THE POTENTIAL AND COSTS OF DISTRICT HEATING NETWORKS

PÖYRY FABER MAUNSELL | AECOM

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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.

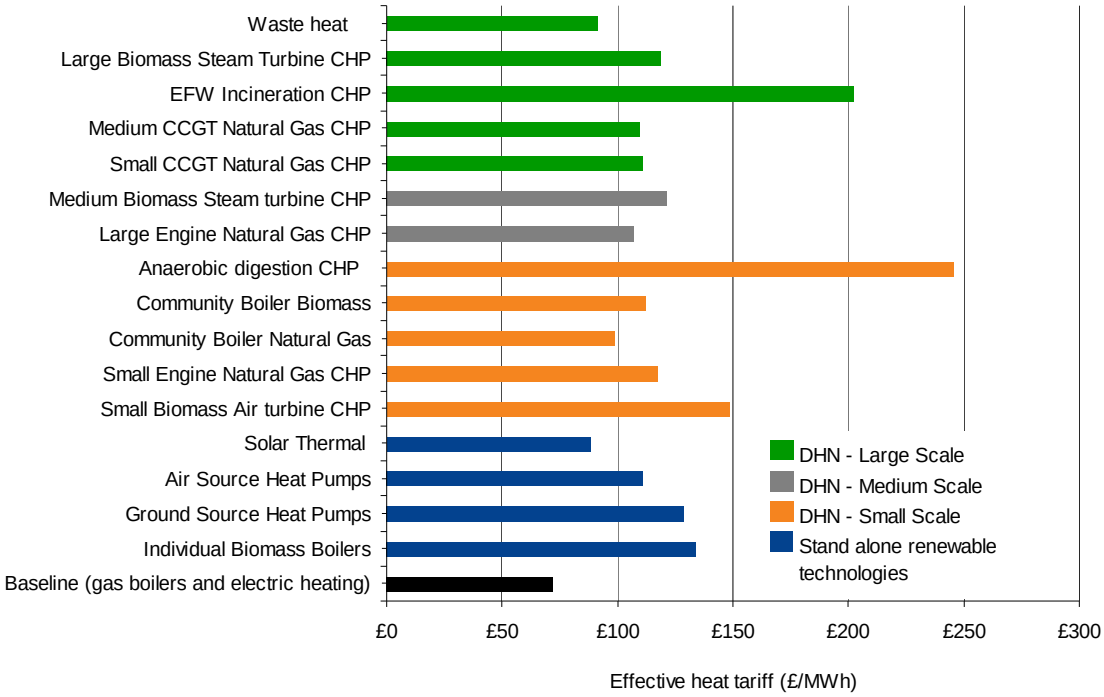
While district heating has been deployed in the UK since the 1950's, it has achieved only a low market penetration and currently provides less than 2% of UK heat demand. This is in stark contrast to the position in many other European countries; in Finland and Denmark, for example, district heating is 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.

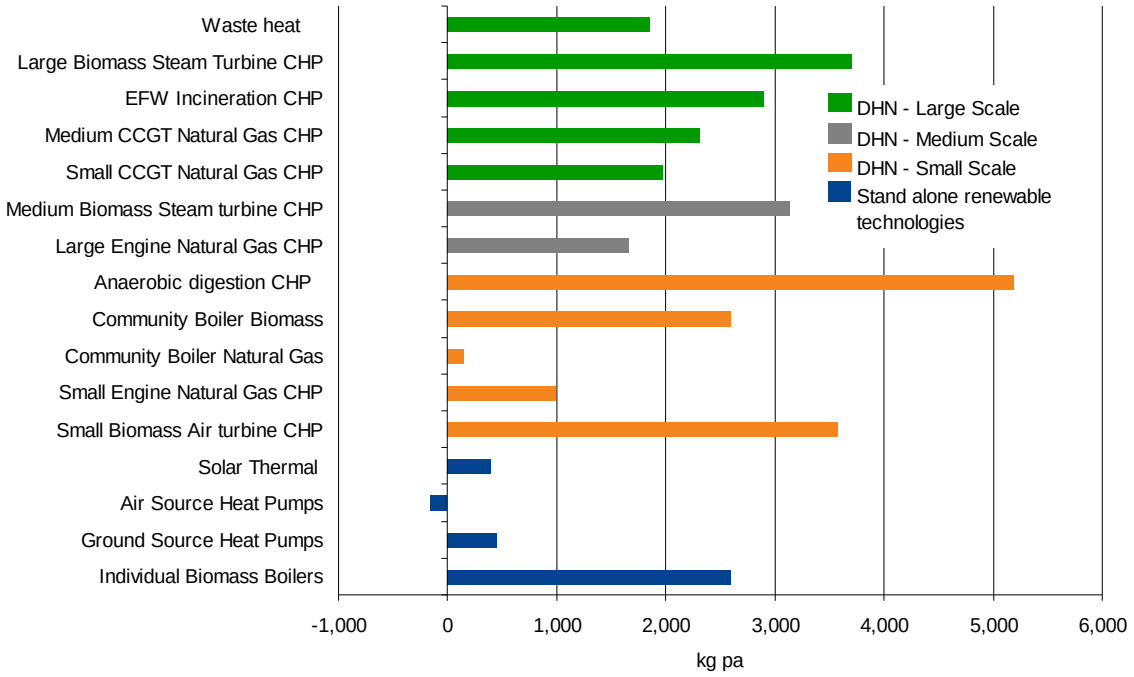
This is not a problem that is exclusive to district heating. As Figure 1 shows, alternative sources of zero/low carbon heat (ground source heat pumps (GSHPs), air source heat pumps (ASHPs), solar thermal or individual biomass boilers) are also not currently

commercial against conventional heating systems in built-up areas based on the assumptions used in this modelling.

Incorporating the value of carbon savings

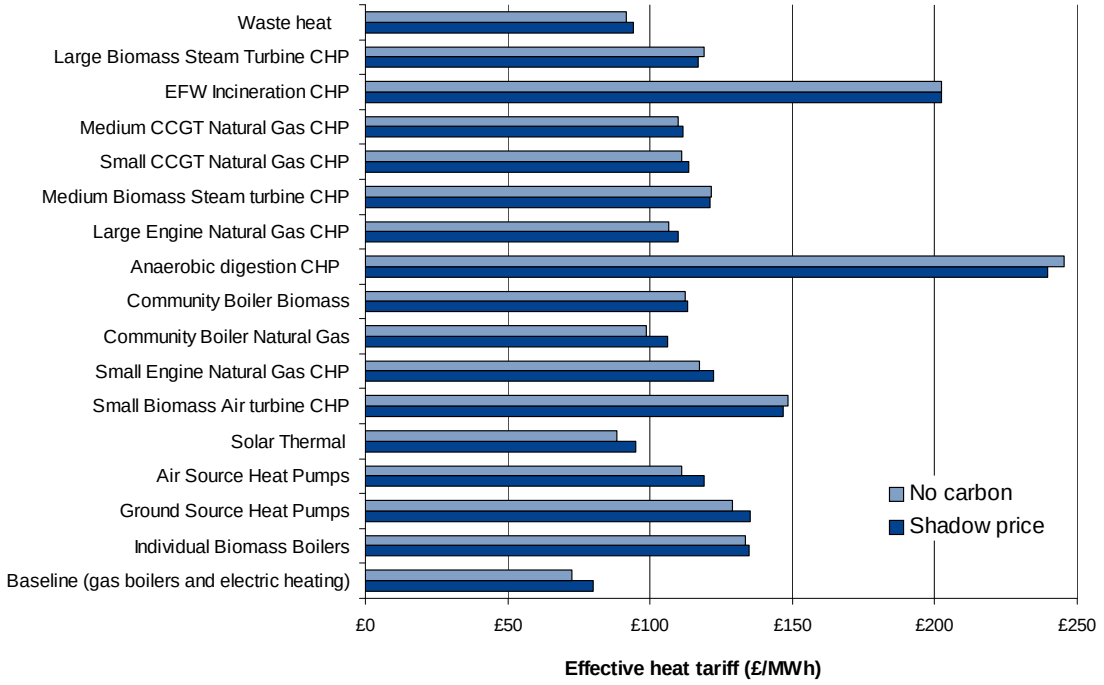
The main benefit of moving to district heating or renewable technologies is expected to be the carbon savings they can deliver. Figure 2 shows the potential annual savings achieved for a composite benchmark dwelling from each technology. For example, we calculate that a district heating network covering 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

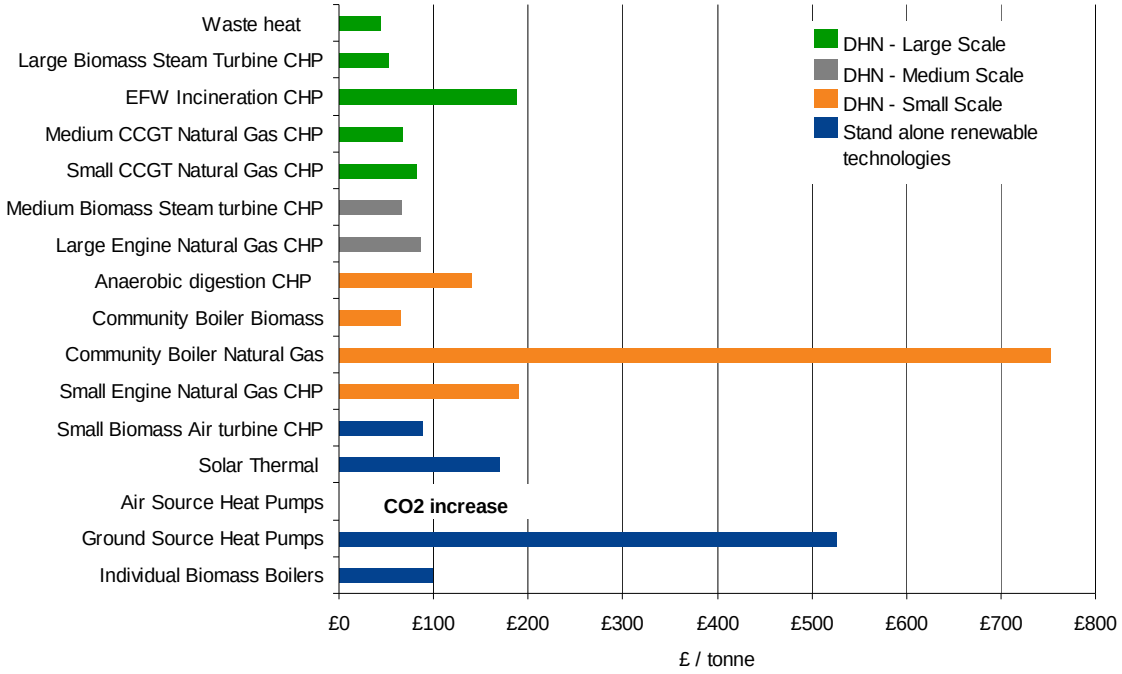


Comparison of district heating and renewable heat

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 tCO$_2$/MWh (our analysis is based on 0.43 tCO$_2$/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 three 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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