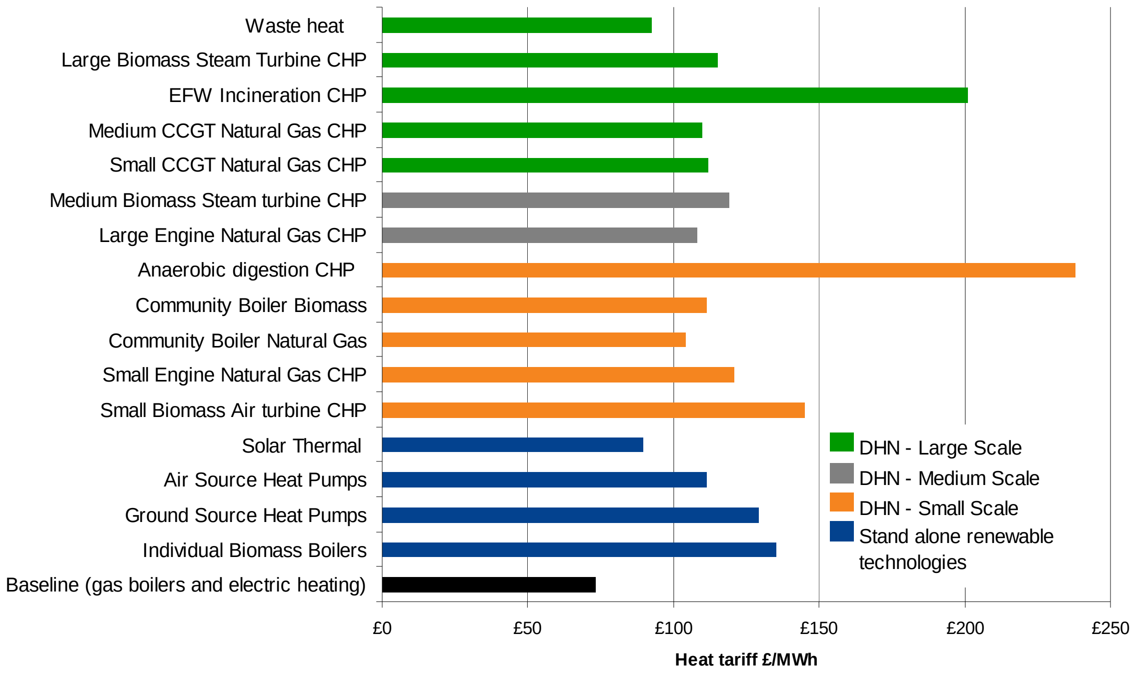


Source: Pöyry Energy Consulting and Faber Maunsell

3.4.2 Current market framework

As a final sensitivity on the effective heat tariff we have assessed the impact of the current commercial framework on the carbon price and revenue incentives available to these options. On this basis we have assumed an EU ETS framework for carbon price (rather than the shadow price) at a fixed price of £20/t CO_2[7], together with Renewable Obligation Certificates (constant at the current buy out price) and Levy Exemption Certificates (constant at current levels). This result is shown in Figure 16.

Figure 16 – Current commercial position on carbon and other policies



Source: Pöyry Energy Consulting and Faber Maunsell

This result identifies why district heating and the counterfactual technologies are not being deployed by commercial companies at the current time. On this basis, the baseline mix (gas and electric heating) remains the most cost effective heating option. However, the majority of the district heating options remain more cost effective than the stand-alone renewable technologies.

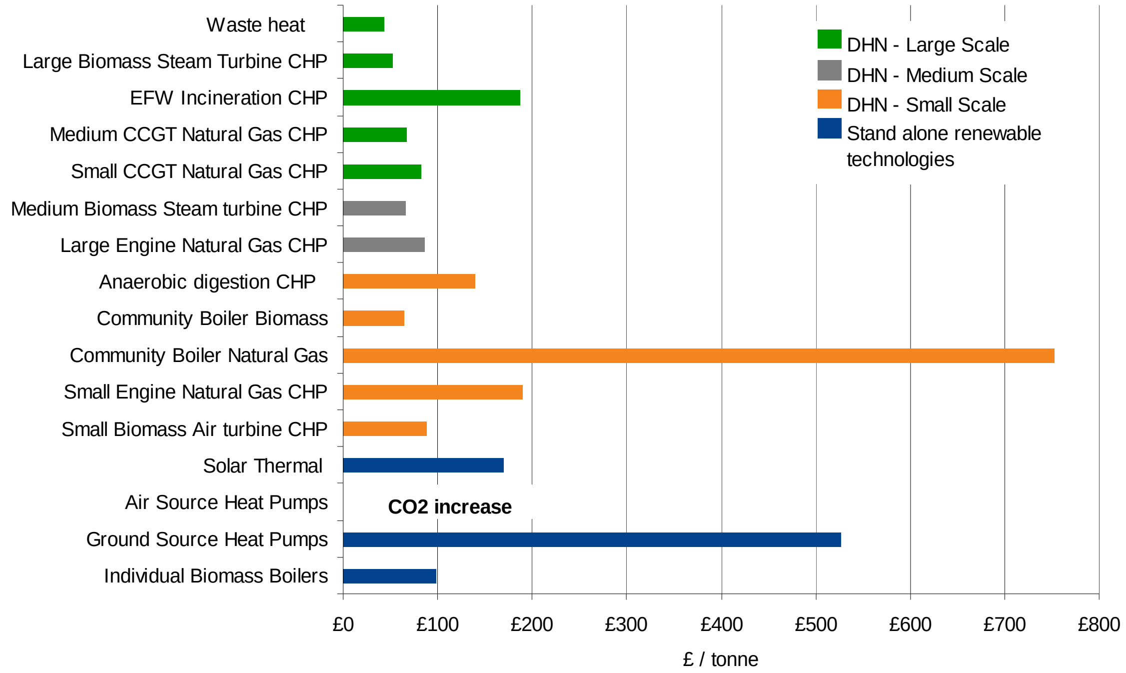
3.4.3 Carbon abatement

Using these assumptions we are also able to calculate a carbon abatement cost (£/tonne). The results shown in Figure 17 show the cost of abating the next tonne of CO_2 is in general cheaper in the district heating options than the counterfactual options.

Nevertheless, these carbon abatement costs are above the shadow price of carbon when resource costs are calculated at a 10% discount rate.

7 This is the DECC central carbon price scenario

Figure 17 – Implied carbon abatement cost



Source: Pöyry Energy Consulting and Faber Maunsell

3.5 Decarbonising the electricity network

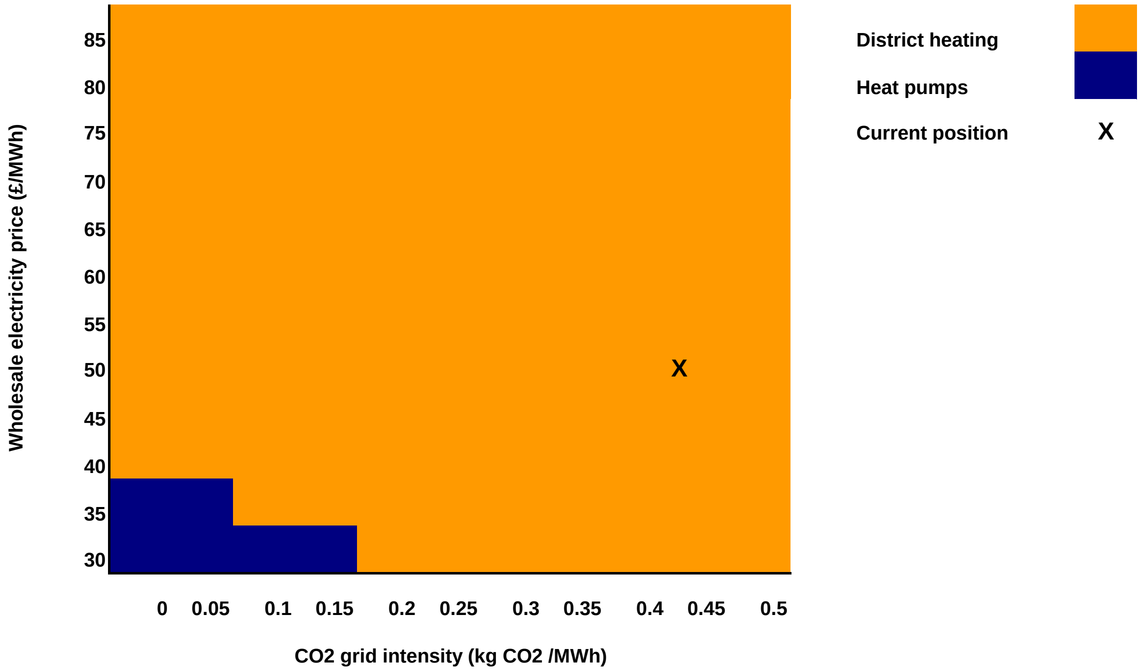
In general, where DHNs can achieve a high penetration in a built up area, the carbon abatement costs of district heating options are comparable with, or better than, the most cost-effective renewable counterfactual. However given the expectation of lower carbon intensity on the electricity network in the future, it is important to assess whether district heating would still provide the greatest benefits. The reason for this analysis is there may be competition for finance between the low carbon heat technologies, such as district heating, and decarbonising the electricity system.

It is anticipated that decarbonising the electricity network would lead to an increase in the cost effectiveness of heat pumps. Therefore to assess this we have considered a number of scenarios which look at the long term impact of a decarbonised electricity system on the best option for carbon abatement. In this analysis we have compared the district heating and heat pumps at a grid CO_2 intensity ranging from 0 to 0.5 kg CO_2 / MWh and an electricity price ranging from £30 / MWh up to £85/MWh. All results are shown for the medium dwelling and assume no other support or value of carbon.

Under the first two cases we have assessed the 'cheapest' marginal abatement technology at a 10% discount rate and separately at a 3.5% discount rate. The 10% case is shown below in Figure 18. The phase diagram identifies the combinations of carbon intensity and wholesale electricity price for which each of the technologies is most cost effective as a means of carbon abatement.

As is shown, district heating remains the most competitive carbon abatement option except in the case of low grid intensity and low energy price. However it is unlikely that low grid CO_2 intensity and fuel prices can coexist due to the costs of additional renewable, nuclear and/or CCS (Carbon Capture and Storage) technology. The current position is shown with an X.

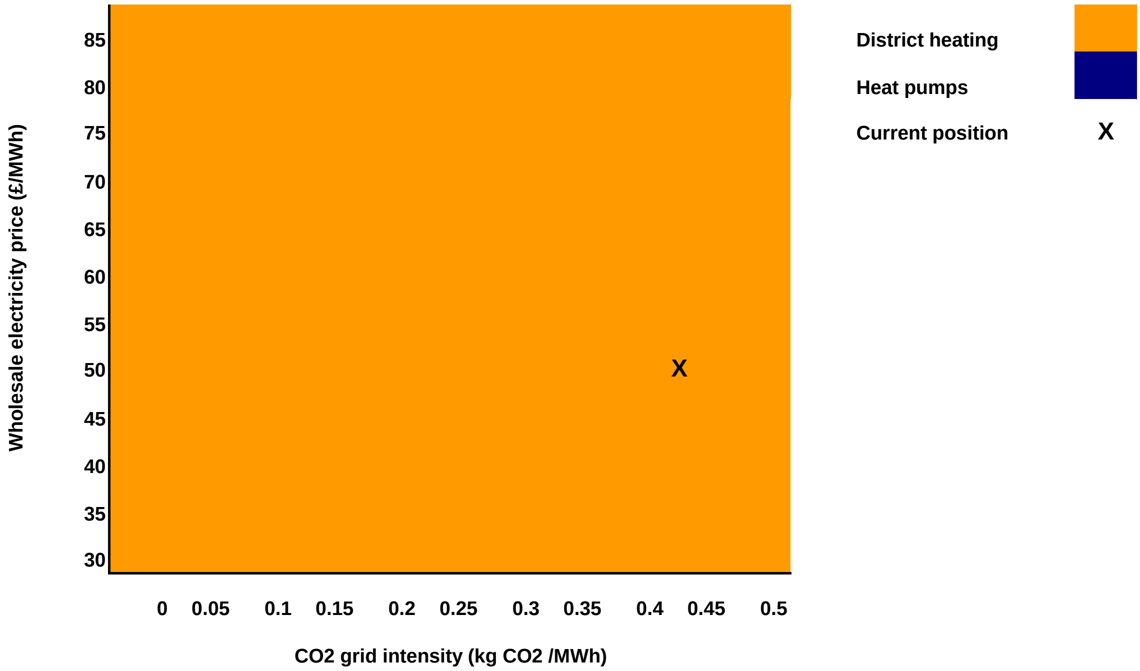
Figure 18 – Phase diagram for carbon abatement at 10%



Source: Pöyry Energy Consulting and Faber Maunsell

This second chart (Figure 19) shows the same comparison at a lower discount rate of 3.5%. As expected at this level district heating remains the best option as the reduced rate of return increases the cost effectiveness of the capital intensive technologies.

Figure 19 – Phase diagram for carbon abatement at 3.5%



Source: Pöyry Energy Consulting and Faber Maunsell

However, these results are dependent on the specific assumptions we have made in regard to the technologies. As we state in 0 we have assumed a slightly lower COP for the heat pumps based on SAP 2005 than in previous studies. Therefore for completeness, in Figure 20, we have assessed the carbon abatement using higher COP on the heat pumps.

The results in Figure 20 predict that heat pumps become more competitive at higher electricity prices and higher grid CO_2 intensities. These results show that improvements in the efficiency of heat pumps will alter the balance between heat pumps and district heating, but to favour heat pumps over district heating:

- decarbonisation would need to be at comparable wholesale electricity prices with now; and
- the speed of decarbonisation would need to be fast (most carbon savings for DHNs are in the early period of operation reflecting changes in the gas boiler mix and improvements in building efficiency).

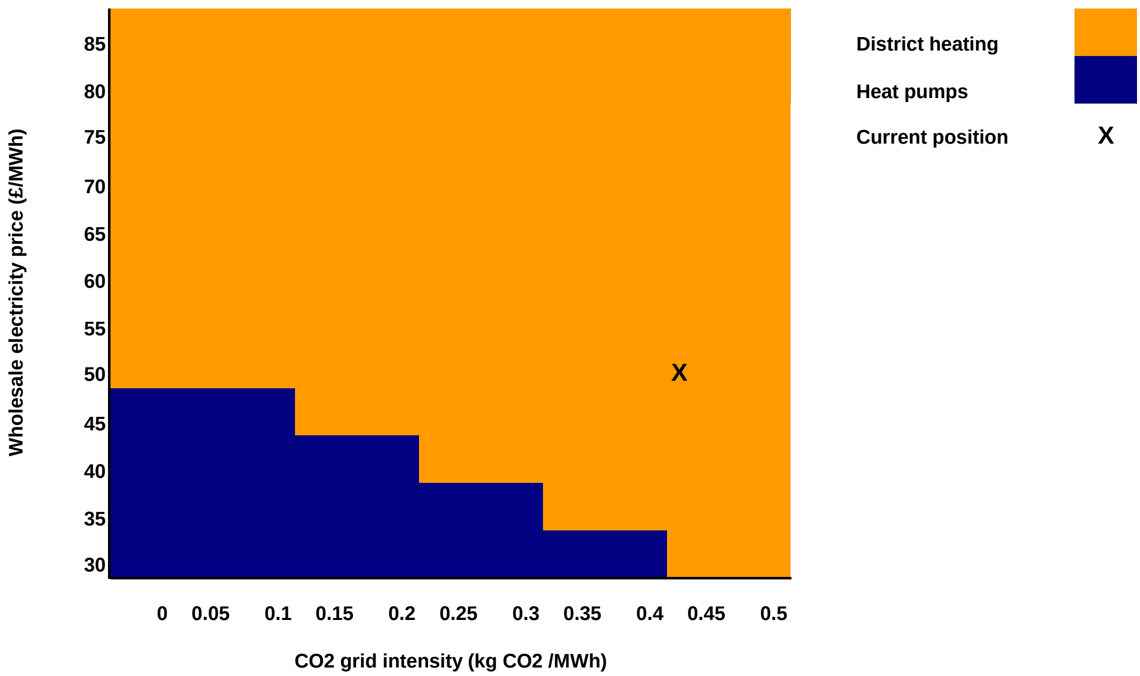
Figure 21 shows the impact of reducing the discount rate of the heat pumps by 2% (while keeping that for the district heating technologies constant). The results imply heat pumps are relatively insensitive to changes in the discount rate (of this magnitude).

Finally, Figure 22 shows a combination of this reduced discount rate and the higher COP. The results still indicate that in the future district heating will remain the more cost effective carbon abatement technology in built-up areas, assuming that at the lower CO_2 intensities the electricity price will be above £55/MWh.

The conclusion here is not that heat pumps are undesirable, but that they are not a cost effective solution for large-scale mixed building type heat supply. As we describe in Annex A there are around 4 million households excluded from our national take-up model (as we have explicitly assumed that DHNs are not efficient in rural areas), therefore there is still a large potential for heat pumps in those areas and in detached housing more generally.

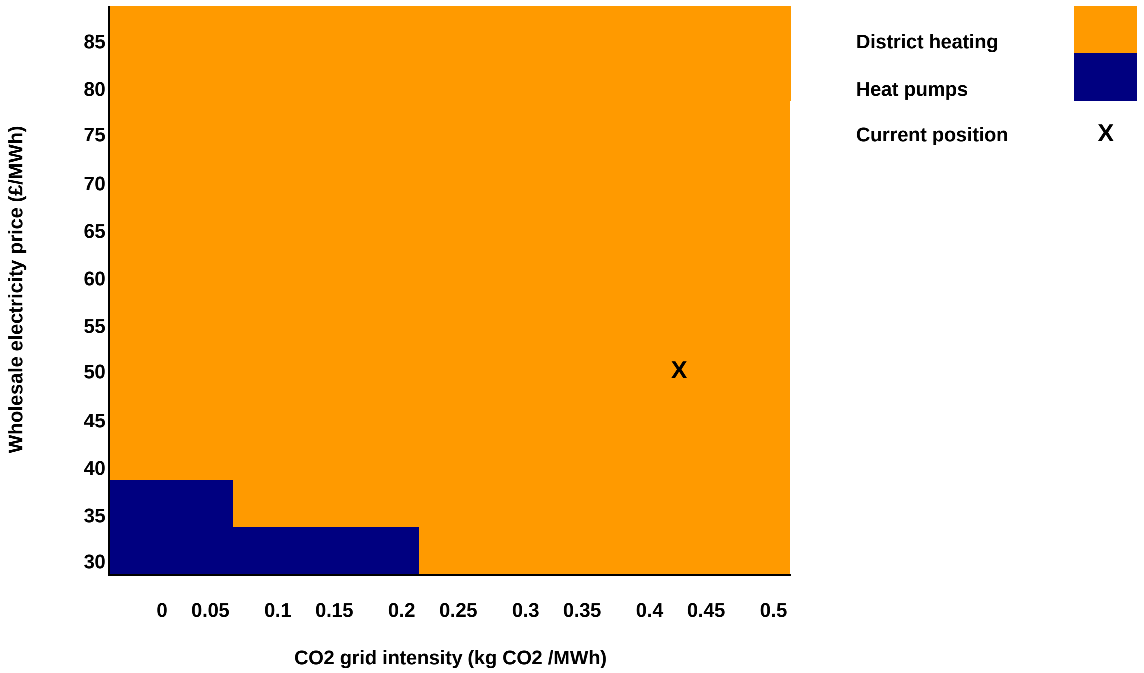
Since our analysis suggests most district heating would be gas-based, at least in the short-term, stand alone renewable options will still be needed to assist compliance with the 2020 renewable energy targets.

Figure 20 – GSHP and ASHP at higher COP (3.2 and 2.5 respectively) 10%DR



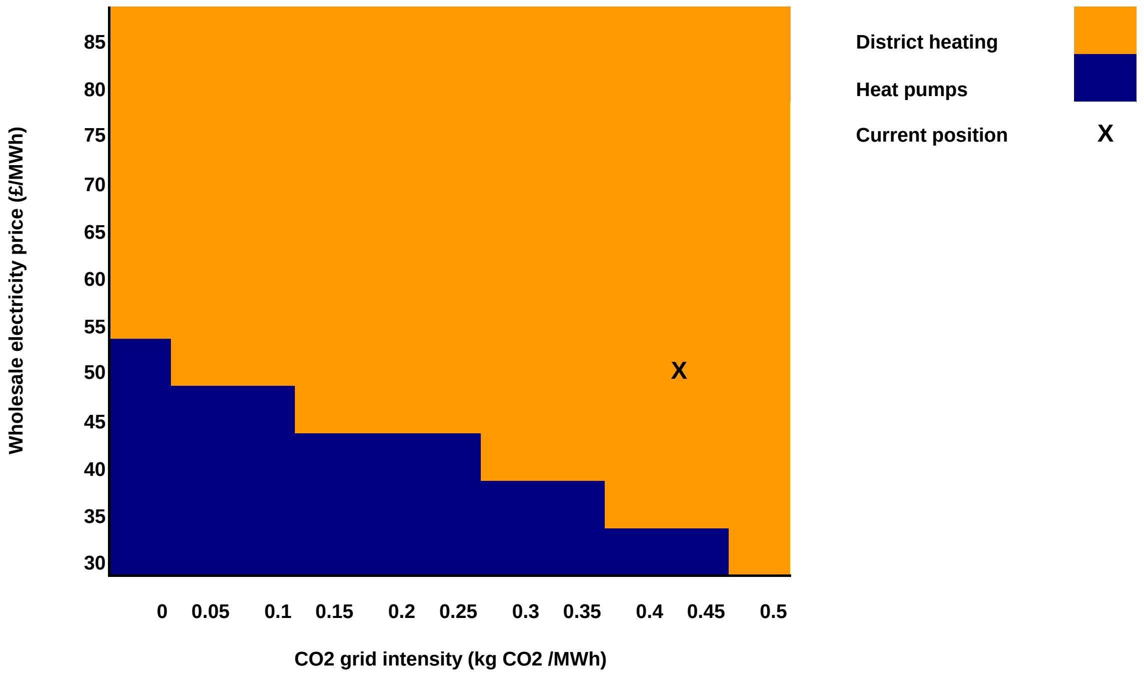
Source: Pöyry Energy Consulting and Faber Maunsell

Figure 21 – GSHP and ASHP at 8% discount rate with other technologies at 10%



Source: Pöyry Energy Consulting and Faber Maunsell

Figure 22 – GSHP and ASHP at 8% discount rate with other technologies at 10%, plus GSHP and ASHP at higher COP (3.2 and 2.5 respectively)



Source: Pöyry Energy Consulting and Faber Maunsell

4. BARRIERS TO DHN DEVELOPMENT

4.1 Introduction

Responses to the Heat Call for Evidence highlighted three types of barrier to district heating:

- regulatory barriers that restrict the installation or evolution of a network;
- financial barriers associated with raising the volume of capital required (or being able to borrow at acceptable rates); and
- commercial barriers related to the underlying cost competitiveness of district heating with other technologies.

Our findings, informed through workshops, interviews and review of international experience, have in the main agreed with these conclusions. In this chapter we summarise our investigation of specific barriers that adversely affect the commercial position of DHNs relative to conventional heating systems. We have summarised these in three main areas:

- economic barriers;
- general institutional issues; and
- carbon price.

Although we present these barriers separately it will become clear that there are many interactions. In particular, the institutional issues add to the risk or cost faced by a developer, reinforcing the economic barriers.

4.2 Economic barriers

While several small scale district heating schemes have been successfully deployed in the UK, historically large-scale schemes to replace individual heating systems have not been commercially competitive. As has been identified in the previous chapter, the main cause of this lack of cost competitiveness is the upfront capital costs associated with the construction of plant, heat network and connections. A scheme of similar size to that in Vienna, serving over 270,000 people, may cost in the region of £1.5bn to construct and connect, in addition to any costs of the heat plant itself.

This large initial capital injection makes the cost of capital (or discount rate) a core driver of the cost competitiveness of any district heating scheme. Since the cost of capital reflects the risk of investing in the project, we can categorise the economic barriers as those that impact on project risk (actual or perceived), project cost and access to capital.

4.3 Project risk

The issues faced by district heating are not necessarily unique – many investments undertaken by the private sector have similar characteristics and therefore present similar problems to investors. However our analysis and anecdotal evidence from industry experts seems to imply that district heating is likely to return less income and create more uncertainty than other large scale investments. Therefore it is necessary to identify whether this is the case and ultimately why this is the case.

The problems associated with accessing finance were summarised within the recent DECC consultation. As they stated, there is a lack of experience of district heating in the

UK, which coupled with lengthy payback periods, mean that there are few investors willing to consider district heating networks. In the case of district heating therefore, it is not necessarily the scale of investment which prevents deployment, but the potential risks in construction and operation of the network, which affect the willingness of the private sector to invest.

There are a series of risks attached to the construction and operation of DHN which will affect the appetite of private sector investment. Below we identify the principal areas of risk and illustrate ways in which the market or governments have sought to mitigate these risks.

4.3.1 Technology

Technology risk is relevant to potential investors when a technology is relatively new or untried. The potential risks relate to the confidence that a technology is sufficiently developed and tested to operate on a large scale and over a long period. In the case of DHNs, whilst the technology is not extensively used in the United Kingdom, it is well-established in a number of other European countries. This experience should allay some of the concerns regarding the technology and also provides some empirical evidence of the costs and benefits of DHNs.

Potential UK-based private sector investors have limited experience of DHNs particularly large scale schemes and it will therefore be important in the short-term to develop understanding using the proven experience of existing networks from around Europe to demonstrate the established nature of DHN technology. Corporate investors such as utilities should already have a better understanding and not need as much education. In the medium-term, expansion of the local market should further reduce any residual technology risk.

4.3.2 Construction

Construction risk will be important given the high upfront capital costs of DHNs, particularly since research suggests that costs appear higher in the UK than other countries in Europe (due to limitations in the supply chain and perceived skills shortage in the UK).

In typical private sector investments (PFI, PPPs), the construction risk has been managed through turnkey arrangement (EPC contract – Engineer, Procure, Construct) or similar structures whereby the contractor takes on the risk and requirement to deliver the project to pre-agreed specifications and on an agreed timetable with financial penalties for any failure to meet these targets, thereby insulating the investors form construction risk. Recently there has been a move to EPCM contracts – Engineering, Procurement and Construction Management – where the contractor does not take responsibility for the overall project but is responsible for managing the various contractors.

An alternative strategy that is often used is to take out insurance cover over the construction risk, although recent developments in insurance markets suggest that such cover may be less readily available and more expensive.

Policy options here may look to address either the high upfront capital costs – through, for example, capital grants that may be available for all schemes or for an initial volume of investment – or the risk associated with delay or over-run in the construction programme. The latter may involve public sector underwriting of construction cost over-runs and loss of earnings due to delay, but equally important will be minimising the planning risk during the initial stage of project development.

4.3.3 Off-Take

The off-take risk is probably the most complex risk to manage.

In order to procure private sector investment, the revenue stream of the project will need to be as secure as possible (this implies an interaction between off-take and pricing risk). The main complexity will be to balance the size of any DHN between the initial base load that can be as close to guaranteed as possible and the potential to develop the network to a much broader level of usage.

Achieving a satisfactory base load heat demand will be risky if it relies upon securing commitments from a large number of private sector users (both residential and commercial) to switch from their current heating systems to a district heating network. With the exception of large new private sector developments, there will be high costs of marketing and substantial inertia to overcome. The most likely base load users will be central or local government related consumers (social housing, offices, hospitals, prisons, schools etc.). A long term off-take contract from such customers could provide the basis for securing a minimum level of revenue for a given project. This may allow a project to be developed and then potentially extended to cover a wider customer base, particularly with private sector housing stock.

Given the importance of public sector loads to the initial viability of developments, routes through which these loads may be made available to schemes should be a priority. This may involve targets on central and local government to achieve minimum shares of heat demand from their premises to be sourced from DHNs, or promotion of DHN options in planning and development strategies.

Reducing the off-take risk in relation to private housing may occur through different mechanisms. One mechanism is to change customer decisions regarding switching to district heating networks through increasing the cost competitiveness of the technology. A means of achieving this may be specific tax incentives or the imposition of a carbon tax, though these may need to be combined with guarantees regarding ongoing price competitiveness. Alternatively, the focus for incentives may be on energy suppliers through, for example, low carbon heat obligations.

Other options may focus on overcoming customer inertia through providing connection and installation subsidies, or, in more extreme circumstances, through the mandating of connection in specific district heating zones. This latter may not sit well with the current consumer choice in other areas of the energy market. However, this may be a much quicker way of achieving a desired result than relying on private sector momentum evolving naturally. Administrative intervention – for example in providing terms for standardised contracts – may also be beneficial.

Finally, off-take risk may be removed if revenue is not linked to volume. Introducing availability payments for approved projects may be an alternative means of mitigating the risk for the private sector, with the public sector assuming that risk as happens in some PFI projects.

4.3.4 Maintenance and Management

Maintenance of DHNs will be a factor in ongoing private sector investment and will ideally be managed through a long term contract, potentially with the original constructing contractor or a utility type business to guarantee a set level of availability of the system. The main concern here is the availability of contractors to operate the scheme. Promotion of the local supply chain for DHNs may be beneficial in this regard.

4.3.5 Pricing

In order to encourage private sector investment, the profitability of the project should not be too variable. That is, there should be a close correlation between the input fuel cost and the off-take tariff.

Private sector investors have historically participated in projects where there is exposure to relatively volatile energy prices and should generally be able to accept some risk in this area. A number of hedging instruments exist, although their time periods are normally substantially shorter than the life of a DHN investment. Interestingly, there are some natural hedges within technologies. For example, gas-fired CHP has a natural hedge between its input fuel price, the cost of the conventional alternative and the expected electricity wholesale price in the current market.

During the operational phase of the project, structures such as long term supply contracts could be put in place to minimise fuel supply risk in absolute terms. The larger risk may be around the off-take tariff, where competition from alternative fuels may imply heat tariffs are indexed to these technologies. Here, consumer subsidies or discounts may mitigate the risk to consumers of switching (helping to overcome inertia), whereas offering floor price guarantees to suppliers (along the lines of feed-in tariffs) offers direct support to suppliers in this regard.

Formal price regulation, as observed in Denmark is a more extreme alternative that may be more appropriate where decisions to mandate connections have been taken.

4.3.6 Summary of project risk

We believe the main risk factors for developers and investors alike are:

- a perceived lack of experience and knowledge of district heating schemes in the UK;
- coordination problems associated with managing the simultaneous development of heat sources (or connections to existing sources), distribution networks and end-user connections;
- significant revenue variability because of a lack of understanding of tariffing options or the exposure to take-up risk if long-term contracts have not been agreed;
- concern over potential redundancy in the network in the longer-term if alternative technologies (e.g. heating from de-carbonised electricity) were to become more competitive;
- financing costs are raised as these factor in uncertainty over revenue; and
- lack of familiarity with the concept of district heating amongst consumers and the public sector.

We also believe that developers/investors may perceive a lower risk for other technologies than DHNs, further widening the commercial gap.

4.4 Project costs

The cost of introducing district heating to the existing UK building stock is high and often higher than that in other countries where district heating has been introduced. Some of this cost is structural in nature and specific to the UK – reflecting the composition of the housing stock or the incumbent heat supply infrastructure – but there are some barriers that are artificially increasing the cost of district heating. We describe the main cost drivers below.

4.4.1 Housing stock

One key difference between many of the countries that have successfully deployed large-scale district heat networks and the UK, is the make up of the housing stock. In these other countries there are a greater proportion of flats than in the UK, lowering network costs for the same number of consumers but also increasing average heat densities. Both these factors make district heating development more economic. Since the housing stock evolves slowly, it is likely that this will be a natural barrier to economic development.

4.4.2 Contracting

Currently there are no standardised contracts that can be used by district heating developers in the UK. This means that developers must seek advice from lawyers and contracting experts to negotiate each individual contract thus increasing the costs to the developers.

The district heating market may therefore benefit from a standard set of terms and conditions. These standard terms and conditions could be developed solely by the Government, or in cooperation with the district heating industry (the CHPA has recently taken an initiative in this area). In addition, because these represent a fixed cost, they have a larger impact on the economics of smaller schemes since larger schemes benefit from economies of scale.

4.4.3 Existing gas networks

In the majority of countries where district heating has been successfully introduced, there had been limited or no centralised gas networks in place prior to the development of the district heating networks. This meant that individuals tended to be using individual heating options (oil, wood, coal) that did not already benefit from the economies of scale associated with a centralised transmission or distribution network. Therefore, although consumers still faced costs to install DHNs, the benefits were better defined and larger than they are where there is existing (and regulated) network delivery infrastructure for gas and electricity, such as in the UK.

Within the Netherlands where the gas networks are more developed, district heating take up is lower. This is despite widespread use of CHP within industry in the Netherlands. In Denmark, the competition with other fuel sources was overcome through mandating connection to district heating systems in designated DH zones.

In Finland, district heating did not have to compete with existing networks since much of the system was introduced as towns were expanded from the 1950's. The lack of a requirement to retrofit heat networks and substitute for, or compete with, other centralised fuel supply infrastructure meant that networks could achieve a critical mass more easily. This highlights the attractiveness of a business model that focuses initially on new developments (the growth in which was outside the scope of this study).

4.4.4 Mains cost for district heating

Developers have found that costs in the UK for civil works, such as pipe works, are more expensive than in other countries across Europe. One explanation may be the immaturity of a reliable district heating supply chain. Historically, district heating schemes in the UK have had problems with equipment being fit for purpose and/or reliable; including problems with:

- compliance with air regulations;

- limited stocks, import availability;
- manufacturing capacity;
- space in buildings for boilers, and
- fuel storage.

While some of the equipment supply issues appear to have been resolved, there is a recognised shortage of skills in the UK and limited domestic contractors or suppliers with experience in this area. During the course of this study, concerns have been raised regarding the availability of UK companies to provide:

- appropriate design of schemes;
- installation and maintenance services;
- good geographic coverage of required services; and
- training and awareness among architects, engineers, and plumbers.

Because of the lack of familiarity with the techniques and processes required, contractors often apply high risk premia to their quotations for work – especially given the potential large contractual exposure they face if construction is delayed.

Mains costs are also increased by the logistical complication of laying district heating mains. Installing and coordinating heat networks in existing streets significantly increases the cost of the network, on some estimates leading to a potential doubling of costs relative to new build developments. Streetworks are complicated by cross boundary issues between local authorities as well as the need to involve transport authorities, all of which can add cost and programme delay to decentralised energy schemes. Coordination is a major cost.

4.4.5 Summary of project cost issues

There are several potential factors that are raising costs artificially. These include:

- lack of local expertise and an established supply chain – this may raise the cost of procurement (there is prima facie evidence that network development costs in the UK are higher than in markets with more established district heating systems). This reflects a lack of experience amongst civils contractors in the UK and hence a high risk premium being added to the cost;
- lack of standardisation in contract structures for district heating developers (though there is ongoing work in the industry to address this);
- competition against the sunk costs of existing networks;
- inability to access full revenues from CHP-based schemes because of the incentives in current distribution charging methodologies to pursue the ‘private wires’ approach; and
- significant additional marketing costs if sufficient volume commitments are to be achieved upfront.

4.5 Access to capital

One attraction of DHNs for private investors is the expected longevity of projects. Typically investors find long term projects attractive, provided that the revenue stream is sufficiently secure and generally based on the concept of ‘availability’ rather than short term market demand. The more that can be done in structuring a project to ensure a long term stable cash flow, the more attractive a project will be to private sector investors.

Private sector equity investors in DHN projects could potentially come from a range of investor classes. Different classes of investor have different objectives and ability to take on risk. Investors in the early stages of projects – design and construction – would probably come from a relatively small group of investors who may be willing to invest the time in understanding the risk profile and potential for DHN projects and will seek a commensurate high return on their investment. There are a range of infrastructure funds who may consider such projects under the right circumstances. That is, provided that they can become sufficiently confident that the revenues of the project will be sufficiently secure. Such investors would seek to hold their investment for the development and construction phase of the project. In general, these conditions do not exist in the UK at present.

Looking forward, if these initial barriers can be overcome, then, in the operational phase, a wider range of investors could be interested in locking into a long term investment, with the risk profile being reduced through the demonstrable operation of the asset. Initial investors will often sell down their investment at this stage, the lower risk profile of the project allowing them to achieve a gain on their investment and securing their higher required return.

4.6 Institutional issues

Several aspects of the current regulatory and institutional framework in the UK have been suggested as potential barriers to further district heating development. These include:

- electricity distribution charging arrangements;
- public perception of DHNs; and
- the role of, and incentives on, the public sector in promotion of district heating schemes.

4.6.1 Distribution charging

In the case of electricity from CHP for district heating, current Government policies may be unintentionally driving developers down the routes of single isolated CHP systems, the so called ‘private wires’ approach.

One example of this is the treatment of electricity distribution charging. It appears that currently these charges do not reflect the reality of transferring power across the electricity network. In addition the market for trading electricity disadvantages exports from decentralised energy as participation costs are high and low prices are available for the relatively small amounts produced compared with large central plants.

This perversity alongside the other costs of participating in the electricity market means that district heating developers may avoid full connections to the networks. The implication of this policy is that the companies would not get full value from CHP-based schemes.

These issues have been assessed by Ofgem and it was hoped that some would be resolved within a ‘single charging mechanism’ for electricity distribution. However this process recently broke down and has left any changes in an uncertain position.

4.6.2 Public perception

In some countries residents would prefer district heating to alternative measures, due to the perceived reliability and availability of heat from a centrally controlled district heating scheme compared with individually owned and operated systems. In Finland for example, district heating is seen as the incumbent heat supply technology in cities, and individual gas boilers are perceived as unreliable. This problem of convincing customers in the UK (without mandating it) to switch to district heating, given its UK reputation, will be a key obstacle to overcome in ensuring sufficient take up.

Although consumers are interested in green issues, there is as yet little evidence to suggest that they will pay more for them. This adds to the difficulty in making an economic case either for retrofitting or for new development.

4.6.3 Public sector involvement

The example of those European countries which have successfully developed extensive DHNs strongly suggests that any drive to deploy low/no-carbon heat through district heating must be led by the public sector. Potential private sector investors in DHNs will be looking for underwriting of the identified project risks by the public sector and the natural public sector counterparties in urban areas are the local authorities that:

- wield relevant planning powers, including over new development; and
- own, or have close relationships with the owners of, the social housing and public buildings which are likely to form the core of developing schemes.

Some aspects of the role of the public sector may be adding to the barriers facing district heating developers.

4.6.3.1 Conflict with PFI schemes

For example, most studies into district heating have highlighted the need for an anchor load to act as a catalyst for future development. But there is anecdotal evidence that many of these potential loads – for example, hospitals or schools – have been developed under long term PFI contracts which lock in conventional energy supply arrangements and make it impossible to access them as drivers of new schemes.

4.6.3.2 Building regulations

Current building regulations may be encouraging developers to install electric heating into new buildings rather than considering district heating and CHP alternatives. Some developers have pointed to inconsistencies in the interpretation of building regulations and other planning policies across local authorities and other Government departments that may disadvantage district heating networks as a prospective technology option. These inconsistencies often occur because the different, but linked, policy documents are updated and evolve over different timescales.

One area of concern raised was in relation to the 'Merton rule'. In particular some local authorities allow the use of low carbon sources rather than just renewables while others do not. This confusion and lack of clarity will often lead to developers avoiding the CHP or gas-based district heating options. Further education of planning officers, in the form of training or guidance on the full range of heating options, may prove to be beneficial.

4.6.3.3 Coordination of Local Authorities

One barrier faced by developers is coordination between Local Authorities. An example of this in practice is the LDA scheme. They have approached the eco-friendly boroughs (such as Barking) but will need to get others involved to make the scheme a success; and many London boroughs are not attuned to Energy Planning. This involvement will include the various boroughs incorporating DHN into their long term plans.

Planning policy for energy assessment and heating networks may not adequately address the issue of connecting existing buildings to decentralised energy supplies. An example raised was inefficiencies of the London planning policies 4A.4 and 4A.5.

There is also a potential conflict between the requirement of planning authorities to enforce the delivery of carbon reduction measures by the time a building is completed and the timeframe over which heat networks are built out. Buildings which could connect to future heat networks may instead be required to invest in on-site measures which provide lower carbon emission reductions but allow a planning authority to say that targets have been met.

One further problem is that social landlords are restricted by Housing Corporation regulation from recouping investments in decentralised energy systems, which result in lower energy bills for tenants, by commensurate increases in rent. This limits the potential for investment in heat networks for large parts of the existing building stock most suited to decentralised energy.

4.6.4 Summary of institutional issues

Our research has found that existing engagement by local authorities in the promotion of DHNs is variable for three main reasons:

- compared to education and health, energy is not a high priority for local authorities;
- the application or interpretation of building regulations and planning policies by local authorities (and developers) is not transparent or consistent; and
- local authorities are relatively inexperienced in this area.

These institutional issues reinforce the economic barriers identified above because without pro-active engagement, unacceptable risk will remain and private sector investment may not be forthcoming.

4.7 Carbon price

All low- or zero-carbon heat solutions are disadvantaged by the fact that the full cost of carbon (as given by the government’s shadow price of carbon) is not reflected in the cost of conventional heating or electricity production.

The existing market framework and regulatory environment does not adequately reward the carbon emission reductions from decentralised generation, or provide investors with a firm ‘carbon price’ signal. Carbon savings from gas fired CHP are not recognised financially, in the way that Renewables Obligation Certificates (ROCs) reward renewable electricity provision. Incentives such as the Climate Change Levy have not proved to be effective at promoting decentralised energy. Further, the EU Emissions Trading Scheme only applies to larger schemes and the level of support is small compared to, for example, ROCs.

Removal of this market failure would enable district heating, and stand-alone renewable technologies to realise their comparative advantage over inefficient, high-carbon heat and power options. However, as already shown, the removal of this distortion would not materially alter the commercial position of DHNs or the stand-alone renewable alternatives.

4.8 Summary of potential barriers

A summary of the potential barriers to district heating discussed above is presented in Table 5.

Table 5 – Barriers to district heating

Project costs	Project risks	Policy and regulation
High upfront capital costs:	Uncertain volume and customer off take.	Planning constraints.
Cost and availability of finance.	Impact of fuel price uncertainty	Distortions of existing support mechanisms.
Inevitable lead time.	Construction delays and delivery.	Impact on established energy market structures.
Distribution and type of UK housing stock.	Coordination of elements of construction.	Lack of long term commitment to low carbon technologies and support
Customer transaction / inertia costs	Policy uncertainty.	Impacts on customer choice.
		Lack of an established heat market.

Source: Pöyry Energy Consulting and Faber Maunsell

5. UK POTENTIAL FOR DISTRICT HEATING

While technically, district heating schemes may be applied to the whole housing stock, this is not a realistic figure for its national potential. Our analysis of the UK potential for district heating is grounded in economics – i.e. it is based on the volume of heat that may be provided most economically through district heating as opposed to using other technologies (conventional or alternative low-carbon options).

Since current policy and market conditions still leave district heating largely uncompetitive relative to the conventional baseline, the national potential model also investigates how broad changes in the policy or market environment influence economic potential by addressing the barriers to entry identified in Section II of the report. For this study, the focus is on broad changes in the economics of district heating rather than detailed assessment of feasible policies. Consequently, the results look at the impact of the following:

- effective targeting of specific building types/customer groups;
- reductions in CAPEX costs of schemes;
- reductions in the risk associated with schemes, and hence the appropriate discount rate to employ; and
- removal of the carbon pricing externality (i.e. applying the shadow price of carbon across all heat- and power-related emissions) – what we call the 'pure' market situation.

Prior to presenting the main results of the analysis we provide a quick overview of the structure of the national take-up model and the key underlying assumptions.

5.1 National take-up (Community level) model

The analysis is conducted using our national take-up, or community level, model of the UK building stock, a summary of which is provided in Figure 23. The model simulates decisions regarding the take-up of district heating schemes at different levels of disaggregation of load and building type. It takes as inputs the costs of the technologies (and how these may change over time[8]), and the heat load that the systems are required to serve.

It will only introduce district heating where it has a lower net present cost than the conventional baseline for the same heat load.[9] The heat load represents an aggregation of individual building types into tranches and communities – all three of which are described in more detail below.

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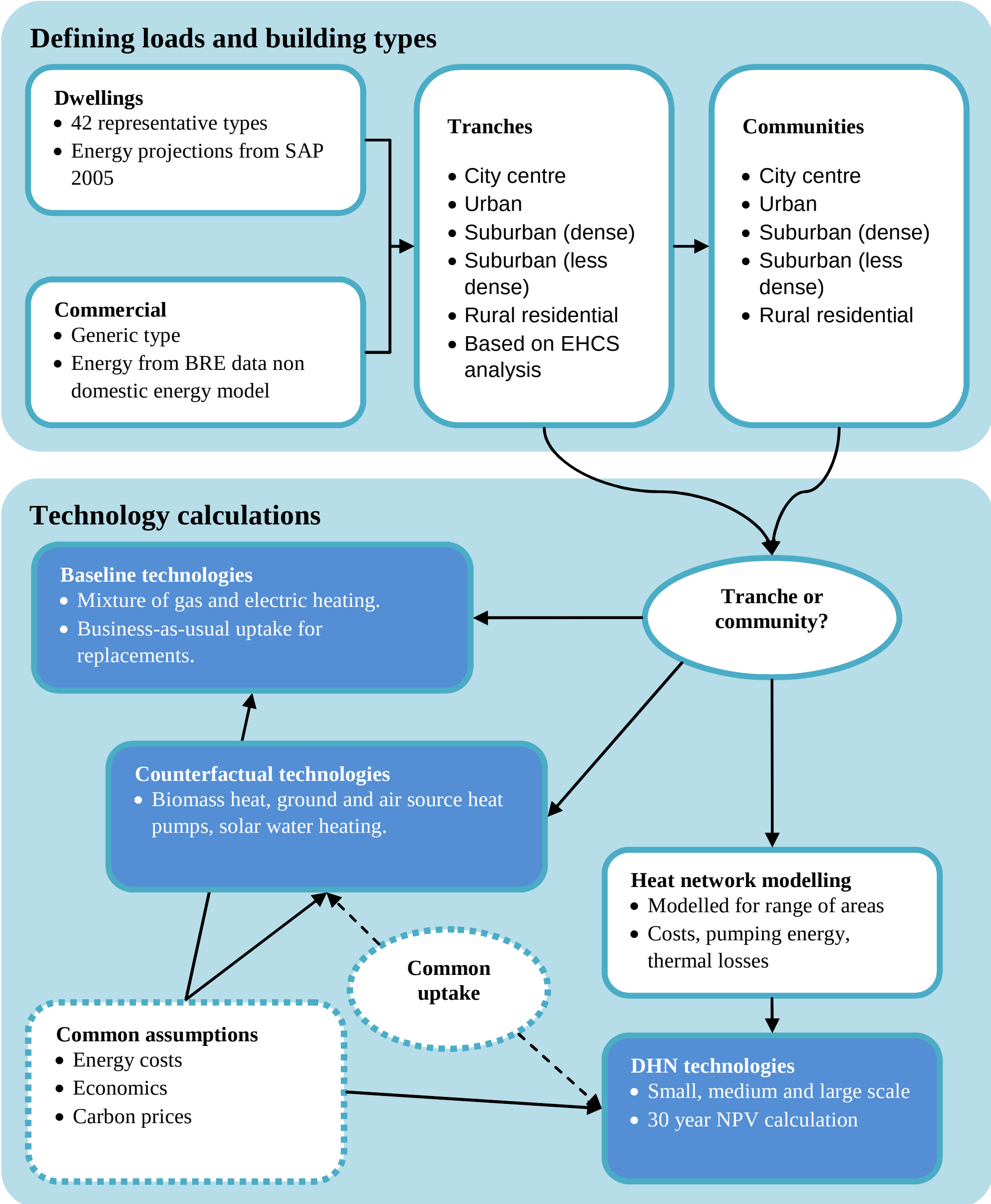
8 This includes assumptions on movements in input fuel prices as well as any reductions in capital costs in low-carbon alternatives that may arise through learning effects.

9 The decision is both in relation to conventional systems and low-carbon alternatives, but it is generally the case that the conventional baseline remains more cost-effective than the alternatives.

Figure 23 – Stylised representation of the national take-up (community) model



Source: Faber Maunsell

5.1.1 Building Types

Individual building types represent the lowest level of energy load. The building types used in the model are the basis of the bottom up approach to the modelling of DHNs, providing a bottom up estimate of energy loads and peak thermal demands. The model consists of a number of dwelling types, taking into account form, age, and existing heating energy type, with energy loads calculated using the Government's Standard Assessment Procedure (SAP 2005) on an individual dwelling basis. Commercial buildings are modelled using a combination of data obtained from the BRE detailing the thermal demands of non-domestic buildings in each postcode district. Types will include primarily retail and offices, with energy loads based on either BRE data or benchmarks. Appendix A provides more details on analysis of domestic and non domestic buildings.

5.1.2 Tranches

A number of different building types make up a single 'tranche'. The tranches and the indicative building types which they contain are:

- *City centre*. Mostly retail and offices with a small element of high density housing (flats).
- *Urban*. A mixture of retail and offices, with high density housing consisting mainly of flats and dense terraced housing.
- *Suburban dense*. Entirely residential consisting primarily of dense terraced housing, flats, and dense semi-detached housing.
- *Suburban less dense*. Entirely residential consisting mainly of semi-detached housing with a small element of low rise flats and less dense terraced.
- *Rural residential*. Typically rural housing estates and large villages or satellite housing estates to towns. Mostly semi-detached housing but with other minority elements.

The tranches represent the lowest level modelling for heat networks, allowing an analysis of small scale systems on a mix of building types. A DHN model could be based on part of a tranche or 'sub-tranche' (for example a small fraction of a town's suburban region) or an entire tranche (the entire suburban area of a town).

5.1.3 Communities

Communities are the top level of DHN modelling. A community represents an entire built-up area and consists of a number of different tranches. Example of communities include; cities, towns, and conurbations. Communities are simulated by modelling a number of distinct sizes falling into different size ranges based on census data [10]. Within each community, the breakdown of tranches varies – for example, a community of over 1 million people will have a greater fraction of city centre than a community of 100,000 people. A small community of 5,000 people would have no city centre tranche component.

Figure 24 illustrates the structure described above. At each level, the type of DHN system potentially suitable is indicated.

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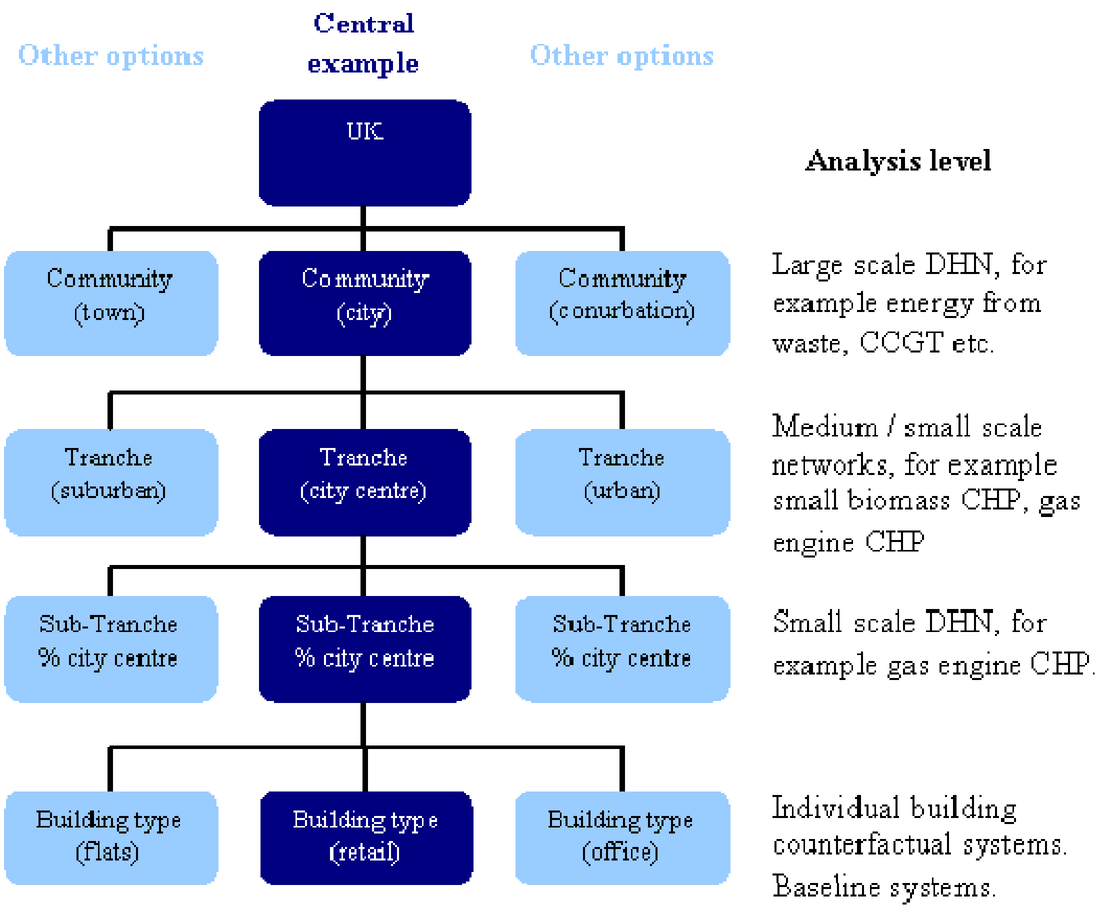
[10] The authors would like to acknowledge the help of Professor Anthony Champion from School of Geography, Politics, and Sociology at Newcastle University for his assistance with defining community sizes using census data.

Figure 24 – Structure of the model



Source: Faber Maunsell and Pöyry Energy Consulting

5.1.4 Model input assumptions

Two broad sets of input assumptions have been constructed for the community model:

- current policy assumptions – this reflects the continuation of the existing policy framework with respect to, in particular, ROCs, LECs and the level and coverage of EU ETS carbon prices; and
- 'pure' market assumptions – where the existing policy mix is replaced with a single carbon price set at the projected shadow price of carbon over the time period of the analysis.

These variants allow us to compare changes that may occur incrementally within the current policy framework as well as the implication of fundamental changes to the current carbon pricing regime.

The assumptions for these two separate approaches are outlined below in Table 6 and Table 7.

Table 6 – Current policy assumptions

Variable	Assumption
Discount rate	10%, 6% and 3.5%
Period assessed	2008 – 2050
Uptake (after 10 years)	80%; 40% in first year
Energy prices	DECC central case
Electricity revenue	DECC central case
CO_2	Included at the DECC central case, in fuel for sources covered by the EU ETS and in electricity generation
ROCs	Constant at the current buy out price
LECs	Constant at the current level

Source: Pöyry Energy Consulting and Faber Maunsell

Table 7 – Pure market assumptions

Variable	Assumption
Discount rate	10%, 6% and 3.5%
Period assessed	2008 – 2050
Uptake (after 10 years)	80%; 40% in first year
Energy prices	DECC central case
Electricity revenue	DECC central case
CO_2	Included throughout at the Shadow Price of Carbon
ROCs	Not included
LECs	Not included

Source: Pöyry Energy Consulting and Faber Maunsell

5.2 Summary of the potential

Table 8 summarises a range of scenarios that reflect different assumptions on the key parameters of the modelling:

- the policy regime;
- the global discount rate;
- the heat network capex reduction; and

- the customer base targeted.

Table 9 presents the impact of these different scenarios on the economic potential of district heating using our community model. The full results for all of our scenarios are provided in Annex F.

Table 8 – Summary of scenario parameters

Scenario	Policy	Discount rate	CAPEX reduction	Customers
1	Current	10%	0	All
2	Current	10%	0	Electric heated
3	Current	6%	0	All
4	Current	3.5%	0	All
5	Current	6%	20%	All
6	Pure	10%	0	All
7	Pure	6%	0	All
8	Pure	3.5%	0	Social housing
9	Pure	3.5%	0	All

Table 9 – Comparison of economic potential of district heating under alternative scenarios

Scenario	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand [11]	Technology used
1	-	-	-	-	-
2	0.07	11.4	1.5	0.3%	Waste heat
3	-	-	-	-	-
4	1.7	15.6	18.9	3.2%	Waste heat, Large biomass steam turbine, Large engine natural gas
5	1.6	14.6	18.3	3.1%	Waste heat, Large biomass steam turbine
6	-	-	-	-	-
7	0.3	11.4	3.1	0.6	Waste heat
8	1.1 – 1.4	15.6 – 16.7	10.1 – 12.1	1.7 – 2.0%	Waste heat, Community boiler biomass
9	3.3 – 7.9	15.6 – 26.3	34.6 – 82.8	5.8 – 13.9%	Waste heat, Community boiler biomass

Source: Pöyry Energy Consulting and Faber Maunsell

The initial cost effectiveness comparison implies that there is little, if any, economic potential for district heating schemes to penetrate the existing housing stock. This is illustrated through the results of the main scenarios investigated under the current policy regime. With no change in the policy and market environment, the economic potential is likely to be limited to a very small segment of the market – the highest cost electric heating customers – and would contribute only a minor 0.3% increment to district heating's share of the national heat market.

11 The results for the 'Percentage of UK heat demand' are based on an assumed UK heat demand of 598TWh.

The discussion on policy has identified several possible options, or combinations of options, to increase the potential. These include:

- reducing risk and hence lowering the applicable discount rate;
- reducing the capital cost of network investment in district heating schemes; and
- fully rewarding the emissions savings associated with more efficient/lower-carbon schemes through the carbon price.

Generic changes have been made to the input parameters to our community-level model, to represent the effect of possible policy initiatives; the impacts of these changes are described below.

5.2.1 Economic potential with lower discount rates

In previous studies of the potential for district heating, it was found that there was significant potential at discount rates of around 6%, but very little potential above a 9% discount rate. The current modelling reinforces the latter finding, but finds that the potential does not increase substantively when the discount rate falls to 6%. In reality, it finds that, without any additional changes to the current policy framework, economic potential does not increase until discount rates are reduced to 3.5% (i.e. the project is effectively completely de-risked and a social rate of time preference is applied).

Under these circumstances the contribution of district heating in the fuel mix may more than double, from around 2% to 5% of total UK heat demand, and would include around 1.7million household connections, still well below the 4 to 6 million range of previous studies.

5.2.2 Economic potential with lower capital costs

Since the major cost competitiveness barrier is the high upfront capital cost, the implication of reducing capital costs has also been investigated. A proportionate reduction in capital costs of 20% has been modelled in the first instance. If a discount rate of 10% is still required, then there is no impact on the economic potential. Indeed, if no change occurs in the discount rate then capital cost reductions in the order of 50% may be necessary to incentivise additional take-up of district heating.

However, if a 20% capital cost reduction can be made in conjunction with a lowering of the required discount rate to 6%, then an economic potential of around 1.6 million households is achievable.

5.2.3 Economic potential with pure carbon pricing

If the current policy regime is replaced with a pure carbon market model, then it remains the case that there is very little potential without a change in the discount rate. The maximum potential for displacing conventional heating by DHNs could be achieved when:

- district heating development is completely de-risked (i.e. a societal discount rate of 3.5% applies); and
- the full shadow price of carbon is applied to the combustion of fossil fuels (in conventional gas heating, in electricity generation and in CHP).

With these ‘pure market’ assumptions, minimising carbon abatement cost against conventional heating across the range of low/no-carbon options suggests that the maximum national potential for DHNs may be in the range of 3.3 to 7.9 million households and 15.6 million to 26.3 million square metres of non-domestic floor-space . This corresponds to an additional share of district heating in the heat mix of between 6% and 14%.

A low discount rate of 3.5% may not be feasible for many projects. As has been previously discussed, the lowest levels of risk may be achievable when there is some form of public sector involvement to minimise the risk. This is less likely to be in terms of investment in the project, and more likely to be in terms of guaranteeing load. Consequently, we have considered a sub-scenario of the pure model, focussing solely on social housing. Though the total market is therefore limited, it still delivers an economic potential of 1.1 to 1.4 million households under the pure market case. This indicates that the public sector may be able to kick start the development of DHNs with appropriate incentives.

5.2.4 Insights from the community model

The results from the community modelling have allowed us to highlight the following conclusions:

- if a social discount rate is applied and support is 'pure' (i.e. solely through a shadow carbon price on all emissions), then the potential is significant;
  - between 6% and 14% of UK heat demand (35 -83 TWh);
- more realistically, if this 'low' risk option is applied only to social housing then an additional 2% of total heat load may still be attainable;
- around 3% of total heat demand can be met cost-effectively if CAPEX is reduced by 20% and schemes only require a 6% rate of return; and
- the schemes work more effectively at scale, utilising waste heat. There is sufficient power generation capacity within a radius of 15km of major conurbations to deliver the required heat.

5.3 Conclusions

The main points to take from this analysis are that:

- prospects for commercially viable district heating technologies look poor, but can improve depending on the level and type of incentives offered; and
- in built-up areas, DHNs are a more cost-effective alternative to most other low- or no-carbon options (at least for the composite dwelling construct we use).

While some non-DHN renewable options have similar economics to DHN, DHN is likely to offer a much larger volume of carbon abatement. This is because of practical restrictions on the delivery of non-DHN renewables and because DHN enables the application of CHP and its relatively unrestricted source of non-renewable CHP fuel.

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6. DELIVERING THE POTENTIAL

The fact that there appears to be scope for a major contribution from district heating to carbon reduction targets in the UK under appropriate circumstances begs the question of how to ensure that district heating can be encouraged. A range of policy initiatives have been used in the UK and have to an extent promoted some expansion in the district heating sector including:

- the Community Energy Programme which operated from 2002 to 2005 financed a number of new schemes and refurbishment of existing schemes;
- suppliers have financed new and existing schemes under their EEC obligations; and
- climate change targets incorporated into planning instruments like the London Plan have resulted in proposals for a number of schemes.

However these policies have yet to, and are unlikely to, incentivise DH to the extent that will be required in order to meet the UK renewable heat and carbon obligations.

On the basis of our analysis, the main options revolve around three elements:

- reducing the commercial risk of DHNs;
- reducing capital costs for DHN developers; and
- increasing the revenue streams for DHNs to compensate for higher costs (though this is less desirable as it may not incentivise appropriate cost reductions in the longer-term).

6.1 Reduction of risk

Our focus on the reduction of risk is on creating an environment where the uptake risk is reduced. It therefore centres on measures to guarantee minimum (or anchor) loads for the development. Sensitivity analysis has shown that, where a guaranteed load of around 80% of the total network capacity can be secured up front through the provision of long-term contracts, etc, then this significantly reduces the risk of stranded assets from oversizing.

Addressing this element of risk has two major challenges – identifying suitable loads and securing their custom for a sufficient period of time.

In many countries where district heating is successful suppliers are able to offer long term contracts for heat (up to 20 years) to secure revenue. In the UK this may appear counter to current energy policy[12] leading to potential unintended consequences for:

- current energy market competition – it is possible there may be distortions in competition between heat and other fuels if heat competition develops on a sufficient scale; and
- heat customer protection – if customers (particularly domestic customers) are tied in to long-term arrangements with a district heating supplier, then it may raise concerns over monopoly power or regarding standards of service.

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[12] However some aspects, such as the RO effectively incorporate a long term commitment.

Either may require some form of government intervention, an issue that is considered in more detail later.

To guarantee volume, we must create the appropriate incentives on heat consumers to consider district heating as a viable option for their energy needs. In general, given the scale of a scheme, this will need to involve some coordination amongst potential users and is therefore best suited to the following three groups:

- new developments;
- local authorities/housing associations/public buildings; and
- large commercial buildings – though it should be noted here that this group of customers may currently have stronger incentives for developing low-risk stand-alone systems.

Whilst district heating will be best suited to these groups, the benefit will be greater still in areas with accessible waste heat, high demand and electrically heated dwellings. In many countries (although to different extents) central planning has been used in the development of district heating. The most extreme case has been in the Danish market in which the municipalities (under central government guidance) set out zones for different heating options, but in both Finland and Austria planning by the municipalities has been vital in developing district heating.

6.1.1 District heat zones

These are zones in which virtually all buildings must be connected to the district heating system. The idea is that, just as it does not make sense to have two competing district heating networks, it does not make economic sense to develop two competing heating systems such as parallel gas and district heating networks. Obviously, zones eliminate the possibility of retail competition in the heat market, but proponents consider that this is justified by a lower total cost, which is in the interest of consumers.

There is weaker form of district heating zones, whereby a local authority may decide that all properties in an area should connect to district heating. But instead of mandating the connection the local authority may undertake some form of active marketing, for example incentives or connecting the government owned property.

One of the key elements to any DHN is the extent to which connection is voluntary. If connection is voluntary, then it may be expected that contractual terms would cover the main elements of the relationship between the producer and consumer in terms of price levels and trends or indexation, minimum standards of service and arrangements in the event of operational failure (i.e. some form of supplier of last resort facility).

The problem with this is that such schemes are unlikely to incorporate a high level of residential customer connections unless done through housing associations, local authorities or new developments, since individual customers are prone to inertia and very risk averse and the private benefits may be small. As such, it would limit the economic potential of schemes.

6.1.2 Increasing local authority responsibility

We have already highlighted that successful schemes across Europe have generally had a strong public sector involvement and that, in the UK, this responsibility would most naturally sit with local authorities.

Of course local authorities will need to form relationships with other public bodies, with developers, with contractors and so on. Special-purpose vehicles might be established to implement schemes, depending on local circumstances. However, the ultimate drive for the development of district heating in their areas should lie with the local authorities.

Our analyses have shown, however, that we would not see an increase in deployment without decisive action from central government, in two areas:

- setting the policy framework within which the local authorities will operate, and imposing the appropriate duties and providing the appropriate powers; and
- providing assistance and guidance to local authorities on matters such as identifying heat demand, planning for district heating development, organisational options for that development, appropriate commercial arrangements, and technical quality control.

This suggests the creation of a body within central government, or closely associated with it, to provide these services and act as a 'champion' for DHN development.

6.1.3 Potential options

Options for reducing project risk include:

- adjustments to planning and building regulations requiring developers of new buildings to consider DHNs along with other heating systems – the benefit of new buildings is that the DHN is not competing against an incumbent network with large sunk costs, but their problem is that heat load will be lower due to better underlying building efficiencies;
- requirements on local authority and government organisations to consider DHN – this may include an obligation or mandating; and
- full mandating of connection in designated district heating zones, along the lines of the policy pursued in Denmark.

These essentially encourage the establishment of large anchor loads through appropriate incentives on potential consumers.

In addition, if the terms of payment for DHN providers were altered, this may also reduce the risk. This may be achieved through guaranteed availability payments for network providers – similar to those provided for in PFI contracts.

6.2 Reducing capital costs

On the investors' side the key risk is high upfront capital costs. Three potential mechanisms to mitigate this would be:

- financial incentives for the prime movers;
- capital grants schemes for network cost. However historically there have been a number of problems with capital grants, both in terms of 'what they are available for' and the administration involved in submitting and supporting applications; and
- low cost borrowing for district heating mains. This could provide a mechanism for the development of decentralised energy supply, where energy centres are financed separately from the pipework infrastructure.

Many renewable heat technologies have high up-front costs relative to non-renewable alternatives, and therefore would benefit from up-front support. However certain technologies (e.g. biomass) may also require some form of ongoing support, because the variable cost of fuel may be higher than that of non-renewable alternatives.

Providing grants that are high enough to defray both up-front, and ongoing costs, could leave the scheme open to abuse. This would compromise the effectiveness and cost-effectiveness of the schemes. On top of this, the necessary scale of a grant program could be large, in which case the administrative burden would be substantial. It is not clear whether economies of scale associated with a single centralised body to oversee grant funding would outweigh the potential benefits of a more competitive framework under other policy options.

To mitigate the high capital costs, we suggest the following possible policy responses:

- provision of capital grants or subsidies to potential developers – this may be achieved through deeming of potential revenues achievable through a renewable heat incentive as well as via specific capital grants; and
- availability of low cost borrowing facilities for the provision of the heat mains.

To the extent that capital costs are temporarily high and may fall to continental European levels over time, any capital grant scheme could be limited to support a small number of specific starter schemes, designed both to illustrate the feasibility of installing a major heat network, and to provide the catalyst for the cost reductions and development of a local supply chain.

6.3 Increasing potential revenue streams

The focus here is initially on the effective unit price of the heat (and power for CHP) provided by the developer. Options here are generally not DHN specific, but include:

- comprehensive carbon pricing framework either through expansion of the existing regime or through carbon taxes;
- renewable heat incentives;
- CHP incentives or obligations; and
- revision to distribution charging arrangements that will enable CHP-based schemes to achieve the full value of their electricity output.

6.4 Is there a need for regulation?

The need for regulation arises when there are insufficient constraints on the behaviour of the service provider through the operation of the competitive market. In these circumstances, the service provider may be able to exploit its position by pricing excessively and/or discriminatorily, providing sub-standard service or operating inefficiently in the longer-term, thereby increasing costs and reducing the benefits of innovation to consumers.

There are several characteristics of the likely operation of DHNs, and of the policy and institutional arrangements necessary to realise economically efficient DHNs, suggest some form of regulatory regime may be required. These include the following:

- It is costly to reverse the initial decision to connect by customers and thus there may be some form of lock-in that the heat provider is able to exploit. This may be particularly true for domestic customers, where maintenance of a 'dual fuel' capability may not be cost-effective.

- The introduction of a DHN may not have the same benefits across all customers and it may thus be necessary to regulate levels and structures of charges to ensure an efficient and fair pricing regime. This is more likely if connection to the DHN has been mandated in an existing location (which may be the only way of overcoming the externalities associated with provision of heat in this way).
- The heat grid, in the longer-term, may become unbundled and subject to third party access rules if there is a push towards competitive heat generation in a similar manner to in electricity and gas.

6.4.1 Price controls

Prices could be regulated or monitored by the competition authorities. In the latter case action may be taken if specific complaints are made. Types of price control involve:

- ex ante price-controls – formal price controls such as previously imposed on the public electricity and gas suppliers, or on use of system charges for TPA; and
- relative price regulation – where the price charged to the user is linked to the charges for competing means of providing heat and where there is existing competition. This has been used for independent gas transporters, and already exists for some district heating schemes in the UK (e.g. Sheffield).

Price controls could provide protection for domestic customers, however it is open to debate as to whether this can be done through existing consumer protection laws or whether direct price regulation would be needed. Other protection measures would include quality of service incentives and contracting standards.

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7. SUMMARY AND CONCLUSIONS

District heating currently contributes only 2% to the UK's heat supply and our analysis suggests that there is limited scope for conversion of existing buildings to district heating under current market and policy arrangements. While district heating may represent a viable alternative for new domestic and non-domestic developments, the high costs of constructing heat distribution mains means the technology is not commercial compared to conventional gas and electric heating systems.

High potential under correct circumstances

However, under appropriate conditions, district heating could significantly increase its contribution to UK building heat demand. To achieve this, the main economic barriers facing new projects – high risk and upfront capital costs – would have to be addressed.

Our analysis has shown that:

- 5% of UK heat demand could be met from district heating with a discount rate of 6% and 20% lower upfront CAPEX costs;
- 10% of UK heat demand could be met with a discount rate of 5% and 25% lower CAPEX costs; and
- 16% of UK heat demand could be met with a discount rate of 3.5% and with carbon priced at the government's shadow price of carbon.

Understanding the drivers of risk and cost for district heating developments is therefore necessary if we are to identify effective means of delivering investment environments in which these potentials can be realised.

Perception of risk in the private sector

Our research has highlighted several areas of risk private sector investors in the UK identify with district heating project development:

- technology risk – lack of familiarity with the concept of district heating and the associated business models;
- construction risk – the need to coordinate construction of heat plant, heat mains and consumer connections increases the complexity of the development;
- off-take risk – the need to identify and secure commitment of anchor loads to underwrite the initial development and the uncertainty over the ability to acquire new customers in the commercial and domestic market in the existing building stock;
- maintenance and management – lack of experienced personnel in utilities or contractors to operate a district heating system; and
- pricing risk – uncertainty over drivers of future heat tariffs, ability top recover costs and potential for future regulatory intervention on allowable tariff charging arrangements.

Some of these risks the market can, and does, address routinely. However, the need for coordinated development of a network with a potentially diverse range of customers and heat sources means there is often residual risk that the market cannot effectively deal with. In these cases policy intervention may be necessary to achieve the desired outcome.

Figure 25 – Overview of Market and Government de-risking strategies

Risk	Market Ability to De-Risk	Government Ability to De-Risk
Technology	•Raise level of understanding through existing schemes in Europe	•Education and facilitation of international knowledge transfer •Project subsidies for first X MW of new schemes (kick-starting local market)
Construction	•EPC/EPCM contracts •Market insurance	•Capital Grants •Project subsidies for first X MW of new schemes •Construction cost/delay insurance •Planning system amendments
Off-Take	•Securing commitment for anchor loads •Scaling of project (limit low utilisation risk)	•Guaranteed demand from central and local government premises •Promotion of DHNs through planning and development strategies •Connection subsidies for new customers •Mandated zoning for DHNs •Tax incentives •Low carbon heating obligations •Availability payments for approved projects
Maintenance and Management	•Long term contract with utility/constructor	•General local supply chain development/support
Pricing	•Long term supply contract •Appropriate indexation in heat tariff and fuel supply contracts	•Carbon tax •Consumer subsidies/discounts •Floor price guarantees for supplier •Formal price-control regulation

Source: Pöyry Energy Consulting

Need to lower risk and capital cost

We believe, and international experience has shown, that the role of the public sector (and local authorities in particular) is crucial in enabling developers to construct low-risk district heating business models. Local authorities have the relevant planning powers and the ability to coordinate between developers and potential consumers given their network of relationships with controllers of large heat loads (e.g. social housing groups, NHS Trusts and public buildings).

Further initiatives from central government are needed to incentivise more active engagement across local authorities:

- establishing a clear policy framework within which the local authorities will operate;
- imposing the appropriate duties on, and providing the appropriate powers to local authorities; and
- providing assistance and guidance to local authorities on district heating feasibility.

Such a role could be the responsibility of a body within central government, or closely associated with it, to act as a ‘champion’ for DHN development.

This framework would need to be supplemented in the medium-term by further measures to facilitate the development of a robust local supply chain for district heating network development. Comparison of UK and European costs has highlighted that estimated UK civils costs are more than double those in European countries with more established district heating businesses. Much of this difference has been attributed to lack of experience in laying district heating mains and hence high risk premia being applied by contractors.

To the extent that this is due to immaturity in the supply chain, a limited capital grants scheme, to support a small number of specific starter schemes, may be appropriate both to illustrate the feasibility of installing a major heat network, and to provide the catalyst for the cost reductions and development of a local supply chain.

Comparison with stand-alone renewable technologies

A further insight of the analysis is that even if zero/low-carbon technologies were to be fully rewarded for the carbon emission savings they offer relative to conventional systems they remain more costly. However, the study has shown that in built up areas, zero/low-carbon options involving DHNs are likely to offer lower carbon abatement costs than the other low carbon technologies, especially if they are able to access large heat loads enabling them to utilise low cost waste heat from large-scale power stations.

In consequence, should Government decide to intervene to support the development of stand-alone renewable heat in built-up areas, it would be inconsistent not to do so for the district heating options. A further implication of this is that stand-alone renewable heat technologies may be best suited for off gas-grid locations and areas of less-dense housing, where the heat mains costs start to rise substantially and district heating technologies are not suitable.

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ANNEX A – MODELLING METHODOLOGY

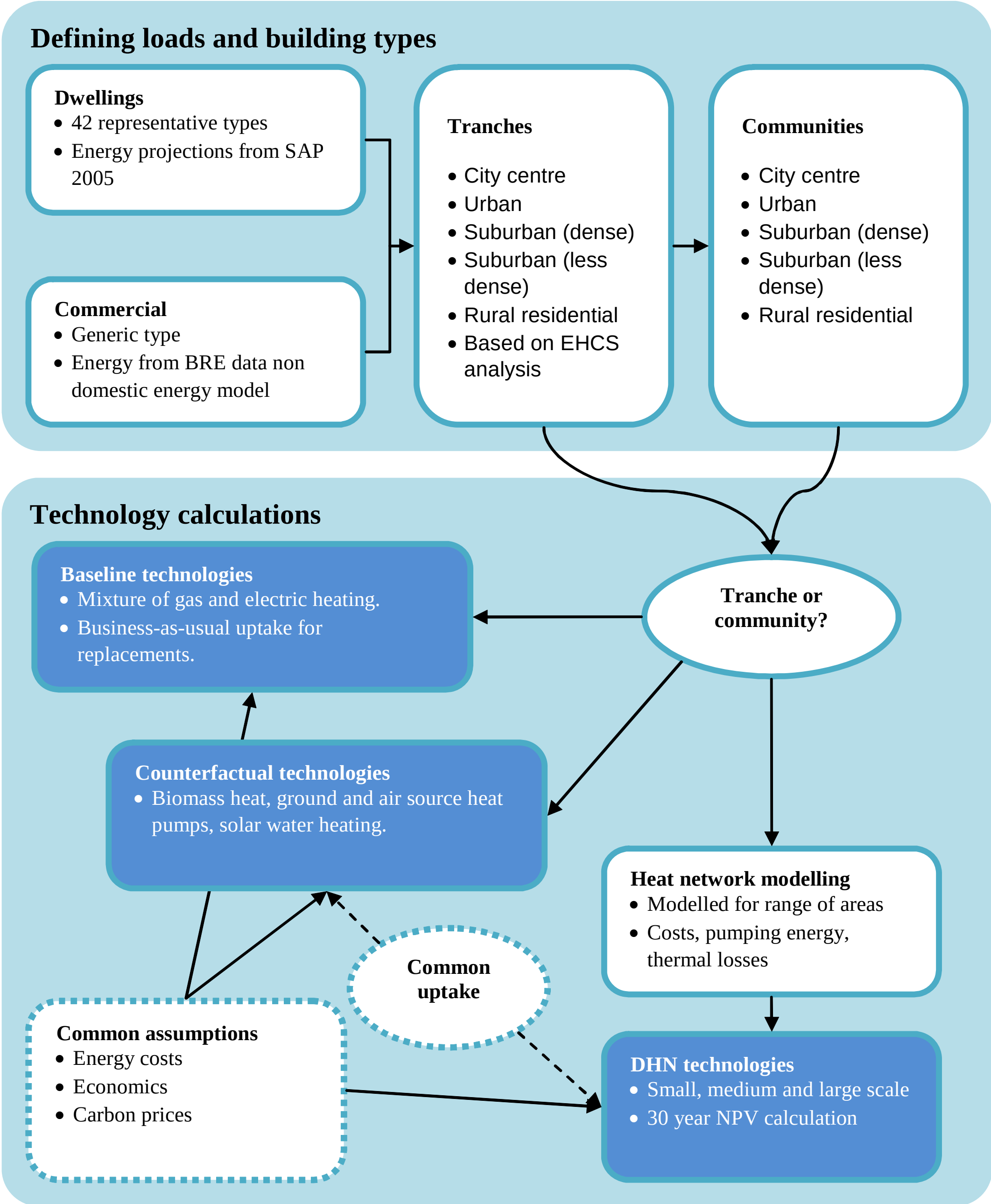
A.1 Overview of modelling

The basis of the results in this report is a computer model which simulates the potential for DHNs in the UK, based on an analysis of the buildings and communities which represent the current UK situation. This model uses a bottom-up approach, where individual building heating demands are calculated which are then assembled into different groups of buildings for the simulation of DHNs and associated technologies. This approach allows baseline sensitivities such as building efficiency to be assessed in terms of DHN viability.

Alongside the assessment of DHNs, a business as usual baseline is calculated for comparison. This allows the economic viability of DHNs to be estimated against the 'do nothing' case. In addition, a number of other 'counterfactual' technologies are modelled which represent an alternative microgeneration scenario to district heating.

The following diagram outlines the main functionality of the model:

Figure 26 – Stylised representation of the national take-up (community) model



Source: Faber Maunsell

A.2 Dwelling energy modelling

The dwelling energy demands are based on an analysis of the English House Condition Survey (EHCS) which can be used to establish the types, size, and efficiency of dwellings representative of the English stock. Further details of this analysis are provided in Annex B. Based on the EHCS analysis, 42 representative dwelling types were selected (21 mains gas heated and 21 electrically heated).

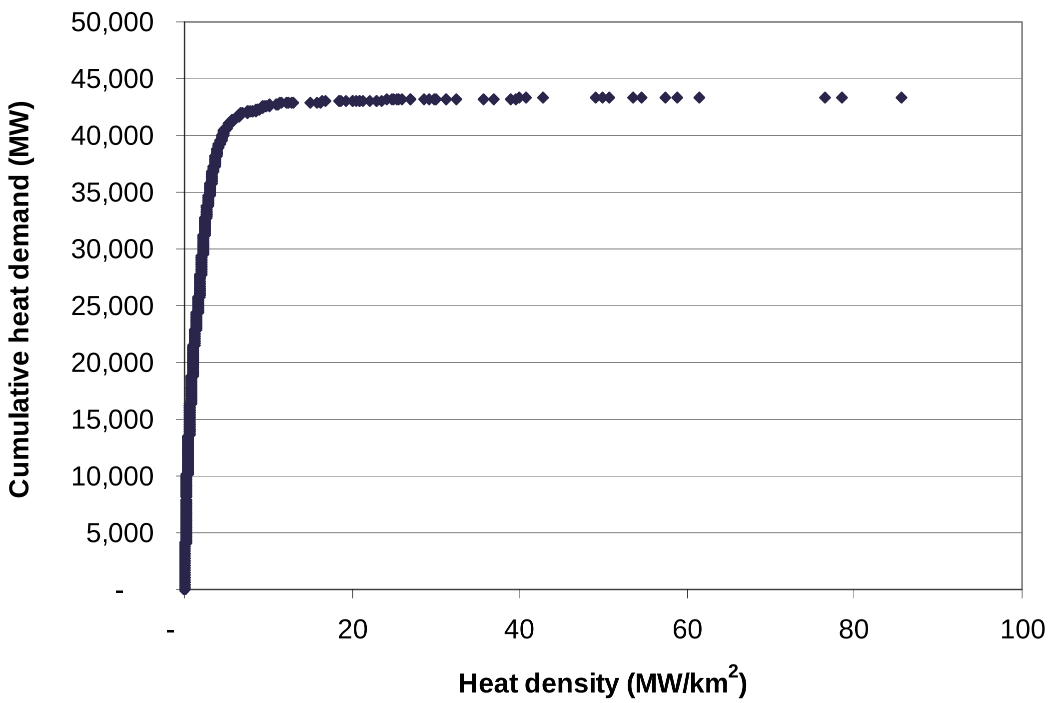
The space heating and hot water demands for each of the dwelling types were modelled using the Standard Assessment Procedure 2005 (SAP2005), and input datasets from the Reduced Data SAP (RDSAP) methodology. The outputs from this modelling are space heating demand (kWh per dwelling), hot water demand (kWh per dwelling), and space heating peak capacity (kW per dwelling).

Input datasets are included to model changes in efficiency over the 2008 – 2050 period resulting from business as usual improvements and schemes such as the Carbon Emission Reduction Target (CERT). These contribute to lowering space heating demands over the period. The model also allows for implementing a number of energy efficiency improvements at the time of DHN installation to maximise CO_2 reduction and efficiency.

A.3 Non-domestic modelling

The non-domestic building sector is based on data provided by the BRE from their non-domestic energy model. This lists the UK postcodes containing non-domestic buildings and the corresponding heat demand (MW) and heat demand density (MW/km^2). The data is filtered for areas of 5 MW/km^2 and then the remaining post code sectors identified by town, and thus size of community. It is assumed in the model that all the post code sectors chosen above 5 MW/km^2 are in city centre or urban locations. Figure 27 shows the distribution of the non-domestic stock, indicating a point at about 5 MW/km^2 above which the heat density rapidly increases, representing dense city centre and urban areas.

Figure 27 – Heat demand distribution in the non-domestic sector



Source: Pöyry Energy Consulting and Faber Maunsell

The non domestic sector heat demands are calculated from the BRE data using a load factor of 20% and an average thermal load of 70 W/m^2. This results in a space heating benchmark of 92 kWh/m^2 based on an average heating efficiency of 75%.

It is assumed that 50% of the stock identified in the BRE dataset is currently using a hot water heating system and therefore suitable for connection to a DHN. The 50% heated using a dry electrical system are disregarded assuming that conversion costs and complexity is a barrier.

A.4 Communities

Individual buildings are grouped into tranches or communities. These groupings are then used as the basis of assessing DHN schemes.

A.4.1 'Tranches'

A number of different building types make up a single "tranche". The tranches and indicative building types contained are:

- *City centre*. Mostly retail and offices with a small element of high density housing (mostly flats).
- *Urban*. A mixture of retail and offices, with high density housing consisting mainly of flats and dense terraced housing.
- *Suburban dense*. Entirely residential consisting primarily of dense terraced housing, flats, and dense semi-detached housing.
- *Suburban less dense*. Entirely residential consisting mainly of semi-detached housing with a small element of low rise flats and less dense terraced.
- *Rural residential*. Typically rural housing estates and large villages or satellite housing estates to towns. Mostly semi-detached housing but with other minority elements.

The tranches represent the lowest level modelling for heat networks, allowing an analysis of small scale systems on a mix of building types. The size of the tranches used in the model is based on a fraction of the overall community size.

A.4.2 'Communities'

Communities are the top level of DHN modelling. A community represents an entire built-up area and consists of a number of different tranches. Example of communities include; cities, towns, and conurbations. Communities are simulated by modelling a number of distinct sizes falling into different size ranges based on census 2001 data table KS01[13,14] Within each community, the breakdown of tranches will vary – for example, a community of over 1 million people will have a greater fraction of city centre than a community of 100,000 people. A small community of 5,000 people would have no city centre tranche.

Table 9 and Table 11 show the split of communities into the different tranches.

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13 Census 2001 Table KS01 'Usual resident population: Key Statistics for urban areas, results by population size of urban area'.

http://www.statistics.gov.uk/StatBase/ssdataset.asp?vlnk=8275&Pos=4&ColRank=1&Rank=240

14 The authors would like to acknowledge the help of Professor Anthony Champion from School of Geography, Politics, and Sociology at Newcastle University for his assistance with defining community sizes using census data.

Table 10 – Domestic: Breakdown of communities into tranches

Community size (population)	Number of dwellings	Number of communities	Dwellings per community	Breakdown of community into tranches by number of dwellings.				
				City Centre	Urban	Suburban - dense	Suburban - less dense	Rural residential
1,000,000 and over	6,158,060	4	1,539,515	6%	24%	30%	30%	10%
500,000 - 999,999	1,563,187	5	312,637	5%	22%	32%	32%	10%
200,000 - 499,999	2,981,156	22	135,507	4%	22%	32%	32%	10%
100,000 - 199,999	2,180,663	37	58,937	2%	22%	33%	33%	10%
50,000 - 99,999	1,714,252	56	30,612	0%	22%	34%	34%	10%
20,000 - 49,999	2,039,377	156	13,073	0%	22%	34%	34%	10%
10,000 - 19,999	1,307,500	214	6,110	0%	22%	29%	29%	20%
5,000 - 9,999	985,888	324	3,043	0%	20%	28%	28%	25%
2,000 - 4,999	1,034,212	765	1,352	0%	10%	25%	25%	40%
1,500 - 1,999	271,468	367	740	0%	5%	23%	23%	50%

Source: Pöyry Energy Consulting and Faber Maunsell

Table 11 – Non-domestic: Breakdown of communities into tranches

Number of communities	Floor area per community (m2)	Breakdown of community into tranches by number of dwellings.				
		City Centre	Urban	Suburban - dense	Suburban - less dense	Rural residential
4	8,934,008	80%	20%	0%	0%	0%
5	664,454	80%	20%	0%	0%	0%
22	519,984	80%	20%	0%	0%	0%
37	413,416	80%	20%	0%	0%	0%
56	-	0%	0%	0%	0%	0%
156	-	0%	0%	0%	0%	0%
214	-	0%	0%	0%	0%	0%
324	-	0%	0%	0%	0%	0%
765	-	0%	0%	0%	0%	0%
367	-	0%	0%	0%	0%	0%

Source: Pöyry Energy Consulting and Faber Maunsell

A.5 DHN simulation

Heat networks are modelled for each community or tranche based on the peak capacity of the groups of buildings and the types of buildings. The model simulates connection to a network over a 10 year period to reflect the fact that heat load on a network builds up over a period of time, and may never reach the maximum potential. For the purposes of modelling, the neat network is sized on maximum potential, but the energy generating technology is sized on maximum uptake.

Heat network costs have been established for each dwelling type (per dwelling) and non-domestic buildings (per m2) based on modelling of representative regions of the UK and UK costs (based on quotes from UK DHN suppliers, Poyry Heat and Power experience, and Faber Maunsell project experience).

The cost of networks is split into infrastructure and connection. Infrastructure costs are incurred on a community or tranche irrespective of the number of buildings connected (the network is sized for maximum potential). Connection costs are only incurred when a building connects, and consist of the pipe work spur from the network, and internal building works including a Hydraulic Interface Unit (HIU) and associated connections.

Where a DHN and medium or large scale energy technology is assessed for a tranche or community, additional cost is included to allow for the larger scale network interconnects.

For example, a heat transmission main from a local power station, or connections between two smaller DHNs to make use of a larger technology.

The network modelling includes thermal losses from the pipes, and also pumping electricity.

Full details of the costs and technical parameters are given in the assumption section of this report, Annex C.

A.6 DHN Technology simulation

Twelve different DHN heat generating technologies are modelled, including a mix of heat only, and CHP systems. Each system is characterised by a minimum thermal capacity, efficiency, heat to power ratio, and costs for capital expenditure and operation and maintenance. Some technologies also include future cost projection indices which assume a reduction over time. Full details of the costs and technical parameters are provided in Annex C.

A technology is only modelled when the thermal load presented by the tranche or community is above the minimum technology capacity. An annual load calculation is used which assumes heat led operation (CHP) with no heat dumping allowed.

Where a DHN is installed in an electrically heated building, a conversion cost is included to allow for the installation of a wet heating system.

A.7 Baseline technologies

A baseline of gas heating and electric heating is assumed in the model. This represents the two most common forms of heating in urban areas. The baseline assumes a business-as-usual uptake of replacements, resulting in a gradual increase in the efficiency of gas boilers over time.

A.8 Counterfactuals

Counterfactual technologies are modelled alongside the DHN technologies for each tranche or community. These technologies represent individual building “low carbon” alternatives to DHNs. Counterfactual technologies include:

- Biomass boilers;
- Ground source heat pumps;
- Air source heat pumps; and
- Solar water heating (in combination with gas / electric heating from baseline).

The technical and economic assessment of the counterfactuals is consistent with the methodology used for the DHN and baseline technologies. The uptake for counterfactuals is the same as the assumed uptake for the DHN connections such that costs and CO_2 can be compared on an equal basis with DHNs.

Full details of the counterfactuals are provided in Annex C.3.

A.9 Economics

A full economic analysis is conducted over a 30 year discounted period. This includes all income and revenue streams. Costs are calculated on a Gross basis (DHN and technology only) and a Net basis (taking into account the offset baseline costs).

Retail and wholesale energy projections are used for the 2008 – 2050 period based on BERR data for wholesale gas scenarios (low, medium, high and high-high). In their basic format, these do not include any grants, subsidies, or taxes (climate change levy for example).

Revenue from the sale of electricity is calculated using the wholesale value of electricity. This is linked to the retail scenario, for example when retail prices are 'high', revenues are also 'high'.

Annex E includes full details of the cost projections used in the model

The economic modelling includes lifecycle replacements which fall within the 30 year analysis period. Each technology has a separate lifetime and replacement cost (expressed as a fraction of initial capital). Full details are provided in the assumptions in Annex C).

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ANNEX B – ASSESSMENT OF DWELLING TYPES

B.1 Introduction

This section provides an overview of the analyses used to assess the types of dwellings to be modelled for assessing the potential of DHNs. All of the analyses is based on the English House Condition Survey (EHCS) 2005, and is centred on two criteria:

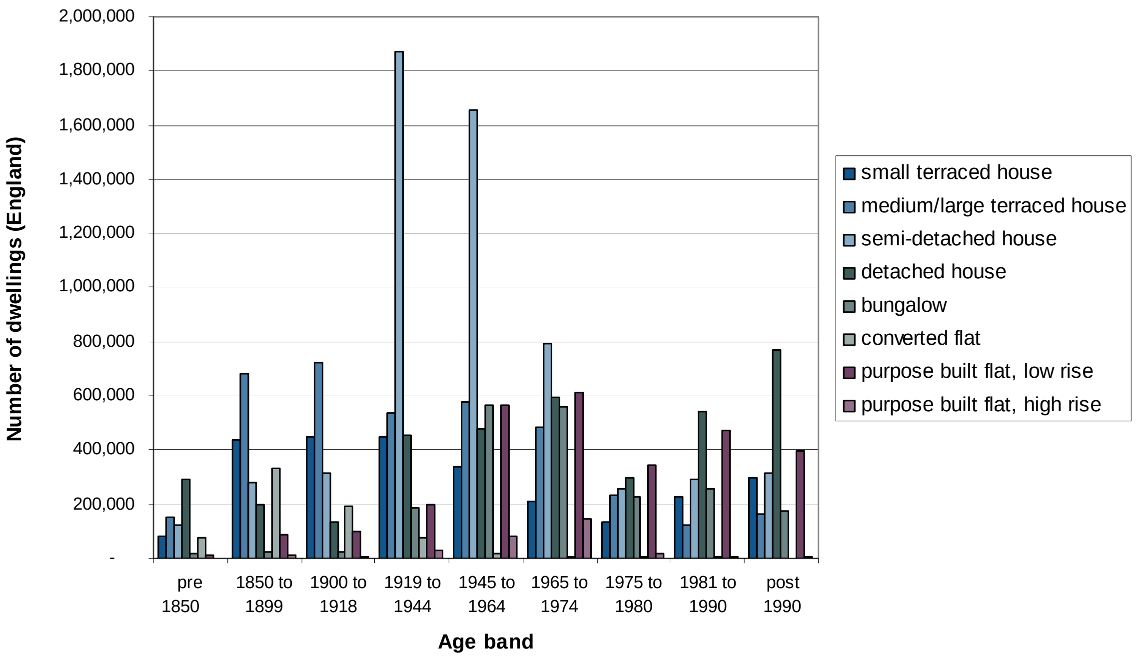
1. Assessment of factors which affect the thermal demand of dwellings.
2. Assessment of factors which can affect the implementation of DHNs.

The following sections provide a brief overview of the analysis and the final section proposes the final split of housing to be assessed.

B.2 Dwelling types

Figure 28 illustrates the types of dwellings for a range of age bands.

Figure 28 – Dwellings by age bands



Source: Pöyry Energy Consulting and Faber Maunsell

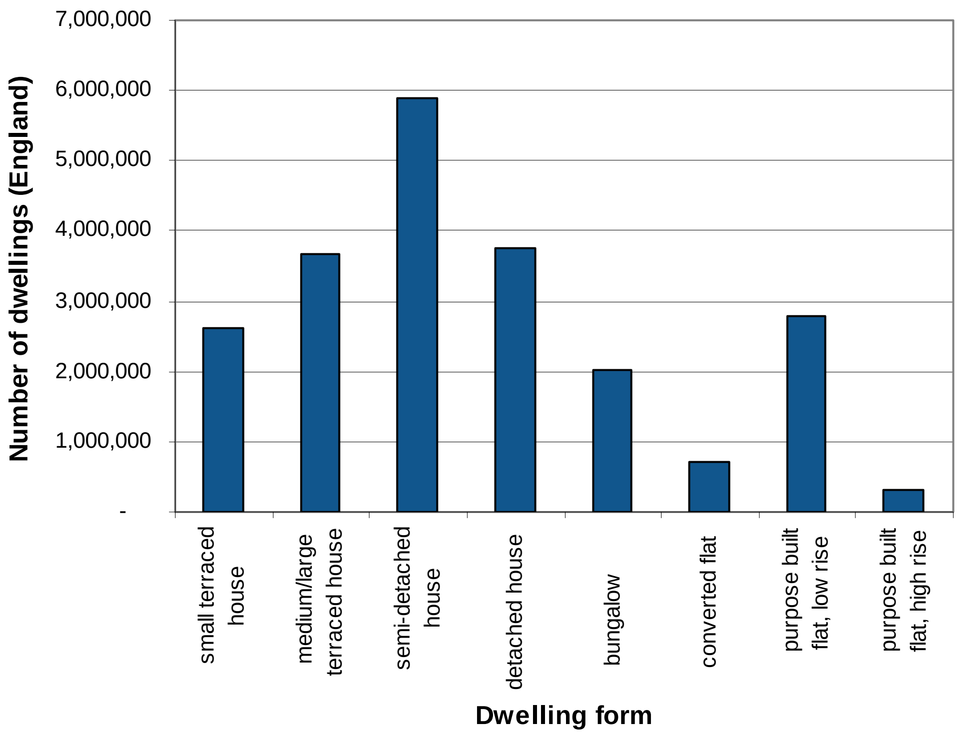
Observations:

- Largest sector is inter and post war semis (1919 – 1974).
- Terraced (small, and medium / large) housing predominant pre 1919.
- Detached housing predominant post 1981 – these may be relatively small but seen as being more attractive in the market than terraced or semis.
- Purpose built high rise flats mainly feature in 1945 – 1974. Probably mainly council blocks built after slum clearances.

- Purpose built low rise featuring strongly post war and second largest sector post 1990. Recent increase perhaps due to emphasis on inner city and urban regeneration.
- Converted flats feature strongly in the 1850 – 1918. These are probably larger terraces and semi-detached houses which have been split into multiple units.

Overall, the dwellings are spread as follows:

Figure 29 – Spread of dwellings



Source: Pöyry Energy Consulting and Faber Maunsell

Figure 29 shows that overall, the largest sector is terraced housing (small and medium / large combined) followed by semi detached. There are almost 4 million detached houses, however the economics of connecting DHNs to these can be poor due to the low thermal density. Purpose build high rise flats form the smallest sector, but perhaps offer a good opportunity for DHNs due to layout and design, and a general current reliance on electricity for heating.

B.3 Dwelling location

The EHCS categorises homes as being in one of 6 area types:

Urban characteristics – Built up areas which would include, cities, large and small towns:

City centre: Land use is predominantly commercial.

Other urban centre: Area around core of towns, small cities or older urban areas swallowed up by a metropolis.

Suburban residential: Outer area of towns or cities, often characterised by large planned housing estates.

Rural characteristics – Very small towns and villages and other type rural locations:

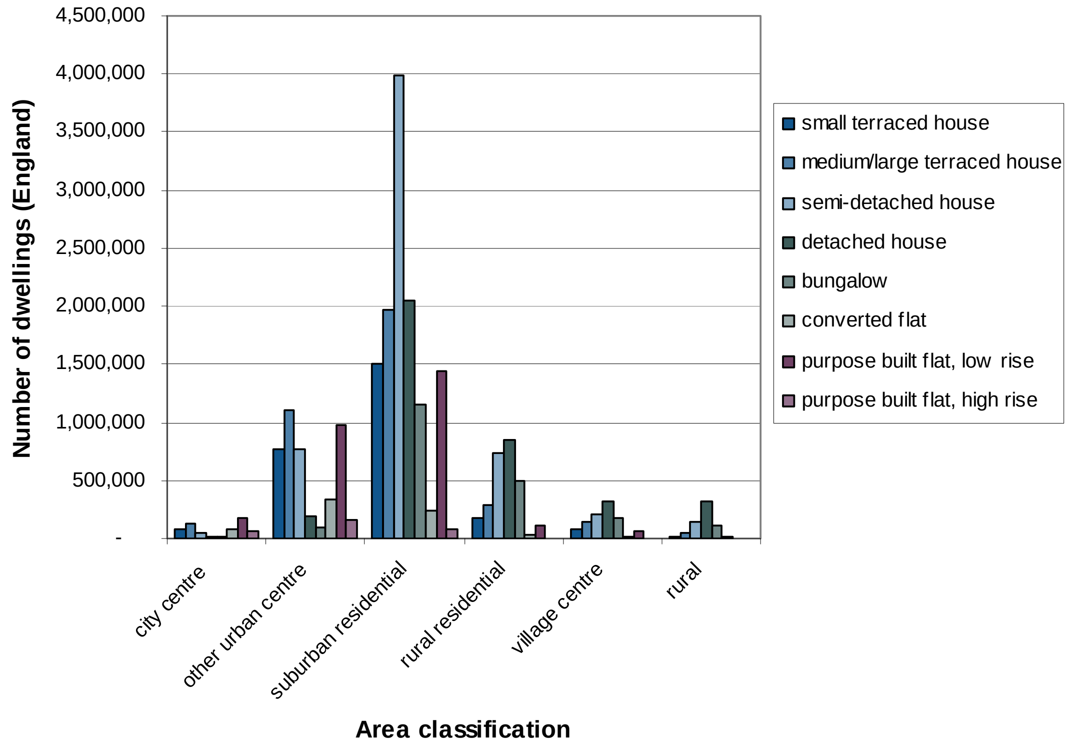
Rural Residential: Residential areas in rural or suburban areas of villages.

Village centre: Traditional villages or centres of suburbanised villages.

Rural: Agricultural areas with Isolated dwellings or small hamlets.

Figure 30 shows the distribution of the house types in these areas

Figure 30 – Distribution of house type by area



Source: Pöyry Energy Consulting and Faber Maunsell

Observations:

- 'Suburban residential' is by far the largest sector, dominated by inter and post war semis, followed by terraced housing.
- Overall, the top five housing types are all in suburbia illustrating the importance of accessing this area.
- 'Other urban centre' is mainly composed of terraced housing, presumable due to the age of the locality. This is also the largest sector of converted flats, probably due to the splitting of the older properties. The second largest type in this area is purpose built flats.

- ‘Rural residential’ also features strongly, with detached housing featuring most strongly. It is likely that the overall housing densities in these areas are relatively low and most communities are relatively small.
- There is a very small fraction of housing in city centres. However these are a key target for DHNs due to high density and the opportunities of combining with commercial building loads.
- Village centre and rural housing is mainly composed of detached housing. It is likely that DHNs are not suited to these areas due to the very low housing densities and small communities.

B.4 Housing condition

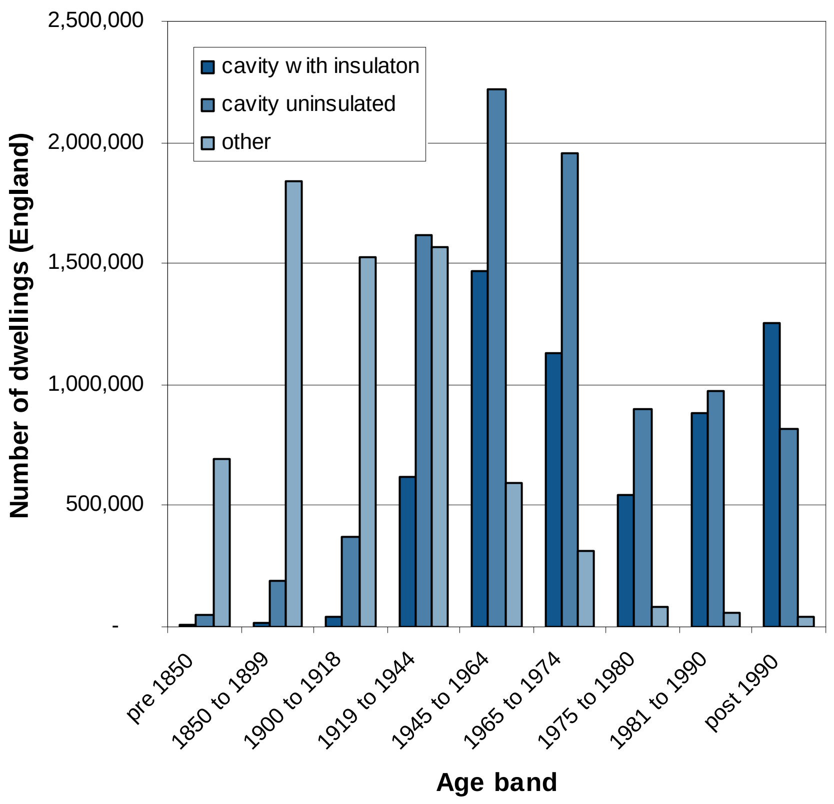
The EHCS can be used to gain an insight into the thermal condition of housing using a number of indicators. For this study, these indicators are limited to:

- Cavity wall insulation (and the availability of cavity walls);
- Loft insulation; and
- Extent of double glazing.

B.4.1 Cavity wall insulation

Figure 31 shows the spread of cavity wall insulation across the age bands:

Figure 31 – Uptake of cavity wall insulation



Source: Pöyry Energy Consulting and Faber Maunsell

Solid walls dominate pre 1919 homes, with solid masonry double brick structures being the norm. The EHCS data suggests some cavities are present – this may be due to alternative build types, or data collection error in the survey. For this study, all pre 1919 dwellings are assumed to have no cavity.

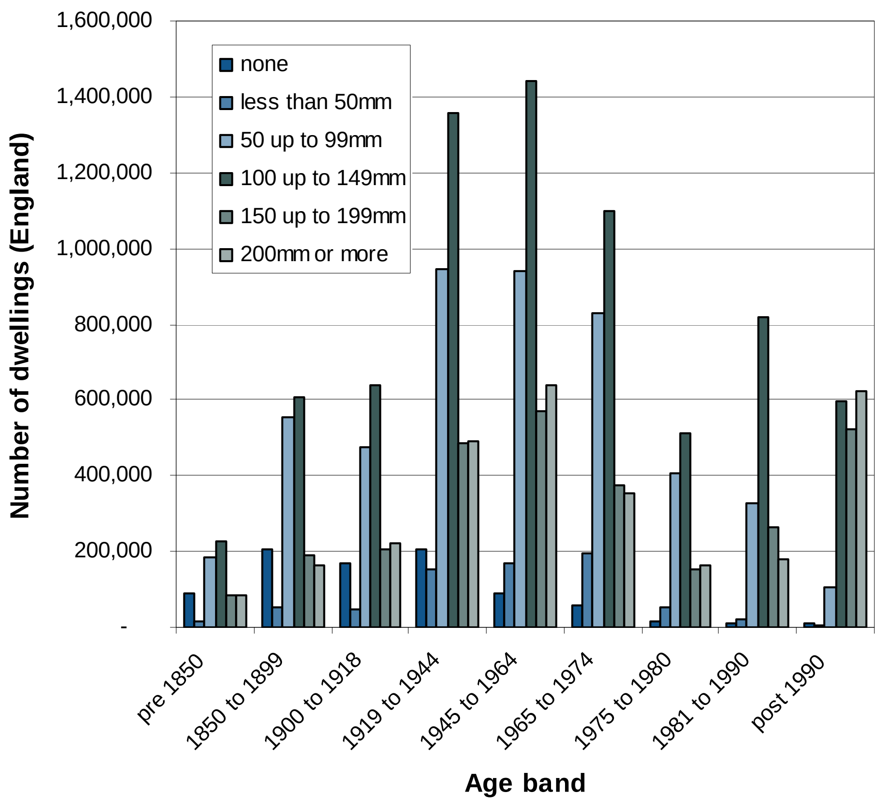
In between 1919 and 1975, there is a spread of solid walls / unfilled cavities / filled cavities. This is largely due to the introduction of Part L building regulations covering energy efficiency mandating better thermal performance. Earlier cavity homes are likely to have brick – cavity – brick construction, with later homes more likely to use a concrete block – cavity brick construction. Most filled cavities are likely to be retrofit.

Post 1975 there are very few solid walls with most dwellings having either unfilled or filled cavities.

B.4.2 Loft insulation

Figure 32 illustrates the amount of loft insulation present in homes from each of the age bands:

Figure 32 – Uptake of loft insulation



Source: Pöyry Energy Consulting and Faber Maunsell

For most of the age bands (certainly before 1980) the spread of loft insulation thickness is relatively uniform. This is due to the retrofit of insulation to dwellings being applicable to dwellings of all ages. After 1990, the thickness increases due to revised Part L Building

Regulations (mandating a maximum U value of 0.25 W / m^{2}K). Very few homes have no insulation at all, presumably due to the low cost and ease of retrofitting.

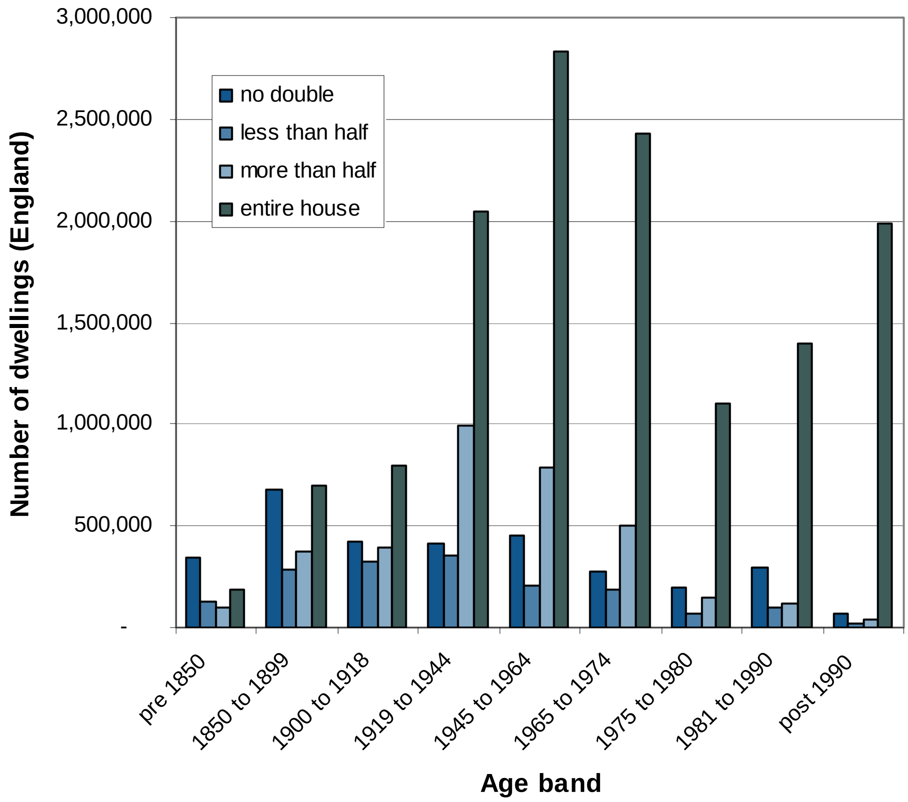
It is likely that the levels of loft insulation will continue to increase – this is a measure which can always be improved by simply adding more layers and today's best practice will almost certainly improve in the future.

B.4.3 Double glazing

Double glazing can provide large energy and CO_2 savings by reducing thermal losses through the windows, whilst also providing benefits of draft proofing compared to older poorly fitting windows.

Figure 33 illustrates the uptake of double glazing for each of the age bands:

Figure 33 – Uptake of double glazing



Source: Pöyry Energy Consulting and Faber Maunsell

There are very high levels of double glazing post 1919. Possible reasons for this include:

- easy retrofit of cheap UPVC with like for like units having minimal impact on aesthetics;
- attractive to homeowners due to improved thermal though reduced draughts etc, and lower maintenance; and
- post 1990 virtually all dwellings have double glazing due to standards in the Part L Building Regulations and market demand.

It is probable that most homes post 1919 could have double glazing installed with minimum impact on the dwelling.

The levels are much lower for pre-1919 homes. This is possibly due to:

- Visual impact – older dwellings typically have large tall windows recessed into the wall, and the retrofit of low price uPVC double glazing can significantly alter the aesthetics of a property.
- Double glazed replacements for sliding sash windows are typically much more expensive than for standard opening units.
- A large number of houses may be historic, in conservation zones, or have listed status preventing the installation of double glazing.
- Older sash windows tended to be much higher quality than more recent glazing, and so there is less chance they have needed to be replaced.

For the pre-1919 dwellings, it is possible that the use of double glazing has almost saturated with the remaining homes maintaining single glazed units.

B.4.4 Fuel and heating type

The heating type and fuel of a dwelling will determine its current CO_2 emissions, and also potentially impact on the feasibility of connecting to a DHN. Table 2 illustrates the availability of the mains gas network, the primary heating fuel and the primary heating system type for each location type.

Table 12 – English housing stock heating characteristics

		City centre	Other urban	Suburban	Rural residential	Village centre	Rural
Gas availability	mains gas available	100%	100%	100%	97%	94%	70%
	no mains gas available	0%	0%	0%	3%	6%	30%
Main fuel type	gas fired	78%	89%	92%	78%	60%	29%
	oil fired	0%	0%	0%	10%	20%	49%
	solid fuel	0%	1%	1%	3%	5%	11%
	electrical	22%	11%	7%	8%	15%	11%
Heating system	Central heating with radiators	71%	83%	88%	89%	83%	85%
	Storage heaters	15%	8%	5%	7%	13%	9%
	Warm air	1%	1%	2%	2%	1%	0%
	Communal/CHP	5%	2%	1%	0%	0%	0%
	Electric celiling / underfloor	1%	0%	0%	0%	0%	0%
	Room heaters	6%	5%	3%	2%	2%	5%

Source: Pöyry Energy Consulting and Faber Maunsell

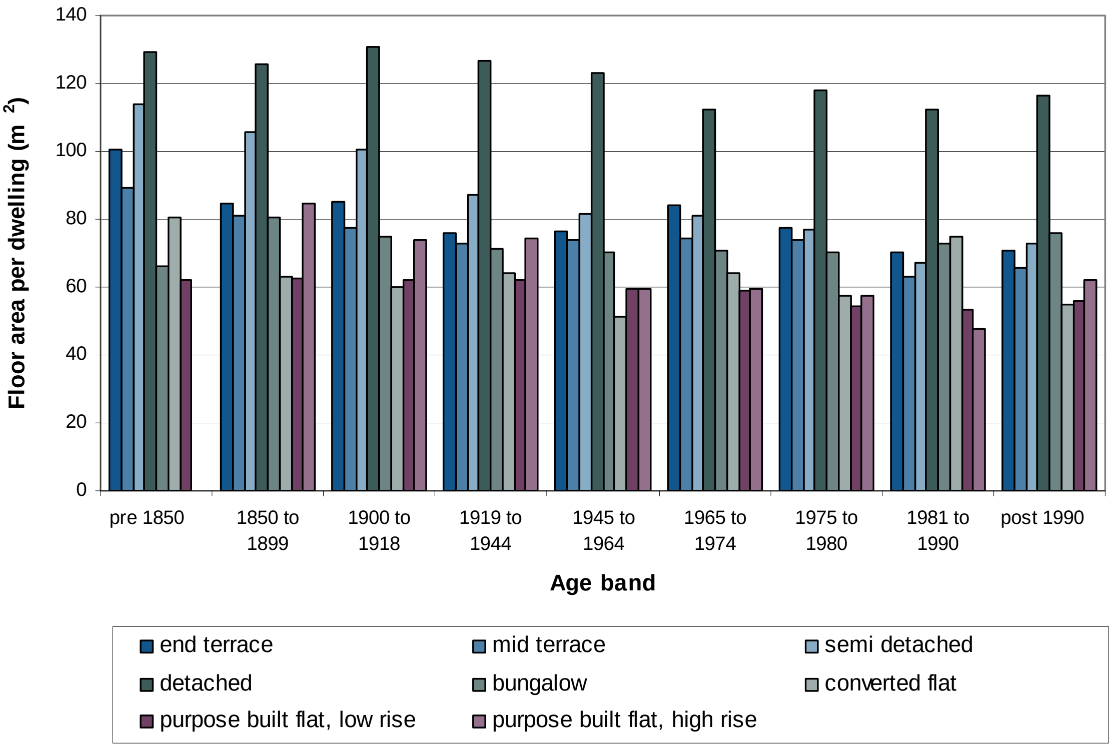
Mains gas is available in all urban and suburban dwellings. This is due to the extensive nature of the UK gas network and is unsurprising. However mains gas is also indicated as being available in 97% of homes in rural residential, and 70% in rural areas. This is surprising and possibly indicates data collection error. Most of these areas are more likely to use oil, LPG or electric heating.

Gas heating is dominant in most urban areas with around 90% in urban and suburban areas. This corresponds well with the number of dwelling using a central heating system with radiators. For both, there is a slight fall in city centre areas due to electrically heated flats.

B.4.5 Average floor areas

Floor area is a key factor for energy consumption, governing the heated space volume. The following chart shows the variation in average floor areas for each of the dwelling types in each age band.

Figure 34 – Floor area by dwelling type and age.



Source: Pöyry Energy Consulting and Faber Maunsell

Figure 34 shows a general reduction in floor area over time, with terraced and semi detached homes in particular reducing in size. The overall range is from circa 50m^2 (flats) to circa 120 m^2 (detached).

Average floor areas are used in the model for each dwelling form and age band. The combination of slightly larger floor areas for older dwellings in combination with poor thermal performance could have a large impact on space heating demands.

B.5 House types used in the model

Based on the above analysis of the EHCS, the following parameters are used to describe the 42 house types used in the DHN modelling.

B.5.1 Outline of modelling

- Dwelling types;
  - Flats – low rise;
  - Flats – high rise;

  - Flats – converted;
  - Terraced (including a sub division into 'small' and 'medium / large');
  - Semi-detached (including a sub division into 'dense' and 'less dense').
- Age bands;
  - Pre 1919;
  - 1919 – 1975;
  - Post 1975;
- Fuel types;
  - Gas (circa 90% overall);
  - Electricity (mainly in city centre);
- Heating type;
  - Wet system (circa 90% overall); and
  - Electricity (mainly flats).
- Condition

All house types modelled as an 'average' based on following.

Table 13 – Average house type

	Pre 1919	1919 – 1975	Post 1975
Cavity wall	Assume no potential. U-value for solid wall	Assume a % of walls have a potential (some still solid). Average U-values based on the number with insulation, number without insulation, and number with no potential (solid).	Assume all insulated. U-value for insulated cavity wall
Double glazing	Current average U-value based on current uptake of dbl glazing. Allow increase in uptake but limit to a % to allow for retention of historic homes.	Assume potential for all homes. Use average U-value based on uptake (somewhere between 4.8 sgl glazed and 2 dbl glazed).	Assume all dbl glazed
Loft insulation	Average U based on current average thickness	Average U based on current average thickness	Average U based on current average thickness

Source: Pöyry Energy Consulting and Faber Maunsell

All values will be increased over time to reflect business as usual uptake based on projections taken from CERT[15].

B.6 Area types for use in the model.

In addition to the 42 house types identified above, the following area types are used to represent tranches in communities:

- City centre;
- Other urban;
- Sub-urban (dense);
- Sub urban (less dense); and
- Rural residential.

These five tranches represent the 5 most dense types identified by the EHCS. The sub division of suburban into 'dense' and 'less dense' is based on an analysis of semi-detached housing and terraced housing where different characteristics can be seen from maps and aerial photographs as follows:

Table 14 – Area type characteristics

	Suburban dense tranche	**Suburban less dense tranche**
Semi detached	Short front gardens with minimal space between dwellings for walkway	Longer front gardens with space between dwellings for garages or car parking.
Terraced	Small terraced homes located directly on street front.	Medium / Large terraced homes with small front gardens.

Source: Pöyry Energy Consulting and Faber Maunsell

B.7 Non – domestic data

For non domestic buildings, we have used the National Non-Domestic Energy and Emissions Model (N-DEEM) data held by the BRE. The N-DEEM database contains detailed data on energy consumption and building structural fabric for a significant sample of non-domestic buildings and national stock data in terms of building use and structural characteristics.

N-DEEM links national floor areas from the NDBS database [activities], to figures for specific energy use, disaggregated by fuel and application.

15 Delivering Cost Effective Carbon Saving Measures to existing Homes http://www.defra.gov.uk/environment/climatechange/uk/household/supplier/pdf/bre-tech-backgrnd.pdf

B.8 Cost differentials between the UK and Europe

In case of open markets and no-price regulation, District Heat (DH) can be commercially viable and competitive against other heating methods, provided DH is produced with cheap fuel, or if the DH is produced through CHP.

However DHNs are very capital intensive. Network construction costs are high especially in the UK compared to Europe (the network will tend to be 60% – 80% of the total cost of the scheme). Hence, due to the needs to invest more on DH network it is clear that the viability of the systems with lower heat densities.

For instance, because of high network connection costs, even in Finland many DH companies are not always eager to connect single family houses, semi-detached houses or even terraced houses to their existing DH system. Alternatively Finnish DH companies may set the connection fee for ‘small scale buildings’ so high that it would anyway be viable to connect them in the point of view of the DH company. However, too high DH connection fee forces the customers often to choose another heating method. It should be pointed out that a Finnish terraced house or ‘row house’ is always connected to the main DH network with only one house branch and a common DH consumer substation equipped with heat exchangers and control valves for space heating and domestic hot water (DHW). The substation serves space heat and DHW to all dwellings locating in the ‘row house’ through building’s internal heat and DHW piping.

Consequently, larger block of flats or other industrial commercial heat consumers are more efficient DH consumers due to higher heat load density and lower connection costs. This fact has been taken into account in London Development Agency’s plans for the development of DH schemes in London. However it is likely that typical UK terraced houses and semi-detached houses which have a requirement for an individual substation, a heat meter and an individual DH network connection for each dwelling will be extremely difficult consumers in respect of the viability and competitiveness of the district heating system.

Connection costs to a DH network are already high regarding DH network construction. However properties will also require substations and heat meters. Costs of substations and heat meters also require analysis and added to the total cost, this will further increase the connection costs of terraced houses and semi-detached houses. Considering the feasibility and real competitiveness of DH system, especially in the UK, connection of terraced houses and semi-detached houses to the DH system should be considered unlikely and always analysed very carefully.

Utilisation of some common space in terraced housing could lower the connection costs, if common space is available. Only one network branch connection and one substation would be needed for a group of houses. Unfortunately, it seems that this is not a very likely option in the UK due to the technical, institutional and even legal limitations.

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ANNEX C – KEY COST AND TECHNICAL ASSUMPTIONS FOR TECHNOLOGIES

C.1 Introduction

This document outlines the cost and performance assumption used in the modelling by Faber Maunsell and Poyry. The values in this document are currently under review and are subject to change later in the project.

C.2 DHN technologies

Table 15 – Small gas engine CHP

Minimum power	500 kWe
Electrical efficiency	28% Based on typical manufacturers efficiencies.
Thermal efficiency	52% Assumes an overall efficiency of 80%.
Lifetime	15 years Based on typical manufacturers lifetimes.
Capital cost	£864 / kWe Data provided by DECC. This includes plant, installation, and associated energy centre building.
Operation and maintenance	£80 / kWe per year Data provided by DECC.
Fraction of capital costs for replacement	80% This assumes that replacement costs are dominated by plant and installation.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 16 – Large gas engine CHP

Minimum power	2 MWe
Electrical efficiency	38% Based on typical manufacturers efficiencies.
Thermal efficiency	42% Assumes an overall efficiency of 80%.
Lifetime	15 years Based on typical manufacturers lifetimes.
Capital cost	£657 / kWe Data provided by DECC. This includes plant, installation, and associated energy centre building.
Operation and maintenance	£48 / kWe per year Data provided by DECC.
Fraction of capital costs for replacement	80% This assumes that replacement costs are dominated by plant and installation.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 17 – Small combined cycle gas turbine

Minimum power	50 MWe
Electrical efficiency	42% Based on typical manufacturers efficiencies.
Thermal efficiency	38% Assumes an overall efficiency of 80%.
Lifetime	25 years Based on information from Siemens http://www.powergeneration.siemens.com/NR/rdonlyres/FE56E31E-E5E6-4413-9A5F-AF0365E09647/0/5_Lifetime_Extension_for_Siemens.pdf
Capital cost	£805 / kWe Data provided by DECC. This includes plant, installation, and associated civils.
Operation and maintenance	£32 / kWe per year Data provided by DECC.
Fraction of capital costs for replacement	90% This assumes that replacement costs are dominated by plant and installation.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 18 – Medium combined cycle gas turbine

Minimum power	90 MWe
Electrical efficiency	45% Based on typical manufacturers efficiencies.
Thermal efficiency	35% Assumes an overall efficiency of 80%.
Lifetime	25 years Based on information from Siemens http://www.powergeneration.siemens.com/NR/rdonlyres/FE56E31E-E5E6-4413-9A5F-AF0365E09647/0/5_Lifetime_Extension_for_Siemens.pdf
Capital cost	£759 / kWe Data provided by DECC. This includes plant, installation, and associated civils.
Operation and maintenance	£32 / kWe per year Data provided by DECC.
Fraction of capital costs for replacement	90% This assumes that replacement costs are dominated by plant and installation.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 19 – Natural gas district heating boiler

Minimum power	100 / kWth
Thermal efficiency	85% Data provided by DECC
Lifetime	30 years Typical minimum lifetime is 20 years and many systems last considerably longer.
Capital cost	£60 / kWth Data provided by DECC. Assumption that this includes plant and installation, but that energy centre building already exists.
Operation and maintenance	£3 / kWth per year Data provided by DECC.
Fraction of capital costs for replacement	100% This assumes that there are no cost benefits at replacement.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 20 – Biomass district heating boiler

Minimum power	100 / kWth
Thermal efficiency	87% Data provided by DECC
Lifetime	15 years Data provided by DECC
Capital cost	£615 / kWth Data provided by DECC. Assumption that this includes plant and installation, and civils for energy centre and fuel storage.
Operation and maintenance	£15 / kWth per year Data provided by DECC.
Fraction of capital costs for replacement	80% This assumes that an element of the initial installation such as civil works and fuel storage can remain for replacement.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 21 – Small biomass air turbine CHP

Power	100 kWe Based on Talbotts BG100 specifications
Electrical efficiency	20% Based on Talbotts BG100 specifications
Thermal efficiency	50% Based on Talbotts BG100 specifications. Specifications provide thermal output of 200 kWth (giving 40% thermal efficiency) and also 80% overall efficiency. 50% chosen as mid value.
Lifetime	15 years Estimated lifetime.
Capital cost	£4,000 / kWe Data provided by Talbotts. Based on total cost of £400,000 for delivery and installation of containerised unit.
Operation and maintenance	£180 / kWe per year Data provided by Talbotts. Based on a service and maintenance contract of £1,500 per month.
Fraction of capital costs for replacement	80% This assumes that an element of the initial installation such as civils and fuel storage can remain for replacement.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 22 – Medium biomass steam turbine CHP

Minimum power	8 MWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Electrical efficiency	17% Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Thermal efficiency	63% Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Lifetime	20 years Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Capital cost	£3,500 / kWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Operation and maintenance	£80 / kWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Fraction of capital costs for replacement	90%

Source: Faber Maunsell and Pöyry Energy Consulting

Table 23 – Large biomass steam turbine CHP

Minimum power	30 MWe Carbon Trust 'Biomass Sector Review'
Electrical efficiency	24% Carbon Trust 'Biomass Sector Review'
Thermal efficiency	56% Carbon Trust 'Biomass Sector Review'
Lifetime	25 years Estimate allowing for increased life over medium scale biomass CHP.
Capital cost	£1,780 / kWe Carbon Trust 'Biomass Sector Review'
Operation and maintenance	£80 / kWe Carbon Trust 'Biomass Sector Review'
Fraction of capital costs for replacement	90%

Source: Faber Maunsell and Pöyry Energy Consulting

Table 24 – Energy from waste: Anaerobic Digestion

Minimum power	1 MWe
Electrical efficiency	32% Based on data from Cogenco http://www.cogenco.co.uk/pdf/digester%20gas.pdf. Typical LCV HCV efficiencies are circa 32 %. This assumes that all waste is pre-sorted or processed. If waste processing equipment is included, the effective electrical efficiency will be circa 25% lower due to parasitic electricity consumption.
Thermal efficiency	48% Based on an overall efficiency of 80%.
Lifetime	20 years Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Capital cost	£7,745 / kWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Operation and maintenance	£775 kWe per year 10% of capex. Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Fraction of capital costs for replacement	80% This assumes major plant replacement, but some aspects such as initial civils work remain.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 25 – Energy from waste: Incineration

Minimum power	24 MWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Electrical efficiency	30% Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR. Assumes an overall efficiency of 80%. 30% electrical efficiency in CHP mode is the upper value provided by DEFRA 'Incineration of Municipal Solid Waste'.
Thermal efficiency	50% Based on an 80% overall efficiency.
Lifetime	20 years Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Capital cost	£8,750 kWe Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Operation and maintenance	£517 kWe per year Ernst and Young 'Renewable Heat Initial Business Case', 2007, study for BERR.
Fraction of capital costs for replacement	70% This assumes that 30% of the initial capital is linked to civils and structural work which can remain at re-fit.
CO_2 emissions	0.1 kg CO_2 / kWh. This estimate assumes that 50% of the MSW is organic (and therefore effectively CO_2 neutral) and the remaining component is plastics. This figure is highly variable and depends on the exact waste composition, and the accounting methodology used for estimating the effective CO_2 benefit of waste treatment processes.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 26 – Waste heat from power stations

Minimum power	30 MWe
Carbon intensity of heat	10% of marginal grid CO_2 intensity Based on a Z-factor of 10. This means that extraction of thermal energy for DHN reduces electrical efficiency by 10%.
Cost of energy	10% of wholesale electricity value This accounts for lost electricity revenue for the power station.

Source: Faber Maunsell and Pöyry Energy Consulting

C.3 Baseline and Counterfactual assumptions

Table 27 – Individual domestic gas boilers

Capital cost	£2,500 per dwelling. This is typical of current UK replacement prices for boiler and controller only. Domestic boiler replacement costs are dominated by installation and vary very little with thermal capacity. This does not include other components of the heating system. It is assumed that the heating system is unmodified at the time of boiler replacement.
Operation and maintenance	£200 per year maintenance contract British Gas maintenance contracts are currently circa £160 p.a to £200 p.a.
Lifetime	15 years. Data provided by DECC
Current average efficiency	76% This is the current average efficiency of boilers in the UK. Based on extrapolation of data from the 'Domestic Energy Factfile 2003', BRE.
Replaced efficiency	91% This is typical of current SEDBUK A-rated condensing gas boilers.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 28 – Individual commercial gas boilers

Capital cost	£45 per kW. Data provided by DECC. This is assumed in the model to be boiler only and does not include any other components of the heating system. It is assumed that the heating system is unmodified at the time of boiler replacement.
Operation and maintenance	£3 per kW Data provided by DECC.
Lifetime	15 years. Data provided by DECC
Current average efficiency	76% Little information is available on the commercial sector. This is the current average efficiency of domestic boilers in the UK. Based on extrapolation of data from the 'Domestic Energy Factfile 2003', BRE.
Replaced efficiency	91% This is typical of current SEDBUK A-rated condensing gas boilers.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 29 – Electric heating

	Domestic	Commercial
Capital cost	£175 / kW Data provided by DECC. This is assumed to include the heating distribution system, for example storage heaters or radiant panels.	£221 / kW Data provided by DECC. This is assumed to include all components of the heating system.
Fraction of capital costs for replacement	100%	100%
Operation and maintenance	£17 / kW Data provided by DECC	£11 / k Data provided by DECC
Lifetime	15 years Data provided by DECC	15 years Data provided by DECC
Efficiency	100% Data provided by DECC	100% Data provided by DECC

Source: Faber Maunsell and Pöyry Energy Consulting

Table 30 – Biomass boiler

	Domestic	Commercial
Capital cost (2008)	£528 / kW Data provided by DECC.	£368 / kW Data provided by DECC.
Fraction of capital costs for replacement	50% This assumes that flue, fuel storage and feed are significant components of initial installation and can remain on replacement of boiler.	50% This assumes that flue, fuel storage and feed are significant components of initial installation and can remain on replacement of boiler.
Operation and maintenance	£18 / kW Data provided by DECC	£18 / kW Data provided by DECC
Lifetime	15 years Data provided by DECC	15 years Data provided by DECC
Efficiency	87% Data provided by DECC	87% Data provided by DECC

Source: Faber Maunsell and Pöyry Energy Consulting

Table 31 – Ground source heat pumps

	Domestic	Commercial
Capital cost	£1,200 / kW Data provided by DECC. This assumes heat pump system only and not the installation of a low temperature heating system.	£1,000 / kW Data provided by DECC. This assumes heat pump system only and not the installation of a low temperature heating system.
Fraction of capital cost for replacement	50% This assumes that ground coils can remain, and only the compressor unit is replaced.	50% This assumes that ground coils can remain, and only the compressor unit is replaced.
Operation and maintenance	£9 Data provided by DECC	£9 Data provided by DECC
Lifetime	20 years Data provided by DECC. This is assumed to be the heat pump compressor unit only, with the ground coils having a significantly longer lifetime.	20 years Data provided by DECC. This is assumed to be the heat pump compressor unit only, with the ground coils having a significantly longer lifetime.
Coefficient of performance (COP)	2.4 (space heating) Based on SAP 2005. A COP of 3.2 is adjusted by 75% to allow for retrofit in dwellings with radiator based systems. Domestic hot water is assumed to be provided by an immersion heater and overall heating COP is weighted to reflect this.	2.5 (space heating) Based on BSRIA Illustrated Guide to Renewable Technologies 2008. Value reflects heating with radiators. Domestic hot water is assumed to be provided by an immersion heater and overall heating COP is weighted to reflect this.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 32 – Air source heat pumps

	Domestic	Commercial
Capital cost	£600 / kW Data provided by DECC. This assumes heat pump system only and not the installation of a low temperature heating system.	£600 / kW Data provided by DECC. This assumes heat pump system only and not the installation of a low temperature heating system.
Fraction of capital cost for replacement	90%	90%
Operation and maintenance	£9 Data provided by DECC	£9 Data provided by DECC
Lifetime	20 years Data provided by DECC. This is assumed to be the heat pump compressor unit only, with the ground coils having a significantly longer lifetime.	20 years Data provided by DECC. This is assumed to be the heat pump compressor unit only, with the ground coils having a significantly longer lifetime.
Coefficient of performance (COP)efficiency	1.9 (space heating) Based on SAP 2005. A COP of 2.5 is adjusted by 75% to allow for retrofit in dwellings with radiator based systems. Domestic hot water is assumed to be provided by an immersion heater and overall heating COP is weighted to reflect this.	2.0 (space heating) This is the minimum COP allowed under the Non Domestic Heating, Cooling and Ventilation Compliance Guide. The value is higher than for domestic to reflect larger more efficient systems, but lower than a commercial ground source system.

Source: Faber Maunsell and Pöyry Energy Consulting

Table 33 – Solar water heating

	Domestic	Commercial
Capital cost	£1,429 / kW EST provide a cost of £3k - £5k per dwelling. Assuming a typical $4m^2$ system (at 0.7 kW / m^2) at the mid point price of £4000, then installed cost is £1429 / kW	£1429 / kW Data provided by DECC suggests same costs for a small scale commercial system as for a domestic installation.
Fraction of capital cost for replacement	90%	90%
Operation and maintenance	£4 Data provided by DECC	£4 Data provided by DECC
Lifetime	20 years Data provided by DECC.	20 years Data provided by DECC.

Source: Faber Maunsell and Pöyry Energy Consulting

C.4 Cost indices for renewable heat technologies

The following values have all been provided by BERR. Prior to 2010, and post 2020, costs are assumed to remain constant.

Table 34 – Cost indices for renewable heat technologies

Year	DHN Biomass heating	Individual Biomass heating	Ground source heat pumps	Air source heat pumps (assumed to be the same as for ground source)	Solar water heating
2010	100%	100%	100%	100%	100%
2011	99%	99%	97%	97%	99%
2012	97%	97%	95%	95%	97%
2013	96%	96%	93%	93%	96%
2014	94%	94%	90%	90%	95%
2015	93%	93%	88%	88%	93%
2016	91%	91%	86%	86%	92%
2017	90%	90%	84%	84%	91%
2018	89%	89%	82%	82%	90%
2019	87%	87%	80%	80%	89%
2020	86%	86%	78%	78%	87%

Source: Faber Maunsell and Pöyry Energy Consulting

C.5 District Heating Costs

The following table provides the costs per a dwelling of installing the heat network infrastructure, branches, and connections. These costs assume no prior heat network infrastructure in the area, with all dwellings fitted with individual heating systems.

Table 35 – District heating costs

Dwelling type	DHN Infrastructure cost	DHN Branch cost	HIU and heat meter	Total cost
Small terrace	£2,135 Based on outline network design and costing	£1,912 Based on outline network design and costing plus additional costs for HIU and metering.	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£6,347
Medium / Large terrace	£2,135 Based on outline network design and costing	£2,255 Based on outline network design and costing plus additional costs for HIU and metering.	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£6,690
Semi-detached dense	£2,719 Based on outline network design and costing	£2,598 Based on outline network design and costing plus additional costs for HIU and metering.	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£7,617
Semi detached less dense	£2,719 Based on outline network design and costing	£3,198 Based on outline network design and costing plus additional costs for HIU and metering.	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£8,217
Converted flat	£712 Assumes that infrastructure costs for a 3-story converted terrace are split between 3 flats.	£752 Assumes that branch costs for a terrace are split between 3 flats with an HIU and heat meter	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£3,764

		for each flat.		
Low rise flat	£1,500 Estimate	£1,500 Internal pipework	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£5,300
High rise flat	£1,000 Estimate	£1,500 Internal pipework	£2,300 (includes £1,600 HIU, £200 for heat meter, and £500 for installation)	£4,800

Source: Faber Maunsell and Pöyry Energy Consulting

When a DHN is provided with heat from a larger scale system, a heat mains pipe is required to transfer the heat from the generator to the network. These are classes as medium scale (for example, connecting two neighbouring networks) or large scale (for example, importing heat from a nearby power station).

The following table indicates the costs of these components per dwelling:

Table 36 – Costs per dwelling

	Cost per dwelling	Assumptions
Medium scale	£3,300	(Estimate – Work in progress)
Large scale	£4,500	(Estimate – Work in progress)

Source: Faber Maunsell and Pöyry Energy Consulting

C.6 Conversion costs from electric heating

The following table provides the cost of conversion to a wet central heating system. The following assumptions are made:

- costs include for all heating system pipework and radiators and associated installation;
- costs do not include connection to an HIU (this is included in HIU installation costs);
- removal of a DHW cyclinder and immersion heater (if present) is assumed, with new DHW mains fed pipework installed to the HIU; and
- the HIU is assumed to be located at the front of the house close to DHN branch connection.

(note – the current costs are estimates and data is currently being obtained from suppliers 30th October 2008)

Table 37 – Conversion costs from electric heating

Dwelling type	Cost	Notes
Terraced house	£3,500	Estimate
Semi detached house	£4,500	Estimate
Converted flat	£2,500	Estimate
Low rise flat	£2,500	Estimate
High rise flat	£2,500	Estimate

Source: Faber Maunsell and Pöyry Energy Consulting

ANNEX D – DHN POTENTIAL

D.1 Introduction

Although substantial work was carried out in the late 1970's culminating in Energy Paper 35 published in 1979, the most recent study was commissioned by the then DETR in 1998. This work was updated in 2002 for the Carbon Trust and has since been published by the BRE[16]. The original work was carried out by Merz Orchard, the Welsh School of Architecture and Ilex.

The report recognised the distinction between a technical potential, where the technology would be technically feasible and an economic potential, where the DHNs would offer a given rate of return on the investment. DHNs can be technically successful both at a small-scale and in low density areas; in Denmark for example even small villages and detached houses are supplied by DHNs. Most of the UK population lives in urban areas and the technical potential is therefore very large.

The emphasis at the time of these studies was to establish the potential for DHNs supplied by Combined Heat and Power (CHP) rather than by other forms of heat supply. The basis of the study involved analysing the economic case for CHP/DH in each of the c8000 postcode sectors, assuming spark-ignition gas-engine CHP plants were to be used. The heat demands were estimated for each postcode sector and the costs of DHNs estimated based on the heat density of the postcode area. This enabled the economic potential for DHNs to be established for a range of discount rates.

A later report commissioned by Defra in 2006 and published in October 2007 quantified the potential for CHP in three sectors – buildings, community heating and industry. This report was produced in accordance with the requirements of the EU Cogeneration Directive. It was based on an investor perspective rather than a societal model and was therefore not in accordance with the Green Book. CHP potential associated with DHNs was assessed against a discount rate of 9% real and only those potential schemes returning a higher IRR than 9% real were included in the summary totals. The body of the report however provided results for 6% and 3.5% discount rates. The Community Heating part of the report was still based on the earlier modelling approach used by Merz Orchard in 1998.

The above reports indicated a potential capacity for cost-effective CHP at a discount rate of 6% of between 18,300MWe and 21,500MWe. This was equivalent to heat supplied by DHNs of 114 TWh p.a. to 150TWh p.a. and about 5.5million to 6.5million dwellings or about 25% of the current housing stock together with other non-domestic buildings. Carbon savings are quoted as 4.3 to 5.1 million tonnes p.a. equivalent to CO_2 savings of 15m to 18.7m tonnes p.a.

These results are for the 6% real discount rate. Higher figures are found for the 3.5% discount rate in the Defra October 2007 report with a total heat delivered of 230TWh p.a., but the economic potential drops sharply for discount rates of 9% and above.

It should be noted that the 6% discount rate does not mean that all of the CHP/DH schemes based on individual postcode sectors have a rate of return of 6%. The analysis

16 BRE Client Report 211 – 533, The UK Potential for Community Heating with Combined Heat and Power, BRE 2006.

is based on including those sectors with a positive NPV at a 6% discount rate which means that the IRRs will all be above 6%. As the potential drops sharply above 9% it is reasonable to say that most of the IRRS will fall in the range 6% to 9%.

A significant assumption built into the modelling is that the market penetration is assumed to be 40% initially, rising to 80% over 8 years.

The Sustainable Development Commission has published a report which also examined the potential for District Heating and drew extensively on the earlier DETR study. It was particularly interested in the potential in low and medium density housing. It concluded that the 5.5m to 6.5m numbers of dwellings could be achieved but the authors considered the assumption on market penetration of 40% to 80% to be optimistic without specific regulation in the market.

The University of Oxford Environmental Change Institute '40% House' report also drew on the DETR study to establish a future scenario where the CO_2 emissions of UK housing would be reduced by 60% nationally by using a wide variety of approaches including demolition and replacement of the worst performing stock. This report concluded that 4.4m existing dwellings and 2.1m new dwellings would need to be supplied by DHNs by 2050 in order to meet the overall objective. This would represent 22% of the housing stock in 2050.

Table 38 provides a summary of the conclusions from these reports.

Table 38 – Summary of conclusions

Source	TWh heat at >6% IRR	Nos of dwellings at >6% IRR	TWh heat at >9% IRR
DETR (1998-2002)	114	5.5m	19.4
Defra Oct 2007	150	6.5m	0.63
Environmental Change Institute		4.4m existing	

Source: Pöyry Energy Consulting and Faber Maunsell

The numbers of dwelling types from the census data in England and Wales are:

- purpose built flats 2.89m;
- converted flats 0.85m;
- terraces 5.60m;
- semi-detached 6.95m; and
- detached 4.98m.

Hence the average of the above DHN estimates of 5.5 m dwellings (for England and Wales) represents about 90% of the total of flats of all types together with about 50% of the terraces.

Previous work has identified the high density areas of purpose-built flats as having the greatest potential followed by terraces and then semi-detached homes. This is largely on the basis of overall heat density for an area. There is however some justification for re-examining the potential in higher density semi-detached streets as the linear heat density – i.e. amount of heat demand per metre of street length may in fact be similar with semis and terraces (due to heat losses from flank walls). Although the branch length from a street main to the property is longer with semi-detached dwellings there is the potential for the branch connection to be shared between two houses.

A specific report on the potential development of Community Heating in London was commissioned by the GLA from PB Power. This was published in 2006[17]. This report identified a number of high priority areas, selected on the basis of heat density, index of multiple deprivation, existing DH systems and areas of significant redevelopment.

D.2 Analysis of heat density in England and Wales

Higher density urban areas would have a higher heat demand per km^2 and hence would be expected to have lower DH costs and greater potential for a cost-effective scheme. This heat density relationship has its limitations however, a better correlation may be with a linear heat density, i.e. the amount of heat demand per unit length along a street. For example, long back gardens would result in low area heat density but would have limited impact on DH costs. The distance houses are set back from the road *is* important however to determine the costs of heat main connections and this parameter is reflected in the area heat density.

The heat density[18] of an area can be estimated using census data of house types and the physical area of the census unit used. A preliminary analysis has been carried out using the census data for housing in England and Wales.

The house types in the census are given as:

- Detached;
- semi-detached;
- terraces;
- purpose-built flats;
- converted flats (often from terraced houses);
- flats in commercial buildings; and
- other (e.g. caravans).

Data is also available on tenure i.e. owner occupier, public sector rented, private sector rented.

The numbers of dwellings of each type and an estimate of the heat demand has been calculated and plotted against the heat density for each census output area[19]. The figures below illustrate the following:

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17 Community Heating Development Study for London, PB Power, for the GLA, 2006

18 Heat density is defined as the annual heat demand in kWh divided by 8760 to give an annual average demand and then divided by the area of the sector in km^2

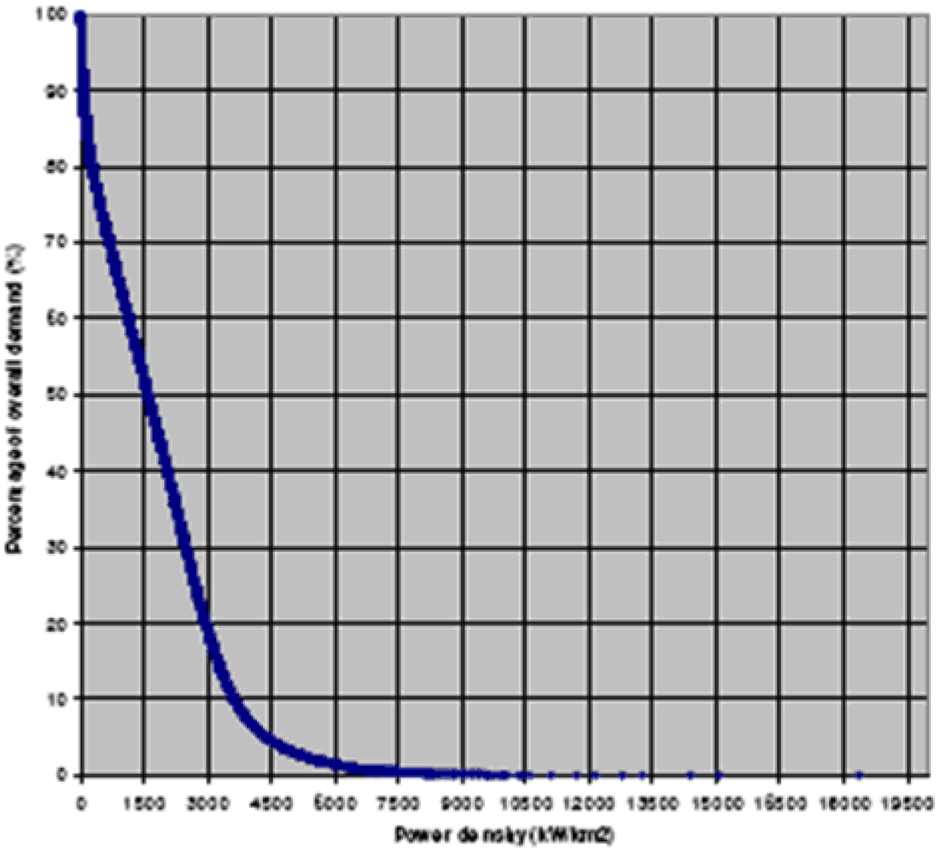
19 In the analysis we have used both postcode sector (c8000 datasets for England and Wales) and Super Output Areas (lower) (34,000 datasets for England and Wales)

The proportion of heat demand for dwellings in the higher density region (defined as being above 3000kW/km^2) is 20%. As can be seen this could be represented by 90% of the flats and about 20% of the terraces.

At heat densities lower than 3500kW/km^2 there is a change in the slope of the curve such that the potential increases significantly as the density decreases. In this region the number of semi-detached houses becomes significant reducing the heat density. At lower heat densities there is a gradual increase in the number of detached houses and semi-detached houses at the expense of terraced houses.

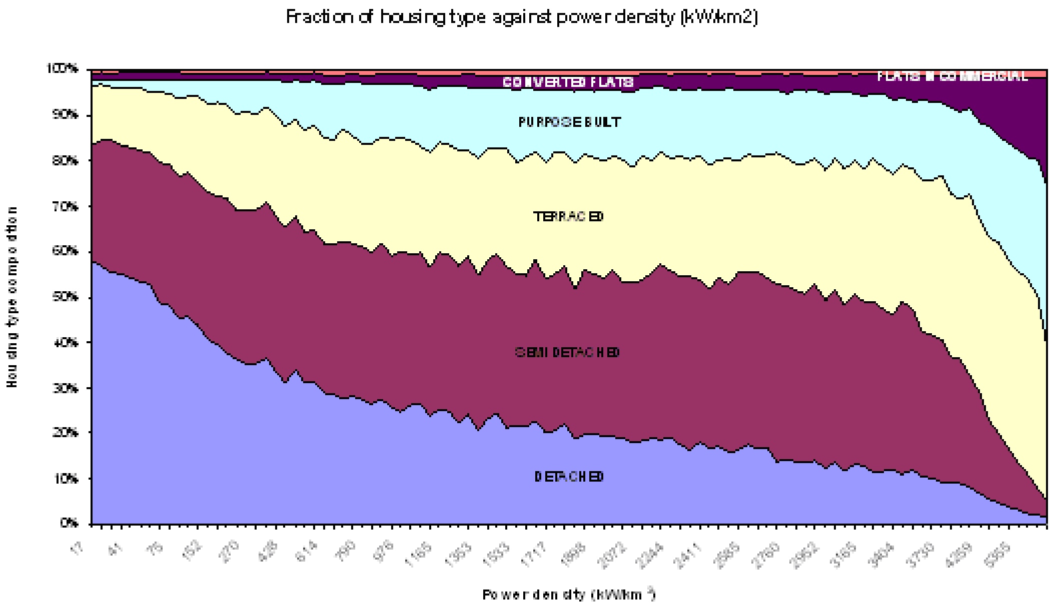
This housing data is shown in Figure 35 through to Figure 37 below.

Figure 35 – Cumulative heat demand for dwellings compared to heat density



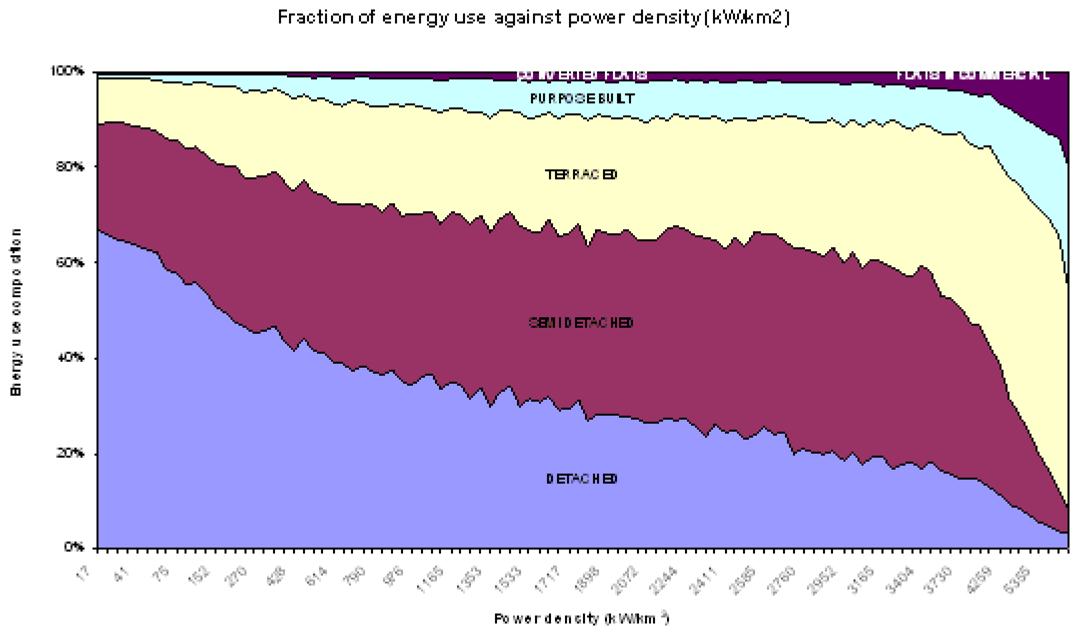
Source: Pöyry Energy Consulting and Faber Maunsell

Figure 36 – Housing types and heat density as percentage of total number of dwellings in each area



Source: Faber Maunsell and Pöyry Energy Consulting

Figure 37 – Housing types and heat density as percentage of heat demand in each area



Source: Faber Maunsell and Pöyry Energy Consulting

D.3 District heating potential for non domestic buildings

From previous work, within the 114 TWh DH heat supply potential at a 6% discount rate, around 44 TWh of heat was supplied to the commercial and public sector. This included 82 universities, 200 hospitals and industrial and warehouse buildings. We have analysed below the different sectors using more recent data from the BRE and this indicates for various reasons that this may be an overestimate of the potential.

Characterisation of the potential in the non domestic sector is significantly more difficult than with dwellings, due to the range of types and ages of buildings and uses. Whilst a number of comprehensive datasets are available to characterise the domestic stock in terms of type, location and energy efficiency, very little equivalent data is available for commercial buildings.

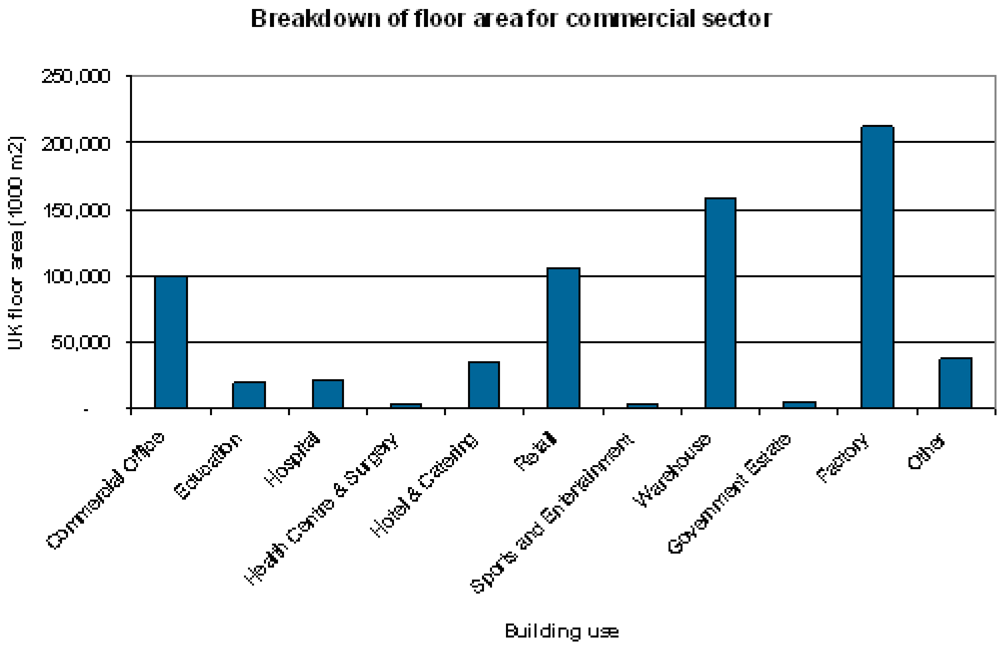
The discussion below is based on two sets of data which can be used to establish some bounds to the potential in the commercial sector:

BRE Non Domestic Energy Model (NDEM) database. This can provide the floor areas for a number of different commercial building uses on a UK scale. The data is based on VOA returns.

Energy consumption benchmarks. A number of benchmarks are available for the assessment of energy consumption – this discussion uses the most up to date set of CIBSE benchmarks developed for producing Display Energy Certificates (DECs). These provide a typical practice level and thus can be used to represent the average UK stock.

Figure 38 illustrates the breakdown of floor areas for the commercial building sector based on the BRE NDEM. Factories and Warehouses are the two largest sectors, representing 30% and 22% of the overall floor areas respectively. The next two highest sectors are retail and commercial offices at around 15% each. Thus the remaining types made up of education, healthcare, hotels and catering, government estate, and 'other' account for less than 20% of the overall stock by floor area.

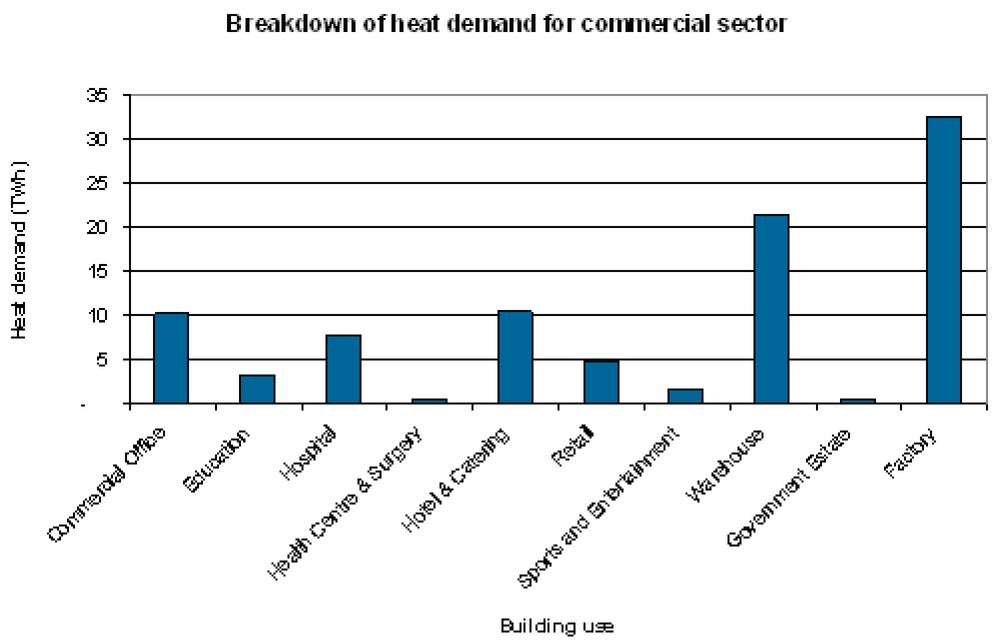
Figure 38 – Breakdown of floor areas for the commercial building sector



Source: Faber Maunsell and Pöyry Energy Consulting

The heat demands are calculated by multiplying the floor areas by the relevant DEC benchmarks. The breakdown is given in Figure 39, with a total heat demand of 93.2 TWh (this is less than the 123 TWh demand given in the Heat Call for Evidence – this may be due to the omission of 'other' building types in the calculation due to unknown use, differences in the benchmarks used, and an element of heat provided by electricity particularly in the retail sector, which has been omitted).

Figure 39 – Breakdown of heat demand for the commercial building sector



Source: Faber Maunsell and Pöyry Energy Consulting

Factories and warehouses account for almost 60% (54 TWh) of the heat demand of the assessed building types. However assessing the potential of including these on a DHN is very difficult. Firstly, the buildings are often low density (single storey) and hence present a low thermal demand per unit area. In addition, business parks are often spread out with large spaces between buildings. Secondly, it is likely that these building will be located on out-of town estates, or increasingly in isolated areas, for example alongside motorways (as is the case for many distribution centres). Thirdly, if a sufficient thermal load does exist, then a local CHP / heat network may be as effective on a site basis as connection to a DHN. For these reasons, it is not intended to include factories and warehouses in the modelled assessment.

Hotels and catering represent 11% (10 TWh) of the assessed commercial thermal load. This is correspondingly higher than their floor area would suggest and is due to the long occupancy hours and high heat demands associated with ventilation and domestic hot water use. Current detail on the location of hotels and catering is not available, but it could be assumed that buildings located in city centres and urban regions may be feasible for connection to a DHN. However, increasingly, large business hotels are located on the edge of towns and motorways, and these may not be feasible for DHN connection due to their isolated location. Assuming that 50% of hotel and catering businesses were connected to a DHN, the target heat load would be 5.2 TWh.

Commercial offices are the next largest sector at 11% (10 TWh) of the assessed load. These buildings are largely located in city centres and urban regions and so the potential for connection to a DHN could be relatively high. In addition the daytime heat demand can help balance out morning and evening peaks on residential schemes, maximising CHP run hours and improving the economics. However there are potential technical difficulties with connecting – plant rooms on modern blocks are often located on the roof and so DH pipework would need to be routed through the building at a potentially high cost. It is also important to consider that office accommodation has a relatively short life between re-furbishment or demolition and new build, and with improvements in thermal efficiency and increases in internal gains, many modern offices may have a more limited demand for space heating in the future, making DHN connection less viable. In more thermally efficient buildings, the peak load may be limited to a morning peak, providing limited benefit from diversity with residential loads.

Hospitals are the next largest heat demand at 8% or 7.7 TWh per year. Hospitals have a high heat demand due to requirements for adequate space heating and high levels of domestic hot water. Due to this they are often viewed as "anchor loads" for DHNs although this may be as much due to the hospital acting as a catalyst for DHN developments rather than a thermal load requirement. In addition, it is likely that a hospital will use a site-wide heating system (traditionally on steam) for its own purposes and not be connected to a wider district scheme. The potential for hospitals to feature in DHNs is of course limited by the number of hospitals, with typically only one site per a town. A hospital is a good candidate for a site-based CHP / heating network solution in any case and there are many examples of hospital CHP projects with no connection to surrounding buildings.

The retail sector only represents 4.9 TWh (5%) on Figure 39. This figure may be a significant under-estimate with a large fraction of heating provided by electricity (which is not captured in this data). Whilst benchmarks are available covering both electric heating and fossil heated retail units, there is no information on the breakdown by floor area and so a detailed assessment in not possible. The potential of DHNs to meet the 4.9 TWh fossil heated units could be relatively high, with the majority of retail units located in city centres and urban areas of high density. The BRE NDEM data suggests an average floor area of 193m^2 / retail unit suggesting that most retail is small street front based units where DHN costs would be similar to those for terraced housing. However the benefits and cost effectiveness of DHNs in retail may be limited by an overall limit in heat demand (short daytime hours) and low demands due to internal gains (largely lighting) and lack of domestic hot water demand. It is unknown whether electric heated retail units would connect to DHNs due to high conversion costs from electric to water based heating systems. For systems with a central boiler DHN connection may be feasible, but with individual heating elements around the building, conversion costs would be significant and disruptive.

Education is the final sector of significant interest. The 3.3 TWh demand (3% of total commercial assessed) covers both schools and further and higher education establishments – unfortunately no data is available on the breakdown into each education sector. Schools (primary and secondary) are typically located in residential and urban areas and so there could be potential for connection to a DHN. Schools will offer the benefit of daytime heat demand, and so contribute to the diversity of DHN schemes. Some university campuses are located out of town in which case a local site wide system may be viable, but not connection to a wider district scheme. For other university forms, with limited knowledge on breakdown, it is not possible to provide a generic conclusion.

Table 39 provides a summary of the loads which may have potential for connection to DHNs given the discussion above given a low and high boundary. It is important to note that Figure 38and Figure 39 are based on the assumptions given and have been given to provide a high level comparison of the commercial building sector with the residential sector.

Table 39 – Potential for connection by sector

Key sector	Potential for DHN connection (low)	Potential for DHN connection (high)	Assumptions
Factories and warehouses	0 TWh	0 TWh	Assumes that DHN connection not viable due to locations.
Hotels and catering	5.2 TWh	5.2 TWh	Assumes that 50% of sites are in higher density city centre and urban areas.
Commercial offices	5.1 TWh	5.1 TWh	Assumes that 50% of sites are in higher density city centre and urban areas.
Hospitals	0 TWh	3.9 TWh	Low case assumes that site schemes are preferable or currently in existence. High case assumes 50% connection to DH
Retail	3.9 TWh	3.9 TWh	Assumes that 80% of fossil heated retail is located in city centre and urban areas with DHN connection potential.
Education	1.6 TWh	2.6 TWh	Low case assumes that 50% of education floor space is schools located in residential areas. High case assumes 80% is located in residential areas
Total	15.8 TWh	20.7 TWh	

Source: Pöyry Energy Consulting and Faber Maunsell

The lower value of 15.8 TWh corresponds to 1.7% of total UK heating demand, or 12.9% of non-domestic heating demand. The higher value of 20.7 TWh represents 2.2% of total UK heating demand and 17% of total non-domestic demand. The overall likely potential for heat provision through DHNs to the non-domestic sector is therefore limited. If about 20% of the total dwellings heat demand was to be supplied by DHNs then it would be reasonable to assume that a further 10% of this demand (i.e. 2% of the national total) could also be supplied to non-domestic buildings.

The concept of an anchor load is widely accepted as key in facilitating the development of a DHN. This can provide a sufficient load which can form a baseline demand improving the economics of a scheme. A large scale anchor load (for example, a large hospital site) can also act as a catalyst for DHN development by providing a large initial customer from where the scheme can grow.

In terms of the UK potential, anchor loads are not necessarily an essential factor. Where a load is of sufficiently large size, it is likely that a site scheme would be viable on its own without connecting to a district scheme. In addition, the loads are not available in all areas of the country or across each community, and for widespread DHN deployment to be achieved, schemes should not rely on being located close to an anchor.

The concept of acting as a catalyst is of interest when discussing policies and initiatives – whilst an anchor load may not significantly improve the economics or viability of a scheme, it could provide an initial customer from where a scheme can organically grow. The nature of these loads (hospitals and universities for example) means they can be more easily encouraged to contribute to DHNs through government intervention.

D.4 District Heating and Cooling

The cooling energy demand for buildings (nearly all non-domestic buildings and mainly commercial offices and retail areas) is normally met by locally installed electric chillers. The electricity demand for cooling equipment is estimated at 9TWh p.a. (Defra October 2007). The CoP of local existing chillers is perhaps around 3 on average indicating a cooling demand of about 27TWh. If this was all supplied by absorption chillers with a CoP of 0.67 the heat demand would be about 40TWh. This is clearly much smaller than the total space and water heating demand for the UK of 598TWh p.a. The impact of any consideration of cooling on the potential for DHNs is therefore likely to be small. However, most cooling demand is found in city centres, areas of high building density, where DHNs are most likely to be viable. In this context the provision of cooling may be an important element of a DHN/DC system.

There are three principle ways in which lower carbon emissions can be achieved with DHNs or District Cooling Networks (DCNs)

Install absorption chillers within each building and use low carbon heat from the DHN as the energy source. The main advantage of this approach is that the existing DHN can be used to a greater capacity. The disadvantage is that the building owners have to agree to additional plant and there may be space restrictions. This approach is being encouraged for example in Goteborg and Seoul.

Install absorption chillers at the central CHP plant and distribute cooling energy through a separate DCN. The advantage is economies of scale for the absorption chiller and potentially higher efficiencies. The disadvantage is the cost of a separate DCN. DCNs are relatively high cost because the temperature difference between flow and return is small implying larger pipes than for a heating supply and also because the utilisation of this asset over the year is limited. This is the approach adopted by the Southampton City Centre scheme.

Install centralised high efficiency electrical chillers and distribute cooling energy through a separate DCN. This may be as efficient as a centralised absorption chiller in terms of CO_2

savings depending on the CO_2 emissions factor used for electricity and the CoPs of the chillers. This is the approach adopted in Stockholm (where the reject heat from the chillers is supplied to the DHN) and in many US cities e.g. Minneapolis St Paul and Chicago.

The centralised chiller options may offer the potential for further energy efficiency improvements for example utilising chilled water storage to take advantage of free cooling at night.

D.5 Conclusions

On the basis of previous work it is reasonable to conclude that 4.4m to 6.5m dwellings could be supplied with DHNs provided that a rate of return over 6% real is considered economically viable and provided that the market penetration rates assumed can be achieved in practice with only a limited discount on heat costs.

Non-domestic buildings can also be supplied from DHNs where suitable density exists although the overall technical potential is likely to be limited to between 15.8 TWh and 20.7 TWh. This is less than the previous estimates of 44 TWh at 6%.

This number of dwellings equates to a heat density of approximately 3000kW/km^2 or above.

If lower discount rates are used in the analysis the potential is much larger. A critical issue is whether the large number of mid 20th century semi-detached houses can be economically connected to DHNs. There is no obvious cut-off in the trend of heat density. The lower density areas will have more detached houses and semi-detached houses with greater spacing between the houses, with wider roads and larger gardens.

More detailed work on the design and costs of networks in the semi-detached housing sector is recommended to establish the parameters under which the DHN could be economic.

ANNEX E – FURTHER INPUT ASSUMPTIONS

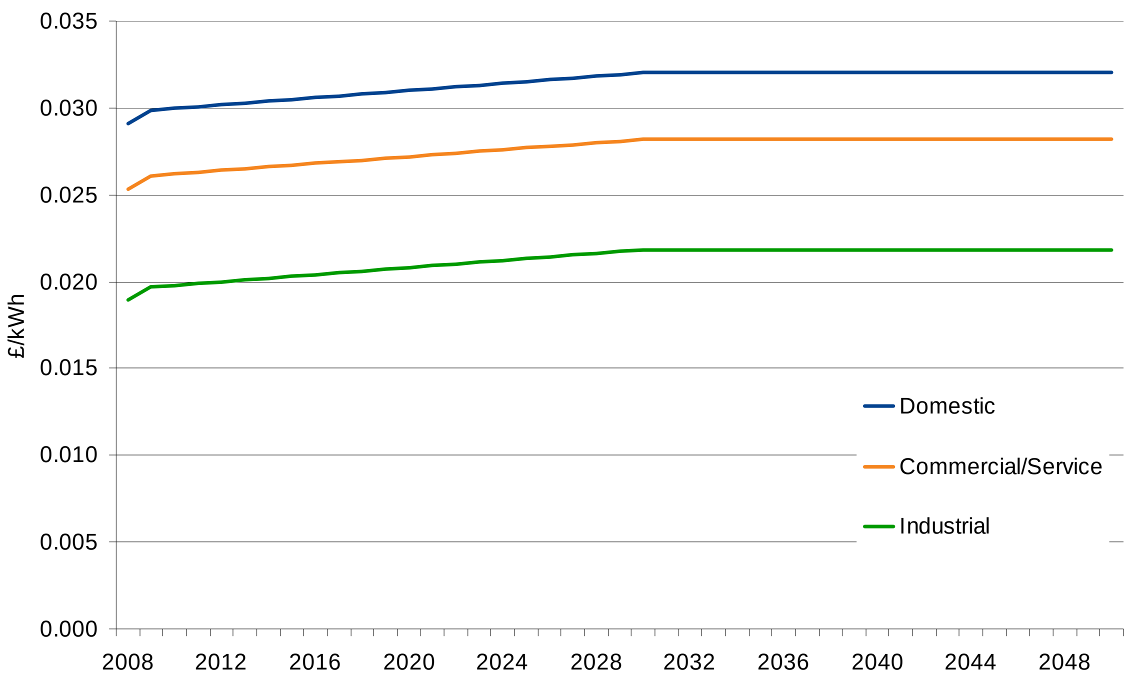
E.1 Introduction

This annex outlines the remaining input assumptions used in the national potential modelling. These

E.2 Gas input costs

Figure 40 presents DECC's central view for gas input costs by customer type.

Figure 40 – Gas input cost

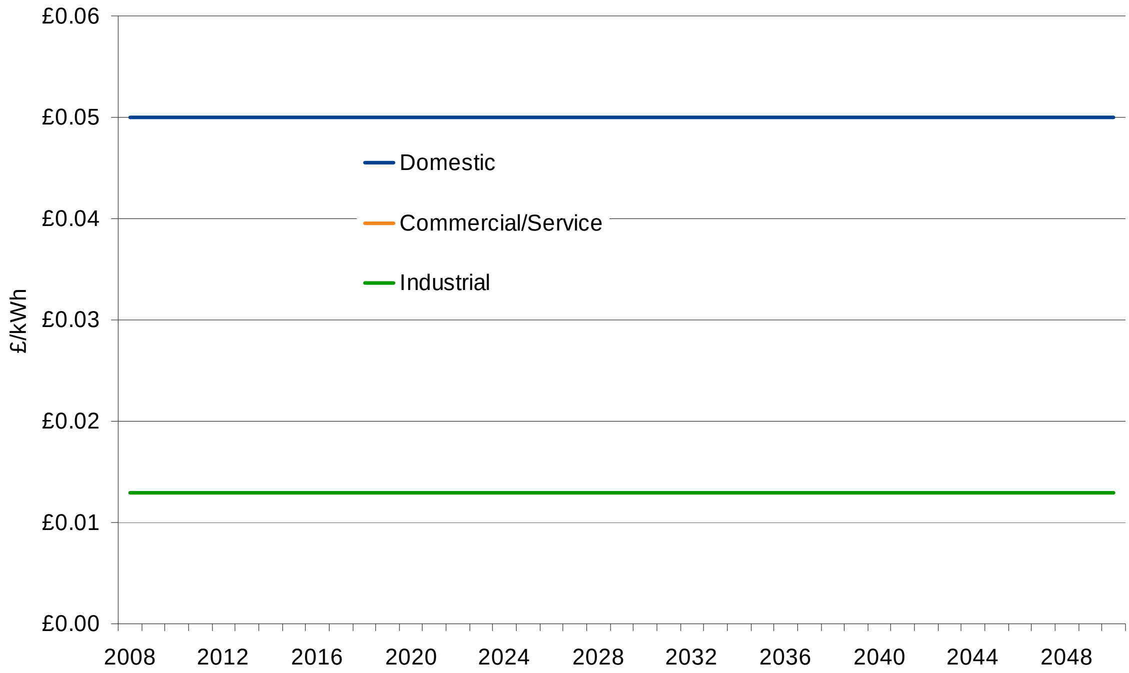


Source: DECC

E.3 Biomass input costs

Figure 41 presents DECC's central view for biomass input costs by customer type.

Figure 41 – Biomass input cost (£/kWh)

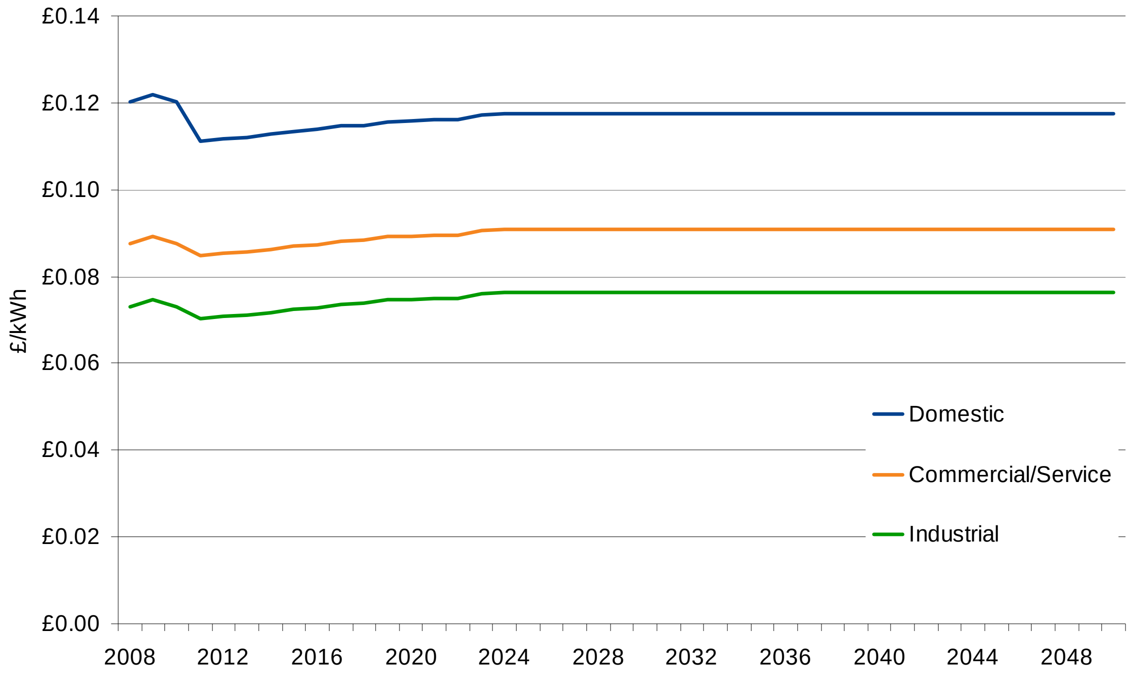


Source: DECC

E.4 Electricity input costs

Figure 42 presents DECC's central scenario for electricity input costs by customer type.

Figure 42 – Electricity input cost

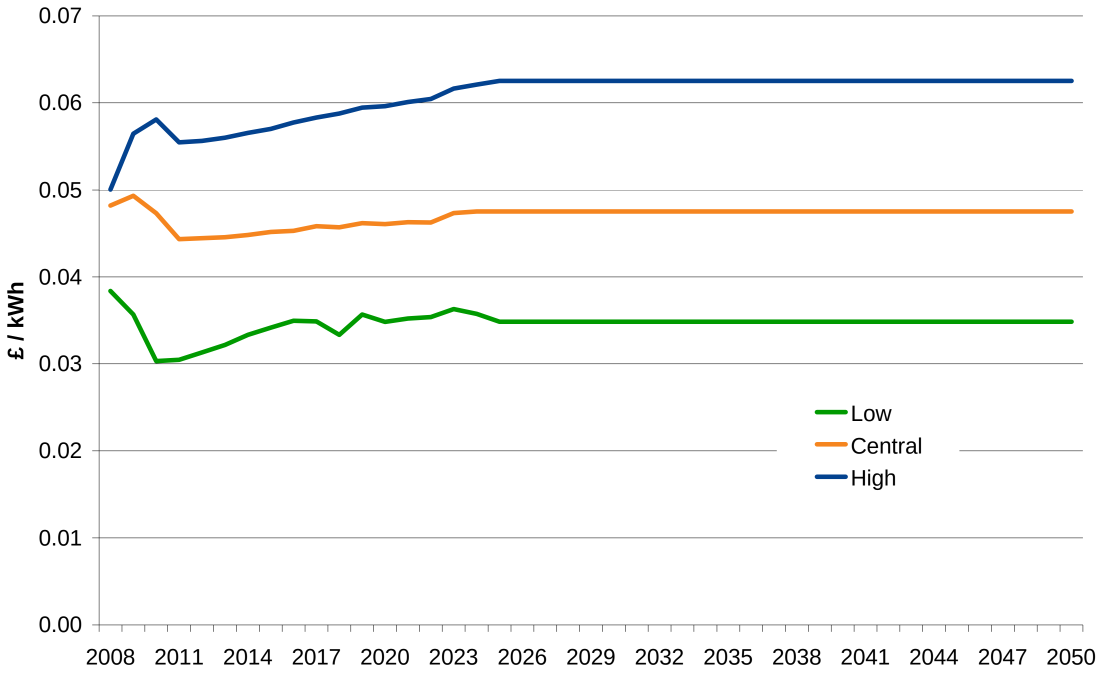


Source: DECC

E.5 Electricity Sale Price

Figure 43 presents DECC's Electricity sale price projections based on the wholesale projections.

Figure 43 – Electricity sale price

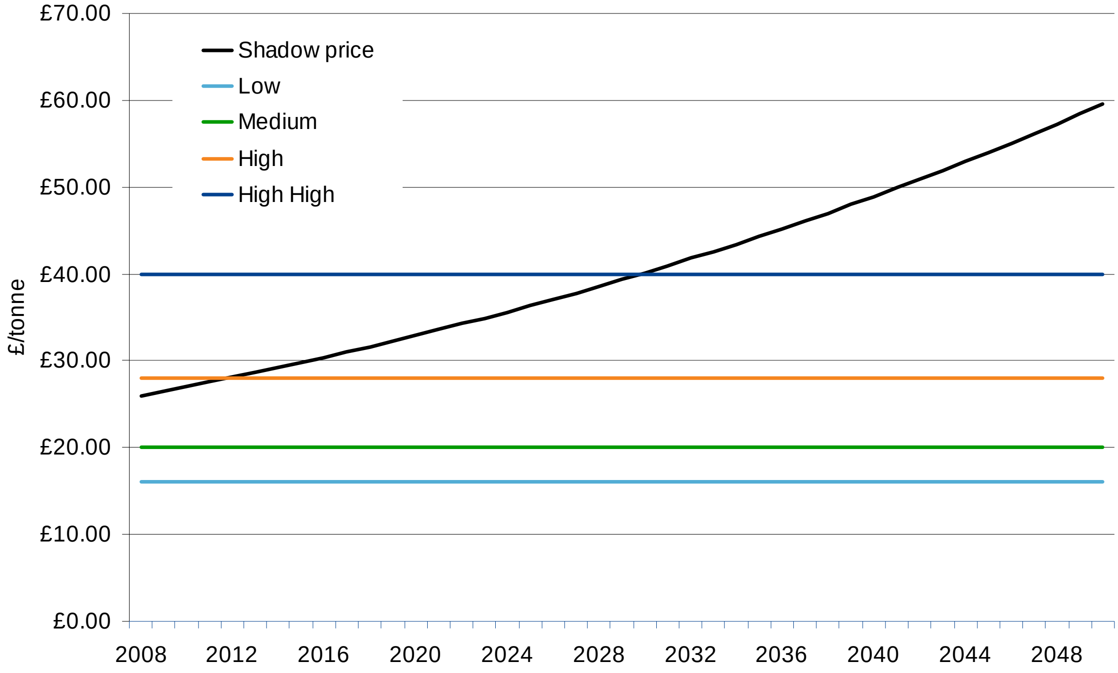


Source: Pöyry Energy consulting and Faber Maunsell

E.6 Carbon assumptions

Figure 44 presents DECC's carbon projections.

Figure 44 – Carbon projections



Source: DECC

E.7 Remaining variables

Table 40 presents DECC's views on electricity and heat sale price, ROC value, LEC value and Energy from waste (EFW) gate fees.

Table 40 – Variable summary table

Variable	Value
Heat sale price	£0.070 / kWh
ROC price	£0.034 / kWh
LEC price	£0.004 / kWh
EFW gate fee (for AD and incineration)	-£0.0397 / kWh

Source: DECC

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ANNEX F – IMPACT OF BARRIERS AND RISK ON PRIVATE SECTOR INVESTMENT

F.1 Implications for project returns and the IRR

The section above highlights the potential problems associated with constructing and operating a DHN from the perspective of an investor. The importance to a potential investor is that each one of these factors will have an impact on the return they are able to get from a scheme. Therefore to investigate how these risks impact on the potential Internal Rates of Return (IRR) we have used the financial cash flow model underpinning the national take-up model to investigate how changing revenues, costs and heat load impacts on the overall return to an investor.

F.2 Investor risk

The comparative cost assessment used a fixed discount rate of 10% real, pre-tax, and assumed any potential private investors would require this rate of return. Under this assessment we highlighted the impact on the effective heat tariff required by each technology. However, to fully assess the commercial opportunities in these projects it essential to calculate what IRR can be achieved and how sensitive this is to changes in the various core assumptions

F.2.1 Underlying assumptions

The IRR analysis below assumes that the current market and policy regime is maintained and thus includes carbon on the basis of an EU ETS type mechanism, as well as access for schemes to LECs and ROCs. The table below outlines the key assumptions used in this analysis.

Table 41 – Assumptions for the cash flow model

Variable	Assumption
Fuel Prices	DECC central scenarios
Electricity sale price	Fixed at £48/MWh
Uptake of scheme	100 per cent in year 1
Sizing of scheme	Perfect foresight (optimal sizing)
Cost of carbon	Included at £20/tonne
Electricity ROC price	Constant at the buy out price (£34/MWh)
Cost of heat / Heat tariff	Assumed to be at £70 /MWh (in line with the average baseline cost of heat for dwellings)
LECs	Constant at current value (£4.56/MWh)
CAPEX support	Assumed at zero
Grid electricity generation efficiency	45 per cent (based on gas)
Grid CO_2	Marginal gas

Source: Pöyry Energy Consulting and Faber Maunsell

F.2.1.1 Overview

We have assessed 7 district heating options, 2 from each size band (1 gas and 1 renewable) and waste heat.

We have then considered the impact on the IRR of these technologies, in relation to:

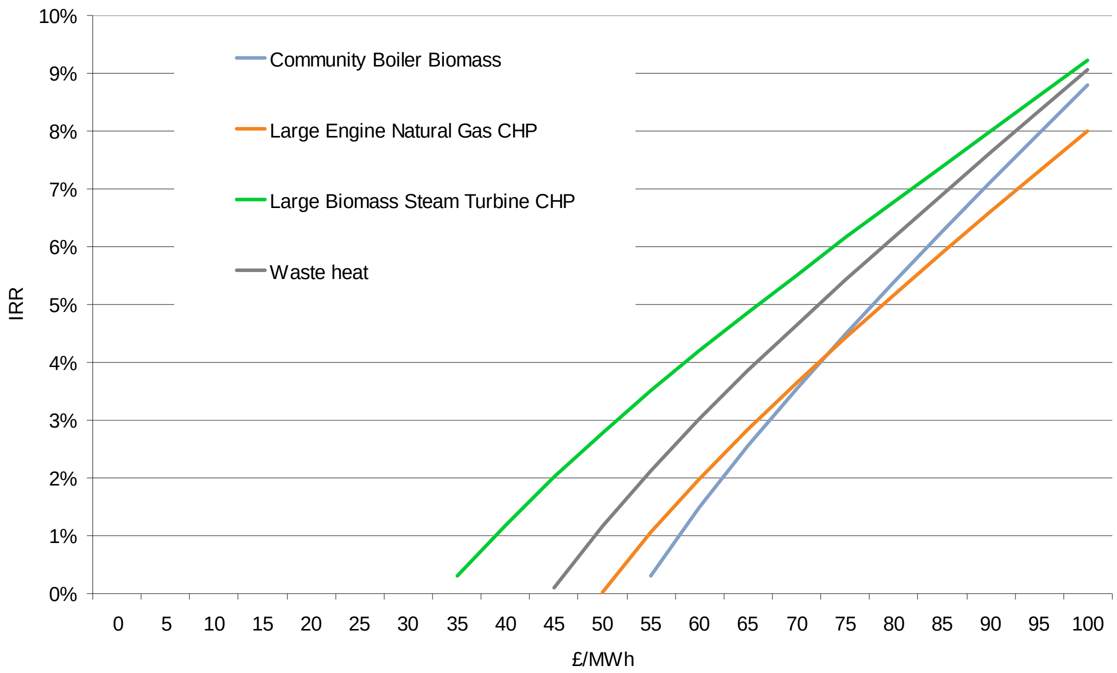
- changes to the implied heat tariff;
- changes to other revenues streams (wholesale electricity and 'support' revenues, including carbon);
- changes to the take-up rate; and
- the impact of providing assistance with the CAPEX cost.

F.2.1.2 Implied heat tariff

In reality the required heat tariff is likely to be linked to conventional alternatives, as any district heating operator would have to price the heat at or under the heat cost currently paid by customers. This link is likely to be a result of the interaction between conventional cost and some DH technology costs (input gas price).

Given the heat tariff required by the district heating it may be necessary to increase the cost of conventional heating options, to ensure competitiveness, but this may adversely affect fuel poverty (for those individual not on the district heating scheme).

Figure 45 – Heat tariff impact



Source: Pöyry Energy Consulting and Faber Maunsell

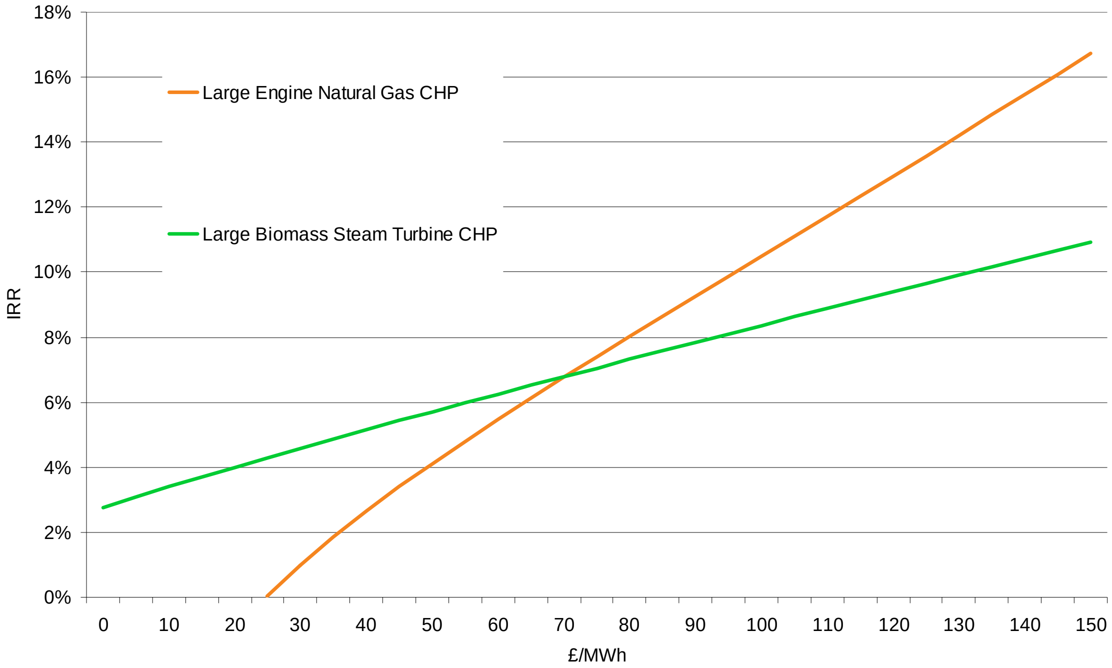
The results predict that the majority of the options would require a heat tariff of between £50 – 55/MWh in order to earn any return (given the assumptions in Table 41). Even if a heat tariff of £100/MWh could be achieved, only the community boiler natural gas would produce a return above the 10% commercial level.

F.2.1.3 Increase in revenue for electricity

This second sensitivity looks at the impact of increases revenue streams linked to electricity generation (including sale on the wholesale market, ROCs and LECs). This sensitivity is only relevant for CHP (as they produce electricity alongside heat), and would also increases cost of conventional electric heating and small-scale renewable counterfactuals

In Figure 46 we see that larger gas options (Medium CCGT and Large gas engine) benefit most from electricity revenue due to the ratio of electricity output to costs. The renewable (biomass) options also reach commercial rates of return but require much higher level of revenue. The community boilers and the waste heat district heating schemes are unaffected as they either don't produce electricity (community boilers) or the electricity revenue is already accounted for (waste heat).

Figure 46 – Electricity revenue impact



Source: Pöyry Energy Consulting and Faber Maunsell

Although the chart shows that electricity based revenues of approximately £90/MWh and above lead to commercial rates of return, it is important to be cautious regarding these secondary income streams. Over reliance on revenues from other markets (i.e. not Heat) can be risky, as experienced in Denmark where the level of electricity generation from district heating CHP led to a collapse in the electricity price.

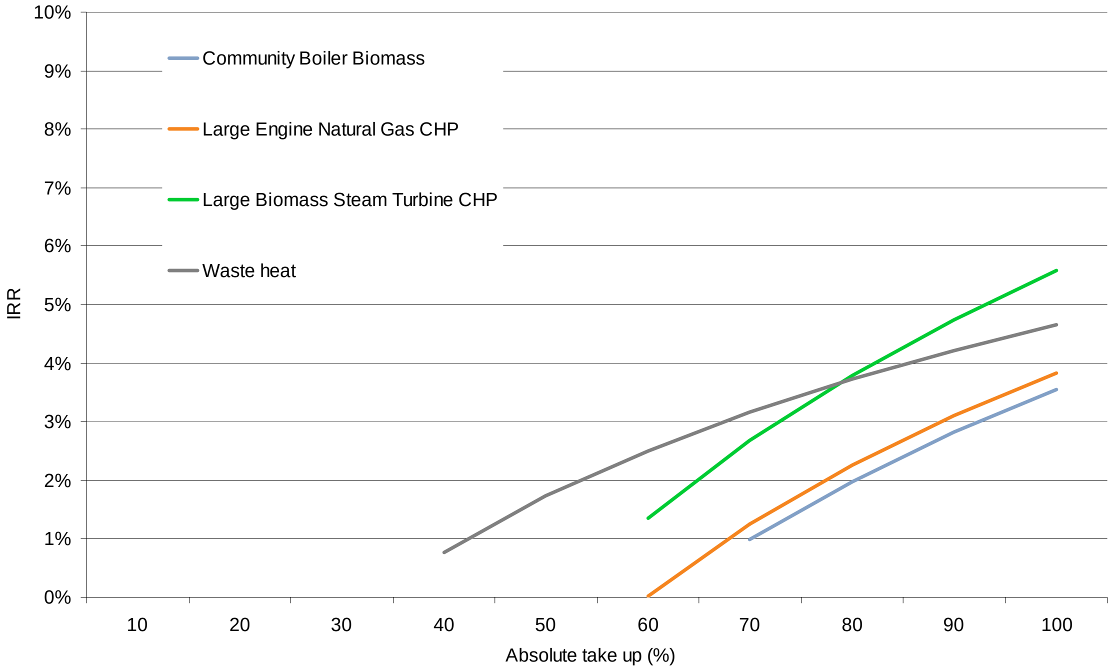
F.2.1.4 Take up risk

As shown in section 3, the take up risk (or phasing of investment) is one of the key risks faced by the developers of these schemes.

This sensitivity assesses the impact of the rate of return from capping the uptake of the schemes at various percentages while continuing to assume that the scheme had been built to meet 100% take up.

The results show that a take up of at least 40% of the assumed level is needed for any of scheme make a return, and the majority of the schemes assessed a uptake of 70% would be required for a return. Looking at the specific technology options the results suggest small-scale projects with small number of customers may be more attractive in early stages, however in reality these may hit scale constraints for funding. Again this highlights the fact that without guaranteed offtake, high risk in over-sizing the scheme

Figure 47 – Assessment of take up risk



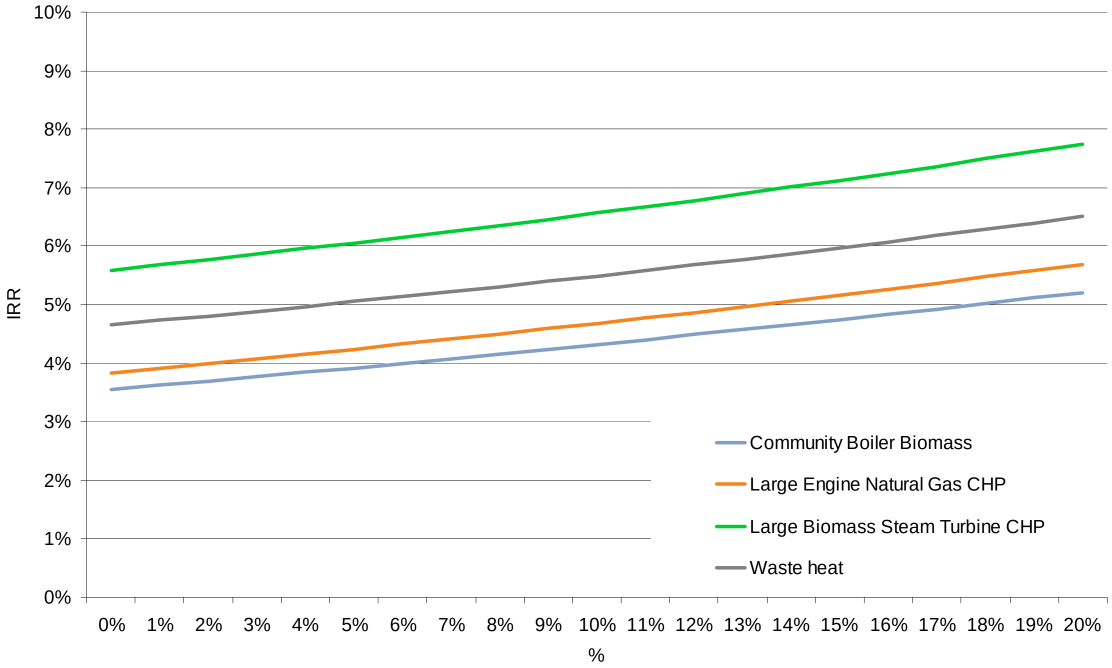
Source: Pöyry Energy Consulting and Faber Maunsell

F.2.1.5 Capital support

This final sensitivity considers the impact of a support mechanism that reduces the upfront capital costs on the IRR. Along with take up, the upfront capital costs have been identified as a key risk to potential investors in district heating (with this type of support cost over-runs and/or construction delays will be important considerations).

These results appear to show that for an incremental subsidy of 10% across all capital costs will result in an increase of approximately 1% in the IRR. But even a reduction of 20% in the upfront (year 1) capital is not enough for these schemes to achieve a commercial rate of return.

Figure 48 – Reducing the upfront capital cost



Source: Pöyry Energy Consulting and Faber Maunsell

ANNEX G – FULL RESULTS OF NATIONAL POTENTIAL SCENARIOS AND SENSITIVITIES

The following analysis presents the full results from each of the scenarios modelled.

G.1 Current policy

G.1.1 Impact of the discount rate

This section sets out the impact of changes in the required rate of return on the potential for district heating under the current policy assumptions. In Table 42 we have presented the potential for district heating under the current policy, with DECC's central view of future fuel and carbon prices, and at 10%, 6% and 3.5% discount rates.

Table 42 – Impact of discount rate on DHN potential (Current Policy)

	Total number of DHN	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand	Technology used
10 %	-	-	-	-	-	-
6%	-	-	-	-	-	-
3.5%	0 – 18	0 – 1.7	0 v 15.6	0 – 18.9	0% – 3.2%	Waste heat Large biomass steam turbine Large engine natural gas

Source: Pöyry Energy Consulting and Faber Maunsell

Under the current policy assumptions the model predicts no district heating will be commercially viable at 10% and 6% discount rate. Under a 3.5% discount rate the model predicts it would be economic to commence the development of 18 district heating networks which would eventually serve approximately 1.7 million dwellings. In addition the schemes would also serve approximately 15.6 million m^2 of commercial property. Under these assumptions, the model predicts that 3.2% of UK heat demand can be met from district heating.

In this case, while these networks would be economic over an assumed 30-year life, it would not be economic to initiate further district heating at a later date; these networks, and only these networks, would be economic at any time during the period to 2050.

The networks would be supplied by a mix of large gas-fired CHP engines, large biomass CHP steam turbines and by waste heat from (relatively) nearby power stations.

G.1.2 Policy interventions

In Table 43 we present the potential for DHN by changing two types of policy measure, in isolation and combined under the current policy assumptions at a 10% rate of return. The policy measures assessed are a reduction in the initial capital costs of 20% and secondly an increase in revenue of 20% above DECC's central case. In addition to these two support measures we have also modelled the impact of targeting only those customers with electricity heating.

Table 43 – Impact of policy interventions under current policy (10%)

	Total number of DHN	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand	Technology used
10%, 20% CAPEX reduction	-	-	-	-	-	-
10%, 20% revenue increase	-	-	-	-	-	-
10%, CAPEX and revenue	-	-	-	-	-	-
10% Electricity customers only	0 – 4	0 – 0.1	0 – 11.4	0 – 1.5	0 – 0.3%	Waste heat

Source: Pöyry Energy Consulting and Faber Maunsell

Assuming the 10% required rate of return and under the current market framework the model predicts that these individual policies or a combination of both are unable to encourage the development of any district heating within the UK.

The results from targeting only the electricity customers show that it will economic to commence the development of a small number of district heating schemes. The model predicts it would be economic to commence the development of 4 district heating networks which would serve approximately 0.1 million dwellings. In addition the schemes would also serve approximately 11.4 million m2 of commercial property. Under these assumptions the model predicts that 0.3% of UK heat demand can be met from district heating.

G.1.3 Policy interventions 6% rate of return

Following on from section G.1.2 we have assessed whether the same policy measures could have any impact on the deployment of district heating if the investment was further de-risked. To model this we have reduced the discount rate to 6% which is considered to be the return required by network operators in other sectors. These are presented in Table 44.

Table 44 – Impact of policy interventions under current policy (6%)

	Total number of DHN	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand	Technology used
6%, 20% CAPEX reduction	0 – 13	0 – 1.6	0 – 14.6	0 – 18.3	0% – 3.2%	Waste heat, Large biomass ST
6%, 20% revenue increase	-	-	-	-	-	-
6%, CAPEX and revenue	0 – 562	0 – 3.5	0 – 26.3	0 – 38.8	0 – 6.5%	Waste heat, Large biomass ST, LENG

Source: Pöyry Energy Consulting and Faber Maunsell

Under the assumption of additional support to reduce initial capital costs by 20%, the model predicts it would be economic to commence the development of 13 district heating networks which would eventually serve approximately 1.6 million dwellings. In addition the schemes would also serve approximately 14.6 million m^2 of commercial property. Under these assumptions the model predicts that 3.2% of UK heat demand can be met from district heating. However, the combination of de-risked investment and increased electricity revenue still results in no potential for district heating.

Combining both policy measures under the de-risked current market framework doubles the heat load served by district heating compared to CAPEX support alone. Under this case it would be possible to commence the development of 562 district heating networks which would eventually serve approximately 3.5 million dwellings. In addition the schemes would also serve approximately 26.3 million m^2 of commercial property. Under these assumptions the model predicts that 6.5% of UK heat demand can be met from district heating.

In all of these cases, while these networks would be economic over an assumed 30-year life, it would not be economic to initiate further district heating at a later date; these networks, and only these networks, would be economic at any time during the period to 2050. In this case the networks would be supplied by a mix of, large gas-fired CHP engines, large biomass CHP steam turbines and by waste heat from (relatively) nearby power stations.

G.2 Pure market

G.2.1 Impact of discount rate

This section set out the impact of changes in the discount rate on the potential for district heating under the pure market assumptions (Table 7). In Table 45 we have addressed the potential under the pure market assumptions (with no incentives or market interventions, but with net carbon emissions valued at Shadow Price), at discount rates of 10%, 6% and 3.5%.

Table 45 – Impact of discount rate on DHN potential (pure market)

	Total number of DHN	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand	Technology used
10%	-	-	-	-	-	-
6%	0 – 4	0 – 0.3	0 – 11.4	0 – 3.6	0 – 0.6%	Waste heat
3.5%	27 – 68	3.3 – 8.0	15.6 – 26.3	34.6 – 82.8	5.8% – 13.9%	Waste heat Community boiler biomass

Source: Pöyry Energy Consulting and Faber Maunsell

At the 10% required rate of return under these assumptions the model predicts no district heating is commercially viable. However by reducing the required rate of return to 6% the model predicts it would be economic to commence the development of 4 district heating networks which would eventually serve approximately 0.3 million dwellings. In addition the schemes would also serve approximately 11.4 million m^2 of commercial property. Under these assumptions the model predicts that 0.6% of UK heat demand can be met from district heating. The networks would ultimately be supplied entirely by waste heat from (relatively) nearby power stations.

Under this de-risked scenario of 3.5% rate of return and pure market assumptions the model predicts it would be economic to commence the development of up to 68 district heating networks which could serve approximately 8.0 million dwellings. In addition the schemes would also serve 26.3 million m^2 of commercial property. Under these assumptions the model predicts that 13.9% of UK heat demand can be met from district heating.

Each of these networks would serve an entire community. Again, these networks, and only these networks, would be economic at any time during the period to 2050.

These networks would be supplied by waste heat from (relatively) nearby power stations.

G.2.2 Policy interventions

In Table 46 we have presented the potential for district heating from targeted different policies at a 3.5% rate of return. In the first case we have considered the impact of targeting only social housing. Secondly we have removed a number of the available district heating technologies, leaving only the large and small gas-engine CHP options. This will allow us to investigate the growth of district heating from these small 'starter' schemes.

Finally we have investigated how robust the district heating options are to the differing futures for fuel prices, using the relevant DECC scenarios.

Table 46 – Targeted policies under pure market assumptions (3.5%)

	Total number of DHN	Number of domestic connections (million)	Number of commercial connections (million m2)	Heat output TWh	Percentage of UK heat demand	Technology used
Social housing	9 – 830	1.1 – 1.4	15.6 -16.7	10.1 – 12.1	1.7% – 2.0%	Waste heat CBB
Large and small gas engines	-	-	-	-	-	-
Low fuel price	40 – 68	1.8 – 8.0	19.3 – 26.3	20.1 – 82.8	3.4% – 13.9%	Waste heat, LENG
High fuel price	68 – 2003	6.7 – 8.0	24.4 – 26.3	62.7 – 82.8	10.5% – 13.9%	Waste heat, CBNG, CBB

Source: Pöyry Energy Consulting and Faber Maunsell

The results from targeting only the social housing show it would be possible to commence the development of up to 830 district heating networks (each serving a whole community) which would eventually serve approximately 1.4 million dwellings and 16.7 million m^2 of commercial properties. Under these assumptions, the model predicts that 2.0% of UK heat demand can be met from district heating. These community results are identical under the current policy and the pure market assumptions.

In this case a large number of Community Boiler Biomass DHN would be developed around 2020. This means that it would be possible to serve more customers by deploying the DHN through individual tranches rather than on a community wide basis.

In the second case where we assess the small 'starter' schemes there is no deployment of district heating; this is because these technologies remain too costly compared to the current base line heating options.

In the final two cases we have considered the impact of changing the fuel price (either to DECCs low or high case). The model predicts that the maximum potential for district heating is unchanged independent of whether we assume the low or high fuel prices. Under these assumptions the model predicts it will be possible to develop 68 district heating networks. These would serve approximately 8 million UK dwellings, and 26.3 million m^2 of commercial properties. In total the model predicts that almost 14% of UK heat demand can be met from district heating.

However the ‘range of the possible potential’ for district heating differs greatly between the two fuel price assumptions. Under the low fuel price assumptions development would be limited to 40 networks serving approximately 1.8 million UK dwellings, and 19.3 million m^2 of commercial properties (3.4% of UK heat demand). Whereas under the high fuel price assumptions 2003 networks could be possible, serving 6.7 million UK dwellings, and 24.4 million m^2 of commercial properties (10.5% of UK heat demand).

QUALITY AND DOCUMENT CONTROL

Quality control			Report's unique identifier: 2009/204
Role	Name	Signature	Date
Author(s):	John Macadam		1/05/2009
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Approved by:	Gareth Davies		1/05/2009
QC review by:	Beverly King		1/05/2009

Document control			
Version no.	Unique id.	Principal changes	Date
v1_0		First draft for comments	18/02/2009
V2_0		Final draft for comments	03/04/2009
V3_0		Final for publication	30/04/2009

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