Cost Benefit Analysis of the potential for High-Efficiency Cogeneration and Efficient District Heating & Cooling in Ireland

As required under Article 14 of the Energy Efficiency Directive

December 2015

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1. EXECUTIVE SUMMARY

1.1 Key findings

- The heat demand in Ireland is generally low density in nature. The heat mapping and analysis of linear heat density demonstrates that around 90% of the heat demand is at densities too low to make DH a viable proposition.
- The potential for heat networks at 3,000 MWh / km and 5,000 MWh / km linear heat densities1 is negligible at less than 0.1% of the country's heat demand.
- At 10,000 MWh / km linear heat density, an economic potential of around 300 GWh per year(roughly 30,000 dwellings) is identified with a cost benefit of around €33million NPV, largely based on a large zone in Dublin This is equivalent to around 1.5% of Ireland's heat demand, and therefore whilst small, still an appreciable potential.
- If the heat density was lowered, the technical potential may increase, but the proportion which is uneconomic is likely to increase. The relatively small potential for heat networks will mean that CO2 and primary energy savings at a national level will not be significant.
- The analysis shows that the most likely potential appears to be based around two types of district heating schemes:
    - Large scale schemes (in Dublin) which have a small cost benefit over the counterfactual technology options, and which are reliant on a source of waste heat from power stations for economic viability, although other heat sources are only marginally non cost effective.
    - Small scale schemes (potentially outside of Dublin), where there is a much larger cost benefit in terms of levelised cost, but the overall heat provision potential is very limited. These types of scheme are likely to be located where more expensive existing heating sources prevail (potentially off the gas network). The predominant heat network heat source is boilers due to the small scale of the schemes.
- Whilst the economic potential for heat networks is identified as relatively low, appropriate programmes and support mechanisms will need to be put in place at a national or local level if specific opportunities are to be realised.
- It will be important for the public sector to take a lead if any of the schemes are likely to succeed. In particular it is recommended that a detailed energy masterplanning assessment of Dublin is commenced making use of information from this study, and Dublin specific studies, with a view to identifying heat network areas for further feasibility testing [2].
- In virtually all areas, alternative low carbon technology options at a building scale, such as heat pumps, can provide a more cost effective heat source than heat networks. This

[1] Linear heat density can be expressed as MWh heat demand per km road length and is a useful proxy for heat network costs and viability.
[2] Codema have conducted studies in areas of Dublin to identify where district heating may be suitable: http://www.codema.ie/media/news/most-areas-suitable-for-district-heating-in-dublin-city/

suggests that future priorities for Ireland should be generally concentrated around the deployment and incentivising of building scale technologies including building scale CHP.

1.2 Introduction

This document provides the national comprehensive assessment for Ireland to support compliance with Article 14(1,3) of the Energy Efficiency Directive (EED) 2012/27/EU, in accordance with the method outlined in Annex IX Part 1 [3] . These requirements for Ireland are transposed in SI 426, part 5, with the SEAI responsible for carrying out the assessment[4]. The key aim is to identify the national potential and economic potential for heat networks and high efficiency cogeneration (referred to hereafter as Combined Heat and Power or CHP) across Ireland based on a heat mapping process.

Heat networks and cogeneration can offer a number of benefits economically, environmentally, and socially, and the EED and national policy aims to promote their use where viable. In line with the EED requirements in Annex IX, Part 1, this study aims to identify the national potential for district heating networks and cogeneration so that a more detailed understanding can be obtained of how these may benefit Ireland, and support the development of further policy and guidance in this area.

Key factors which influence the economics of heat networks and cogeneration are (see section 2.3):

- Heat density. Heat networks are more cost effective in areas of higher heat density.
- Baseline heating costs. A higher baseline cost means that the potential cost benefit from a heat network is greater
- Heat supply price. The use of energy efficient technologies such as cogeneration, or waste heat sources, can provide heat at a lower cost than baseline heat sources such as boilers.

In simple terms, the investment in a heat network needs to be offset by the difference in price between what heat can be supplied for, and what heat can be sold for.

1.3 Methodology

The methodology used in this study follows a range of guidance produced, including the Article 14 Annex IX, Part 1 on Cost benefit Analysis, the Article 14 Guidance Note issued by the European Commission, and the JRC best practice and informal guidance note.[5]

It should be noted that the Guidance Note on Article 14 and the JRC informal guidance both provide a framework in which the assessment should be conducted. This study has reflected this guidance in focussing on elements and methods which are applicable to Ireland, as detailed throughout.

The categories of technology examined in this report are:

- high efficiency cogeneration[6];

[3] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN
[4] http://www.irishstatutebook.ie/eli/2014/si/426/made/en/pdf
[5] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0449&from=EN
[6] Defined in Article 2 (34) of the Energy Efficiency Directive as cogeneration meeting the criteria laid down in Annex II: cogeneration that fulfils the following criteria: — cogeneration production from cogeneration units shall provide primary energy savings calculated according to point (b) of at least 10 % compared with the references for separate production of heat and electricity,
— production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high- efficiency cogeneration

- efficient district heating and cooling[7]; and
- efficient individual heating and cooling[8].

To model the above cases, the following technology typologies are used:

- Counterfactual. These are the business as usual technologies and include boilers (gas, oil and solid fuel), and electric heating. This represents the case where customers continue to install technologies currently in use such as boilers.
- Alternative low carbon technologies. These are building scale systems and include heat pumps, biomass boilers, and micro / small scale CHP. This represents the scenario where individual customers choose a more efficient or renewably fuelled technology for their building.
- District heating technologies. These are large scale solutions which can provide heat to very large sites or heat networks, and include large gas CHP, biomass boilers, biomass CHP, waste heat from power stations and industry, large heat pumps, and geothermal. In this case, an organisation develops the heat network and heat supply, and individual customers choose to connect.

A range of scenarios are examined in the report which are based around the availability of different technologies. These scenarios are used to assess the sensitivity to technology availability to allow for future uncertainty.

Cooling has been excluded from the analysis. This decision was taken due to the low level of cooling demand (and hence very small likely potential for cooling networks), a lack of data describing cooling demand and other metrics necessary for a national CBA, and the lack of benefit offered by cooling networks. See section 3.4 for further details on cooling.

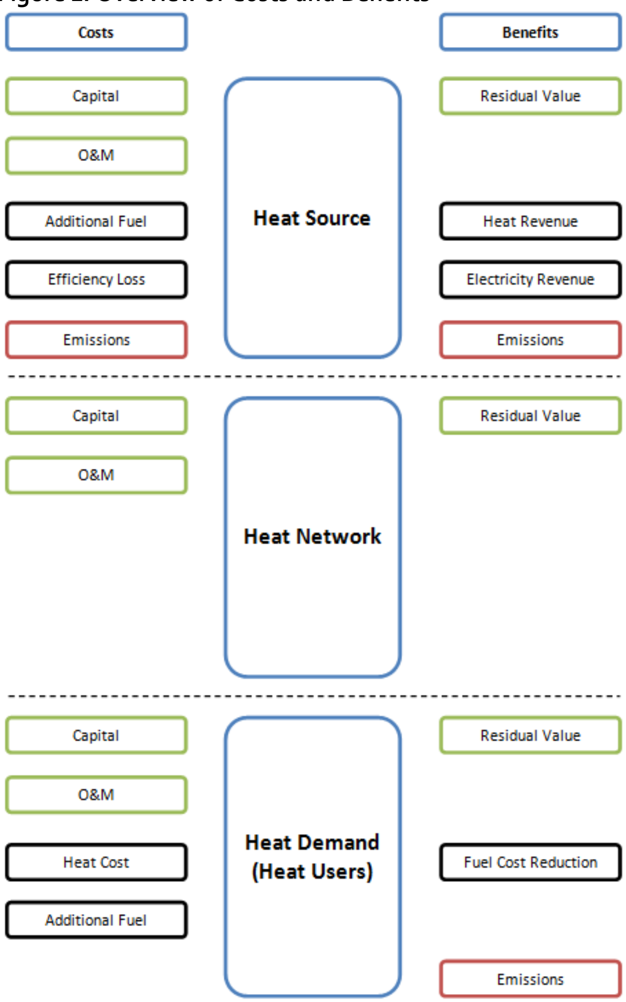
— cogeneration production from cogeneration units shall provide primary energy savings calculated according to point (b) of at least 10 % compared with the references for separate production of heat and electricity,
— production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high- efficiency cogeneration

[7] Defined in Article 2 (41) of the Energy Efficiency Directive as district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat

[8] Defined in Article 2 (43) of the Energy Efficiency Directive as individual heating and cooling supply option that, compared to efficient district heating and cooling, measurably reduces the input of non-renewable primary energy needed to supply one unit of delivered energy within a relevant system boundary or requires the same input of non-renewable primary energy but at a lower cost, taking into account the energy required for extraction, conversion, transport and distribution

The costs and benefits of each scenario for the future use of these technologies to the economy as a whole are estimated and forecast in line with the CBA guidance. These forecasts include all the costs and benefits of future use of these heating technologies, regardless of which economic actors bear the costs or enjoy the burdens. The costs and benefits taken into account include: the costs of installing and operating new heating infrastructure, the costs of conventional heat provision avoided and any environmental benefits. They are represented by the heat source, the heat network (where applicable) and the heat demand / user, as illustrated in Figure 1. The net present economic value of each scenario - relative to a counterfactual case where current technologies continue to be used for all purposes – is calculated. These net present values provide a measure of the net benefits of adopting these technologies to the economy as a whole. On this basis, the most economically advantageous scenarios are identified.

Figure 1: Overview of Costs and Benefits



It is possible that the installation of heat networks could result in some disruption and associated costs. These are likely to be highly specific to location, and highly variable and therefore the CBA does not quantify them. The design of schemes should consider the issue of disruption and mitigate this wherever possible.

1.4 Heat mapping

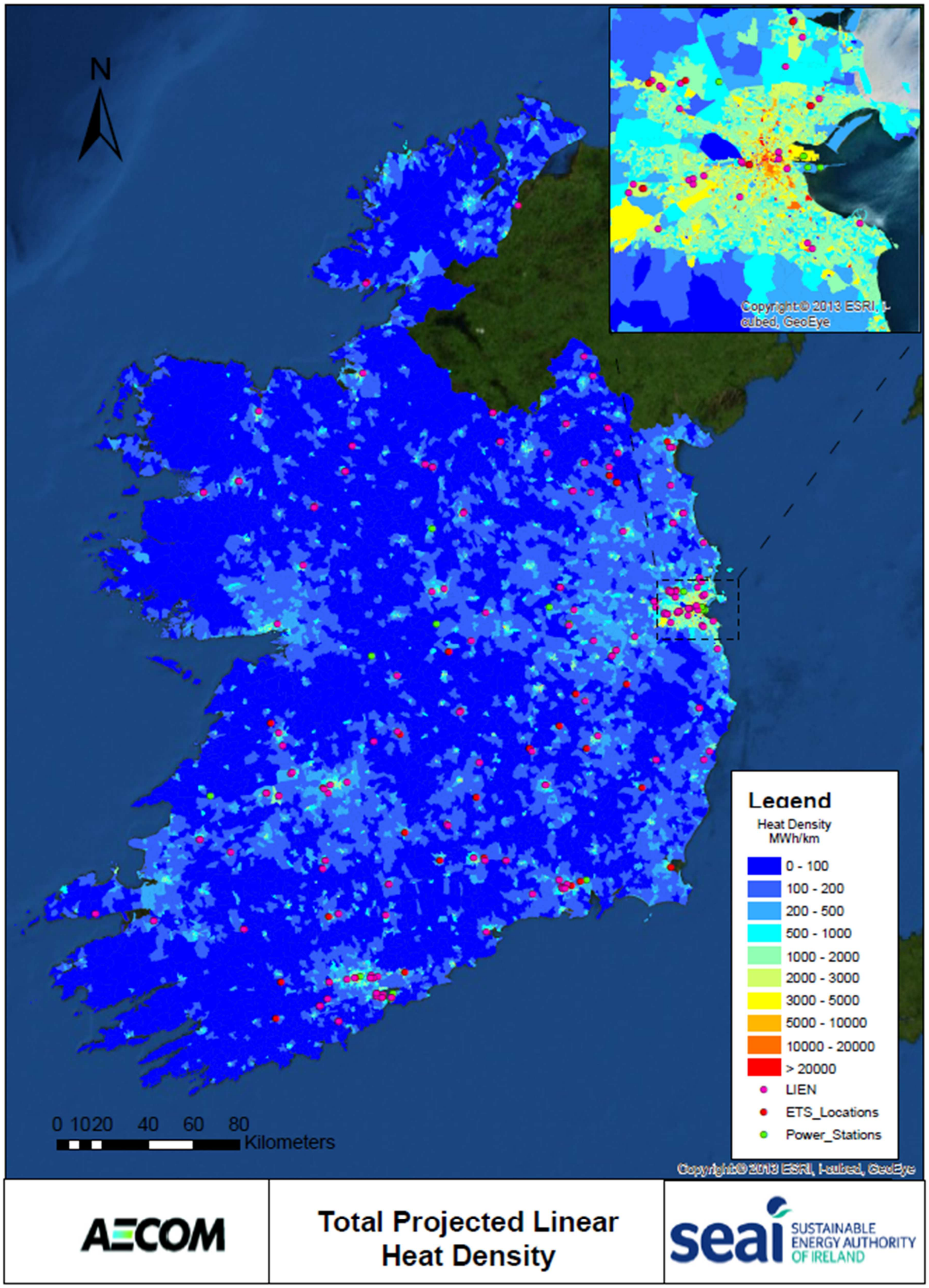
Heat mapping describes the spatial distribution of heat demand based on information on the building type, (a residential dwelling, a commercial or public sector building or an industrial site), the type of fuel used to generate the heat and other metrics such as area of buildings, and current and planned energy efficiency measures. The combination of a detailed dataset and spatial distribution means that heat maps can be used for the analysis of community energy schemes, or other schemes where spatial and geographic information may be of use.

The development of an Ireland-wide heat map forms the basis for the assessment of district heating networks and high efficiency CHP potential analysis in this work. It is required to understand the spatial distribution and density of heat demands. The example map below in Figure 2 shows the primary data used in the CBA which is linear heat density. Linear heat density is a measure of heat demand per unit road length, and is a useful proxy for assessing the costs and viability of heat networks (this is due to heat networks typically using roads for installation as per other utilities). Heat demands are also produced for a 10 year projection (in line with Article 14 guidance) which include the effects of growth and thermal efficiency improvements, and reflects a period (2025) where any activities post this report may result in large scale uptake of heat networks. The spatial resolution used is the Small Area which provides greater spatial resolution in urban areas where the analysis also requires a greater resolution. Small Areas are areas of population comprising between 50 and 200 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi). Small Areas were designed as the lowest level of geography for the compilation of statistics in line with data protection and generally comprise either complete or part of townlands or neighbourhoods.

The availability and quality of data needs to be considered and understood when viewing these heat maps, and the resulting analysis. This study is at a national scale and therefore relies on data which is available and which covers the whole country. This results in a number of assumptions being made which would need refining for any local study. It also means that there is potential for the heat density to not fully reflect local areas:

- The heat density is based on GIS road length information. It is likely that in some areas, the proportion of road length required for network development is less, meaning that the heat density may be under predicted in these areas.
- Where information is not available at a small area level, average values are taken from a larger spatial level. This results in some averaging of the assumptions, which again my reduce heat density in some areas.
- Sectors where suitable proxies for energy consumption are not available at a national level, requiring the use of measured energy information. For the public sector, there is very limited recording of energy consumption at a building level, and no national record of public sector buildings, and sizes. The use of gas information (where address matching has been possible) only for the public sector means that it is likely the public sector heat loads are underestimated, which may impact on heat densities.

Figure 2: Heat map showing linear heat density for the 10 year heat demand projections across all sectors.

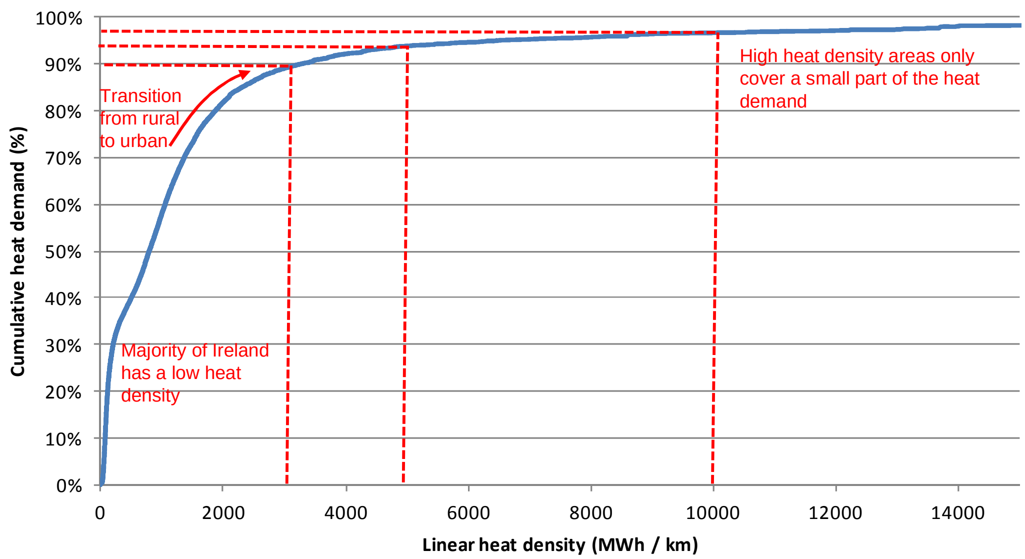


1.5 System boundaries

The heat maps are used to produce a series of "system boundaries" which define zones for inclusion in the analysis based on linear heat density so that areas which may be suitable for district heating are identified. These zones are formed by filtering out areas above a certain threshold heat density such that only high density zones are identified. Full details of how system boundaries have been defined and identified are provided in section 6.2.

Thresholds have been investigated by analysing the heat density curve for Ireland in Figure 3 which plots linear heat density per Small Area versus cumulative heat demand. It demonstrates that around 10% of national heat demand is in areas of high heat density (predominantly urban areas) whereas 90% is in areas of lower density.

Figure 3: Analysis of linear heat density across Ireland to identify suitable thresholds for the formation of system boundaries[9].



The analysis of linear heat density demonstrates that only around 10% – 20% of Ireland's heat demand lies in areas which may be described as reasonably high in density. These are likely to be urban areas such as town centres and cities. The system boundaries selected therefore assess different levels of heat density in these areas corresponding to approximately 10% (3000 MWh / km), 6% (5000 MWh / km) and 3% (10,000 MWh / km) of the national heat demand. The zones identified for each system boundary are largely based in Dublin, but also include areas of other towns and cities. As the threshold is increased, the number of zones reduces and they concentrate further on Dublin.

1.6 Principal scenarios

The following scenarios have been assessed:

- Scenario 1: this scenario explores the zones where the levelised costs (€/MWh) of heat networks are lower than those for the counterfactual. This means that heat networks

[9] Note that the Linear Heat Density (LHD) scale is limited to 15,000 to allow the shape of the curve to be observed. This has meant that some Small Areas with extremely high LHDs are not shown

show a lower €/MWh for the provision of heat to these zones than the counterfactual technologies and can thus be considered economic.

- Scenario 2: this scenario includes the zones where the levelised costs (€/MWh) of heat networks are lower than that for the alternative low carbon technologies and the counterfactual, and are therefore the most economic option. This means that heat networks show a lower €/MWh for the provision of heat to these zones than the counterfactual and alternative low carbon technologies.
- Scenario 3: this scenario refers to zones where the levelised costs (€/MWh) of alternative low carbon technologies are lower than that for the counterfactual. This means that alternative low carbon technologies show a lower €/MWh for the provision of heat to these zones than the counterfactual technologies.

Table 1: Definition of Principal scenarios evaluated in the CBA and number of zones per boundary

Principal scenarios	Description	Number of zones for each boundary		
		3,000 MWh/km (85 zones)	5,000 MWh/km (53 zones)	10,000 MWh/km (35 zones)
Scenario 1	Zones where heat networks are better in economic terms (€/MWh) than counterfactual technologies.	18 (21%)	12 (23%)	15 (43%)
Scenario 2	Zones where heat networks are better in economic terms (€/MWh) than alternative low carbon technologies and the counterfactual technologies.	10 (12%)	7 (13%)	10 (29%)
Scenario 3	Zones where alternative low carbon technologies are better in economic terms (€/MWh) than counterfactual technologies.	66 (78%)	37 (70%)	27 (77%)

1.7 Results

The cost benefit analysis conducted for each scenario demonstrates that for the 3,000 MWh / km and 5,000 MWh / km boundaries, the potential for cost effective district heating is negligible at around 0.04% of the national demand or less. Conversely, the cost effective potential for alternative low carbon technologies (at a building scale, such as heat pumps) is large with the majority of the zones identified being cost effective.

As the threshold is increased to 10,000 MWh / km, there is a large increase in the cost effective potential of heat networks due to the inclusion of a large zone in Dublin. The system boundary covers around 3% of the national demand, of which half is identified as technically suitable for connection to heat networks, and a quarter as cost effective (1% of the national heat demand). The 10,000 MWh / km system boundary is therefore selected for subsequent analysis.

Table 2: Modelling results for the 10,000 MWh/km system boundary, results for Net Present Cost[10] (NPC)

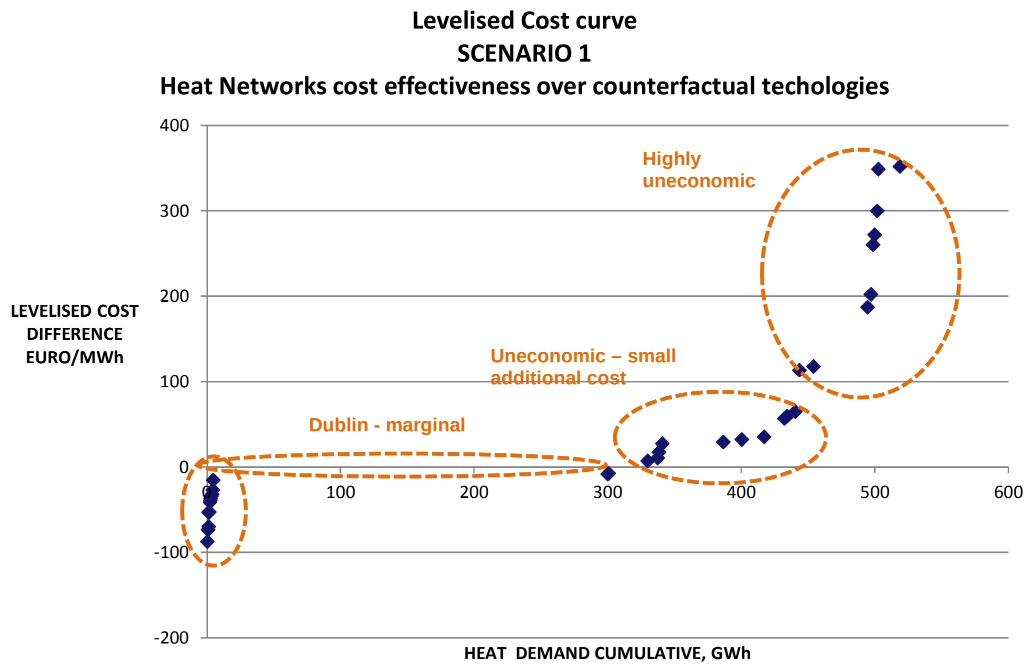
Principal scenarios	NPC € million			Max NPC Difference € million
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€502		€468	-€34
Scenario 2	€8	€8	€6	-€2
Scenario 3	€1,009	€679		-€330

Table 3: Modelling results for the 10,000 MWh/km system boundary, results for Annual Heat Demand

Principal scenarios	Annual Heat Demand GWh/year			Max Difference GWh/year
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	510		301	-209
Scenario 2	5	4	4	0
Scenario 3	1,056	1,141		85

Analysis of the different technology scenarios for the 10,000 MWh / km system boundary indicates that the use of waste heat (from power stations or industrial processes) is likely to be an important component to meeting the cost effective potential, with the potential dropping from circa 300 GWh per year to circa 6 GWh per year with the removal of waste heat. However analysis of the different technology scenarios demonstrates that other forms of low carbon heat network heat supply technologies are only marginally un-economic and therefore should still be considered as a heat network heat source.

Figure 4: Levelised cost difference versus cumulative heat demand for scenario 1 – Heat Networks cost effectiveness over counterfactual technologies, for 10000 MWh / km system boundary

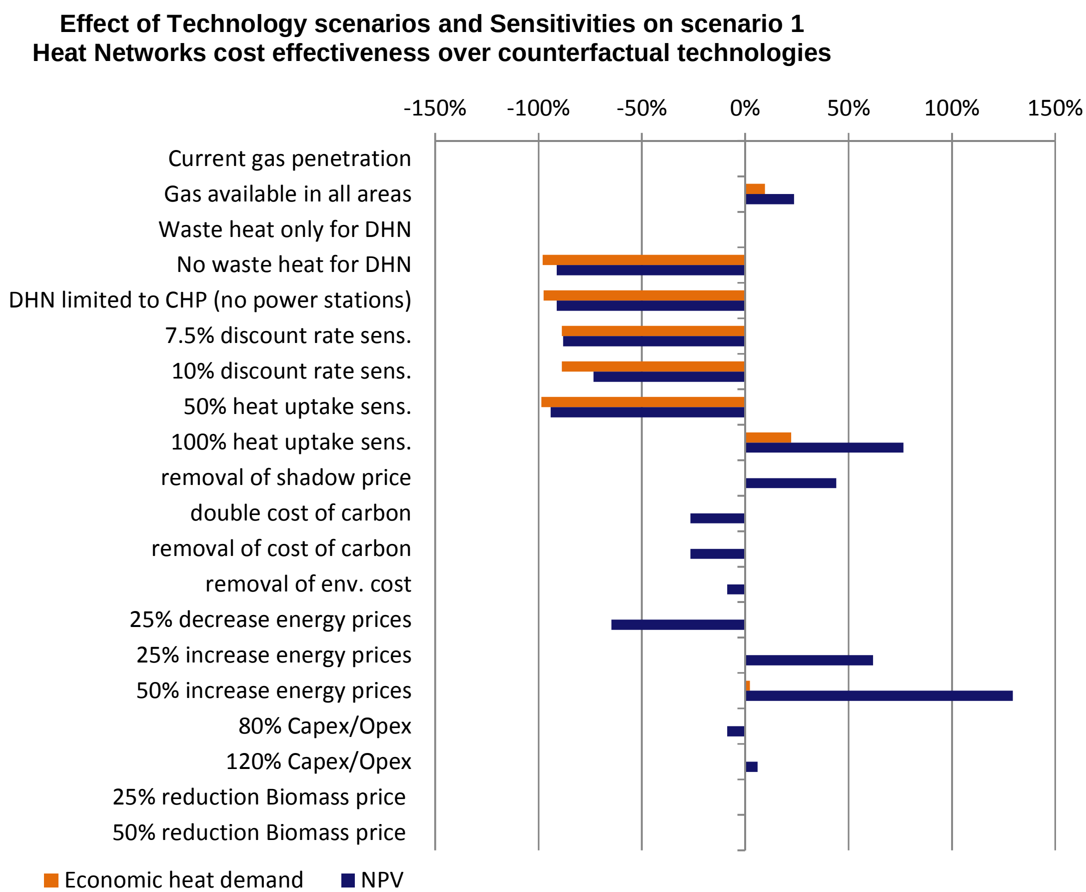


[10] Total discounted net cost over the lifetime period of assessment

The heat supply curve in Figure 4 shows the levelised costs[11] for each zone versus cumulative heat demand. It demonstrates that a small number of zones are cost effective, and a large proportion of the heat demand in the system boundary is marginally cost effective. However zones which are not cost effective have a significant additional cost.

Sensitivity analysis was used to assess the impact of changes in discount rate, level of heat uptake, absence of shadow prices, varying energy prices, and costs (capital and O&M). The results for a comparison of heat networks to the counterfactual heating technology (the scenario which gives the largest economic potential of around 300 GWh) are shown in Figure 5. The results show that the economic potential is relatively insensitive to some changes (capital expenditure and operational expenditure, environment costs, and biomass costs), moderately insensitive to ,carbon costs, and shadow prices, but is more sensitive to discount rates (which may define appropriate funding sources), heat uptake rates and technology availability.

Figure 5: Sensitivity analysis for heat networks compared with counterfactual technologies (scenario 1). A positive value shows either an increase in economic potential (GWh) or value (NPV-net present value).



[11] Levelised costs are an expression of energy costs in terms of cost per MWh, and are independent of technology lifetime and discounting, allowing comparison across a range of sources.

1.8 Planning and design issues

The results from this CBA demonstrate that heat networks could be cost effective for up to around 300 GWh of Ireland's heating demand, or 1% of the national demand, largely based in Dublin. At present the fact that there is a cost effective potential, but with little or no development of heat networks, means that a number of barriers must exist which need to be overcome in order for heat networks to be more widely adopted. These barriers need to be understood and overcome.

Barriers can be categorised as:

- Project development and capital costs. These include complex scheme development processes, high capital expenditure combined with low rates of return, and complex coordination with many stakeholders.
- Project risks. These include existing market perception, the risk around customer uptake and contracts, energy costs, and policy uncertainty.
- Policy and regulation. There is currently a lack of regulation for heat networks which can be both an advantage and disadvantage. There is also an absence of long term vision for heat networks, and fiscal incentive for their development. Given the extremely limited potential for heat networks in Ireland, it is unlikely that highly disruptive changes will be made to existing policy and mechanisms. However there are areas where improvements could be implemented:
- Development of long term strategy and objectives for heat networks, and the role of the public sector in this.
- Consideration of changes to existing energy markets to facilitate uptake of heat networks and CHP, in particular the coordination with the gas network roll out.
- Further technical and financial analysis at a more local level, in particular in Dublin, to identify schemes for delivery.

Ireland could consider the development of a dedicate heat network support unit as used in the UK (which has a similar low level of existing network development). This could provide coordination support, technical advice, and funding for feasibility work, to ensure that the early steps to developing a network are achieved leading to the development of business cases to attract finance.

1.9 Conclusions

Based on the outputs of this study, the following conclusions can be drawn from the results:

1) The heat mapping and analysis of linear heat density demonstrates that around 90% of the heat demand is at densities too low to make DH a viable proposition. Based on the selected system boundaries, the potential for heat networks at 3,000 MWh / km and 5,000 MWh / km linear heat densities is negligible at less than 0.1% of the country's heat demand. Whilst there may be some schemes which exist at these density levels (for example, clusters of social housing with fuel poverty, co-location of public buildings, etc.), this means that the majority of Ireland's heat demand will not be suitable for district heating. Where further analysis is made for low density areas, it will be important to use more detailed local information to identify the opportunities. Likewise for cooling, whilst the

national potential may not be large, and the benefits may be small, suitable opportunities should still be identified and explored where sufficient data is available.

2) At 10,000 MWh / km linear heat density, an economic potential of around 300 GWh per year (in the region of 30,000 dwellings) is identified with a cost benefit of around €33million NPV, largely based on a zone in Dublin This is equivalent to around 1.5% of Irelands heat demand, and therefore whilst small, still an appreciable potential. Further analysis could be conducted to examine other thresholds to see whether this potential may improve. However at 10,000 MWh/km, around half of the identified technical potential (areas which could connect to heat networks from a technical perspective) is economic, and so it is unlikely that the economic potential will increase at higher heat densities, due to the smaller target demand. If the heat density was lowered, the technical potential may increase, but the proportion which is uneconomic is likely to increase. The relatively small potential for heat networks will mean that CO_2 and primary energy savings at a national level will not be significant.

3) The analysis shows that the most likely economic potential is based around two types of district heating schemes:

   a) Large scale schemes (in Dublin) which have a small cost benefit over the counterfactual technology options, and which are reliant on a source of waste heat from power stations for economic viability, although other heat sources are only marginally non cost effective.
   b) Small scale schemes (potentially outside of Dublin), where there is a much larger cost benefit in terms of levelised cost, but the overall heat provision potential is very limited. These types of scheme are likely to be located where more expensive existing heating sources prevail (potentially off the gas network). The predominant heat network heat source is boilers due to the small scale of the schemes.

4) Whilst the economic potential for heat networks is identified as relatively low on a national level, appropriate programmes and support mechanisms will need to be put in place at a national or local level if specific opportunities are to be realised. It will be important for the public sector to take a lead if any of the schemes are likely to succeed. In particular it is recommended that a detailed energy masterplanning assessment of Dublin is commenced making use of information from this study, and Dublin specific studies, with a view to identifying heat network areas for further feasibility testing.

5) In virtually all areas, alternative low carbon technology options at a building scale, such as heat pumps, can provide a more cost effective heat source than heat networks. This suggests that future priorities for Ireland should be generally concentrated around the deployment and incentivising of building scale technologies including building scale CHP.

2. INTRODUCTION

2.1 Overview

The Energy Efficiency Directive[12] stipulates that all Member States must carry out a Comprehensive Assessment of the potential for the application of high-efficiency cogeneration[13,14] and efficient district heating and cooling.

Article 14 of the Energy Efficiency Directive sets out the core elements of the assessment which include:

- the development of a 'heat map' of the national territory identifying heating and cooling demand; and
- a cost-benefit analysis (CBA) facilitating the identification of the most resource and cost efficient solutions to meeting heating and cooling needs.

This report provides the results of the heat mapping and CBA processes and forms a core element of the Comprehensive Assessment required under the Energy Efficiency Directive.

2.2 Policy Context

The Energy 2050 Roadmap[15] published by the European Commission in 2011 sets out a number of scenarios for developing a decarbonised energy sector across Europe over the coming decades. Increasing energy efficiency is identified as a critical factor in achieving this goal.

The Energy Efficiency Directive of October 2012 (which has been transcribed into national law via secondary legislation[16]) provides the central requirements for this report.

In October 2014, the European Council agreed an ambitious target to cut greenhouse gas emissions by 40%[17] across the EU by the year 2030[18]. Energy efficiency measures are viewed as a key driver to achieve these results, including the provision of efficiency energy supply through cogeneration and district heating, the subject of this study.

At a national level, the National Energy Efficiency Action Plan (NEEAP) sets out how Ireland will achieve its energy saving target of 20% below 1990 levels by 2020[19]. The NEEAP notes that over 300 MWe of combined heat and power (CHP) has been installed in Ireland. This is predominantly powered by natural gas[20].

The NEEAP also notes that district heating has very limited levels of development in Ireland. Issues identified include the population dispersal patterns, nature of housing stock, temperate climate and

[12] Directive No 2012/27/EU of the European Parliament and of the Council of 25th October 2012, available at http://www.dcenr.gov.ie/energy/en-ie/Energy-Efficiency/Pages/Energy-Efficiency-Directive.aspx

[13] High-efficiency cogeneration provides primary energy savings of at least 10% compared with the references for separate production of heat and electricity. In addition, production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high-efficiency cogeneration

[14] The Commission for Energy Regulation (CER) provides a certification process for high-efficiency cogeneration. See Certification Process for High Efficiency CHP published by the CER

[15] Communication(2011) 885 final from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (December 2011)

[16] Statutory Instrument No 426 of 2014

[17] Relative to 1990 levels

[18] Statement by President Barroso following the first day of the European Council of 23-24 October 2014

[19] National Energy Efficiency Action Plan 2014 (Department of Communications, Energy and Natural Resources)

[20] Combined Heat and Power in Ireland 2012 Update, available at. http://www.seai.ie/Publications/Renewables_Publications_/CHP/CHP_in_Ireland_2012_Report.49053.shortcut.pdf

relatively low levels of forestry (to provide fuel for biomass heating). The viability of district heating is heavily dependent on heat densities (see section 2.3 below) and therefore the assessment of heat density through heat mapping is a core component of this study.

The SEAI published a report in June 2015 examining Unlocking the Energy Efficiency Opportunity[21]. This report contributes to national policy development in energy efficiency and provides a detailed analysis of a range of measures that could ensure 2020 energy efficiency targets are met in the most cost-effective way. Some of the datasets developed for the Unlocking the Energy Efficiency Opportunity report have been used to contribute to this study. It is important to understand the role that energy efficiency can take in reducing energy demand before the provision of efficient energy sources, such that the energy hierarchy is followed. For example, heat should only be supplied via cogeneration and district heating to buildings which are already thermally efficient to ensure that overall energy demand is limited.

It is expected the results contained in this report will help to identify key policy measures that may be put in place in order to achieve Ireland's energy policy objectives.

2.3 District heating and cooling – an introduction

District heating networks consist of a series of insulated pipes which are used to transfer heat (usually hot water) between 2 or more buildings from a heat supply (see Figure 6). The networks can connect to a range of different building types (domestic, commercial / public sector and industrial) and use a range of heat sources. The networks comprise a flow pipe (higher temperature) which usually connects to a heat exchanger in each building where heat is extracted for the building's heating system. The cooler water is returned in the second return pipe. The level of control at a building is the same as for an individual boiler system and from the customer perspective, there is no difference in how heat is delivered. Modern heat networks use high quality pre-insulated piping systems (either steel or plastic pipes encased in foam insulation) and as a result have very low heat losses when designed and installed in line with best practice.

Heat networks can offer a number of advantages over individual building systems including:

- The aggregation of heat demands means that larger more efficient forms of heat generation can be used, in particular cogeneration (often termed Combined Heat and Power - see 2.4 below). This allows for an overall reduction in primary energy use, with lower CO_2 emissions, and consequential economic benefits.
- They can allow access to waste heat sources, such as heat from power stations or industry. Connecting to these sources would generally not be viable for an individual building. This can also offer a revenue in the form of a heat tariff to these installations.
- They offer flexibility for the future, allowing large numbers of buildings to have heat provided by alternative sources.
- They can be more economic than conventional building scale systems though more energy efficient generation, and economies of scale, allowing lower cost heating to customers.
- They are typically managed and operated by professional organisations, ensuring long term reliable energy supply.

[21] Unlocking the Energy Efficiency Opportunity (SEAI, June 2015)

As a result of their benefits, district heating networks are used extensively in many North European countries. Of particular note is Denmark where buildings in most urban areas are connected to district heating networks, and it is estimated around 60% of the national heat load is met from district heating networks. This is as a result of heat planning in the 1970s identifying heat networks as a suitable option for improving energy efficiency and heating costs, in the absence of national natural gas resources. As a consequence of the level of uptake, it is accepted by customers as the standard form of heating.

District heating networks can be expensive to install due to the costs of the pipework and equipment, and the civil works associated with installing. Due to the location of buildings, roads are typically used for the routing of networks requiring trenching and reinstatement of roads, and installation around existing utilities. There can also be an economic cost associated with disruption in some areas although this is difficult to estimate and is highly dependent on the specific situation. Where possible, routes away from roads can be used, although land ownership needs considering so that access rights can be obtained. The high installation costs mean that the economic and financial viability of networks can depend on a number of factors:

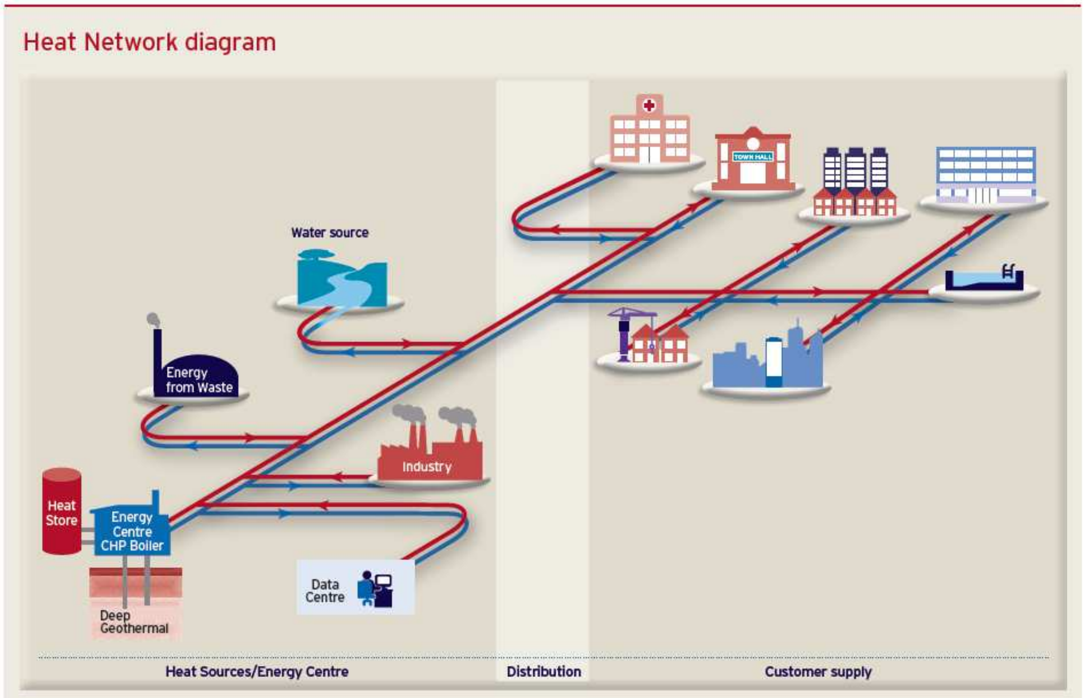
- Cost of heat. Where low cost heat is accessible (for example heat from a power station that is currently being released into the atmosphere or into water systems), then the high cost of network infrastructure can be offset by low cost of energy supply. This means that networks are likely to be more viable.
- Heat density. The viability of schemes improves as the ratio of heat load connected to investment is increased. This can be expressed in terms of heat density. In areas of high heat density, more heat can be distributed and sold over the same size network allowing greater economic return. This means that district heating networks are typically located in areas of high heat density such as town centres and cities.
- The type of customer. Networks are generally more cost efficient when connected to large customers, limiting the amount of small distribution pipework which is required. For example, a heat network connected to 10 large buildings is likely to be more economic than the same network connected to 100 smaller buildings with the same overall heat load. This means that large commercial, public sector buildings, and blocks of flats are more viable than smaller buildings and individual houses.

The concept of heat density is important for district heating network assessment at a strategic level (such as the national assessment in this report.

Area heat density is shown as a unit of heat per unit of area, for example, annual MWh heat demand per km^2. Areas with higher heat density are likely to be more economically viable. Assuming that heat demands are known or can be calculated, this provides a relatively simple method of assessing viability.

A more accurate and useful method is linear heat density (LHD). This uses the same information about heat demands but expresses it per unit length, for example MWh heat demand per km. This is more useful since networks are characterised by their length, and not the area they cover. A proxy for network length is road length since it can be assumed that in most urban areas where district heating networks may be viable, they will be routed along the majority of roads to connect to the majority of buildings. Linear heat density is used as the basis of this study.

Figure 6: Schematic of District Heating Network, showing energy supply, distribution and customer supply[22]



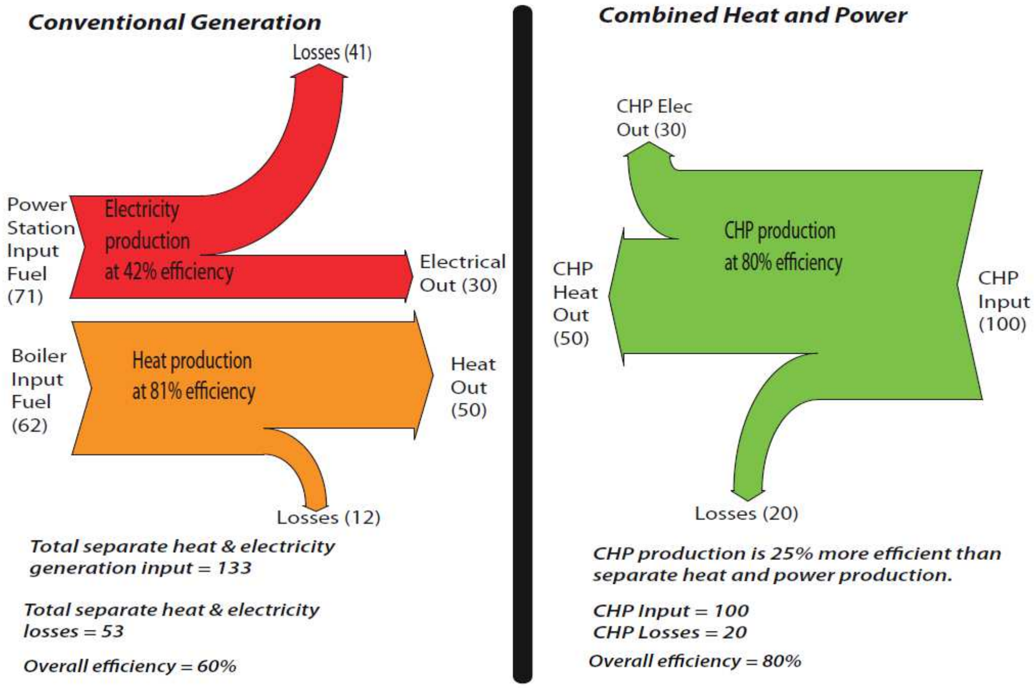
2.4 Cogeneration – an introduction

Cogeneration refers to the simultaneous production of heat and power. It is often referred to as Combined Heat and Power (CHP). In a conventional supply system of heat from boilers, and electricity from the national electricity grid, the heat is provided at a relatively high efficiency (typically up to 90%), but the electricity generation efficiency is much lower (typically around 40% – 50% on average). As a result, a large amount of heat is wasted during the electricity generation process.

A CHP system generates electricity, but also makes use of the waste heat from the process for heating, often via a District Heating Network. This means that the overall efficiency of generation from a CHP system is higher than for the conventional boiler and grid electricity. This concept is illustrated in Figure 7. The higher overall efficiency of a CHP system means that the overall heat and electricity generation is more economic than from separate boiler and grid electricity supplies.

[22] Investing in the UK's Infrastructure: Heat Networks. UK Trade and Investment, and DECC. 2015. https://www.gov.uk/government/publications/investing-in-the-uks-heat-infrastructure-heat-networks

Figure 7: The efficiency benefits of CHP over conventional power generation and boilers (Source - SEAI[23])



CHP systems can take a variety of forms:

- Building / small scale (10s – 100s kW). Gas fired reciprocating engines are the predominant form of CHP at this scale, although other technologies exist such as Stirling engines and fuel cells. Fuel cells in particular currently considered pre-commercial although their high efficiency means that there is much development interest.
- Large gas engines (100s kW – MW). These are often based on marine or railway propulsion engines, and are used extensively in large individual sites (for example hospitals) or on district heating networks. The technology is mature and reliable, and can be operated economically when appropriately located on sites with a suitable heat demand. Gas turbines can also be used, but the high cost means they are generally suited to applications where higher temperatures are necessary, such as industrial sites, and are not necessary for district heating networks.
- Bioenergy CHP. CHP systems can be fuelled by bio-fuels, either liquid or gas (usually in engines), or biomass (usually in steam turbine systems). Biomass systems are generally only suitable at larger scales (10s MW) and are most common at this scale. Smaller biomass systems have been developed and trialled, they are not considered a mature technology with little uptake.
- High grade heat from power generation. This could be from smaller scale power generation systems, such as waste to energy plants (typically circa 10MW electric), or

[23] CHP in Ireland 2015 Report. http://www.seai.ie/Publications/Statistics_Publications/CHP-in-Ireland/CHP-in-Ireland-2015-Report.pdf

from larger power stations (typically 100s MW or above). The extraction of heat generally results in a small loss of electricity production, defined by the Z-factor. For example a Z-factor of 7 means that for every 7 units of heat extracted, electrical output reduces by 1. This small penalty can still result in large CO_2 reduction and low cost heat.

In general, CHP systems have a high capital cost (compared with boilers), and are therefore sized to meet the baseload heat demand. Conventional boilers (gas or oil) which have a low capital cost are then used to meet peak heat demands and provide back up. For example, around 80% of the annual heat demand on a scheme could potentially be met with a thermal capacity of only 25% of the peak demand. The CHP system would therefore be sized at 25% of peak. In the periods of peak heat demand (for example a peak period on cold day), the boilers would be used to supplement the supply.

Where the capacity of the heat is not limited by overall capital expenditure (for example, taking heat from a power station where the capacity of the station is much larger than the heat demand of the scheme), then sizing for baseload may not be required, but a boiler back-up requirement will remain for resilience in the event of no heat being available from the power station.

Key factors to consider for the economics of cogeneration are:

- Capital cost. This is determined by both the technology type and size. Where a good baseload heat demand exists and the sizing of the CHP system can be optimised, the systems can be more economic.
- Operation costs. These can be relatively high for small cogeneration units but can reduce with scale. The costs associated with systems such as biomass and energy from waste are generally higher than conventional gas engine CHP, but these can be offset by lower fuel prices, and also attributable to other benefits (such as waste management).
- Efficiency. Larger stand-alone CHP units generally have a higher efficiency than smaller units, and therefore are more economic. For heat extract from power stations, the Z-factor determines the reduction in electricity revenue, and therefore the effective heat price.
- Electricity sales. The electricity from a CHP system will need to be sold to a customer to generate revenue. Where the sale is directly to a retail customer (a final user), a high price (approaching retail price) can be obtained. Where the sales are to an electricity supplier (a re-seller), then a wholesale value will obtained which can be around half of retail, having a significant impact on the economics.
- Fuel costs. In general the higher efficiency of cogeneration means that increases in fuel prices should be advantageous to cogeneration technologies and improve the economics further. However this is linked to the electricity revenue which must also increase to maintain the economic performance. The concept of "Spark-Spread" is important and is the difference between the gas input price, and the electricity sales price. As the spark-spread increases, the economics of cogeneration improve. For technologies using renewable fuels such as biomass, then the market for individual fuels can have a large impact on the economics.

2.5 Status and progress of CHP in Ireland

The comprehensive assessment performed to meet Article 14(1) of the EED (2012/27/EU[24]) must include the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC[25].

The CHP Directive (2004/8/EC[2]) concerns the promotion of cogeneration based on a useful heat demand in the internal energy market. The purpose of the directive is to increase energy efficiency and improve security of heat supply within the EU by creating a framework for the promotion and development of high-efficiency CHP based on useful heat demand and primary energy savings in the internal energy market.

The Directive contains the following main provisions:

- Adopt the EU definition for high-efficiency CHP;
- Introduce a mechanism to guarantee the origin of electricity from high-efficiency CHP;
- Ensure support schemes for CHP are compliant;
- Ensure electricity tariffs and conditions to grid access are fair;
- Commit to analyse national potentials for CHP, identify the barriers which may prevent the realisation of the national potential and report progress towards achieving that potential.

The status and progress of CHP in Ireland is reported on yearly through the "Combined Heat and Power in Ireland Report", of which the ninth and latest was issued in November 2015[26]. This reports the following overview:

- The installed capacity of CHP in Ireland at the end of 2014 was 339 MWe (336 units), of which 311 MWe (262 units) was operations, and increase of 2.8 MWe (0.9%) in operating capacity from 2013.
- Natural gas fuelled 91.8% of the operational capacity in 2014. Oil products fuelled 2.8%, biogas 2.0%, biomass 1.7% and solid fuel 1.7%.
- In 2014, 7.4% of Ireland's electricity was from CHP installations, compared with 7.3% in 2013.
- In 2014 CHP installations met 6.4% of Ireland's total thermal energy demand.
- The use of CHP in 2014 avoided 382 kt CO2 emissions when compared with separate electricity and heat production.
- There was a primary energy saving of 23% or 1,859 GWh from CHP plants in 2014 compared with separate heat and energy production.

[24] Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. OJEU. 2012

[25] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC. OJEU. 2004

[26] Combined Heat and Power in Ireland – 2015 Update. SEAI. November 2015

The report also outlines the policy steps taken with respect to encouraging CHP and fulfilling Ireland's legal requirements, referencing the EU Directives or Commission Decisions 2004/8/EC[2], 2007/74/EC[27], 2008/952/EC[28], and 2012/27/EC[1]. These policy steps include:

- High efficiency CHP Certification;
- CHP Deployment Programme;
- Renewable Energy Feed-In Tariff;
- Renewable Heat Incentive;
- Tax Relief;
- Targets and Planned Growth.

In 2009 SEAI (then SEI, Sustainable Energy Ireland) published "Combined Heat and Power (CHP) Potential in Ireland" which brings together the targets for CHP uptake as laid out in the Energy White Paper "Delivering a Sustainable Energy Future for Ireland[29]", as well as technical studies regarding barriers to CHP implementation and adoption, such as "An Examination of the Future Potential of CHP in Ireland[30]".

The work undertaken and published by the SEAI indicates that the requirements of the CHP Directive have been met.

2.6 Summary

Heat networks and cogeneration can offer a number of benefits economically, environmentally, and socially, and the EED and national policy aims to promote their use where viable. In line with the EED requirements, this study aims to identify the national potential for district heating networks and cogeneration so that a more detailed understand can be obtained of how these may benefit Ireland, and support the development of further policy and support in this area.

Key factors which influence the economics of heat networks and cogeneration are:

- Heat density. Heat networks are more cost effective in areas of higher heat density.
- Baseline heating costs. A higher baseline cost means that the potential cost benefit from a heat network is greater
- Heat supply price. The use of energy efficient technologies such as cogeneration, or waste heat sources, can provide heat at a lower cost than baseline heat sources such as boilers.

In simple terms, the investment in a heat network needs to be offset by the difference in price between what heat can be supplied for, and what heat can be sold for.

[27] Commission Decision of 21 December 2006 establishing harmonised efficiency reference values for separate production of electricity and heat in application of Directive 2004/8/EC. OJEU. 2007

[28] Commission Decision of 19 November 2008 establishing detailed guidance for the implementation of Annex II to Directive 2004/8/EC for the European Parliament and Council. OJEU. 2008

[29] Delivering a Sustainable Energy Future for Ireland. Irish Government. 2007.

[30] An Examination of the Future Potential of CHP in Ireland – A Report for Public Consultation. Irish Energy Centre. 2001.

3. SCOPE

3.1 Report Objective

The Energy Efficiency Directive imposes certain obligations on Member States. One of these is a requirement for each Member State to carry out a “Comprehensive Assessment” of the potential future use of high-efficiency cogeneration and efficient district heating and cooling in its territory. These Comprehensive Assessments must include a description of current heating and cooling demand and a forecast of future changes in these together with a map of: demand points, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points. On this basis, the assessment must identify potential future use of high-efficiency cogeneration and district heating and strategies to ensure that as many as possible of these potential uses are adopted.

The objective of this report is to provide the National Comprehensive Assessment for the Republic of Ireland. The SEAI are charged with this obligation in SI 426 and have therefore commissioned this work.

As defined in Annex VIII of the Energy Efficiency Directive, the Comprehensive Assessment will include a range of elements. The elements of the Comprehensive Assessment included in this report are:

> (a) a description of heating (see section 4.3 and Appendix 3) and cooling demand (see section 3.4);
>
> (b) a forecast of how this demand will change in the next 10 years, taking into account in particular the evolution of demand in buildings and the different sectors of industry (see Appendix 3);
>
> (c) a map of the national territory, identifying, heating and cooling demand points, existing and planned district heating and cooling infrastructure and potential heating and cooling supply points (see sections 3.4 and 4);
>
> (d) identification of the heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration, and by district heating and cooling (see section 3.4 and 6.4);
>
> (e) identification of the potential for additional high-efficiency cogeneration, including from the refurbishment of existing and the construction of new generation and industrial installations or other facilities generating waste heat (see section 6.4); and
>
> (f) identification of energy efficiency potentials of district heating and cooling infrastructure (see section 3.4 and 6);
>
> (g) strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potential in point (e) in order to meet the demand in point (d) (see section 8.3);
>
> (h) the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC (see section 2.5);
>
> (i) an estimate of the primary energy to be saved (see section 6.4); and
>
> (j) an estimate of public support measures to heating and cooling, if any, with the annual budget and identification of the potential aid element. This does not

prejudge a separate notification of the public support schemes for a State aid assessment (see section 8.3).

Points (d), (e) and (f) are assessed using a Cost Benefit Analysis as detailed in Part 1 of Annex IX of the Energy Efficiency Directive.

3.2 Technology

The categories of technology examined in this report are:

- high efficiency cogeneration[31];
- efficient district heating and cooling[32]; and
- efficient individual heating and cooling[33].

In addition to these high-level technology categories, there are sub-categories for selected technologies. For instance, the provision of efficient district heating and cooling may include using heat from existing power stations, industry or new generation. The area examined includes the Republic of Ireland.

To model the above technology categories, the following technology groupings have been used.

- Counterfactual. These are the business as usual technologies and include boilers (gas, oil and solid fuel), and electric heating. This represents the case where customers continue to install technologies currently in use such as boilers.
- Alternative low carbon technologies. These are building scale systems and include heat pumps, biomass boilers, and micro / small scale CHP. This represents the scenario where individual customers choose a more efficient or renewably fuelled technology for their building.
- District heating technologies. These are large scale solutions which can provide heat to very large sites or heat networks, and include large gas CHP, biomass boilers, biomass CHP, waste heat from power stations and industry, large heat pumps, and geothermal. In this case, an organisation develops the heat network and heat supply, and individual customers choose to connect.

Table 4 provides details of the technologies in each category.

[31] Defined in Article 2 (34) of the Energy Efficiency Directive as cogeneration meeting the criteria laid down in Annex II: cogeneration that fulfils the following criteria:
— cogeneration production from cogeneration units shall provide primary energy savings calculated according to point (b) of at least 10 % compared with the references for separate production of heat and electricity,
— production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high- efficiency cogeneration

[32] Defined in Article 2 (41) of the Energy Efficiency Directive as district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat

[33] Defined in Article 2 (43) of the Energy Efficiency Directive as individual heating and cooling supply option that, compared to efficient district heating and cooling, measurably reduces the input of non-renewable primary energy needed to supply one unit of delivered energy within a relevant system boundary or requires the same input of non-renewable primary energy but at a lower cost, taking into account the energy required for extraction, conversion, transport and distribution

Table 4: Summary of technologies included

Group	Technology types
Baseline (business as usual)	▪ Natural gas boiler ▪ Off grid boiler (Oil and LPG) ▪ Solid fuel boiler (including open fires for domestic) ▪ Electric heating
Alternative low carbon technologies (building/site scale)	▪ Air source heat pump ▪ Ground source heat pump ▪ Biomass boiler ▪ Domestic micro CHP (Stirling engine and fuel cell) ▪ Non domestic micro CHP (small gas engine) ▪ Gas turbine CHP (industrial)
District heating network supply technologies	▪ Gas engine CHP (small and large) ▪ Biomass boiler ▪ Biomass steam turbine CHP ▪ Waste heat from power stations ▪ Waste heat from industry ▪ Geothermal (heat only, and CHP) ▪ Ground source heat pumps

The technology selection has been used to represent a range of primary technology types and fuels, suitable for a national scale assessment. It is acknowledged that there are a number of additional sub-types which could be examined on specific schemes, and this study aims to represent these in the primary typologies.

It is important to note that the analysis in this study requires national level datasets, and where there are likely to site-specific factors for energy supply, these will only be in the analysis when included in a national dataset. In particular:

- Waste heat from industry. The EU-ETS dataset provides the only spatial information available describing industrial demands, and energy use, allowing an assessment of waste heat potential. Therefore whilst waste heat may be available from other sites (including the Large Industry Energy Network – LIEN – sites), these are not included as potential heat sources due to absence of data or data confidentiality issues (in the case of LIEN).
- Data centres. Waste heat can be captured from data centres although the availability of waste heat and viability of accessing the waste heat can be highly site specific and depend on the method by which they are cooled. Heat from district heating networks could also be used to provide cooling to data centres though absorption chilling. However as stated in section 3.4 this may not provide any benefits and depends heavily on the data centre format. When further information is available on the size and location of data centres,

they could be included in the analysis, but at present are excluded due to absence of suitable data.

- Anaerobic digestion (AD). AD is first and foremost a waste treatment technology and its location should be heavily influenced by waste availability, waste location, and suitable areas for the digestate. These factors combined with the large areas for AD, and rural nature of its operation mean that it is not a key technology for connection to heat networks and therefore not considered of strategic importance in this work.

It is possible that these sources of waste heat, alongside others, could have a useful potential in Ireland. Therefore any further analysis at a local level which can use site specific data should ensure that they are included where relevant.

The availability of geothermal heating has been included in the assessment. Geothermal mapping conducted for the SEAI has been included in the GIS analysis to identify areas which may be suitable for geothermal heat supply (either though CHP or heat only systems)[34]. This study assumes for simplicity that areas with a temperature of 90°C or more at a depth of 2500m would be suitable for a geothermal system.

Natural gas based technologies are limited to areas where natural gas is available. As a proxy, these areas are identified based on small areas where natural gas is used in the residential sector as this is the most detailed information available on connection availability. To test the sensitivity of this, a scenario is also examined where natural gas is available in all areas.

The technology assessment does not include the impact of fuel supply chain capacity in terms of technical potential.

Full details of the technologies and assumptions used are provided in Appendix 2.

3.3 Guidance

The following guidance documents have been used in the development of this report.

- Energy Efficiency Directive published by the European Commission – in particular Article 14 and Annex IX which pertains to cost benefit analysis[35]
- Guidance Note on Article 14 published as a working document by the European Commission[36]
- Public Spending Code published by the Central Expenditure Evaluation Unit (CEEU) of the Department of Public Expenditure and Reform (DPER) – in particular section D-03: cost benefit analysis and section D-02: financial appraisal[37]. The CEEU reviewed and provided feedback to the assumptions and methodology used in this work.

[34] http://www.seai.ie/Renewables/Geothermal_Energy/Geothermal_Maps/
[35] DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, available at http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
[36] COMMISSION STAFF WORKING DOCUMENT Guidance note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Article 14: Promotion of efficiency in heating and cooling, available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0449&from=EN
[37] The Public Spending Code, available at http://publicspendingcode.per.gov.ie/

- Guide to Cost-Benefit Analysis of Investment Projects (2014) published by the European Commission[38]
- Best practices and informal guidance on how to implement the Comprehensive Assessment at Member State level, JRC Science and Policy Reports (draft report provided to Irish government in July 2015)
- Background report on best practices and informal guidance on installation level CBA for installations falling under Article 14(5) of the Energy Efficiency Directive, JRC Science and Policy Reports (Reference draft report provided to Irish government in July 2015)

It should be noted that the Guidance Note on Article 14 and the JRC informal guidance both provide a framework in which the assessment should be conducted, but allow for a degree of flexibility in terms of approach and scoping of what is included and not included. This study has reflected this guidance in focussing on elements and methods which are applicable to Ireland, as detailed throughout this report. Of particular note is the inclusion of cooling, as detailed in section 3.4.

3.4 Cooling

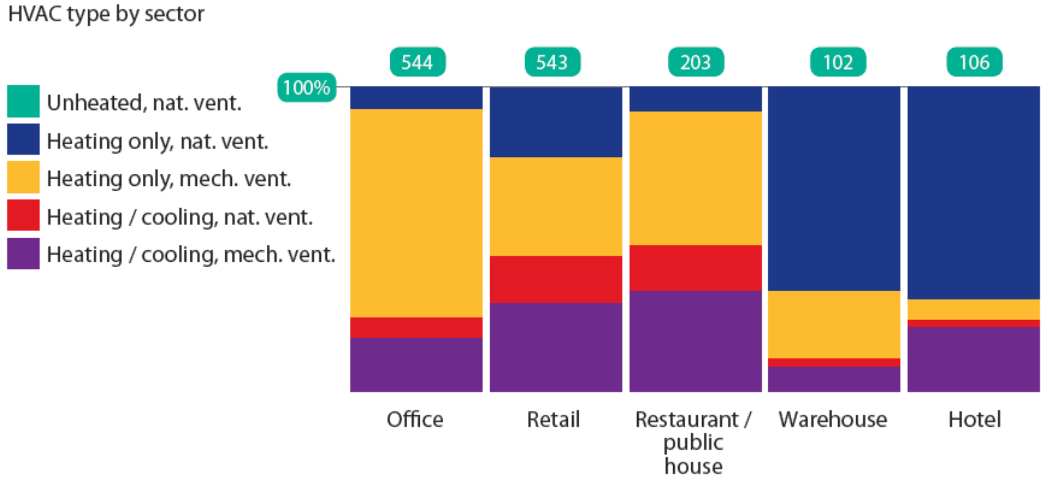
3.4.1 Cooling demands

Article 14 and the associated guidance include the use of cooling as part of the assessment where relevant. The most likely demands for cooling in Ireland are:

- Industrial uses. In particular, in the food processing and distribution industries, and data centres.
- Commercial space cooling. This is most likely to be concentrated in larger newer highly serviced commercial buildings. However there will also be some small scale cooling (using systems such as split-units) in smaller buildings. Analysis by the SEAI shows that cooling uptake varies by sector with around 25% of offices and hotels having cooling, and up to around 50% of retail and restaurants / public houses (see Figure 8).
- Services. Some institutions, in particular healthcare, will have a large cooling demand.

[38] Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020 , December 2014, available at http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

Figure 8: Breakdown of HVAC type in commercial buildings[39].



Cooling is not used extensively in the residential sector, with use limited to either a small uptake of portable units, or whole-house cooling in premium apartments and homes. Both of these are likely to be infrequently used and limited to the hottest summer periods due to absence of overheating in other periods.

For the industrial sector, cooling will typically be provided by large on-site chillers and the amount of cooling will justify large scale high efficiency cooling equipment. In the commercial and service sectors, cooling will generally either be of sufficient scale to justify large high efficiency chillers (for example a system providing the needs of a whole building), or be provided by a large number of small disaggregated systems (typically split units) which are often installed as a retrofit.

The requirement for comfort cooling in Ireland is limited, especially in comparison with countries with a warm climate. As a consequence, the SEAI do not collect data on cooling due to the climatic conditions. For example, degree day data from Dublin airport shows a heating degree day demand of 2347 heating degree days for 2014/15, whilst the cooling degree day demand was only 66 cooling degree days in the same period, with 90% of that occurring in June, July, and August[40]. The cooling demand for individual buildings will be influenced by both the weather (cooling degree days) and also the building internal gains.

Providing a reasonable assessment of cooling demands on a geographic basis across Ireland requires sufficient data which is not available for this work. Obtaining this data and producing suitable models where required would be a large project and is not justified by the small potential. The following limitations have been identified:

- There is limited information available on the size and type of buildings on a geographic basis. The methodology outlined for heating is given in Appendix 3, but a similar approach for cooling is considered unreliable because the demand for cooling has a much greater degree of variability and will depend more heavily on the types of buildings and uses, and occupant preferences. .

[39] Extensive Survey of the Commercial Buildings Stock in the Republic of Ireland. SEAI 2015 http://www.seai.ie/Publications/Energy_Policy_Publications/Energy_Modelling_Group_Publications/Extensive-Survey-of-Commercial-Buildings-Stock-in-the-Republic-of-Ireland.pdf

[40] Data from Dublin airport has been selected due to the availability of cooling degree day information. For comparison, the 20-year average heating degree day data from the SEAI is 2100.

- The requirement for cooling is heavily dependent on the individual building's use and design and the uptake of cooling in Figure 8 demonstrates that cooling systems are only present in some buildings. There is no information which indicates how much these systems are used, the type of system, or locations.
- For industrial sites, the cooling demand is likely to be very specific and require appropriate information from each site. Whilst the national industrial sector is relatively well characterised, there is very little geographic information available describing sites. Information is held by the Large Industry Energy Network (LIEN) but is not available for use outside of the LIEN programme.

In general cooling is becoming more common due to higher expectations on thermal comfort and increased internal gains (from IT equipment for example). It is also expected that the requirement for cooling may increase with climate change and corresponding hotter summers. However unless specific internal conditions are necessary, such as in laboratories, then cooling demands can usually be reduced though a combination of improved natural ventilation / mechanical ventilation design, and changes to user behaviour and expectation. Therefore similarly to heating where thermal efficiency should be considered before alternative forms of heat supply, the reduction or removal of cooling demands should be considered before the use of cooling systems and networks.

The SEAI will continue to monitor the availability of data for cooling and any potential changes in demand, so that suitable analysis is conducted when required.

3.4.2 The provision of cooling with district networks and cogeneration

Cooling is conventionally provided by electric chillers located at the site of cooling demand. These could be large centralised systems, or smaller split systems.

Cooling can be provided through networks similarly to the provision of heat. There are two basic configurations:

- Using a dedicated cooling network. A second system of pipes can be used to distribute chilled water to individual buildings. These are often less expensive than district heating network pipes as they do not need to be heavily insulated. The coolth is provided from a central chiller (predominantly electric or absorption) [41].
- Using distributed chillers. Coolth can be provided by absorption chillers located at individual buildings or sites, which are powered by heat from a district heating network. This means that less network infrastructure is required, but more plant is required at a building level. Data centres are one potential suitable coolth load.

The use of dedicated electric chillers on a cooling network will not provide any appreciable efficiency benefit over similarly efficient chillers at a building level. The exception to this would be where this system allows for heat capture from the cooling chillers for use on a District Heating Network or other heat load. This type of system can be used at a building scale where there is simultaneous cooling and heating demand.

[41] The term "coolth" is used to describe cooling energy demand. Analogous to "warmth".

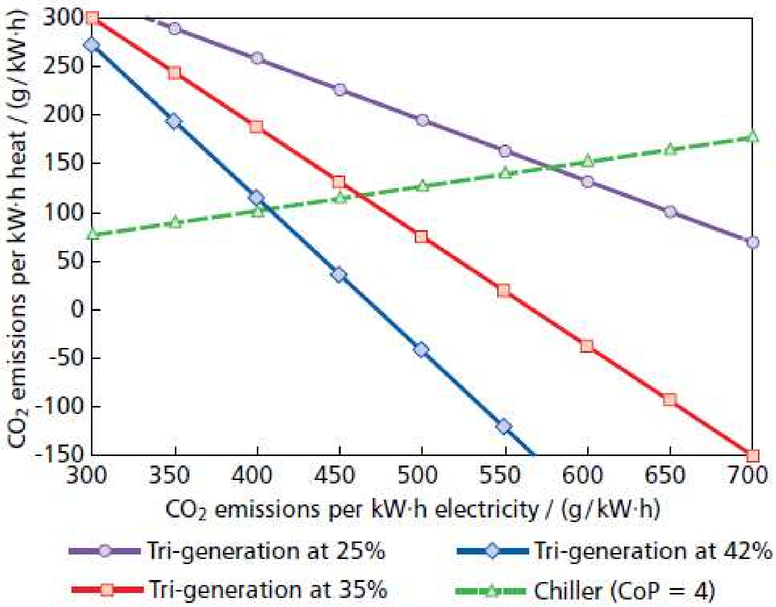
A key driver used for using cooling networks is when heat-driven absorption chillers are used for generating coolth. Absorption chillers are generally only viable at a larger scale (at least hundreds of kW coolth), and have a low efficiency compared with electric chillers with the coolth output at around 70% of the thermal input. Due to the low efficiency, absorption chillers are only viable when considering either waste heat or low carbon heat:

- Waste heat which would otherwise not be used (for example industrial waste heat) can be suitable for absorption chillers since the cooling efficiency is not as important. However the economic viability will still need to consider the cost of obtaining the heat (including the equipment to extract the heat in the form of heat exchangers, and heat network requirements) in comparison with the use of conventional electric chillers.
- Low carbon heat can be sourced from CHP systems for absorption chillers. A common approach is to use absorption chillers to increase the baseload heat demand for CHP systems in the summer, allowing the engines to continue operating when otherwise they would be unused, or dumping heat. High efficiency CHP operation is generally achieved when little or no heat is dumped and is defined in the EED (Annex II) as providing at least 10% primary energy demand reduction compared with separate provision of heat and electricity.

The use of waste heat is limited to specific applications where a suitable waste heat source if available. Absorption chillers generally require a medium temperature or higher (typically 80 °C or more). This therefore limits the applications to high grade waste heat sources such as industrial flue gas heat extraction.

The use of CHP generated heat for absorption chillers is becoming less viable from a CO_2 perspective. Under current grid electricity conditions with a CO_2 intensity of around 0.468 g / kWh (see Appendix 1), a typical gas engine CHP and absorption chiller (the red line in Figure 9) will produce coolth with a CO_2 intensity almost the same as an efficient chiller (green line in Figure 9). As the grid decarbonises further, the electric chiller will become the lower carbon option. As the grid continues to decarbonise, it is clear from Figure 9 that a gas based CHP system will have significantly higher CO_2 emissions than a heat only CHP system and separate electric chillers.

Figure 9: Comparison of tri-generation with electrically driven chillers (Note: tri-generation efficiencies refer to the CHP electrical efficiency; overall CHP efficiency is taken as 80% in all cases). Three CHP trigeneration systems are shown with electrical efficiencies of 25%, 35% and 42%. The corresponding chiller has a COP of 4. Source – CIBSE AM12[42]



3.4.3 The inclusion of cooling in this assessment

The discussion of cooling in the sections above identifies some key issues:

- Low demand for cooling. Cooling demands in Ireland are limited to certain sectors, and due to climatic conditions are small in proportion to total energy demand and heat demand. The benefits of cooling networks are therefore likely to be small in relation to heat networks.
- Lack of suitable data. There is very little data on existing cooling demands, in particular where cooling demands are located and how large they are. A previous assessment of cooling use by the SEAI is at a national scale, and cooling can't be modelled on a geographic basis without further data, which is not currently available. Many cooling demands are likely to be comprised of small cooling units which cannot viably be connected to a network.
- Limited potential and benefits. The potential deployment applications for cooling networks are limited. Specific locations with a suitable cooling demand could make use of absorption chillers where a suitable waste source of heat is available. However the generation of heat for the use in absorption chillers is likely to result in additional CO_2 emissions over conventional electric chillers.

Based on this discussion, it has been determined that due to the low return and high level of effort required to overcome the data restrictions, cooling cannot be included in the energy mapping for this

[42] Combined Heat and Power for Buildings. CIBSE AM12. 2012.

study. . It is also considered that the limited benefits of district cooling over conventional high efficiency electric chillers, and the deployment constraints, means that it should be scoped out of the CBA, even if sufficient data was available.

However the use of cooling networks should be considered on a site specific basis where sufficient information is available, and where a configuration can be developed which does provide an economic and environmental benefit.

4. HEAT MAP

4.1 Introduction to heat mapping

Heat mapping describes the spatial distribution of heat demand based on information on the building type, (a residential dwelling, a commercial or public sector building or an industrial site), the type of fuel used to generate the heat and other metrics such as area of buildings, and current and planned energy efficiency measures. The combination of a detailed dataset and spatial distribution means that heat maps can be used for the analysis of community energy schemes, or other schemes where spatial and geographic information may be of use.

The development of an Ireland-wide heat map forms the basis for the assessment of district heating network and high efficiency CHP potential analysis in this work. Key components of the heat map development are:

- Description of current heating and cooling demand covering the domestic, commercial, public, and industrial sectors.
- Forecast of how this demand may change over the next 10 years.
- Mapping of heating and demands, and mapping existing and planned heat supply schemes.

This section of the report provides a high level description of the heat mapping process. Full details are provided in Appendix 3.

4.2 Methodology and assumptions

The heat map is based an analysis of detailed high resolution sector specific data which are used to calculate heat demands. Two complementary approaches have been applied:

- Bottom up. Calculating demands based on characteristics of the heat users.
- Top down. Using measured energy consumption data. National statistics have been used to help verify the bottom up assumptions where comparable data is available.

The reconciliation process from these two approached and the outcome is discussed in Appendix 3.

The heat mapping dataset produced describes:

- heat demands for domestic and non domestic (public sector, commercial, and industrial) buildings. These are annual heat demands (both for 2015 and 2025), and linear heat density
- industrial demands and waste heat availability for EU ETS sites
- the location of industrial sites within the Large Industry Energy Network group
- road lengths used for the calculation of linear heat density; and
- key energy supply technologies including power stations

The heat map data is presented as a GIS map with a Small Area resolution. Small Areas are areas of population comprising between 50 and 200 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi). Small Areas were designed as the lowest level of geography for the compilation of statistics in line with data protection and generally comprise either complete or part of townlands or neighbourhoods. There is a constraint on Small Areas that they must nest within Electoral Division boundaries[43]. Another benefit of using small areas is that since they are defined by the number of homes, they are generally smaller in terms of geographic area in

[43] Census 2011 Boundary Files, Central Statistics Office, available at http://www.cso.ie/en/census/census2011boundaryfiles/

areas of high heat density (due to more homes per km^2) and therefore offer a greater resolution in areas where heat networks are more likely to be viable.

A range number of datasets and assumptions have been used in the construction of the heat map, detailed in Appendix 3. Due to the geographic area covered and the national nature of this work, the datasets and assumptions are necessarily available for national coverage. It is therefore not possible to conduct analysis where the information is not contained in the national datasets. This means that area specific factors which may be known about (such as a specific factory for example), may not be included in the national map if they are not in the national datasets. However any further mapping of local areas could be used to identify and assess these location specific factors.

It should be noted that whilst the heat map includes public sector loads, the availability of data at a national level describing the public sector buildings was poor. Therefore only public sector buildings heated by gas, and which could have locations identified, are included in the dataset. Further details are provided in Appendix 3.

The GIS system was used to set up system boundaries for the analysis of high efficiency heating potential. This allowed the filtering of the heat map by linear heat density to select Small Areas that meet the criteria for the selection of zones to conduct the technical assessment of heat network potential (see section 6.2).

It is important to note that the **baseline** is defined as the data set obtained through the heat map modelling to estimate the heat demands per sector in 2015 (current demands). The CBA modelling is based on the forecast 2025 demand obtained through the heat map modelling, and is known as the projected heat demand or projected heat density.

The methodology, assumptions and modelling carried out to develop the heat maps is described in detail in Appendix 3.

The following sections provide examples of the heat maps. Further maps are provided separately to this report, and the full GIS dataset has been provided to the SEAI for subsequent analysis and plotting.

4.3 Heat maps

Figure 10 and Figure 11 below show two example maps:

- Total baseline heat demand. This is an assessment of the current heat demand shown as MWh per Small Area. Due to the absolute nature of the data, the map shows a wide range of demands across the country, although there is an increase per Small Area in towns and cities, as demonstrated in the Dublin section. This is probably due to a greater mix of sectors in these areas, whereas rural areas are more dominated by residential demands.
- Total projected (2025) linear heat density. This is the linear heat density expressed as MWh / km, and based on the 10 year forecast heat demands. It clearly demonstrates that high heat density areas are concentrated in towns and cities, whilst rural areas have a very low heat density. The demand changes for the 2025 heat density to account for both growth and thermal efficiency improvements, as described in Appendix 3.

Figure 10 - Total baseline heat demand

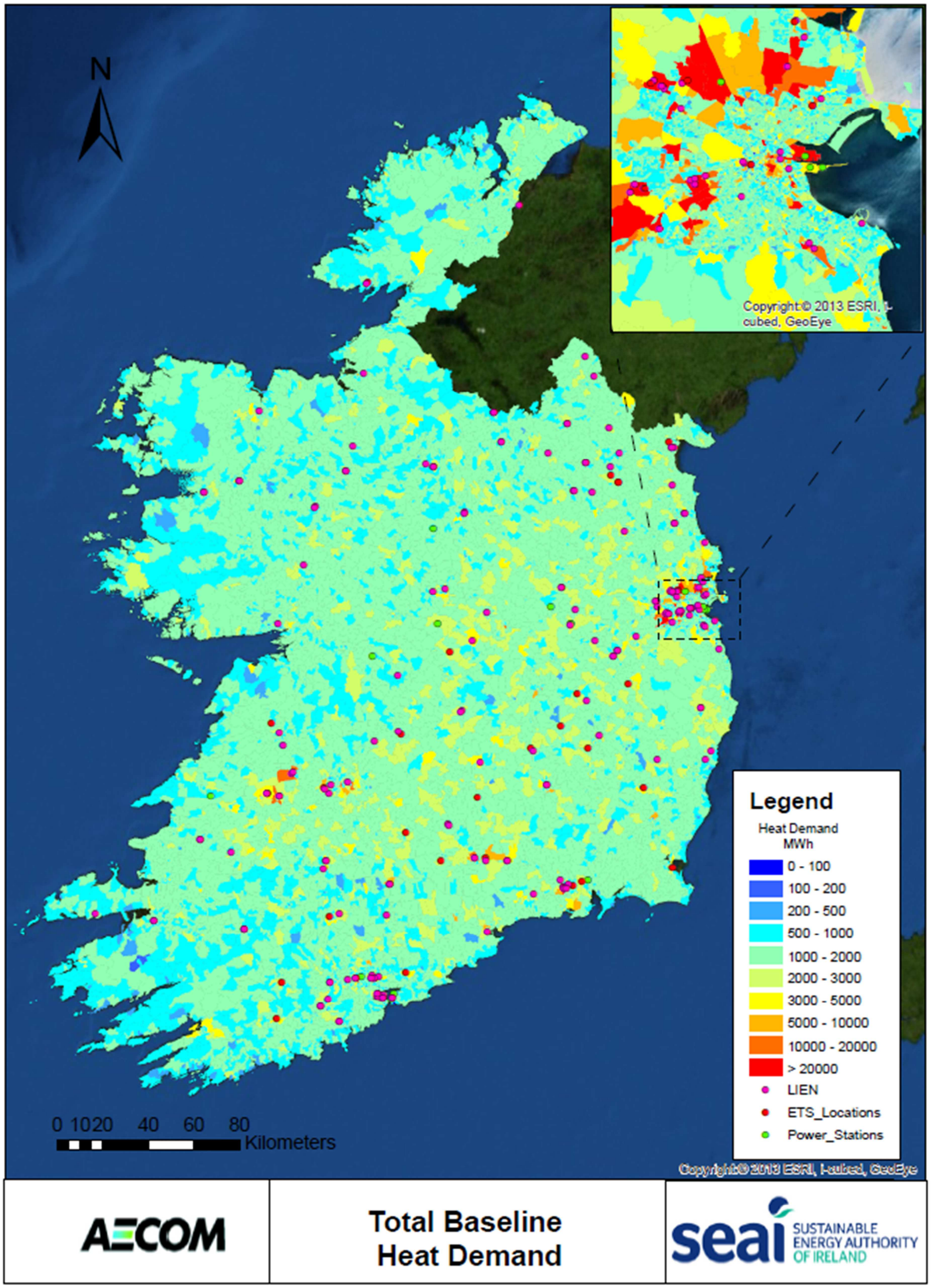
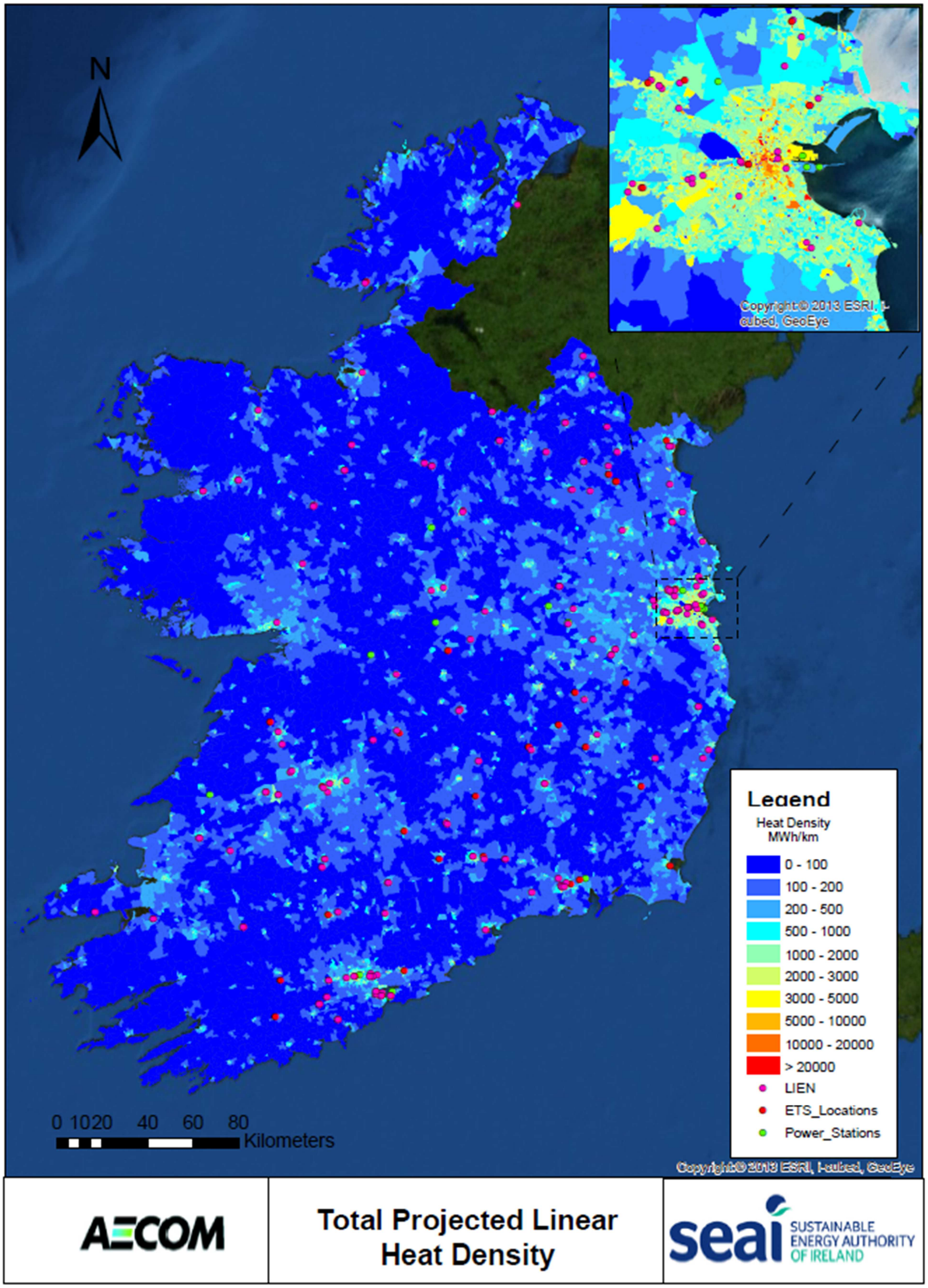


Figure 11 - Total 2025 Forecast Linear Heat Density



The following map snapshots are provided in addition to this document. These provide a selection of views of different aspects and layers of the GIS heat map provided as part of this work.

1. Total Baseline Heat Demand: shows the total heat demand in the baseline (2015) year
2. Total Baseline Linear Heat Density: shows the linear heat density in the baseline (2015) year
3. Total Baseline Linear Heat Density without sites: shows the total heat demand in the baseline (2015) year excluding LIEN and ETS sites
4. Total Projected Linear Heat Density: shows the forecast linear heat density in 2025
5. Total Projected Linear Heat Density without sites: shows the forecast linear heat density in 2025 excluding LIEN and ETS sites
6. Total Baseline Commercial Heat Density: shows the commercial heat demand in the baseline (2015) year
7. Total Baseline Domestic Heat Density: shows the domestic heat demand in the baseline (2015) year
8. Total Baseline Industrial Heat Density: shows the industrial heat demand in the baseline (2015) year
9. Total Baseline Public Sector Heat Density: shows the public sector heat demand in the baseline (2015) year
10. Total Projected Baseline Commercial Heat Density: shows the forecast commercial heat demand in 2025
11. Total Projected Domestic Heat Density: shows the forecast domestic heat demand in 2025
12. Total Projected Industrial Heat Density: shows the forecast industrial heat demand in 2025
13. Total Projected Public Sector Heat Density: s shows the forecast public sector heat demand in 2025
14. Threshold Map for 3000 Linear Heat Density: shows identified zones with forecast Linear Heat Density over 3,000 MWh/km in 2025
15. Threshold Map for 5000 Linear Heat Density: shows identified zones with forecast Linear Heat Density over 5,000 MWh/km in 2025
16. Threshold Map for 10000 Linear Heat Density: shows identified zones with forecast Linear Heat Density over 10,000 MWh/km in 2025.

5. METHODOLOGY

5.1 Methodology Overview

The method of assessment used in this study is a cost benefit analysis (CBA). The methodology used is based on the national and European guidance referenced in Section 3.3.

Based on the results of the heat mapping exercise and a review of the available technologies, a range of scenarios have been developed as described in section 6. These allow investigation of different system boundaries and technology options. These scenarios are all evaluated against a heat demand and supply baseline which includes energy efficiency improvements in line with current SEAI projections and growth in population and economic activity. The supply baseline assumes heat provision from counterfactual heat technologies which customers currently use, predominantly boilers. Section 6 provides further detail.

The costs and benefits of each scenario for the future use of these technologies to the economy as a whole are estimated and forecast into the future. These forecasts include all the costs and benefits of future use of these heating technologies, regardless of which economic actors bear the costs or enjoy the burdens. The costs and benefits taken into account include: the costs of installing and operating new heating infrastructure, the costs of conventional heat provision avoided and any environmental benefits. The net present economic value of each scenario - relative to a counterfactual case where current technologies continue to be used for all purposes – is calculated. These net present values provide a measure of the net benefits of adopting these technologies to the economy as a whole. On this basis, the most economically advantageous scenarios are identified.

5.2 Cost and Benefits

Each of the scenarios is defined in terms of:

- heat source;
- heat network; and
- heat demand/user.

These three factors define the essential features of any future scenario for the use of district heating.

The ***heat source*** is one of:

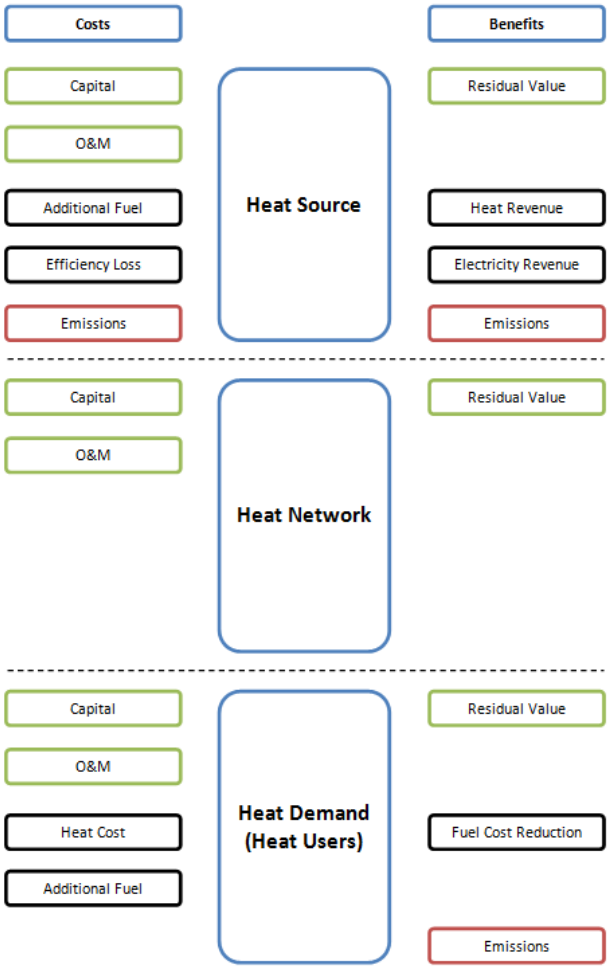
- Existing power station
- Existing industry
- New CHP plant
- New low carbon heat generation plant

Schemes, in general, require a ***heat network***. The scale of network required is determined by the relative location of heat sources and heat demands linear heat density. The concept of linear heat density is discussed in section 2.3 and is an important metric to take into account when considering the viability of heat networks. It is notable that some scenarios (e.g. alternative low carbon technologies at the building level) do not require a district heating network, although they may include some small scale networks (for example, linking two buildings). Section 3.2 provides further detail on the technology typologies.

The heat mapping process determines the level of ***heat demand*** and its characteristics.

A diagrammatic overview of the cost and benefits as they apply to each element (heat source, heat network and heat demand/user) is shown in Figure 12.

Figure 12: Overview of Costs and Benefits



The following table provides a summary of the key costs and benefits associated with each scenario element.

Table 5 - Key costs and benefits associated with each scenario element

Scenario Element	Cost	Benefit
Heat Source Each scenario assumes certain heat sources are available for district heating	Capital cost– the additional capital cost of providing heat for a district heating system from the source O&M cost – the additional operating and maintenance costs arising from using the heat source for district heating Additional Fuel Efficiency Loss – additional fuel use at the heat source, for example a factory or electricity generator, may increase its fuel use or reduce its output if it is also providing heat to a district system Emissions – the heat source may produce extra emissions if it is providing heat to a district network. This will have an environmental cost	Heat revenue– The installation will have remaining use at the end of the appraisal period which will be taken into account as a residual value. Residual value – the owner of the heat source will receive revenue for providing heat to a district network. This will be a cost to the users of the heat. Electricity revenue – For CHP only Emissions reduction in emissions from electricity generation for CHP only
Heat Network A district heating infrastructure will be required to distribute heat to users	Capital cost – cost of providing this new infrastructure O&M cost- Ongoing cost of operating and maintaining this infrastructure	Residual value The infrastructure will have remaining use at the end of the appraisal period which will be taken into account as a residual value
Heat Demand (Heat Users)	Capital cost – Once off costs to users of connecting to an using district heat O&M cost – ongoing costs to users of operating and maintaining their new heating equipment Heat cost – charges paid by users for the district heating services. This will offset against the revenue received by the heat source Additional Fuel Cost – Any additional fuel costs incurred by the heat user	Residual value The equipment in the users home or premises will have remaining user at the end of the appraisal period which will be taken into account as residual value Fuel cost reduction The costs of conventional, boiler based, heating avoided by switching to district heating, Emissions The emissions such as CO_2 avoided by switching from conventional to district heating.

It is notable that elements may balance out in the economic assessment used in the CBA. For example, the heat cost (a cost for the heat demand) is equal to the heat revenue (a benefit to the heat source). Therefore, these cancel out and the price on each unit of heat does not impact the net present value in the economic appraisal. This approach means that heat is considered to be delivered in a cost neutral manner at a societal level as both the costs and benefits remain within the Irish economy, and that there are no transaction costs or other "hidden" costs.

The installation of heat networks may incur disruption in urban areas and there may be associated costs. For example, there is likely to be an impact on traffic if located in a road or on local businesses if access is limited. The impact of disruption should be considered at a local level on each individual scheme and measures put in place to mitigate where possible. However for this national assessment, the costs of disruption are not included since they will be highly scheme specific and variable. If these disruption costs are very high for a specific scheme, then they could have an appreciable impact on the viability of the scheme. However the disruption issue is often seen as a non-financial risk element in schemes and could be viewed as more of a local political risk.

The individual costs and benefits and their method of evaluation are discussed in the following sub-sections.

6. OPTIONS ANALYSIS

6.1 Options Overview

In order to identify the national potential and economic potential for high-efficiency cogeneration and district heating, a range of options (or scenarios) are examined.

There are two key elements of each scenario, namely the system boundary and technology used to supply the heat.

The system boundaries are defined by the level of linear heat density considered as a viable threshold based on the linear heat density curves presented in this section. The output of the heat mapping process is the key determinant of the linear heat density and therefore the system boundaries used. This study examines a number of linear heat density thresholds as discussed in section 6.2.

For each of the system boundaries, the projected 2025 heat demand and corresponding linear heat density is calculated. This takes into account projected improvements in thermal efficiency of buildings, and projected heat demand growth in each sector. Energy efficiency is considered at the top of the energy hierarchy to ensure that overall energy demands are reduced where possible. Analysis of this is available for Ireland examining the costs and benefits of energy efficiency improvements[44]. Best practice heat network design determines that energy efficiency should be considered first, and the approach and outputs of this work reflect this. This means that networks are not oversized, neither do their economics rely on selling heat to inefficient customers.

The counterfactual heating supply is calculated and includes an assessment of the heat supply in terms of cost and performance. The counterfactual technologies (listed in section 3.2) consist of boilers with a range of fuel types, and electric heating. A fuel switch to natural gas (to simulate customer preference or policy impact) is also assumed in areas where the natural gas network exists, as detailed in Appendix 3. The counterfactual information is used to calculate the levelised cost of heat in 2025 for each customer and technology type[45]. As described in section 5.1, it is assumed in the economic assessment that heat is delivered through alternative low carbon technologies or heat networks to customers at a price equivalent to their current counterfactual costs.

In addition, to the counterfactual technologies, a range of technologies are examined under the following categories:

- High Efficiency Cogeneration[46]
- Efficient district heating[47]

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[44] This includes Unlocking the Energy Efficiency Opportunity (see footnote 21) and the National Energy Efficiency Action Plan (NEEAP) , available at http://www.seai.ie/Publications/Energy_Policy_Publications/Energy_Service_Companies/Ireland%E2%80%99s_second_National_Energy_Efficiency_Action_Plan_to_2020.pdf

[45] The "levelised" cost is a unit price of heat (price per MWh) which is independent of technology lifetime or discounting. It therefore allows comparison between different heat sources.

[46] Defined in Article 2 (34) of the Energy Efficiency Directive as cogeneration meeting the criteria laid down in Annex II: cogeneration that fulfils the following criteria:

— cogeneration production from cogeneration units shall provide primary energy savings calculated according to point (b) of at least 10 % compared with the references for separate production of heat and electricity,

— production from small-scale and micro-cogeneration units providing primary energy savings may qualify as high- efficiency cogeneration

[47] Defined in Article 2 (41) of the Energy Efficiency Directive as district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat

- Efficient individual heating[48]

The technologies assessed under these categories are described in section 3.2 and are either at a building scale (alternative low carbon technologies) or connected to a district heating network. For each system boundary, the various technology options are compared to the counterfactual. The scenario that delivers the highest net present value (NPV) is deemed to be the most economically advantageous.

6.2 System Boundaries

System boundaries are defined to limit the assessment of areas which may offer cost effective potential heat demands, and to define their size to be modelled. The system boundaries are defined by a series of zones representing geographic areas, for example part of, or all of a town. The zones consist of Small Areas[49] which have a linear heat density above the set threshold linear heat density. As the set threshold is increased, the number of eligible Small Areas which fall above the threshold reduces in number, and therefore the heat demand included in the system boundary is also reduced. However, the zones which remain are of a higher linear heat density, and therefore potentially more viable for heat networks.

GIS (Geographical Information System) analysis has been used to construct the zones for each threshold from Small Areas. The following rules are used:

- Where Small Areas are adjacent (are touching each other), they are combined to form a larger area which is part of a zone.
- Where individual Small Areas or groups of Small Areas (aggregated as above) are located within 2 km of each other, they are combined to form a zone (implying a heat network connection)[50].

A zone is thus made up of one or more Small Areas, and may include areas separated by up to 2 km.

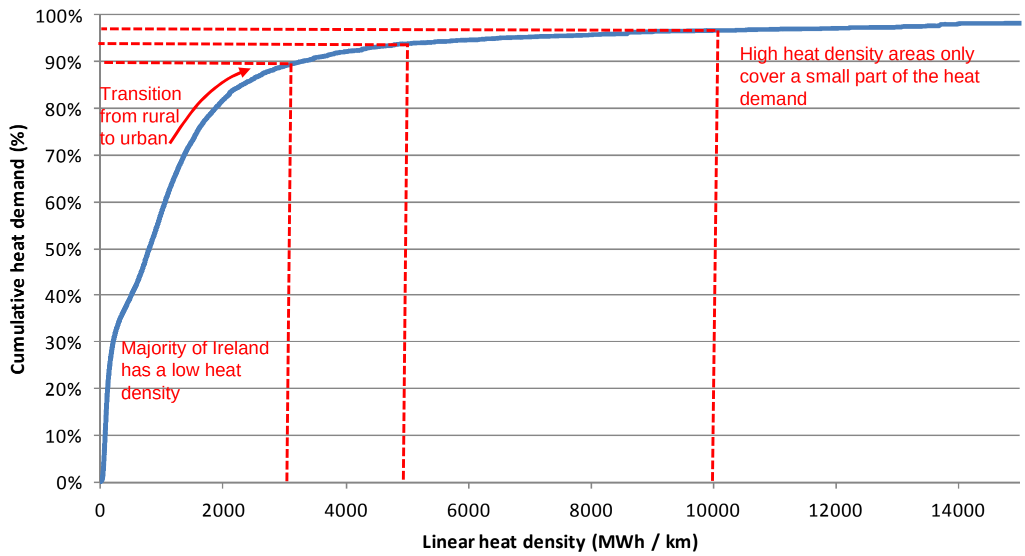
The threshold densities have been identified for analysis based on the heat demand curve for Ireland shown in Figure 13 (see explanation following diagrams). This indicates that most (~80%) of the heat demand in Ireland is at levels of heat density of less than 2000 MWh/km. Analysis of the sectors included is shown in Figure 14.

[48] Defined in Article 2 (43) of the Energy Efficiency Directive as individual heating and cooling supply option that, compared to efficient district heating and cooling, measurably reduces the input of non-renewable primary energy needed to supply one unit of delivered energy within a relevant system boundary or requires the same input of non-renewable primary energy but at a lower cost, taking into account the energy required for extraction, conversion, transport and distribution

[49] Small Areas are areas of population comprising between 50 and 200 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi). Small Areas were designed as the lowest level of geography for the compilation of statistics in line with data protection and generally comprise either complete or part of townlands or neighbourhoods.

[50] This buffer approach and distance is suggested in the JRC guidance.

Figure 13: Analysis of linear heat density across Ireland to identify suitable thresholds for the formation of system boundaries[51].



The curve in Figure 13 shows the cumulative heat demand from each individual small area ordered by linear heat density. The small areas on the left of the chart are therefore very low density, and those on the right very high density. The chart therefore can be used to show the relationship between total heat demand and heat density, and clearly demonstrates that the majority (around 80%) of Ireland's heat demand is in lower density areas which are predominantly rural or low density urban in nature.

The low density areas are unlikely to be suitable for heat networks, but the gradient of the curve in this section of the chart shows that if the viability threshold does lie within this range, the potential for heat networks in terms of national heat demand is very sensitive to the linear heat density. Figure 14 shows the split in heat demand by sector for each small area, also ordered by linear heat density. It demonstrates that the predominant loads in these low density areas are domestic heat demands. This could correspond to edge of town heat densities where larger commercial and industrial facilities may be based.

At around 85% of heat demand, there is a turning point in the curve which represents the sub urban and urban areas of Ireland. This lies in the region of around 1500 MWh/km to 2000 MWh/km linear heat density. Above this point, the remaining 10 % of heat demand lies in areas of reasonably high density. The gradient of the curve above 2000 MWh/km suggests that the national potential for heat networks is reasonably insensitive to the linear heat density.

[51] Note that the LHD scale is limited to 15,000 to allow the shape of the curve to be observed. This has meant that some Small Areas with extremely high LHDs are not shown

Figure 14: Split in heat demand by sector ordered by Linear Heat Density (LHD) (as in Figure 13 above). The split between sectors is averaged over 50 Small Areas to allow the trends to be more easily observed when plotted

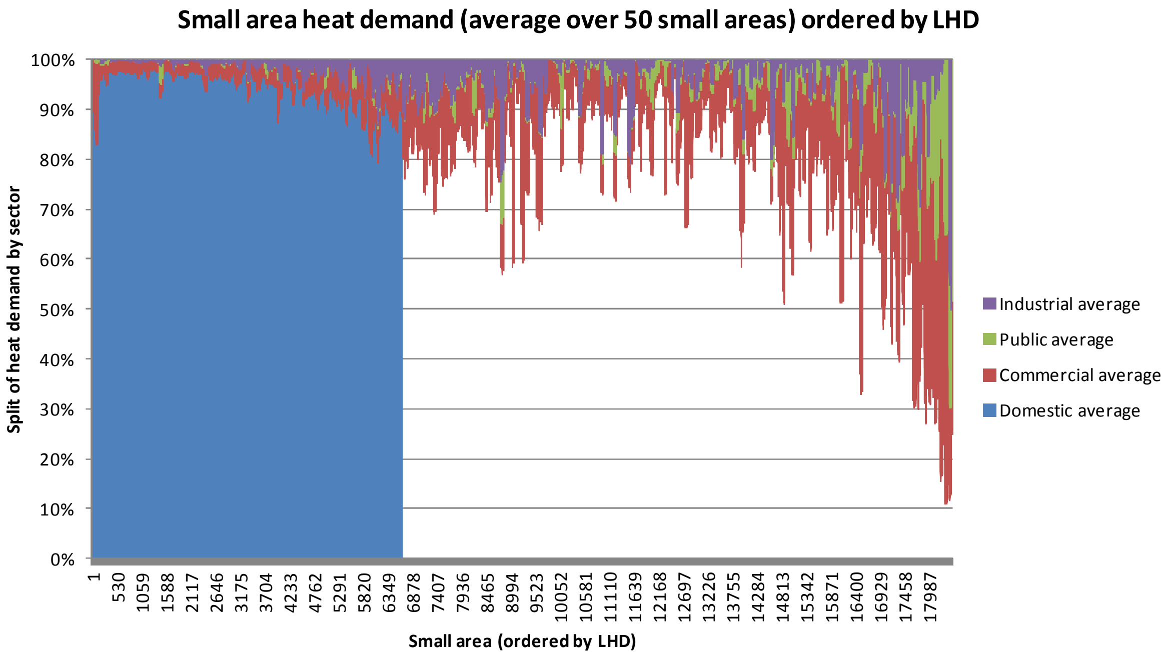


Figure 15: Split in heat demand by sector ordered by Linear Heat Density (as in Figure 13 above). These results are not averaged, to illustrate the level of variation at similar levels of Linear Heat Density (LHD)

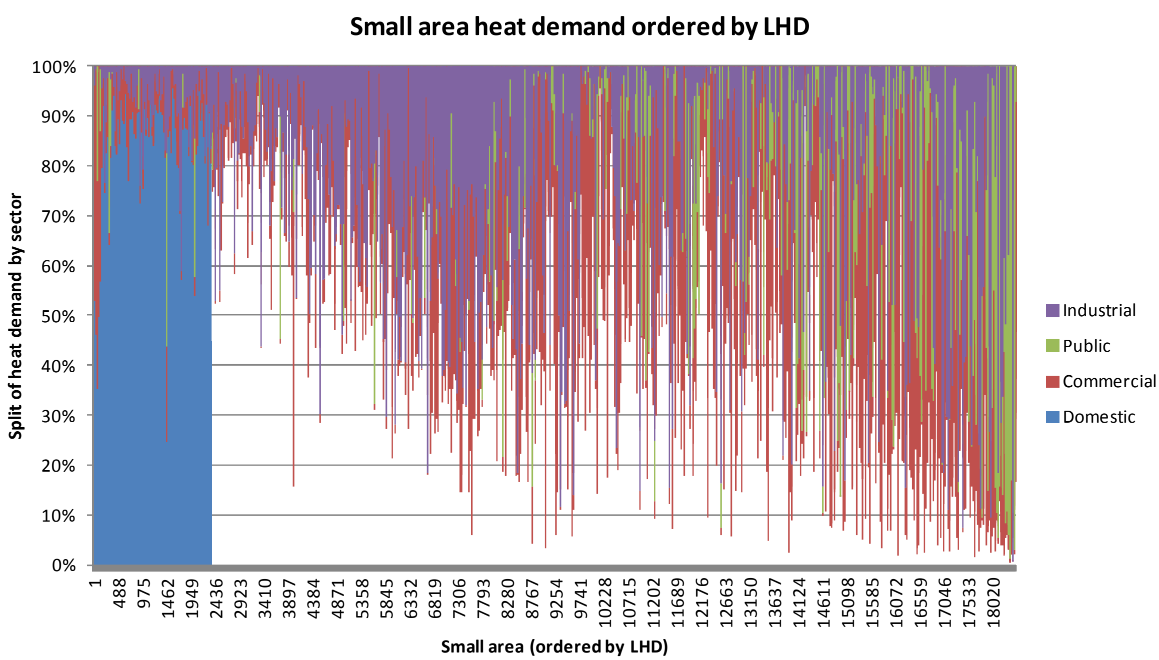


Figure 14 demonstrates that as the heat density increases, there is a general trend in shift away from residential loads, to an increase in commercial, public sector, and industrial. The following are identified:

- Commercial demands are generally highest for the highest heat densities. These are likely to be commercial areas of Dublin.
- Public sector loads are also dominant at very high heat densities. This may partially be influenced by the public sector dataset being based on gas consumption, and therefore skewed towards reporting of buildings in urban areas.
- There is a small increase in industrial and commercial heat loads in moderate heat densities (this can be seen in small areas around number 7407 on the X-axis of Figure 14).

Overall, there is a large degree of variation in sector split at similar heat densities, which can be seen better in the non-averaged results in Figure 15 demonstrating the need for areas specific studies for more detailed analysis.

Based on the information above, the following thresholds have been selected for the system boundaries:

- 3,000 MWh / km
- 5,000 MWh / km
- 10,000 MWh / km

These boundaries cover the range of densities where heat networks may be viable, and a suitable spread of national heat demand potential within this range from around 10% of the heat demand (the maximum potential expected) to around 3%.

When reading the following sections, it is important that the system boundaries are used to define the quantum of heat demand within the total boundary, such that the analysis includes the entire zone. Thus a scheme identified as cost effective in a 10,000 MWh / km zone will not be identified at the 5,000 or 3,000 MWh / km system boundaries, even if the cost effective zone is a sub-set of the lower density larger zones. This is due to the entire zone being assessed, and at 5,000 or 3,000 MWh / km, the overall heat density has reduced to a level which is not viable.

6.2.1 System Boundary 1: 3,000 MWh / km

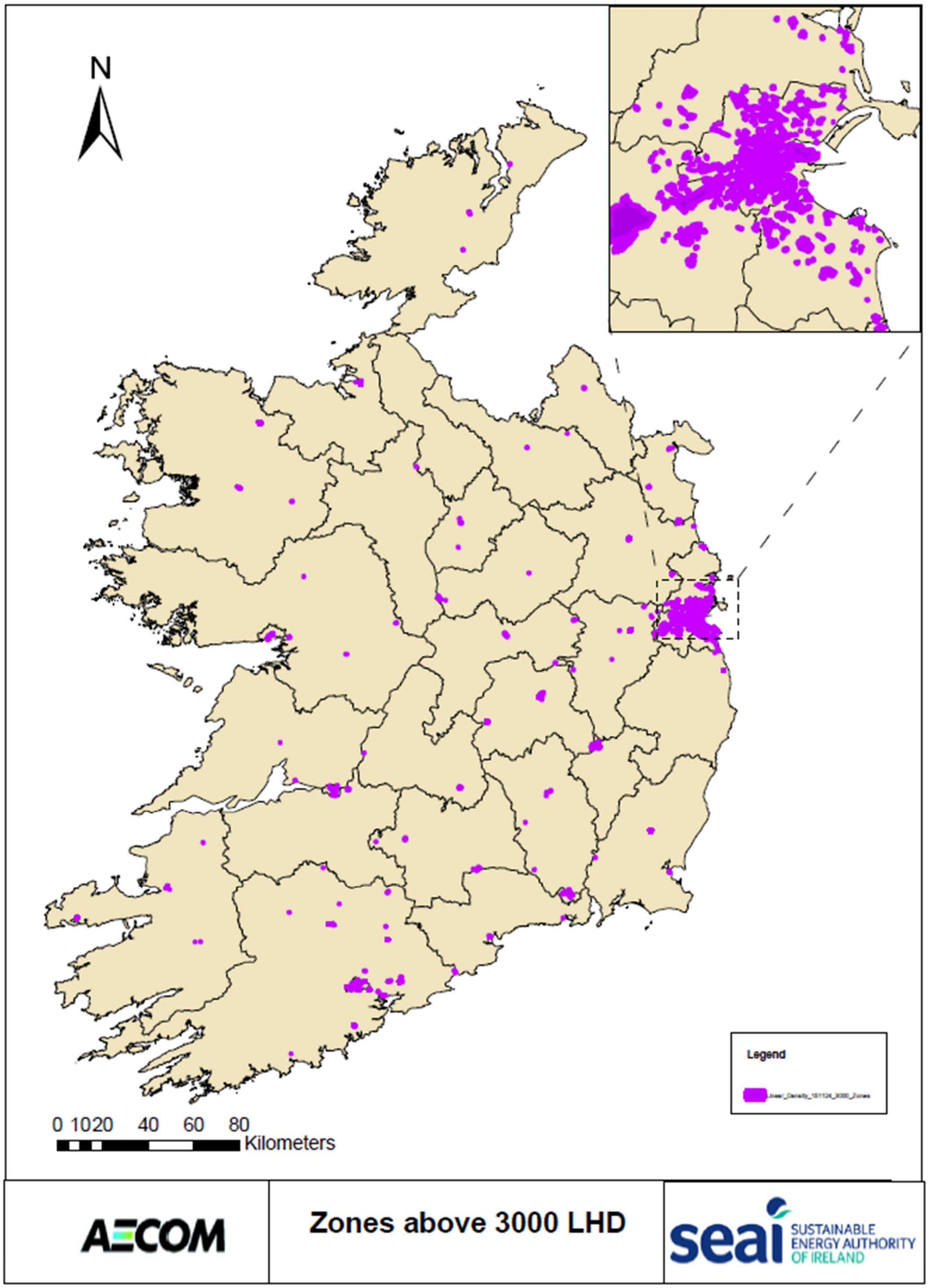
For this system boundary, 85 zones have been identified which include 1,059 Small Areas (just under 6% of all Small Areas in Ireland). The identified heat demand for this system boundary is estimated to be in the region of 3,100 GWh, or about 13% of the total heat demand for the Republic of Ireland.

Table 6: Heat demand of the 3,000 MWh / km system boundary

	Heat Demand GWh/year
National heat demand for the Republic of Ireland	23,000
System boundary (3,000 MWh/km)	3,100

The map of this boundary (Figure 16) demonstrates that the majority of zones are located in Dublin, with other main areas around Waterford, Cork, Limerick, and Galway. There are also a number of much smaller zones spread around the country. These are often made up of a single, or a small number of Small Areas in small and medium sized towns.

Figure 16: Map showing the 3,000 MWh / km system boundary



6.2.2 System Boundary 2: 5,000 MWh / km

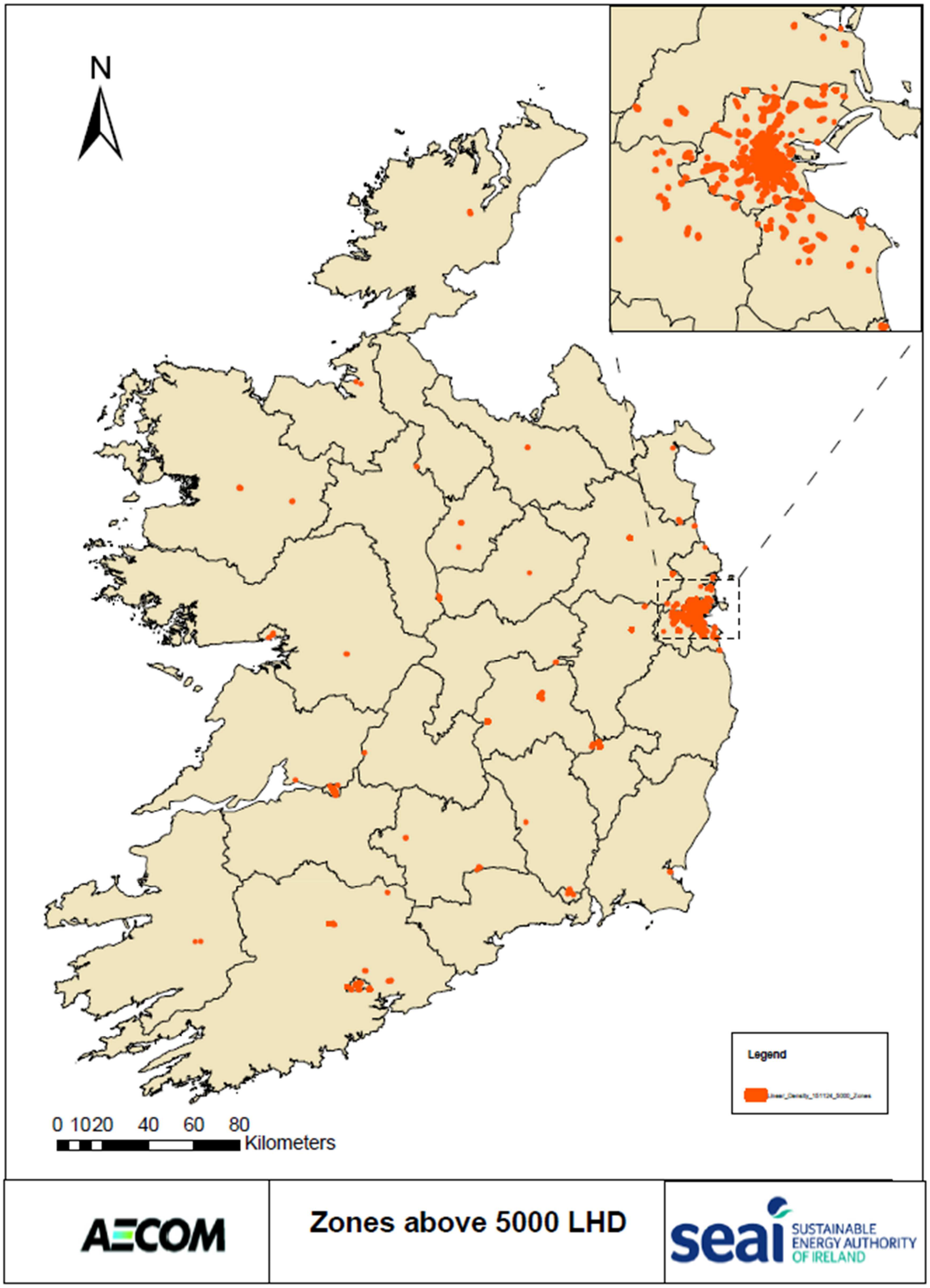
For this system boundary, 53 zones have been identified. These include 469 Small Areas which represent around 2.5% of all Small Areas in Ireland. The identified heat demand for this system boundary is estimated to be in the region of 1,700 GWh, or about 7% of the total heat demand for the Republic of Ireland.

Table 7: Heat demand of the 5,000 MWh / km system boundary

	Heat Demand GWh/year
National heat demand for the Republic of Ireland	23,000
System boundary (5,000 MWh/km)	1,700

The map of this boundary (Figure 17) shows a similar trend to the 3,000 system boundary, but with a reduction in smaller zone numbers, and a reduction and fragmentation of zones in Dublin. In particular, some of the larger zones around the outside of Dublin (representing industrial estates and commercial parks have been removed.

Figure 17: Map showing the 5,000 MWh / km system boundary



6.2.3 *System Boundary 3: 10,000 MWh / km*

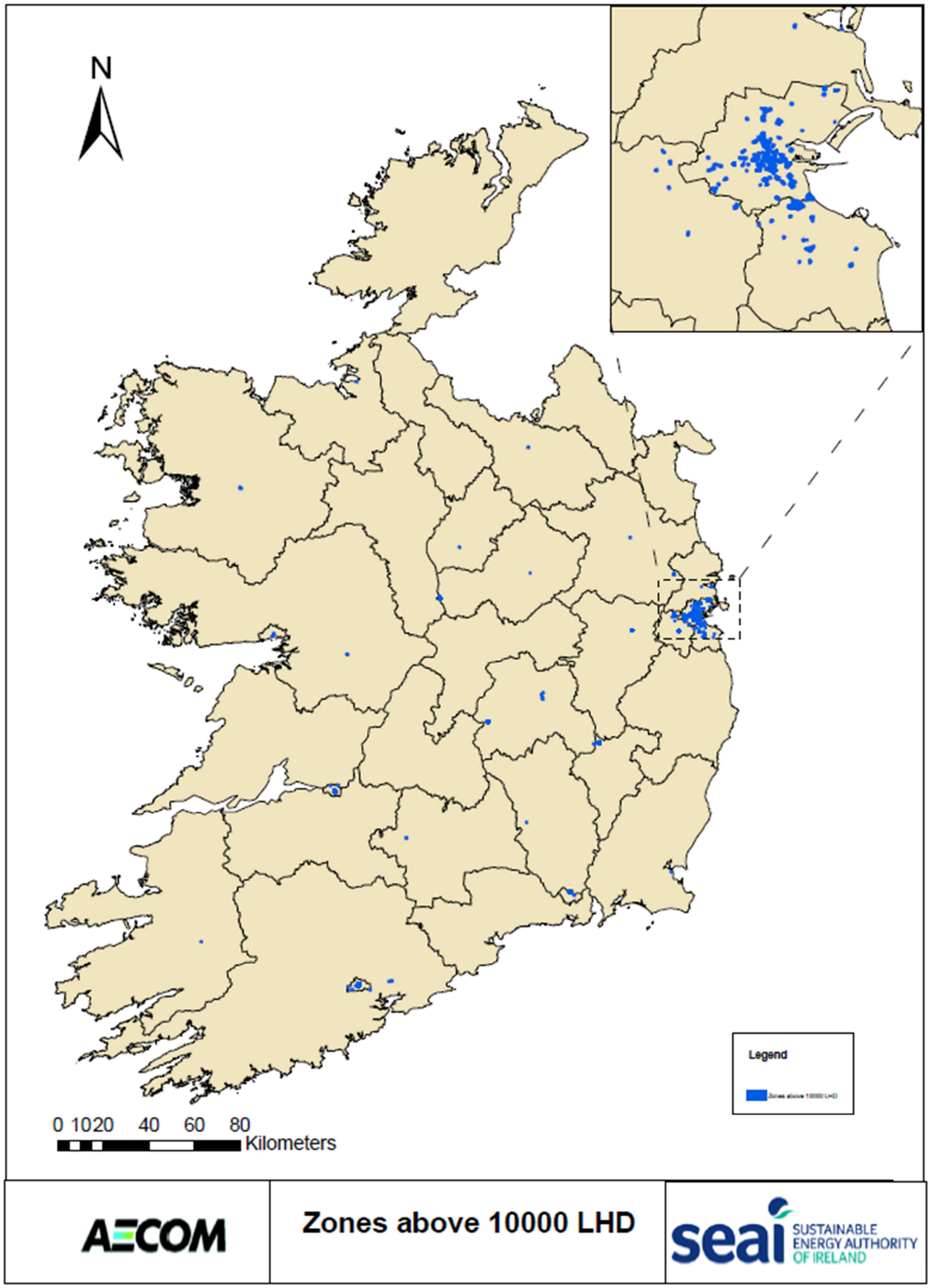
For this system boundary, 35 zones have been identified. These include 209 Small Areas which represent around 1% of all Small Areas in Ireland. The identified heat demand for this system boundary is estimated to be in the region of 1,100 GWh, or about 5% of the total heat demand for the Republic of Ireland.

Table 8: Heat demand of the 10,000 MWh / km system boundary

	Heat Demand GWh/year
National heat demand for the Republic of Ireland	23,000
System boundary (10,000 MWh/km)	1,100

The map of this boundary (Figure 18) shows a significant reduction in the number of zones from the lower densities, with Dublin remaining the main area of interest.

Figure 18: Map showing the 10,000 MWh / km system boundary



6.3 Technology

The modelling examines a number of scenarios based around technology availability. The **principal scenarios** are:

- Heat networks compared with the counterfactual;
- Heat networks compared with alternative low carbon technologies and counterfactual scenarios;
- Alternative low carbon technologies compared with the counterfactual.

Within each of these scenarios, a number of **technology scenarios** have been examined based around the availability of individual technologies or groups of technologies. These include:

- All technologies being available
- Limiting heat network sources to waste heat (from power stations or industry). This explores the potential of using existing heat sources.
- Removing the availability of waste heat from heat network sources. This reflects the potential complexities in connecting to waste heat sources and transmitting heat to heat networks.
- Enabling the use of natural gas based technologies in all zones for heat networks. This is used to identify the importance of natural gas for economic operation.
- Limiting heat network and alternative low carbon technologies to CHP based systems. This explores the potential for CHP as the prime source of heat for networks.

6.4 Principal scenario assessment

This section provides an overview of the results from the modelling of each principal scenario for each system boundary. This provides the initial assessment of potential for heat networks and alternative low carbon technologies, and allows a greater understanding of the importance of the threshold set for identifying the system boundary.

The following scenarios have been assessed:

- Scenario 1: this scenario explores the zones where the levelised costs (€/MWh) of heat networks are lower than those for the counterfactual. This means that heat networks show a lower €/MWh for the provision of heat to these zones than the counterfactual technologies and can thus be considered economic.
- Scenario 2: this scenario includes the zones where the levelised costs (€/MWh) of heat networks are lower than that for both, the alternative low carbon technologies and the counterfactual, and are therefore the most economic option. This means that heat networks show a lower €/MWh for the provision of heat to these zones than the counterfactual and alternative low carbon technologies.
- Scenario 3: this scenario refers to zones where the levelised costs (€/MWh) of alternative low carbon technologies are lower than that for the counterfactual. This means that

alternative low carbon technologies show a lower €/MWh for the provision of heat to these zones than the counterfactual technologies.

Table 9: Definition of Principal scenarios evaluated in the CBA and number of zones per boundary

Principal scenarios	Description	Number of zones for each boundary		
		3,000 MWh/km (85 zones)	5,000 MWh/km (53 zones)	10,000 MWh/km (35 zones)
Scenario 1	Zones where heat networks are better in economic terms (€/MWh) than counterfactual technologies.	18 (21%)	12 (23%)	15 (43%)
Scenario 2	Zones where heat networks are better in economic terms (€/MWh) than both alternative low carbon technologies and counterfactual technologies.	10 (12%)	7 (13%)	10 (29%)
Scenario 3	Zones where alternative low carbon technologies are better in economic terms (€/MWh) than counterfactual technologies.	66 (78%)	37 (70%)	27 (77%)

% figures refer to % zones from each total boundary zones, e.g. Scenario 1 consists of 18 zones for the 3,000 MWh/km boundary. This represents 21% of the total 85 zones in the boundary.

6.4.1 Assessment of 3,000 MWh / km system boundary

The identified heat demand for this system boundary is estimated to be in the region of 3,100 GWh with heat networks potentially able to supply around 52% (1,600 GWh). The results indicate that heat networks have the potential to supply 0.4% of the system boundary demand cost effectively (11 GWh/year). This corresponds to a potential provision of 7% of national heat demand by heat networks; 0.05% cost effectively.

Table 10: Characteristics of the 3,000 MWh / km system boundary[52]

	Heat Demand GWh/year	% of national demand	% of boundary heat demand
National heat demand for the Republic of Ireland	23,000		
System boundary (3,000 MWh/km)	3,100	13%	
Heat Networks potential provision	1,600	7%	52%
Heat Networks potential cost effective provision[53]	11	0.05%	0.4%

52 Figures are rounded except those for the heat networks potential cost effective provision, as they are too small in comparison and rounding would not show enough resolution

53 Compared to counterfactual technologies

The following results show the outputs from modelling the 3,000 MWh / km system boundary.

Table 11: Modelling results for the 3,000 MWh/km system boundary, showing results for levelised cost

Principal scenarios	Levelised Costs €/MWh			Max Levelised Costs Difference €/MWh
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€218		€185	-€33
Scenario 2	€206	€186	€156	-€30
Scenario 3	€136	€100		-€36

Table 11 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum benefit obtained would be €33/MWh (with counterfactual technologies able to provide a cost of €218/MWh compared to €185/MWh from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, the maximum benefit obtained would be €30/MWh (comparing the €156/MWh from heat networks to the €186/MWh from alternative low carbon technologies as these offer lower levelised costs than even counterfactual technologies). Scenario 3 identifies a potential maximum benefit of €36/MWh, with alternative low carbon technologies able to provide €100/MWh and counterfactual showing €136/MWh.

Table 12: Modelling results for the 3,000 MWh/km system boundary, showing results for Net Present Cost (NPC)

Principal scenarios	NPC € million			Max NPC Difference € million
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€26		€23	-€3
Scenario 2	€10	€9	€8	-€1
Scenario 3	€3,008	€2,197		-€811

Table 12 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum NPC benefit obtained would be €3 million (with counterfactual technologies showing an NPC of €26 million compared to €23 million from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, the maximum NPC benefit obtained would be €1 million. In great contrast, scenario 3 identifies a potential maximum NPC benefit of €811 million, with alternative low carbon technologies able to provide about €2,200 million and counterfactual about €3,000 million.

Table 13: Modelling results for the 3,000 MWh/km system boundary, showing results for Annual heat demand

Principal scenarios	Annual Heat Demand GWh/year			Max Difference GWh/year
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	16		11	-5
Scenario 2	7	6	4	-2
Scenario 3	3,006	3,183		177

Table 13 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks would be able to provide 5 GWh/year less heat demand than counterfactual technologies (with counterfactual technologies showing a potential heat demand provision of 16 GWh/year compared to 11 GWh/year from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks would be able to provide 2 GWh/year less heat demand than counterfactual technologies or alternative low carbon technologies. Again scenario 3 shows the highest difference with a potential maximum benefit of around 177 GWh/year higher heat demand provided by alternative low carbon technologies over the potential provision by the counterfactual (around 3,000 GWh/year).

Table 14: Modelling results for the 3,000 MWh/km system boundary, showing results for Primary Energy

Principal scenarios	Primary Energy GWh			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	519		469	-10%
Scenario 2	196	112	182	63%
Scenario 3	77,348	56,708		-27%

Table 14 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks use 10% less primary energy (469 GWh) than the counterfactual technologies (519 GWh) over the period of the CBA (24 years). In scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks use 63% more primary energy (182 GWh) than alternative low carbon technologies (112 GWh), with counterfactual using even a higher amount (196 GWh). Scenario 3 identifies that alternative low carbon technologies use 27% less primary energy than counterfactual ones although the magnitude of use is of about 500 times higher than for scenario 2.

Table 15: Modelling results for the 3,000 MWh/km system boundary, showing results for CO_2

Principal scenarios	CO_2 kt			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	111		94	-15%
Scenario 2	39	21	34	62%
Scenario 3	14,482	10,257		-29%

In zones where the cost per MWh is lower for heat networks (Table 15) compared to the counterfactual (scenario 1), heat networks are able to offer potential CO_2 savings of 15% (94 kt) over the period of the CBA (24 years). In scenario 2, for zones where the heat networks cost per MWh is lower compared to the counterfactual and alternative low carbon technologies, heat networks appear to emit 62% more CO2 (34 kt) than alternative low carbon technologies (21 kt). Scenario 3 identifies that alternative low carbon technologies potentially would emit 29% less CO_2 than counterfactual ones. Again the magnitude of emissions is much higher here (in the region of 500 times at over 10,000 kt) than for scenario 2.

Key observations from the results are:

- Heat networks are only cost effective for around 11 GWh/year of heat demand (compared with counterfactual, scenario 1) or 4 GWh/year (compared with alternative low carbon technologies and counterfactual – scenario 2). This is a range of approximately 0.02% to 0.05% of national heat demand (Table12).

- Alternative low carbon technologies are cost effective (compared with the counterfactual – scenario 3) for nearly 3,200 GWh per year, or approximately 14% of the national heat demand (Table 12). This corresponds to 66 of the 85 zones in this boundary (Table 8).
- Heat networks could provide a maximum cost benefit of €3 million for economic schemes (compared with the counterfactual – scenario 1). The cost benefit of alternative low carbon technologies in scenario 3 is 270 times this at €811 million in scenario 3 (Table 11).
- Primary energy savings from heat networks are around 10% for schemes which are economic (compared with the counterfactual – scenario 1), with 27% for alternative low carbon technologies in scenario 3 (Table 13).
- CO_2 savings from heat networks are around 15% (compared with the counterfactual – scenario 1), lower than for alternative low carbon technologies in scenario 3 at around 29% (Table 14).

Figure 19 shows the Heat Networks cost effective zones and the very small amount of heat demand they can supply. The gap to the zone around the 1,000 GWh corresponds to a zone in Dublin covering nearly 800 Small Areas (zone with very high heat demand) which is marginally more expensive than the counterfactual.

Figure 19: Levelised cost difference versus cumulative heat demand for scenario 1 – Heat Networks cost effectiveness over counterfactual technologies, for 3000 MWh / km system boundary

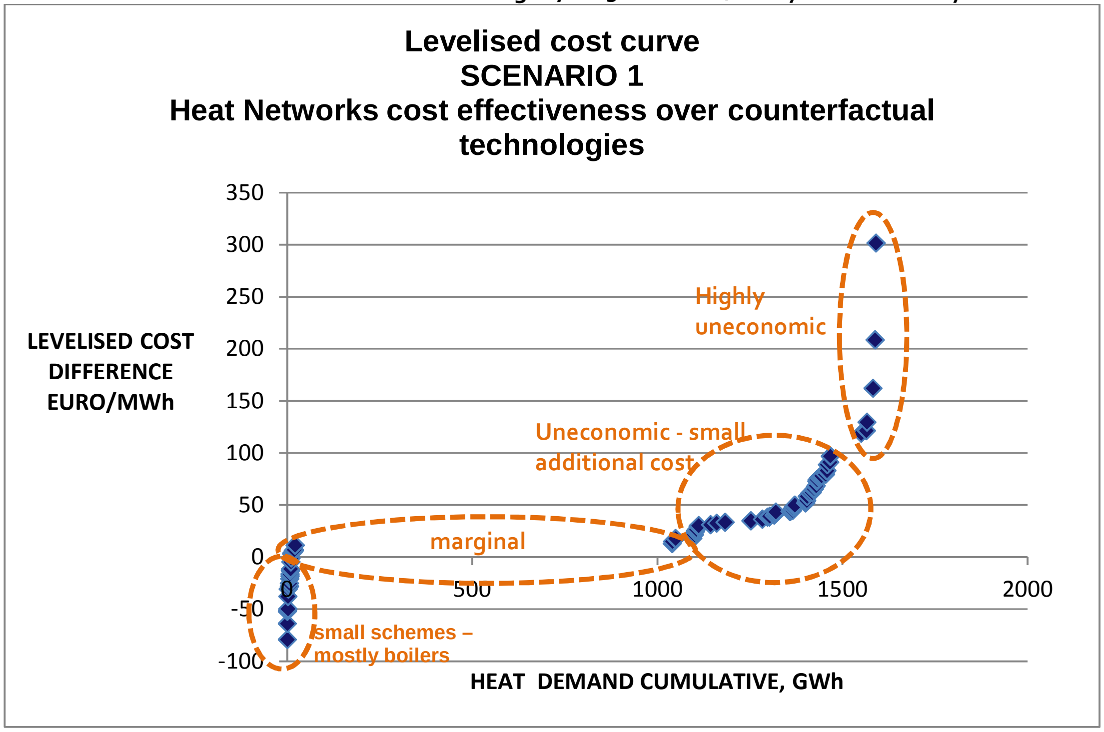


Figure 20: Levelised cost difference versus cumulative heat demand for scenario 3 – Alternative low carbon technologies cost effectiveness over counterfactual technologies, for 3000 MWh / km system boundary

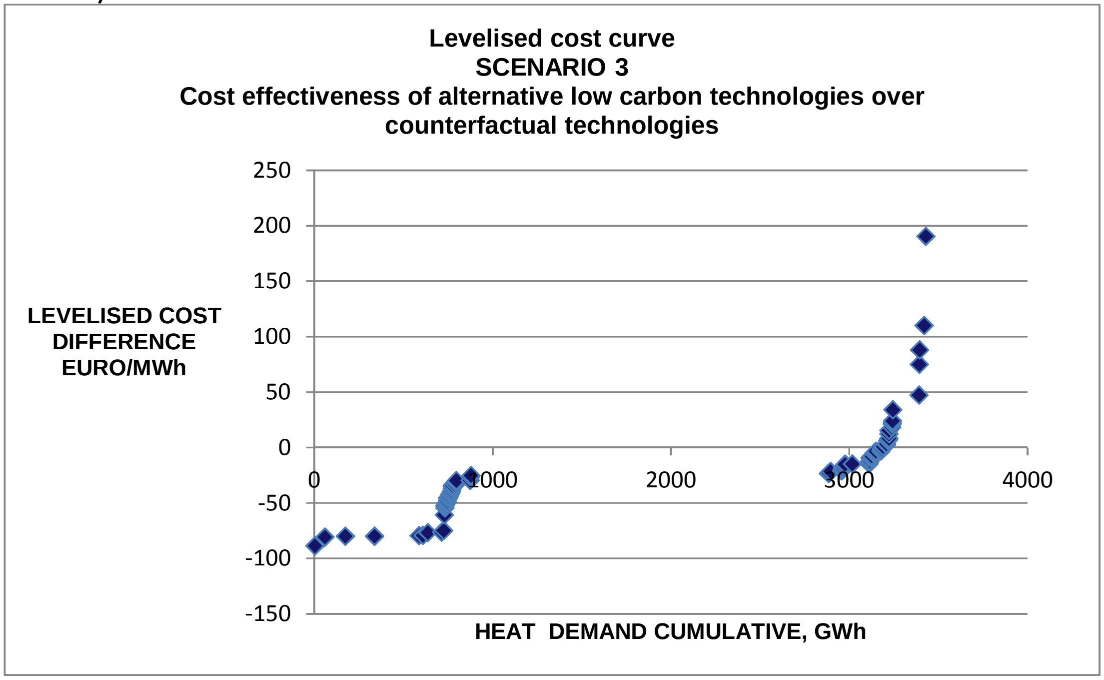
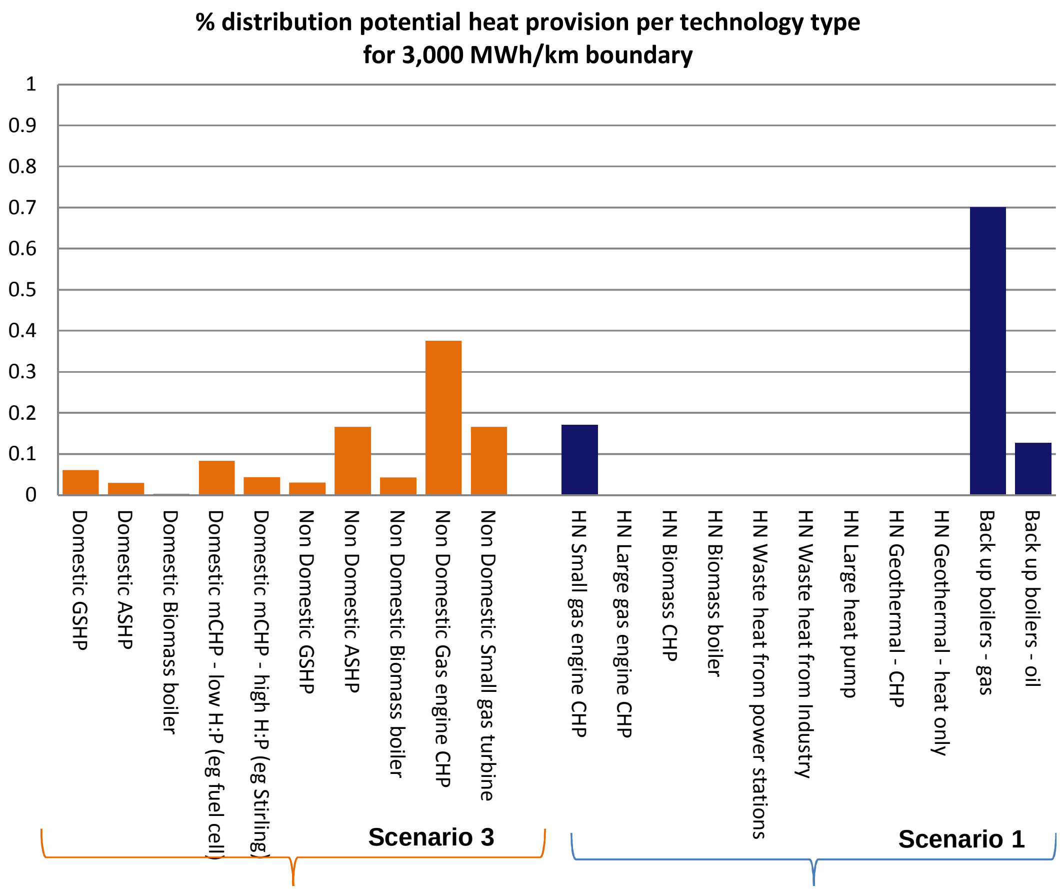


Figure 20 shows that a larger number of zones can be supplied cost effectively by alternative low carbon technologies over the counterfactual than by heat networks. There are a number of zones which show an economic benefit of around €80 / MWh, and then a reduction in benefit until the large Dublin zone is reached, which provides a benefit of around €20 / MWh.

The split in heat source for both heat networks and alternative low carbon technologies is shown in Figure 21 below which identifies the relative importance of different heat supply technologies. The results are presented as a % of heat provision from both technology types, and therefore do not indicate the absolute difference in heat supply between heat networks and alternative low carbon technologies. For heat networks, small scale gas CHP engines (a scale appropriate to building level installation) are shown as the only primary heat supply technology offering viable potential. This is likely to be due to the small heat demand of the zones identified as being economic, and the limitations on using larger technology options such as waste heat or large scale CHP. As a result of the heat demand of the zones, the majority of heat supply is from boiler plant. This suggests that efficient district heating schemes with boiler supply can still provide cost benefits in certain areas over the counterfactual.

Non domestic alternative low carbon technologies show a higher potential for supply of the heat demand than in the domestic sector, with Non Domestic Gas Engine CHP able to provide almost 40% of the total demand.

Figure 21: % distribution potential heat provision per technology type for the 3,000 MWh/km system boundary for cost effective alternative technologies (scenario 3) and heat networks (scenario 1) over counterfactual technologies



6.4.2 Assessment of 5,000 MWh / km system boundary

The identified heat demand for this system boundary is estimated to be in the region of 1,700 GWh with heat networks potentially able to supply around 53% (900 GWh). However, the results also indicate that heat networks have the potential to supply only 0.3% of the system boundary demand more economically than the counterfactual (5 GWh). This corresponds to a potential provision of 4% of national heat demand by heat networks; but only 0.02% of this is expected to be cost effective.

Table 16: Characteristics of the 5,000 MWh / km system boundary[54]

	Heat Demand GWh/year	% of national demand	% of boundary heat demand
National heat demand for the Republic of Ireland	23,000		
System boundary (5,000 MWh/km)	1,700	7%	
Heat Networks potential provision	900	4%	53%
Heat Networks potential cost effective provision[55]	5	0.02%	0.3%

The following results show the outputs from modelling the 5,000 MWh / km system boundary.

Table 17: Modelling results for the 5,000 MWh/km system boundary, showing results for levelised cost

Principal scenarios	Levelised Costs €/MWh			Max Levelised Costs Difference €/MWh
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€216		€182	-€34
Scenario 2	€199	€197	€157	-€40
Scenario 3	€134	€97		-€37

Table 17 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum benefit obtained would be €34/MWh (with counterfactual technologies able to provide a cost of €216/MWh compared to €182/MWh from heat networks). For scenario 2, for zones where the heat networks cost per MWh is lower compared to the counterfactual and alternative low carbon technologies, the maximum benefit obtained would be €40/MWh (comparing the €157/MWh from heat networks to the €197/MWh from alternative low carbon technologies as these offer lower levelised costs than counterfactual technologies). Scenario 3 identifies a potential maximum benefit of €37/MWh, with alternative low carbon technologies able to provide €97/MWh and counterfactual showing €134/MWh.

This results and very similar to those obtained for the 3,000 MWh/km boundary.

Table 18: Modelling results for the 5,000 MWh/km system boundary, showing results for Net Present Cost (NPC)

Principal scenarios	NPC € million			Max NPC Difference € million
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€13		€11	-€2
Scenario 2	€7	€7	€6	-€1
Scenario 3	€1,585	€1,135		-€450

Table 18 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum NPC benefit obtained would be €2 million (with counterfactual

[54] Figures are rounded except those for the heat networks potential cost effective provision, as they are too small in comparison and rounding would not show enough resolution
[55] Compared to counterfactual technologies

technologies showing an NPC of €13 million compared to €11 million from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, the maximum NPC benefit obtained would be €1 million (same as in the 3,000 MWh/km boundary). Scenario 3 identifies a potential maximum NPC benefit of €450 million, with alternative low carbon technologies able to provide about €1,100 million and counterfactual showing about €1,600 million.

Table 19: Modelling results for the 5,000 MWh/km system boundary, showing results for Annual heat demand

Principal scenarios	Annual Heat Demand GWh/year			Max Difference GWh/year
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	8		5	-3
Scenario 2	5	4	3	-1
Scenario 3	1,601	1,741		140

Table 19 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks would be able to provide 3 GWh/year less heat demand than counterfactual technologies (with counterfactual technologies showing a potential heat demand provision of 8 GWh/year compared to 5 GWh/year from heat networks). For scenario 2, for zones where the heat networks cost per MWh is lower compared to the counterfactual and alternative low carbon technologies, heat networks would be able to provide 1 GWh/year less heat demand than counterfactual technologies or alternative low carbon technologies. Again scenario 3 shows the highest difference with a potential maximum benefit of around 140 GWh/year higher heat demand provided by alternative low carbon technologies over the potential provision by the counterfactual (around 1,600GWh/year).

Table 20: Modelling results for the 5,000 MWh/km system boundary, showing results for Primary Energy

Principal scenarios	Primary Energy GWh			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	245		234	-4%
Scenario 2	132	85	129	52%
Scenario 3	41,503	31,777		-23%

Table 20 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks use 4% less primary energy (234 GWh) than the counterfactual technologies (245 GWh) over the period of the CBA (24 years). In scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks use 52% more primary energy (129 GWh) than alternative low carbon technologies (85 GWh), with counterfactual using even a higher amount (132 GWh). Scenario 3 identifies that alternative low carbon technologies use 23% less primary energy than counterfactual ones although the magnitude of use is almost 375 times higher than for scenario 2.

Table 21: Modelling results for the 5,000 MWh/km system boundary, showing results for CO_2

Principal scenarios	CO_2 kt			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	48		46	-4%
Scenario 2	24	16	24	50%
Scenario 3	7,707	5,640		-27%

Table 21 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks are able to offer potential CO_2 savings of 4% (emitting 94 kt of CO_2) over the period of the CBA (24 years). In scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks appear to emit 50% more CO2 (24 kt) than alternative low carbon technologies (16 kt). Scenario 3 identifies that alternative low carbon technologies potentially would emit 27% less CO_2 than counterfactual ones. Again the magnitude of emissions is much higher here (in the region of 350 times at over 5,000 kt) than for scenario 2.

Key observations from the results are:

- Heat networks are only cost effective for around 5 GWh/year (compared with counterfactual – scenario 1) or 3 GWh/year (compared with alternative low carbon technologies and counterfactual – scenario 2). This is less than 0.03% of national heat demand (Table 5) and could be viewed as negligible.
- Alternative low carbon technologies are cost effective (compared with the counterfactual – scenario 3) for around 1700 GWh per year, or approximately 7% of the national heat demand (Table 5). This corresponds to 37 of the 54 zones in this boundary.
- Heat networks could provide a maximum cost benefit of €2 million for economic schemes (compared with the counterfactual – scenario 1). The cost benefit of alternative low carboon technologies in scenario 3 is over 200 times this at €450 million (Table 17).
- Primary energy savings from heat networks in scenario 1 are around 4% for schemes which are economic, compared with 23% for alternative low carbon technologies. (Table 19) in scenario 3.
- CO_2 savings from heat networks at around 4% are lower in scenario 1 than for alternative low carbon technologies at around 27% (Table 20) in scenario 3.

Figure 22 shows the Heat Networks cost effective zones and the very small amount of heat demand they can supply. The gap to the zone around the 600 GWh corresponds to a zone in Dublin covering over 300 Small Areas with a very high heat demand. Figure 23 shows the higher number of zones able to be supplied cost effectively by alternative low carbon technologies over the counterfactual. A similar gap shown corresponds to the same Dublin zone as mentioned above.

Figure 22: Levelised cost difference for HN over Counterfactual versus cumulative heat demand for 5,000 MWh / km system boundary

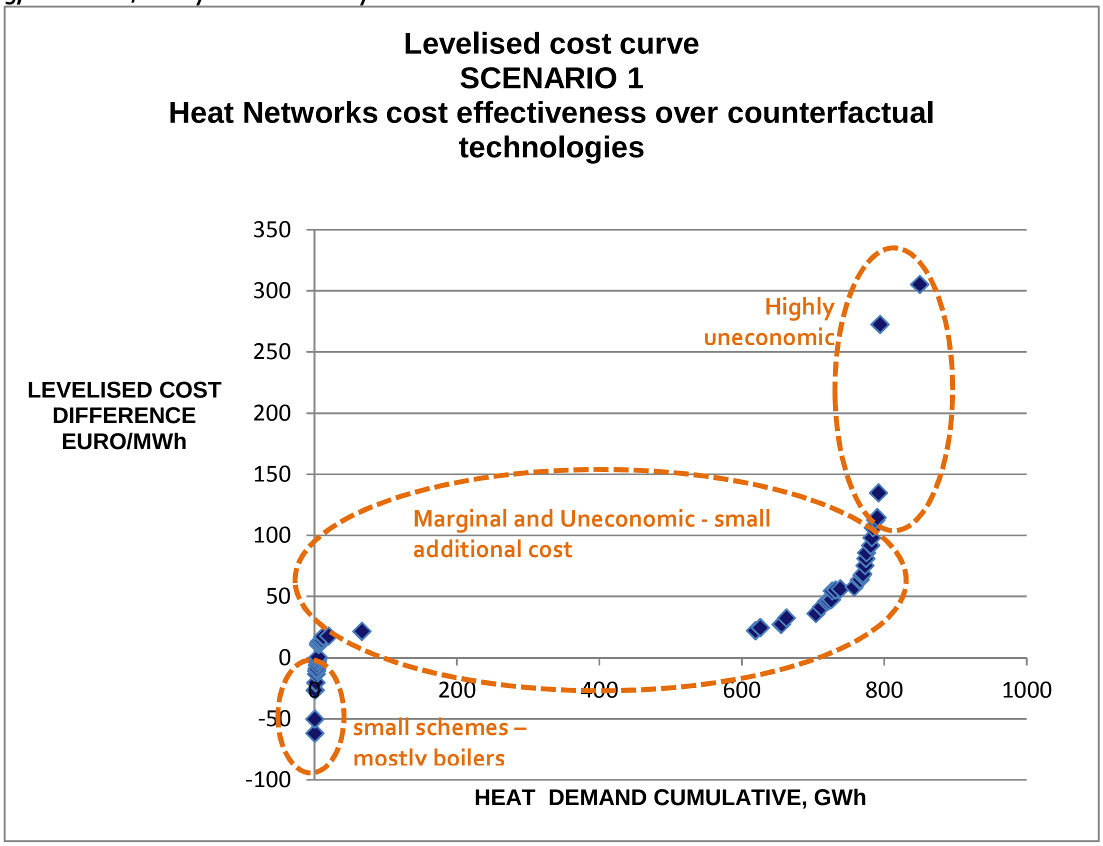
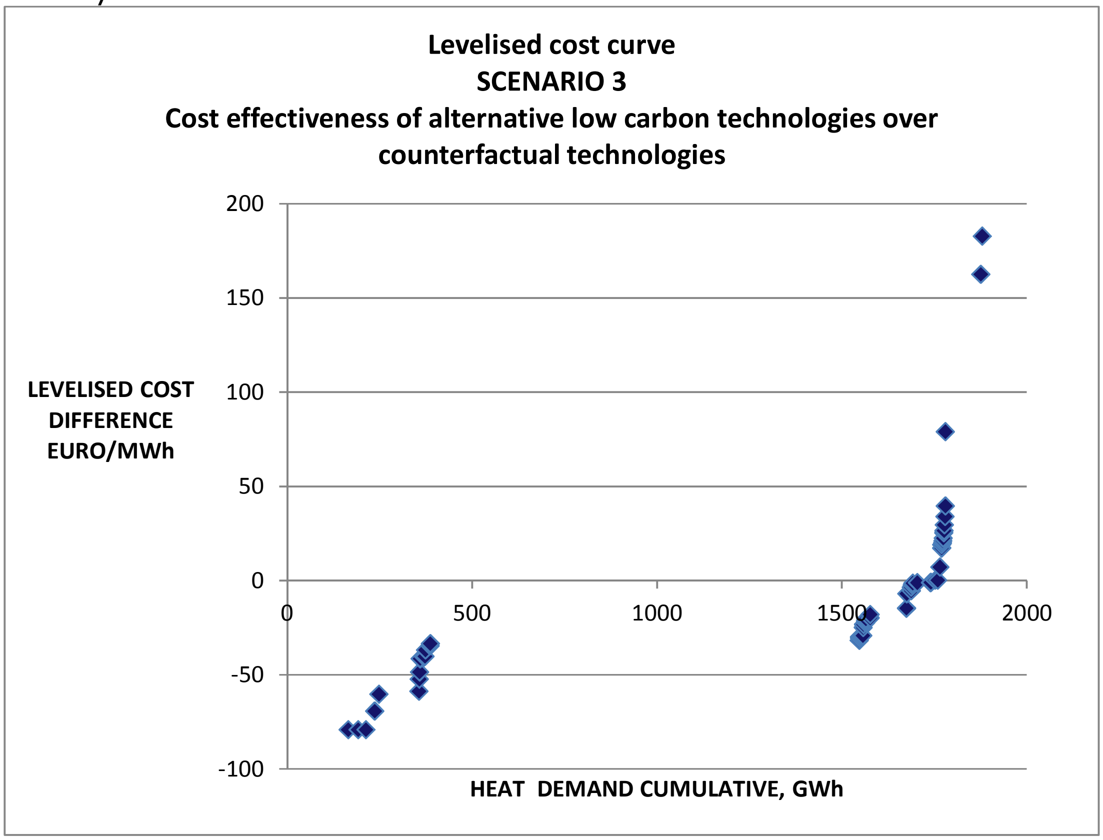
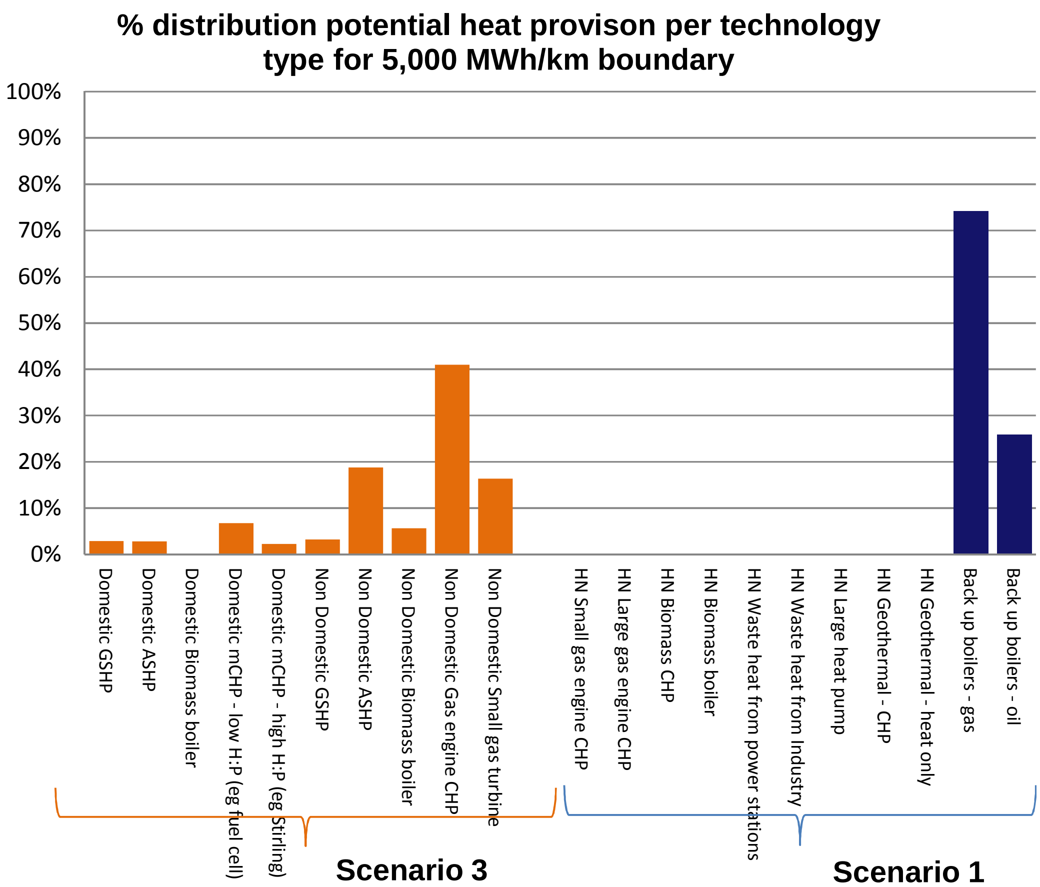


Figure 23: Levelised cost difference versus cumulative heat demand for scenario 3 – Alternative low carbon technologies cost effectiveness over counterfactual technologies, for 5000 MWh / km system boundary



For alternative low carbon technologies, non domestic technologies again show the highest potential for supply of the heat demand, with Non Domestic Gas Engine CHP able to provide 40% of the total. For heat networks, all of the schemes use boilers only. This is likely to be due to the small zone sizes identified as economic, and limitations on the capacity of primary technologies.

Figure 24: % distribution potential heat provision per technology type for the 5,000 MWh/km system boundary for cost effective alternative technologies (scenario 3) and heat networks (scenario 1) over counterfactual technologies



6.4.3 Assessment of 10,000 MWh / km system boundary

The identified heat demand for this system boundary is estimated to be in the region of 1,100 GWh, with heat networks potentially able to supply around 45% (500 GWh). The results indicate that heat networks have the potential to supply 27% of the system boundary demand cost effectively (300 GWh). This corresponds to a potential provision of 2% of national heat demand by heat networks; 1.3% cost effectively.

Table 22: Characteristics of the 10,000 MWh / km system boundary[56]

	Heat Demand GWh/year	% of national demand	% of boundary heat demand
National heat demand for the Republic of Ireland	23,000		
System boundary (5,000 MWh/km)	1,100	5%	
Heat Networks potential provision	500	2%	45%
Heat Networks potential cost effective provision[57]	300	1.3%	27%

The following results show the outputs from modelling the 10,000 MWh / km system boundary.

Table 23: Modelling results for the 10,000 MWh/km system boundary, showing results for levelised cost

Principal scenarios	Levelised Costs €/MWh			Max Levelised Costs Difference €/MWh
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€134		€125	-€9
Scenario 2	€204	€194	€136	-€58
Scenario 3	€130	€88		-€42

Table 23 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum benefit obtained would be €9/MWh (with counterfactual technologies able to provide a cost of €134/MWh compared to €125/MWh from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, the maximum benefit obtained would be €58/MWh (comparing the €136/MWh from heat networks to the €194/MWh from alternative low carbon technologies as these offer lower levelised costs than counterfactual technologies). Scenario 3 identifies a potential maximum benefit of €42/MWh, with alternative low carbon technologies able to provide €88/MWh and counterfactual showing €130/MWh.

[56] Figures are rounded except those for the heat networks potential cost effective provision, as they are too small in comparison and rounding would not show enough resolution
[57] Compared to counterfactual technologies

Table 24: Modelling results for the 10,000 MWh/km system boundary, showing results for Net Present Cost (NPC)

Principal scenarios	NPC € million			Max NPC Difference € million
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	€502		€468	-€34
Scenario 2	€8	€8	€6	-€2
Scenario 3	€1,009	€679		-€330

Table 24 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), the maximum NPC benefit obtained would be €34 million (with counterfactual technologies showing an NPC of €502 million compared to €468 million from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, the maximum NPC benefit obtained would be €2 million. Scenario 3 identifies a potential maximum NPC benefit of €330 million, with alternative low carbon technologies able to provide €679 million and counterfactual showing about €1,000 million.

Table 25: Modelling results for the 10,000 MWh/km system boundary, showing results for Annual heat demand

Principal scenarios	Annual Heat Demand GWh/year			Max Difference GWh/year
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	510		301	-209
Scenario 2	5	4	4	0
Scenario 3	1,056	1,141		85

Table 25 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks would be able to provide over 200 GWh/year less heat demand than counterfactual technologies (with counterfactual technologies showing a potential heat demand provision of 510 GWh/year compared to about 300 GWh/year from heat networks). For scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, no benefit has been identified. Scenario 3 shows a potential maximum benefit of around 85 GWh/year higher heat demand provided by alternative low carbon technologies over the potential provision by the counterfactual (around 1,000GWh/year).

Table 26: Modelling results for the 10,000 MWh/km system boundary, showing results for Primary Energy

Principal scenarios	Primary Energy GWh			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	13,785		11,393	-17%
Scenario 2	152	99	147	48%
Scenario 3	26,748	21,751		-19%

Table 26 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks use 17% less primary energy (11,393 GWh) than the counterfactual technologies (13,785 GWh) over the period of the CBA (24 years). In scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks use 48% more primary energy (147 GWh) than alternative low carbon technologies (99 GWh), with counterfactual using even a higher amount (152 GWh). Scenario 3 identifies that alternative low carbon technologies use 19% less primary energy than counterfactual ones although the magnitude of use is over 200 times higher than for scenario 2.

Table 27: Modelling results for the 10,000 MWh/km system boundary, showing results for CO_2

Principal scenarios	CO_2 kt			Max Difference %
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Scenario 1	2,553		2,097	-18%
Scenario 2	30	18	28	56%
Scenario 3	4,966	3,710		-25%

Table 27 shows that, in zones where the cost per MWh is lower for heat networks compared to the counterfactual (scenario 1), heat networks are able to offer potential CO_2 savings of 18% (emitting about 2,100 kt of CO_2) over the period of the CBA (24 years). In scenario 2, for zones where the cost per MWh is lower for heat networks compared to the counterfactual and alternative low carbon technologies, heat networks appear to emit 56% more CO2 (28 kt) than alternative low carbon technologies (18 kt). Scenario 3 identifies that alternative low carbon technologies potentially would emit 25% less CO_2 than counterfactual ones. Again the magnitude of emissions is much higher here (in the region of 200 times) than for scenario 2.

For information, Table 28 provides a breakdown of costs and heat provision for the base cases (counterfactual, alternative low carbon technologies and heat networks) and the prinicpal scenarios.

Table 28: Modelling results for the 10,000 MWh/km system boundary, showing results for CO_2

Base Cases	Counterfactual	Alternative low carbon technologies	Heat Networks
Capital cost (€ million)	€62,373	€291,649	€463,073
Operation cost (€ million)	€26,967	€120,682	€91,895
Energy costs (€ million)	€801,226	€190,244	€695,619
Emissions costs (€ million)	€102,050	€79,416	€99,623
Environmental costs (€million)	€59,349	€48,613	€61,113
Total costs (€ million)	€1,051,966	€730,605	€1,411,324
Heat provision (GWh/year)	1,102	1,235	520

Scenario 1	Counterfactual	Alternative low carbon technologies	Heat Networks
Capital cost (€ million)	€39,959		€100,529
Operation cost (€ million)	€13,055		€17,528
Energy costs (€ million)	€365,885		€278,624
Emissions costs (€ million)	€50,425		€41,408
Environmental costs (€million)	€32,212		€29,878
Total costs (€ million)	€501,537		€467,967
Heat provision (GWh/year)	510		301
Scenario 2	**Counterfactual**	**Alternative low carbon technologies**	**Heat Networks**
Capital cost (€ million)	€1,035	€3,699	€979
Operation cost (€ million)	€557	€803	€202
Energy costs (€ million)	€5,254	€2,896	€3,692
Emissions costs (€ million)	€591	€355	€561
Environmental costs (€million)	€345	€269	€297
Total costs (€ million)	€7,783	€8,022	€5,731
Heat provision (GWh/year)	5	4	4
Scenario 3	**Counterfactual**	**Alternative low carbon technologies**	**Heat Networks**
Capital cost (€ million)	€59,188	€269,975	
Operation cost (€ million)	€24,746	€112,266	
Energy costs (€ million)	€769,704	€178,131	
Emissions costs (€ million)	€98,076	€73,273	
Environmental costs (€million)	€57,298	€45,147	
Total costs (€ million)	€1,009,012	€678,792	
Heat provision (GWh/year)	1,056	1,141	

Key observations from the results are:

- Heat networks are only cost effective for around 300 GWh/year (compared with counterfactual – scenario 1) or 4 GWh/year (compared with alternative low carbon technologies and counterfactual – scenario 2). This is a range of approximately 0.02% to 1% of national heat demand (Table 21).
- Alternative low carbon technologies are cost effective (compared with the counterfactual – scenario 3) for around 1,140 GWh per year, or approximately 5% of the national heat demand (Table 24). This corresponds to 27 of the 35 zones in this boundary.
- Heat networks could provide a maximum cost benefit of €34 million for economic schemes (compared with the counterfactual – scenario 1). The cost benefit of alternative low carbon technologies in scenario 3 is almost 10 times this at €330 million (Table 23).
- Primary energy savings from heat networks in scenario 1 and alternative low carbon technologies in scenario 3 are similar at around 17% - 19% for schemes which are economic (Table 25).
- CO_2 savings from heat networks at around 18% (in scenario 1) are slightly lower than for alternative low carbon technologies at around 25% (Table 26) in scenario 3.

Figure 25 shows the 10,000 MWh/km boundary zones and the amount of heat demand they can supply. The gap to the zone providing around 300 GWh corresponds to a cost effective zone in Dublin (identified as zone 12 in the modelling) covering over 140 Small Areas which itself would be able to cost effectively supply such an amount of heat demand. Figure 26 shows the higher number of zones able to be supplied cost effectively by alternative low carbon technologies over the counterfactual. A similar gap shown corresponds to the same Dublin zone as mentioned above.

Figure 25: Levelised cost difference versus cumulative heat demand for scenario 1 – Heat Networks cost effectiveness over counterfactual technologies, for 10000 MWh / km system boundary

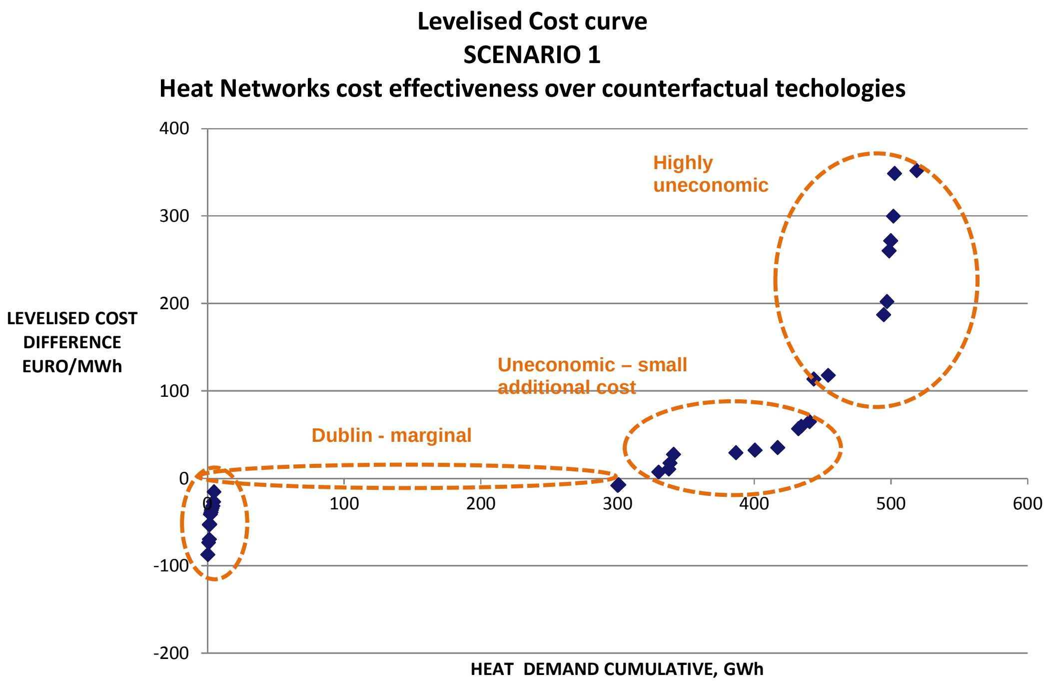
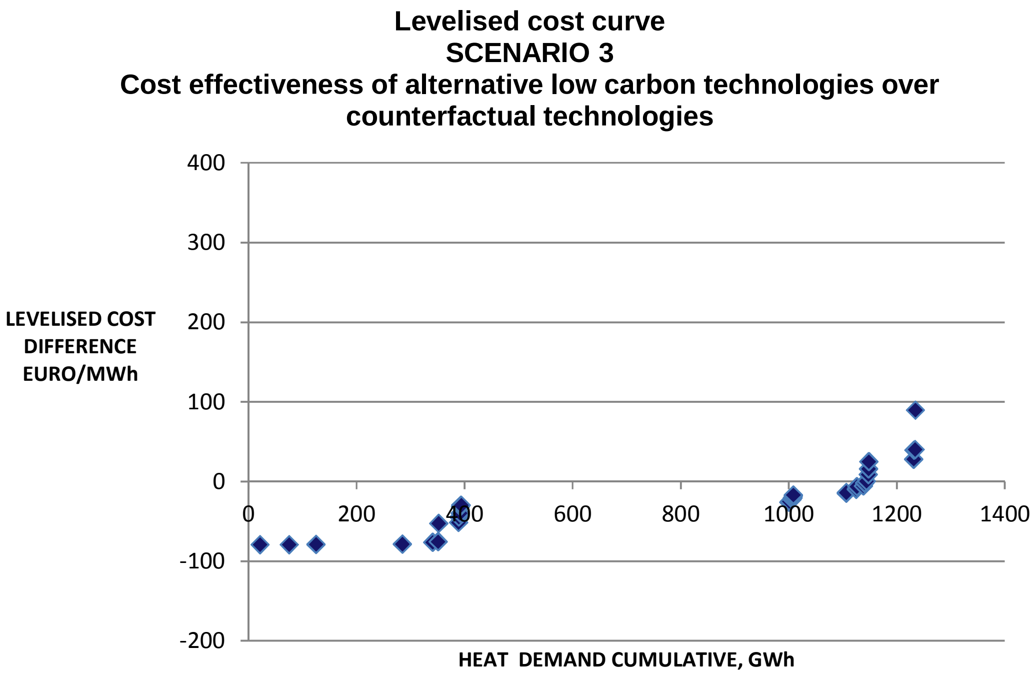


Figure 26: Levelised cost difference for Alternative low carbon technologies over Counterfactual versus cumulative heat demand for 10,000 MWh / km system boundary



Zone 12 identified by its very high heat provision potential cost effectively has the following characteristics:

Table 29: Characteristics of Zone 12 in Dublin (at 10,000 MWh/km boundary)-1

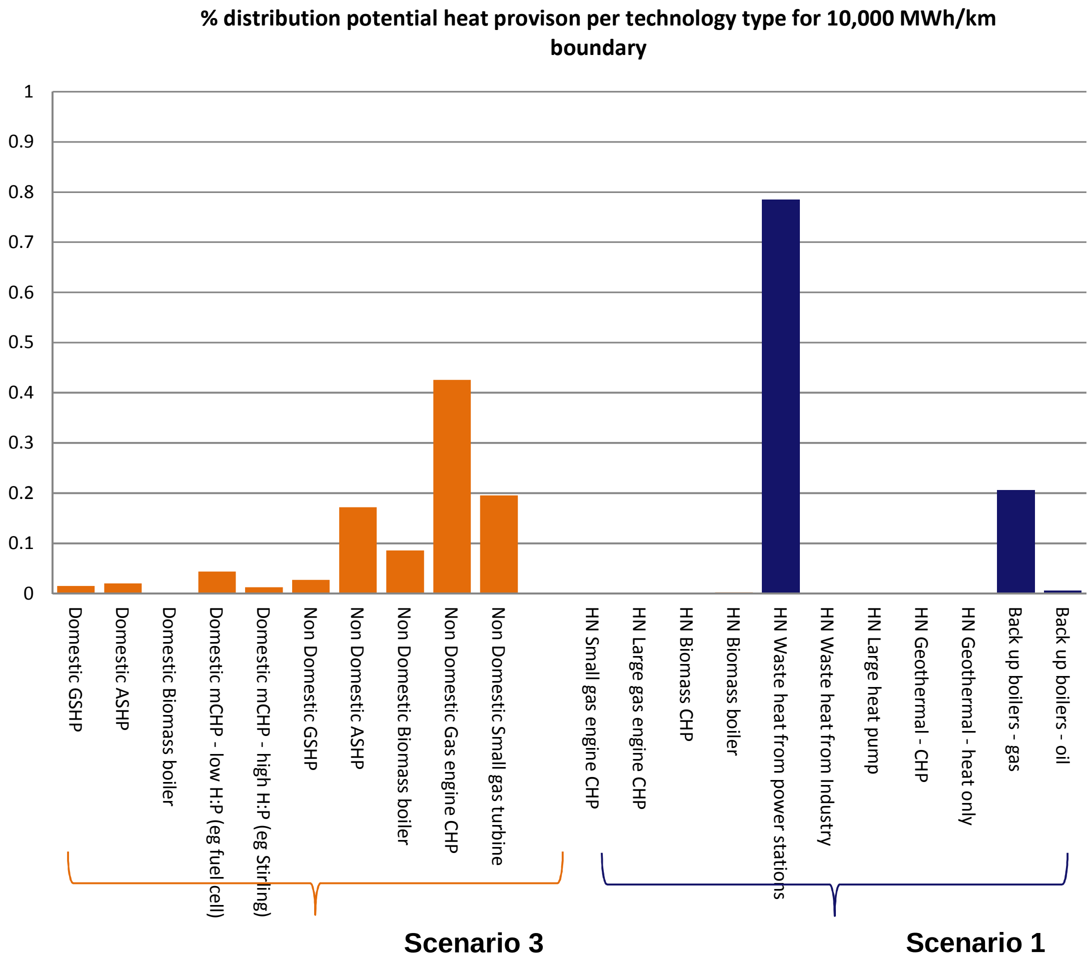
	Counterfactual	Alternative Low Carbon Technologies	Heat Networks
Capital cost (€ million)	€39	€178	€99
Operation cost (€ million)	€12	€63	€17
Energy costs (€ million)	€357	€90	€272
Emissions costs (€ million)	€49	€39	€41
Environmental costs (€million)	€32	€23	€29
Total costs (€ million)	€489	€393	€458
Levelised cost (€/MWh)	€132	€106	€124
Heat provision (GWh/year)	502	606	295

Table 30: Characteristics of Zone 12 in Dublin (at 10,000 MWh/km boundary)-2

ZONE 12		Forecast 2025 Heat Demand MWh/year	N. dwellings
Domestic	Flat	63,619	11,344
	Terraced	10,855	1,302
	Semi Detached	13,156	1,179
	Detached	3,085	229
	Total	90,715	14,054
Commercial	Healthcare	16,940	
	Hospitality	147,703	
	Leisure	20,000	
	Office	80,958	
	Retail	35,963	
	Warehouse	2,395	
	Education	220	
	Other	1,201	
	Total	305,380	
Public sector	Education	67,967	
	Healthcare	27,926	
	Office	19,151	
	Retail	0	
	Restaurant/public house	302	
	Warehouse and storage	0	
	Total	115,346	
Industrial	VO-Low temp	2,273	

For alternative low carbon technologies, non domestic options again provide the highest potential for supply of the heat demand, with Non Domestic Gas Engine CHP able to provide 40% of the total. For heat networks, large waste heat from power stations (in the large Dublin zone) is predominant, with top-up from boilers.

Figure 27: % distribution potential heat provision per technology type for the 10,000 MWh/km system boundary for cost effective alternative technologies (scenario 3) and heat networks (scenario 1) over counterfactual technologies



6.4.4 Summary of system boundary assessment

- Heat Networks are shown to offer very little potential to cost effectively supply the heat demand except at the 10,000 MWh/km system boundary.
- Alternative low carbon technologies appear to offer the best cost effective potential, with non domestic technology types showing the highest level of potential provision.
- Based on the analysis of the principal scenarios and three system boundaries, the 10,000 MWh / km system boundary has been selected for further analysis of the technology scenarios and sensitivities (see section 7). This is because this is the only system boundary which demonstrates a level of economic uptake for heat networks which may be considered strategic and of importance.

6.5 Technology scenario assessment

The following tables show the results for each of the technology scenarios for levelised costs (Table 31), Net Present Costs (Table 32), and GWh/year heat provision (Table 33). The levelised cost curves for each scenario are shown in Figure 28.

Table 31: Levelised costs for each technology scenario (10,000 MWh/km)

Technology scenarios	Principal scenarios	Levelised Costs €/MWh			Max Levelised Costs Difference €/MWh
		Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Current gas penetration	Scenario 1	€134		€125	-€9
	Scenario 2	€204	€194	€136	-€58
	Scenario 3	€130	€88		-€42
Gas available in all areas	Scenario 1	€132		€123	-€9
	Scenario 2	€211	€186	€134	-€52
	Scenario 3	€130	€82		-€48
Waste heat only for DHN	Scenario 1	€134		€124	-€10
	Scenario 2	€197	€184	€131	-€53
	Scenario 3	€130	€88		-€42
No waste heat for DHN	Scenario 1	€212		€161	-€51
	Scenario 2	€204	€194	€136	-€58
	Scenario 3	€130	€88		-€42
DHN limited to CHP (no power stations)	Scenario 1	€206		€152	-€54
	Scenario 2	€197	€184	€131	-€53
	Scenario 3	€130	€88		-€42

The levelised costs of heat networks are €123 - €124 / MWh for economic schemes in scenario 1 where waste heat is available (gas available in all areas and waste heat only for DHN), and increases to €152 - €161 / MWh when waste heat is not available (no waste heat for DHN and DHN limited to CHP). However the cost differential benefit (the reduction in heat network levelised cost over the counterfactual levelised cost) in schemes where waste heat is available is low at around €9-€10/ MWh, whilst it is much higher at over €50 / MWh where waste heat is not used. This highlights that the waste heat schemes offer smaller economic benefits on a levelised cost basis.

The corresponding cost benefits of heat networks (see Table 32) are around €34 million (compared with the counterfactual – scenario 1) increasing to around €42 million when gas is available for all schemes assuming a roll out of the gas network to all urban areas (it should be noted that the costs of gas network rollout are not included in the CBA, partially due to complexity, and partially as the investment is likely to be largely made on the basis of distributing gas to customers not on the heat network). Where waste heat is not available, the cost benefit reduces to €3 million. In comparison, the alternative low carbon technologies provide a cost benefit or around €330 million (scenario 3).

Table 32: NPC for each technology scenario (10,000 MWh/km)

Technology scenarios	Principal scenarios	NPC € million			Max NPC Difference € million
		Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Current gas penetration	Scenario 1	€502		€468	-€34
	Scenario 2	€8	€8	€6	-€2
	Scenario 3	€1,009	€679		-€330
Gas available in all areas	Scenario 1	€607		€565	-€42
	Scenario 2	€11	€10	€7	-€3
	Scenario 3	€1,009	€621		-€388
Waste heat only for DHN	Scenario 1	€503		€469	-€34
	Scenario 2	€9	€9	€7	-€2
	Scenario 3	€1,009	€679		-€330
No waste heat for DHN	Scenario 1	€13		€10	-€3
	Scenario 2	€8	€8	€6	-€2
	Scenario 3	€1,009	€679		-€330
DHN limited to CHP (no power stations)	Scenario 1	€14		€11	-€3
	Scenario 2	€9	€9	€7	-€2
	Scenario 3	€1,009	€679		-€330

When heat networks are compared with the counterfactual (Table 33) in scenario 1 the results show that the heat provision potential is slightly increased (from 301 GWh/yr to 330 GWh/yr) if gas is available in all areas. This remains almost the same when the heat source is limited to waste heat (either power station or industry). However once the availability of waste heat is removed, the potential is significantly reduced to around 6 – 7 GWh/yr. In all technology scenarios, the use of alternative low carbon heat sources (scenario 3) has a much larger potential.

Table 33: GWh heat provision for each technology scenario (10,000 MWh/km)

Technology scenarios	Principal scenarios	Annual Heat Demand GWh/year			Max Difference GWh/year
		Counterfactual	Alternative Low Carbon Technologies	Heat Networks	
Current gas penetration	Scenario 1	510		301	-209
	Scenario 2	5	4	4	0
	Scenario 3	1,056	1,141		85
Gas available in all areas	Scenario 1	625		330	-295
	Scenario 2	7	7	5	-2
	Scenario 3	1,056	1,159		103
Waste heat only for DHN	Scenario 1	511		302	-209
	Scenario 2	6	6	4	-2
	Scenario 3	1,056	1,141		85
No waste heat for DHN	Scenario 1	8		6	-2
	Scenario 2	5	4	4	0
	Scenario 3	1,056	1,141		85
DHN limited to CHP (no power stations)	Scenario 1	9		7	-2
	Scenario 2	6	6	4	-2
	Scenario 3	1,056	1,141		85

Figure 28: Levelised cost curves for each technology scenario.

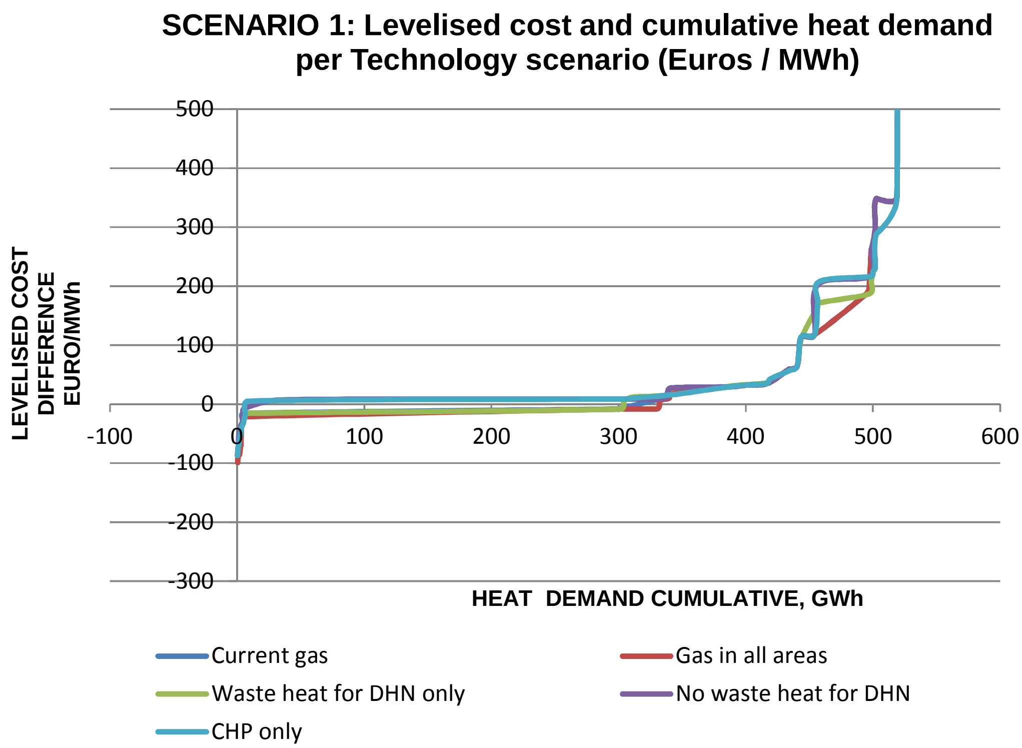
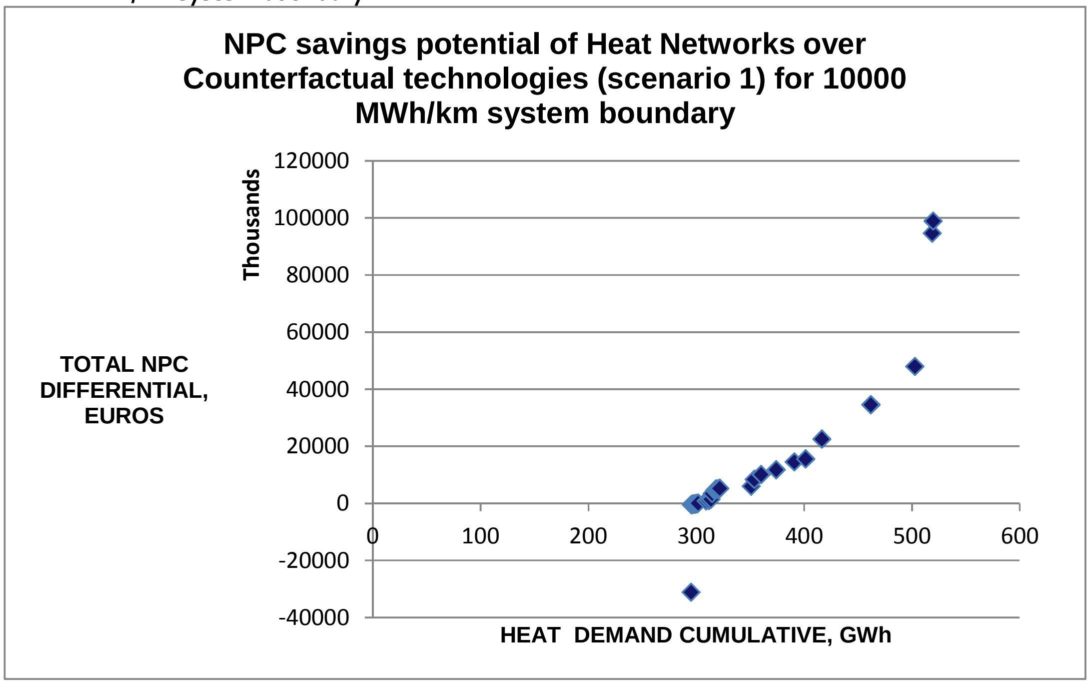


Figure 28 provides the levelised cost curves for each of the technology scenarios. The impact of removing waste heat sources on the large Dublin zone is demonstrated by moving from a negative cost difference to a positive cost difference although it is clear that this difference is marginal. For the uneconomic zones, the technology scenarios change the levelised cost difference, but not significantly.

6.6 Cost effective potential of heat networks

15 zones were identified where heat networks have the potential to be supplied cost effectively with savings of around €33 million overall. The analysis shown in Figure 29 identifies that up to 25 zones offer potential to deliver about 350 GWh on a cost neutral basis (with the non-cost effective zones being effectively funded by the cost savings obtained in the cost effective ones). The overall economic potential is limited, since the largest economic zone in Dublin provides a relatively small cost benefit and could be considered marginal.

Figure 29: NPC savings potential of Heat Networks over Counterfactual technologies (scenario 1) for 10000 MWh/km system boundary



6.7 Summary

This section identifies the most appropriate system boundaries and the subsequent cost effective potential for heat networks and alternative low carbon technologies.

The analysis of linear heat density demonstrates that 10% – 20% of Ireland's heat demand lies in areas which are relatively high in density. These are likely to be town centres and cities. The system boundaries selected therefore assess different levels of heat density in these areas corresponding to approximately 10% (3000 MWh / km), 6% (5000 MWh / km) and 3% (10,000 MWh / km) of the national heat demand. The zones identified for each system boundary are mostly based in Dublin, but also include areas of other towns and cities. As the threshold is increased, the number of zones reduces and they concentrate further on Dublin due to Dublin having some of the higher density areas.

The cost benefit analysis conducted for each principle scenario demonstrates that for the 3,000 MWh / km and 5,000 MWh / km boundaries, the potential for cost effective district heating is negligible at around 0.04% of the national demand or less. Many of the zones demonstrate cost effective potential for alternative low carbon technologies relative to the counterfactual. As the threshold is increased to 10,000 MWh / km, there is a large increase in heat demand which is cost effective for heat networks, largely due to the inclusion of a large zone in Dublin. The system boundary covers around 5% of the national demand, of which less than half is identified as technically suitable for connection to heat networks, and half of that as cost effective (1% of the national heat demand). The 10,000 MWh / km system boundary is therefore selected for subsequent analysis.

Analysis of the different technology scenarios for the 10,000 MWh / km system boundary indicates that the use of waste heat is likely to be an important component to meeting the cost effective potential, with the potential dropping from circa 300 GWh per year to around 6 GWh per year with the removal of waste heat. However the cost benefit with waste heat is relatively small due to the levelised cost being only slightly less than the counterfactual. The additional cost associated with removing the availability of waste heat results in a levelised cost only slightly higher than the counterfactual, and therefore the Dublin zone could be considered marginal.

In summary, the results demonstrate that the economic potential for heat networks in Ireland is small, limited to high linear heat density areas of over 10,000 MWh / km, and most economic with waste heat for large schemes, but only marginally uneconomic with other heat sources.

7. SENSITIVITY ANALYSIS

7.1 Sensitivity Analysis

A sensitivity analysis was carried out to quantify the impact associated with variation in some key assumptions.

The following variables examined in the sensitivity analysis:

- discount rate;
- level of heat uptake;
- absence of shadow prices;
- varying energy prices[58],[59] ; and
- costs (capital and O&M).

All of the results presented here are based on the 10,000 MWh / km system boundary with all technologies being available and for the principal scenario covering current gas penetration.

In the following tables, the following definitions are used:

- **Economic heat demand**: this is the change in heat demand benefit obtained when applying the different sensitivities between heat networks over counterfactual; heat networks over alternative low carbon technologies and counterfactual; and alternative low carbon technologies over counterfactual.
- **NPV (Net Present Value):** this is the change in NPC benefit obtained when applying the different sensitivities between heat networks over counterfactual; heat networks over alternative low carbon technologies and counterfactual; and alternative low carbon technologies over counterfactual.

7.2 Discount rate

The central assumptions are based on a social discount rate of 5%. As a sensitivity, the following discount rates are modelled to represent a more commercial perspective on future value:

- 7.5%
- 10%

Tables 34 and 35 show the effect of these alternative values on the cost effective provision of heat and the net present value respectively.

[58] Using low and high scenarios from the DECC Fossil Fuel Projections, July 2013, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/212521/130718_decc-fossil-fuel-price-projections.pdf

[59] Reference scenario from the EU Energy, Transport and GHG Emissions, Trends to 2050 (EU Commission), Dec 2013, available at http://www.eea.europa.eu/data-and-maps/indicators/transport-final-energy-consumption-by-mode/energy-transport-and-ghg-emissions

Table 34 - Impact of different levels of discount rate on cost effective provision of heat

Sensitivities	Principal scenarios	Cost effective provision of heat GWh/year		Effect of sensitivity	
		Alternative Low Carbon Technologies	Heat Networks	Change in heat provision GWh/year	%
Current gas penetration (5% discount rate)	Scenario 1		301		
	Scenario 2		4		
	Scenario 3	1,141			
7.5% discount rate	Scenario 1		34	-267	-89%
	Scenario 2		4	0	0%
	Scenario 3	1,219		78	7%
10% discount rate	Scenario 1		34	-267	-89%
	Scenario 2		5	1	25%
	Scenario 3	1,185		44	4%

Table 35: Impact of different levels of discount rate on Net Present Value

Sensitivities	Principal scenarios	NPV (€ million)	Effect of sensitivity	
		Benefit over counterfactual	Change in benefit (€ million)	%
Current gas penetration (5% discount rate)	Scenario 1	-€34		
	Scenario 2	-€2		
	Scenario 3	-€330		
7.5% discount rate	Scenario 1	-€4	30	-88%
	Scenario 2	-€1	1	-50%
	Scenario 3	-€339	-9	3%
10% discount rate	Scenario 1	-€9	25	-74%
	Scenario 2	-€1	1	-50%
	Scenario 3	-€357	-27	8%

The sensitivity analysis to assess the impact of the discount rate used (5%) on the economically viable zones shows that:

- For scenario 1, the amount of cost effective heat provision by heat networks (about 300 GWh supply potential) would diminish substantially to about 34 GWh. The cost benefit potential of heat networks would also decrease from an estimated saving of €34 million to €4 million savings (7.5% discount rate) and €9 million savings (10% discount rate). These figures represent a decreased in the region of 89% for heat demand provision, with 88% decrease in NPC savings at a 7.5% discount rate and 74% of the NPC benefit at a 10% discount rate.
- For scenario 2, the amount of cost effective heat provision by heat networks (about 4 GWh supply potential) would increase marginally (in the region of 1 GWh) for a 10% discount factor but the cost benefit potential of heat networks would decrease from an estimated saving of €2 million to €1 million savings under the different discount rates.
- For scenario 3, the amount of cost effective heat provision by alternative low carbon technologies (about 1,141 GWh supply potential) would increase by 7% and 4% respectively for a discount rate of 7.5% and 10%. The NPC benefit shows an increase of 3% and 8%.

Whilst scenario 1 appears to show a higher negative sensitivity to discount factors, scenario 2 indicates an identified small increase in the benefit potential.

These results demonstrate that the deployment of economic heat networks will be heavily dependent on the ability to access low cost finance, and therefore may be reliant on public sector involvement in finance and delivery.

7.3 Heat uptake

The central assumptions are based on a heat uptake of 80%. This means that the majority of eligible customers in an area connect to the heat network over the uptake period. If fewer customers connect, the revenues are reduced which can have an adverse impact on viability. On the other hand, if all customers connect, the increased revenue should improve viability. The following sensitivities are assessed and results shown in Tables 36 and 37:

- 50% uptake
- 100% uptake

Table 36 - Impact of different levels of heat uptake rate over principal scenario

Sensitivities	Principal scenarios	Cost effective provision of heat GWh/year		Effect of sensitivity	
		Alternative Low Carbon Technologies	Heat Networks	Change in heat provision GWh/year	%
Current gas penetration (80% heat uptake rate)	Scenario 1		301		
	Scenario 2		4		
	Scenario 3	1,141			
50% heat uptake	Scenario 1		4	-297	-99%
	Scenario 2		4	0	0%
	Scenario 3	1,102		-39	-3%
100% heat uptake	Scenario 1		368	67	22%
	Scenario 2		4	0	0%
	Scenario 3	1,161		20	2%

Table 37: Impact of different levels of heat uptake rate on Net Present Value

Sensitivities	Principal scenarios	NPV (€ million)	Effect of sensitivity	
		Benefit over counterfactual	Change in benefit (€ million)	%
Current gas penetration (80% heat uptake rate)	Scenario 1	-€34		
	Scenario 2	-€2		
	Scenario 3	-€330		
50% heat uptake	Scenario 1	-€2	32	-94%
	Scenario 2	-€2	0	0%
	Scenario 3	-€294	36	-11%
100% heat uptake	Scenario 1	-€60	-26	76%
	Scenario 2	-€2	0	0%
	Scenario 3	-€345	-15	5%

The sensitivity analysis to assess the impact of the heat uptake rate used (80%) on the economically viable zones shows that:

- For scenario 1, the amount of cost effective heat provision by heat networks (about 300 GWh supply potential) would diminish substantially (to about 4 GWh) for an uptake rate of 50%. The cost benefit potential of heat networks would also decrease from an estimated saving of €34 million to €2 million savings. These figures represent a decrease in the benefit of heat networks over counterfactual in the region of 99% heat provision and 94% for NPC savings, and demonstrate the importance of achieving a good level of customer uptake. For an increase on the heat uptake rate to 100%, the results show improvements on the amount of heat provision of 22% and increased NPC savings of 76%.
- For the scenario 2, the amount of cost effective heat provision by heat networks would not change significantly. This is believed to be due to the very small potential identified in the first place.
- For scenario 3, the amount of cost effective heat provision by alternative low carbon technologies (about 1,141 GWh supply potential) would decrease by 3% for a heat uptake rate of 50%, whilst the NPC benefit also would diminished by 11%. For an increase on the heat uptake rate to 100%, the results show improvements of 2% for heat provision potential and 5% increased NPC savings.

Heat networks appear to be highly sensitive to the customer penetration, and it will be important for schemes to obtain customer buy-in at the earliest stage, combined with offering customers a competitive price for heat to maintain connection.

7.4 Absence of shadow prices and environmental costs

The following sensitivities are assessed and results shown in Tables 38 and 39:

- Removal of shadow price of public funds
- Increase of carbon costs and full removal of carbon costs
- Removal of environmental costs

Table 38 - Impact of shadow pricing and environmental costs on cost effective provision of heat

Sensitivities	Principal scenarios	Cost effective provision of heat GWh/year		Effect of sensitivity	
		Alternative Low Carbon Technologies	Heat Networks	Change in heat provision GWh/year	%
Current gas penetration	Scenario 1		301		
	Scenario 2		4		
	Scenario 3	1,141			
Removal of shadow price	Scenario 1		301	0	0%
	Scenario 2		4	0	0%
	Scenario 3	1,141		0	0%
Removal of cost of carbon	Scenario 1		300	-1	0%
	Scenario 2		4	0	0%
	Scenario 3	1,137		-4	0%
Double cost of carbon	Scenario 1		301	0	0%
	Scenario 2		4	0	0%
	Scenario 3	1,144		3	0.3%
Removal of env. cost	Scenario 1		301	0	0%
	Scenario 2		4	0	0%
	Scenario 3	1,138		-3	-0.3%

Table 39: Impact of different levels of shadow pricing and environmental costs on Net Present Value

Sensitivities	Principal scenarios	NPV (€ million)	Effect of sensitivity	
		Benefit over counterfactual	Change in benefit (€ million)	%
Current gas penetration	Scenario 1	-€34		
	Scenario 2	-€2		
	Scenario 3	-€330		
Removal of shadow price	Scenario 1	-€49	-15	44%
	Scenario 2	-€2	0	0%
	Scenario 3	-€330	0	0%
Removal of cost of carbon	Scenario 1	-€25	9	-26%
	Scenario 2	-€2	0	0%
	Scenario 3	-€305	25	-8%
Double cost of carbon	Scenario 1	-€43	-9	26%
	Scenario 2	-€2	0	0%
	Scenario 3	-€355	-25	8%
Removal of env. cost	Scenario 4	-€31	3	-9%
	Scenario 5	-€2	0	0%
	Scenario 6	-€318	12	-4%

The removal of shadow price of public funds on network costs indicates that this would have the highest positive effect on the NPC benefit obtained from heat networks over counterfactual (scenario 1), with little impact on scenarios 2 and 3. The shadow price reflects the additional cost to the economy of developing heat networks with public sector funding. However, the removal of shadow price (implying a more commercial led approach with commercial funding), may incur other changes such as discount rate, which could cancel out the benefit.

An increase doubling the cost of carbon would increase the NPC savings of heat networks in scenario 1 by around 26% and by 8% for alternative low carbon technologies in scenario 3.

The removal of environmental costs shows a negative effect on heat networks in scenario 1 with a decrease of 9% on NPC savings and of 4% for alternative low carbon technologies in scenario 3.

7.5 Varying energy prices

The energy cost has an impact on both the cost of energy used to provide heat, and revenues from additional energy generation (CHP electricity). Changes in energy costs also have a varying level of impact on the counterfactual vs alternative or heat network technologies, depending on the relative efficiencies. Results for the following sensitivities to energy prices (applied to all fuels and energy sources) are shown in tables 40 and 41:

- 25% reduction
- 25% increase
- 50% increase

Biomass is an option that can be competitive with fossil fuel, particularly off grid, and can improve security of supply and reduce CO_2. Sensitivity to decreases in biomass fuel cost has been investigated to evaluate potential impacts. Results are shown in tables 39 and 40.

Table 40 - Impact of different levels of energy and biomass costs on cost effective provision of heat

Sensitivities	Principal scenarios	Cost effective provision of heat GWh/year		Effect of sensitivity	
		Alternative Low Carbon Technologies	Heat Networks	Change in heat provision GWh/year	%
Current gas penetration	Scenario 1		301		
	Scenario 2		4		
	Scenario 3	1,141			
25% decrease energy prices	Scenario 1		300	-1	0%
	Scenario 2		4	0	0%
	Scenario 3	1,123		-18	-2%
25% increase energy prices	Scenario 1		301	0	0%
	Scenario 2		4	0	0%
	Scenario 3	1,144		3	0.3%
50% increase energy prices	Scenario 1		308	7	2%
	Scenario 2		4	0	0%
	Scenario 3	1,232		91	8%
25% reduction Biomass price	Scenario 1		301	0	0%
	Scenario 2		4	0	0%
	Scenario 3	1,141		0	0%
50% reduction Biomass price	Scenario 1		302	1	0%
	Scenario 2		4	0	0%
	Scenario 3	1,144		3	0%

Table 41: Impact of different levels of energy prices and biomass costs on Net Present Value

Sensitivities	Principal scenarios	NPV (€ million)	Effect of sensitivity	
		Benefit over counterfactual	Change in benefit (€ million)	%
Current gas penetration	Scenario 1	-€34		
	Scenario 2	-€2		
	Scenario 3	-€330		
25% decrease	Scenario 1	-€12	€22	-65%

energy prices	Scenario 2	-€2	€0	0%
	Scenario 3	-€185	€145	-44%
25% increase energy prices	Scenario 1	-€55	-€21	62%
	Scenario 2	-€2	€0	0%
	Scenario 3	-€479	-€149	45%
50% increase energy prices	Scenario 4	-€78	-€44	129%
	Scenario 5	-€1	€1	-50%
	Scenario 6	-€631	-€301	91%
25% reduction Biomass price	Scenario 1	-€34	€0	0%
	Scenario 2	-€2	€0	0%
	Scenario 3	-€337	-€7	2%
50% reduction Biomass price	Scenario 4	-€34	€0	0%
	Scenario 5	-€2	€0	0%
	Scenario 6	-€345	-€15	5%

An increase or decrease of energy prices of around 25% appears to impact the heat networks in scenario 1, decreasing/increasing the NPC benefit expected by around -65% to 62%. This is due to the dominance of energy costs (and revenues) over the lifecycle of a network. However a 25% variation has no impact on the cost effective potential for heat demand provision.

Alternative low carbon technologies in scenario 3 also show a substantial impact on the NPC benefit potential, of around -44% to 45% to 25% change in energy prices. An increase of 25% on energy prices shows minimal/no impact on the benefits of heat networks in scenario 2.

An increase of 50% on energy costs produces a marginal increase in potential cost effective heat provision by heat networks of 2%, and 8% for the alternative low carbon technologies in scenario 3. A dramatic impact is seen with a 50% increase of energy prices on scenarios 1 and 3 on the NPC savings obtained.

The difference between fuel prices and electricity prices is an important factor for CHP systems, and any further analysis of CHP schemes should also examine this difference.

Reductions in the cost of biomass show no impact on the level of provision of heat for any scenario. In terms of NPC savings, no impact is shown on scenarios 1 and 2, and a minor effect is seen on scenario 3, with alternative low carbon technologies providing a 2% and 5% increase in savings respectively from a 25% and a 50% reduction on biomass costs.

7.6 Capital and Operational costs

The following sensitivities are shown for capital and operational costs:

- 80% capital cost and operation cost
- 120% capital cost and operation cost

These changes have no impact on the cost effective provision of heat on any of the scenarios. Effects of these changes on the NPC savings are shown in table 42 below:

Table 42 - Impact of different levels of costs on Net Present Value

Sensitivities	Principal	NPV (€ million)	Effect of sensitivity

	scenarios	Benefit over counterfactual	Change in benefit (€ million)	%
Current gas penetration	Scenario 1	-€34		
	Scenario 2	-€2		
	Scenario 3	-€330		
80% Capex/Opex	Scenario 1	-€31	3	-9%
	Scenario 2	-€2	0	0%
	Scenario 3	-€333	-3	1%
120% Capex/Opex	Scenario 1	-€36	-2	6%
	Scenario 2	-€2	0	0%
	Scenario 3	-€328	2	-1%

In general, sensitivity towards these levels of change over capital and operational cost appear to show a small impact on the potential NPC benefits, with heat networks in scenario 1 producing the highest effect (9% decrease) for a decrease in costs of 20%. This is evident in some of the other sensitivities (for example, the energy costs) where lifecycle costs appear to be the dominant factor.

This result could be due to the dominance of the large Dublin zone (for which the economic viability is not altered), and zones either side of this being sufficiently economic or uneconomic to be unlikely to change.

7.7 Summary

The following figures summarise the ranges of sensitivity studied as well as effect of different technology scenarios.

Figure 30 - Sensitivity analysis for heat networks compared with the counterfactual. The percentage values show variance from the central scenario. A positive value shows either an increase in economic potential (GWh) or value (NPV). The chart also shows effect of the different technology scenarios.

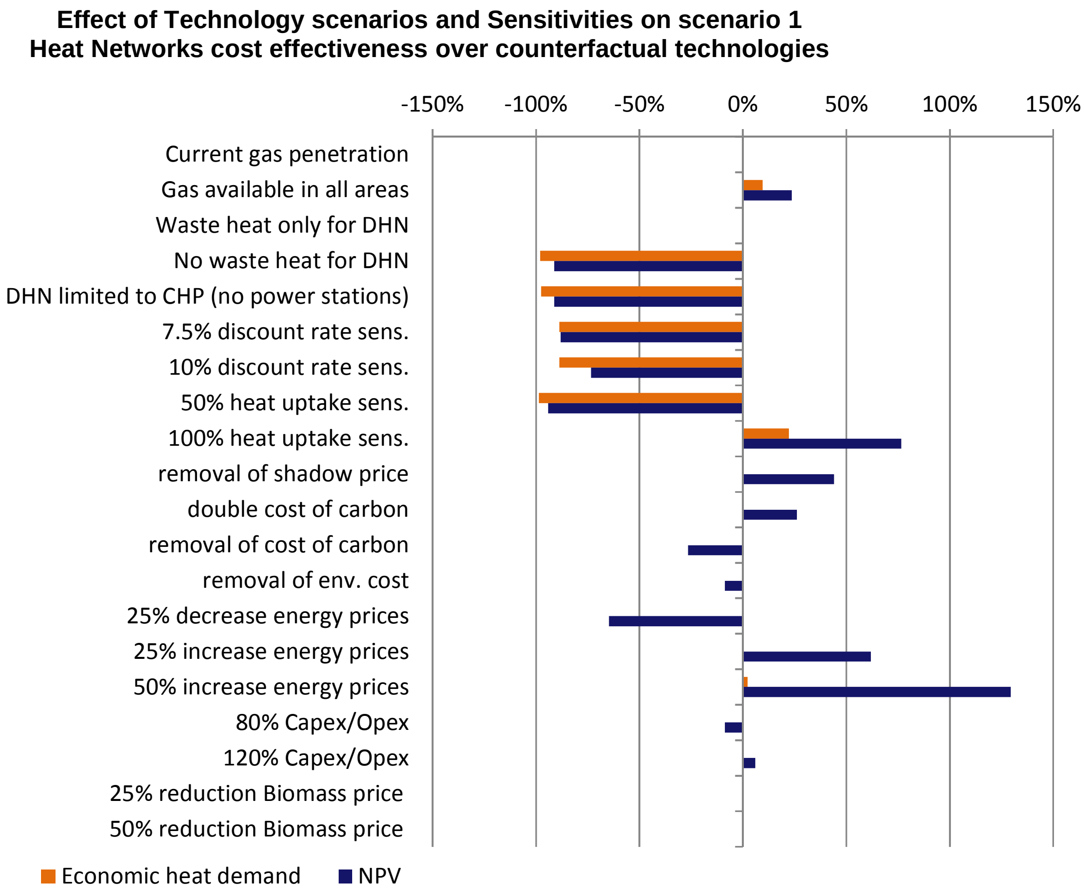


Figure 31 - Sensitivity analysis for heat networks compared with alternative low carbon technologies and the counterfactual. The percentage values show variance from the central scenario. A positive value shows either an increase in economic potential (GWh) or value (NPV). The chart also shows effect of the different technology scenarios.

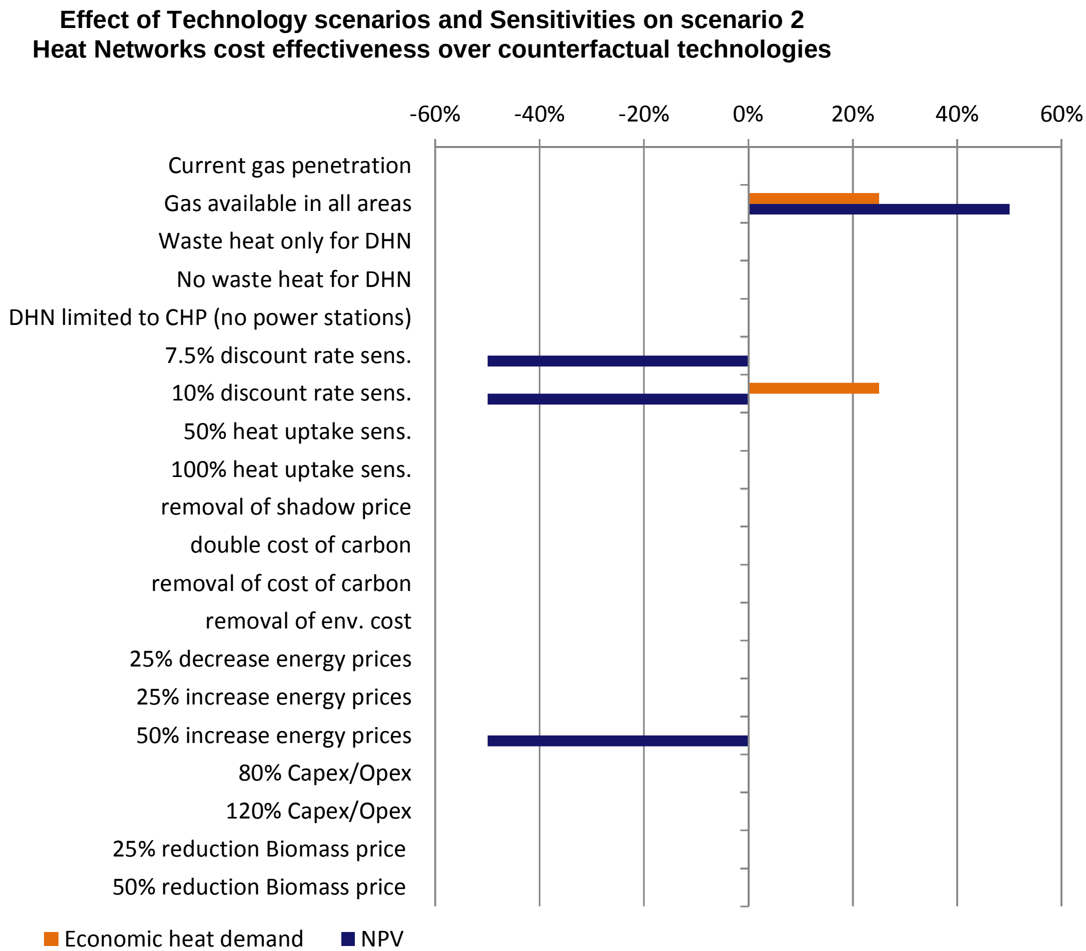
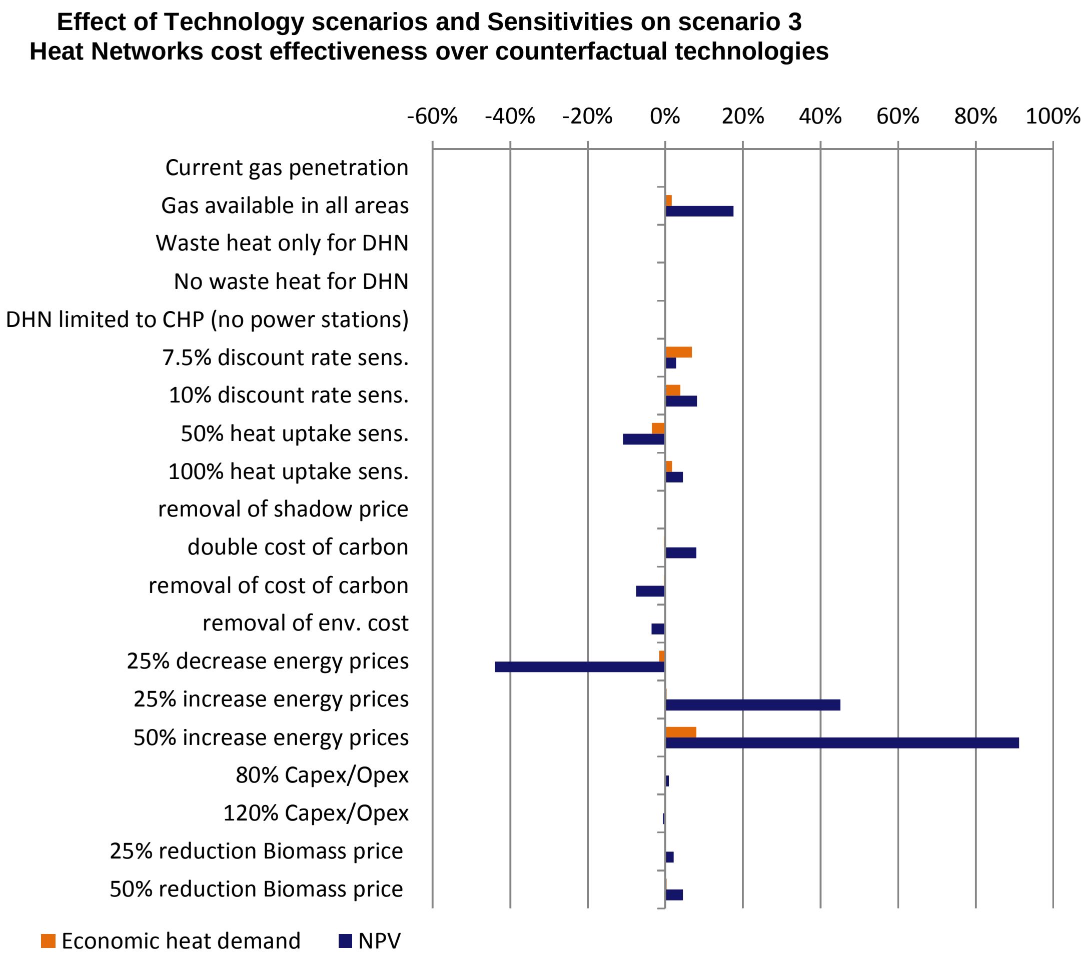


Figure 32 - Sensitivity analysis for alternative low carbon technologies compared with the counterfactual. The percentage values show variance from the central scenario. A positive value shows either an increase in economic potential (GWh) or value (NPV). The chart also shows effect of the different technology scenarios.



- Whilst scenario 1 appears to show a higher negative sensitivity to discount factors, scenario 2 indicates an identified small increase in the benefit potential. Results indicate that the deployment of economic heat networks will be heavily dependent on the ability to access low cost finance, and therefore may be reliant on public sector involvement in finance and delivery.
- Heat networks appear to be highly sensitive to the customer penetration, and it will be important for schemes to obtain customer buy-in at the earliest stage, combined with offering customers a competitive price for heat to maintain connection.
- The shadow price reflects the additional cost to the economy of developing heat networks with public sector funding. Its potential removal (implying a more commercial led approach with commercial funding), may incur other changes such as discount rate, which could cancel out any potential benefits.
- An increase doubling the cost of carbon would increase the NPC savings on heat networks in scenario 1 by around 26% and by 8% for alternative low carbon technologies in scenario 3.

- The removal of environmental costs indicates that this would have a negative effect on heat networks in scenario 1 with a decrease of 9% on NPC savings and of 4% on NPC savings of alternative low carbon technologies in scenario 3.
- The difference between fuel prices and electricity prices is an important factor for CHP systems, and any further analysis of CHP schemes should also examine this difference.
- Reductions in the cost of biomass show no impact on the level of provision of heat for any scenario. In terms of NPC savings, no impact is shown on scenarios 1 and 2, and a minor effect is seen on scenario 3, with alternative low carbon technologies providing a 2% and 5% increase in savings respectively from a 25% and a 50% reduction on biomass costs.
- In general, sensitivity towards capital and operational cost changes appear to show a small impact on the potential NPC benefits. This result could be due to the dominance of the large Dublin zone (for which the economic viability is not altered), and zones either side of this being sufficiently economic or uneconomic to be unlikely to change.

8. PLANNING AND DESIGN ISSUES

8.1 Introduction

The results from this CBA demonstrate that heat networks could be cost effective for around 300 GWh of Ireland's heating demand, or 1.5% of the national demand. This section outlines high level recommendations on how the uptake of heat networks can be increased to help realise this potential, and the corresponding costs benefit. At present the fact that there is a cost effective potential, but with little or no development of heat networks, means that a number of barriers must exist which need to be overcome in order for heat networks to be more widely adopted. It is therefore important to understand these barriers first before making recommendations.

8.2 The barriers to district heating

There are a range of barriers to the development of heat networks. These can be broadly split into three categories, although they are often interdependent and based around risk or perceived risk[60,61]:

- Project development and capital costs
- Project risks
- Policy and regulation

These are discussed further in the following sections.

8.2.1 Project development and capital costs

Risks are present in developing a potential scheme, and sourcing appropriate finance both to fund the scheme itself, but also the scheme development. Some of the main risks are:

- *Length and complexity of scheme development:* The development of a heat network can be a complex and long process. At the first stage, a suitable area needs to be identified, and the heat mapping in this study provides a first assessment. A number of development stages are then required prior to construction which cover technical feasibility and design, financial modelling, engagement with customers, contract development, and business structure development. This process can be very expensive and take a number of years, and is often the reason that schemes do not progress.
- *High capital costs and low rates of return:* The capital investment in heat networks can be significant, and whilst this study identifies schemes which are cost effective, the rates of return are generally low and dependent on long term revenue. The availability of capital funding for networks is often a barrier, especially where schemes have a low rate of return and are unlikely to attract private finance.
- *Complex coordination required with many stakeholders*: The complex nature of district heating projects involving many different parties, combined with the initial high level of

[60] The Potential and Costs of District Heating Networks. Pöyry and AECOM. DECC. 2009, available at http://www.poyry.co.uk/news/potential-and-costs-district-heating-networks-report-decc-poyry-energy-consulting-and-faber-maunsell-aecom

[61] Research into barriers to deployment of district heating networks. BRE, University of Edinburgh and the Centre for Sustainable Energy. DECC. 2013, available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191542/Barriers_to_deployment_of_district_heating_networks_2204.pdf

risk, means that the public sector is often best placed to lead. In general, countries with extensive use of heat networks have taken a public sector led approach, although often in partnership with the private sector. The barrier is that the public sector may need additional resource, skills, and funding, to take schemes though development, especially in countries like Ireland where there is little or no prior experience.

8.2.2 Project risks

There are a large number of risks associated with developing heat networks, as for many other large infrastructure projects. In addition, the immature heat network market in Ireland incurs many additional risks. High level risks are:

- *Market perception:* In countries where heat networks are not prevalent, there is often a perceived risk of the technology. Customers can be sceptical that outsourcing their heat supply to a third party will be reliable and economic. This is often due to a lack of understanding of the technology and customer experience. This view can be reinforced where there have been existing poorly performing networks.
- *Customer uptake:* A high uptake of customer connection is necessary to ensure that the connected heat load provides sufficient revenue to provide a return. It will be difficult to have customers in contract prior to network development and hence this represents a high risk. This risk is usually overcome by developing smaller initial networks with a small number of large customers with whom contracts can be developed. These customers are often the public sector, large commercial buildings, and social housing. Long term contracts are a method for further de-risking, with periods of around 20 years used. Once the initial network has been developed, then further staged development can take place.
- *Energy costs:* Heat networks are susceptible to energy cost variations as with any other energy user. However the long term returns for a network mean that small fluctuations in energy costs can have a large impact on the rate of return. To ensure that customer's energy costs are controlled (often through tracking other utilities such as gas), it is important that the most appropriate energy supply technologies are selected and fuel supplies identified. The advantage of heat networks is that they are source-agnostic, and so are flexible to alternative fuels and technologies in the future as energy prices fluctuate. In combination with energy costs, energy revenues are also a critical factor, as are other allied costs such as energy taxes and environmental costs and benefits.
- *Policy uncertainty:* Heat networks do not fall under regulation (although the heat sources may), and at present there is no firm policy around heat networks in Ireland. This can present challenges and risks to heat network developers, and may act as a barrier to customers who would not be willing to rely on an unregulated utility.

8.2.3 Policy and regulation

There is currently little or no policy aimed directly at heat networks in Ireland, and they do not fall under any regulatory requirements. This can present a barrier to development.

The regulation of heat networks could apply in a number of ways:

- Regulation could be used to identify heat network zones and mandate consumer uptake. This was the approach taken by the Danish Authorities, which has led to the widespread adoption of heat networks nationally.
- Regulation can provide customers with an assured level of service and cost control as with other utilities. This will help reduce the perceived risk of connection to customers, and limit heat prices to a level which is competitive with other forms of heating.
- Regulation can facilitate the development of heat networks, giving them a similar level of priority to other utilities. This could range from the inclusion of heat networks as key infrastructure in the planning process, access to network routes for installation (roads, compulsory purchase, etc.), and de-risking operation.

However, as with any immature market, there can be a number of disadvantages of imposing regulation at an early stage, and a balance needs to be struck between the benefits it offers, and the potential barriers it may impose.

Long term investment decisions require long term policy certainty, and therefore the development of policy around heat networks, and associated elements, will be important to facilitate uptake. Current policy barriers are:

- *Long term vision for heat networks:* Prior to this study, there had been no national assessment in Ireland, and little in the way of local assessments (although Dublin has recently conducted some high level mapping)[62]. It will be important for the Irish government to consider the results of this study and identify how future policy will support heat networks.
- *Fiscal incentives:* Fiscal incentives are available for a wide range of low carbon electricity and heat generation technologies, through direct (e.g. tariffs and grants) or indirect (e.g. carbon pricing) measures. However there are no incentives available for heat networks and the existing incentive structure can often act to distort the market. Heat networks are technology agnostic and provide long term flexibility to a range of low carbon sources, therefore an alternative could be to provide fiscal incentives to heat networks (either through grants or tariffs) to allow technology agnostic networks to be develop.
- *The existing energy market:* Parts of the existing energy market (predominantly networked supplies) are highly regulated and embedded in policy. Heat networks could be seen as a disruptive technology. The absence of policy for them is therefore a barrier and the existing structure of markets can have adverse impacts for heat networks (e.g., the ability to sell electricity from CHP systems). It will be important for Ireland to understand how heat networks can be developed in a way which supplements the existing market, and to develop policy to achieve this.
- *The lack of a heat market:* Heat is not currently perceived as a utility and there is no established heat market in Ireland. Until heat is embedded in national and local policy, this will present a significant barrier which is the foundation of many of the other barriers and risks in this section.

[62] Heat mapping has been conducted by Codema for Dublin: http://www.codema.ie/media/news/most-areas-suitable-for-district-heating-in-dublin-city/

8.3 Recommendations

8.3.1 Policy recommendations

Should the Irish Government with to address the barriers to district heating uptake, it will need to consider how heat networks can be included within national policy if a reasonable level of uptake is to be achieved, as per the requirements of the EED. Whatever approach is taken, it is likely that the public sector (both nationally and locally) will be of prime importance in the development of networks, particularly through the early stages of scheme development.

The development of policy in relation to heat networks will need to consider a range of factors including:

- The role of the public sector (both local and national)
- More detailed Identification of heat network potential for viable areas, and development of targets where appropriate
- Consideration of regulation and existing energy market structure, and regulatory support for consumer connections.
- Consideration of consumer protection (potentially linked with regulation)
- Identification and assessment of fiscal incentives
- Relationship with local policy and planning
- Non-economic support mechanisms including provision of training, technical support, procurement frameworks, etc.

Whilst the heat network market is almost non-existent in Ireland, the existing energy market provides a number of potential benefits which may not be seen in other countries and which policy could target.

There is a large proportion of off-grid heating, even in towns and cities. This means that the baseline heating costs are often higher in terms of cost and risk to consumers. This means that heat networks could provide a number of benefits which are not seen in other countries.

The natural gas network is not prevalent in all urban areas. Heat networks could be viewed as competition for gas networks, but they could also be mutually compatible. The development of heat networks combined with gas CHP could provide more economic heating in some areas, especially where the costs of gas distribution networks are offset. However the heat network could still provide a large load for the gas suppliers into the CHP unit. Therefore the market for gas use is maintained, and lifecycle infrastructure costs reduced. In these circumstances, the gas network operator could be a key stakeholder in the delivery of heat networks. It is therefore recommended that a CBA is required in all areas where the gas distribution network is to be developed, examining the cost benefits of heat networks as an alternative.

This national comprehensive assessment uses linear heat density at a Small Area level to determine economic viability. This level of spatial resolution means that smaller rural groupings of consumers are unlikely to achieve a high enough heat density to be identified as viable DH scheme locations. This means that the outputs of this work will probably be biased towards urban areas (where the greatest potential lies) but that further local analysis should also aim to explore where smaller scale schemes in more rural areas could provide a benefit. It should be remembered that the overall potential for heat networks is small, and that energy efficiency is likely to offer greater cost benefit in most areas.

8.3.2 Implementation recommendations

Achieving a high level of uptake of heat networks in Ireland will require further work to identify and develop schemes, alongside the development of appropriate policy (and potentially regulation). From an implementation perspective, we recommend that Ireland considers the following:

- *National assessments:* This is the first study examining the national potential. The outcomes of this work need to be carefully considered, and additional national assessment work conducted as required. This further work may examine aspects such as sensitivities, different sectors, incentive structures (e.g. a feed in tariff), etc., to input to the wider policy development.
- *Prioritisation of areas:* The heat mapping in this work provides a high level assessment of heat density and can be used to identify areas which may be suitable for heat network development (predominantly city and town centres). This can be used to identify and prioritise areas for further analysis.
- *Local energy masterplanning:* It is recommended that a series of local energy masterplans are conducted for the priority areas. These should provide more detailed heat mapping at a local level (using local data where possible), and take into account the wide range of local opportunities and constraints which may be present. Based on this information, potential heat network schemes can be identified and modelled at concept stage.
- *Feasibility studies:* Once concept networks are identified from the energy masterplanning, more detailed technical and financial feasibility studies can be conducted on individual schemes. This stage will involve consultation with a wide range of stakeholders, including potential customers, and need to consider appropriate business structures.

The next stages of work leading to the development of schemes will depend on the policy route which Ireland chooses to take. However issues such as procurement, legal and contracts, business development, etc. will all need to be examined to allow investment in schemes.

8.4 Delivery mechanisms

This section provides an overview of existing activities within Ireland in relation to heat networks, and also the approach taken in some other countries.

8.4.1 Existing policy and schemes in Ireland

Heat networks are not common in Ireland, and there is little policy or financial support for the development of schemes. This view was shared by the Codema spatial energy demand analysis for Dublin in June 2015[63].

Previously, the SEAI has offered funding towards renewable heat in the form of the ReHeat scheme, which for example, contributed towards Callan (Kilkenny) installing a small heat network[64], or Tralee

[63] Dublin City Spatial Energy Demand Analysis. Codema. Dublin City Council. 2015.

[64] http://www.seai.ie/Renewables/Bioenergy/The_Callan_District_Heating_Case_Study.pdf

Town Council installing a 1MW woodchip fuelled DH system[65]. However, this funding source closed in 2011. The SEAI still offers funding for the Better Energy Communities scheme, but this does not have a specific focus on heat or networks.

However, Ireland has adopted the legal requirements of the European Union Energy Efficiency Regulations into law through S.I. No. 426 of 2014, of which this report contributes towards the fulfilment of the assessment of the potential for district heating and the national CBA.

8.4.2 The UK - Heat Network Delivery Unit (HNDU)

The HNDU was created as a response to "the Future of heating: Meeting the Challenge" produced by DECC in 2013. It was established to encourage local authorities in England and Wales undertake development stages of heat network projects. The organisation provides grant funding of up to 67% of total eligible external costs, for area wide heat mapping studies, to identify and prioritise heat network opportunities. It also supports more specific projects into detailed technical feasibility, design, modelling, contractual arrangements and delivery options. In addition to funding HNDU provides LAs with a number of experts with expertise in all aspects on Heat Network delivery, including project management, finance, engineering, risk management, governance, procurement, and managing stakeholders

Since its inception in September 2013 the Unit has awarded support to 180 unique projects across 115 local authorities including £9.7 million of grant funding. The Unit is currently scheduled to run until March 2016.

As set out in Delivering UK Energy Investment: Networks[66] released in January 2015, DECC analysis suggests the portfolio of HNDU projects could represent between £400 million to £800 million of capital investment opportunity over the next 10 years (on an assumption of 25% to 50% of current projects coming to fruition).

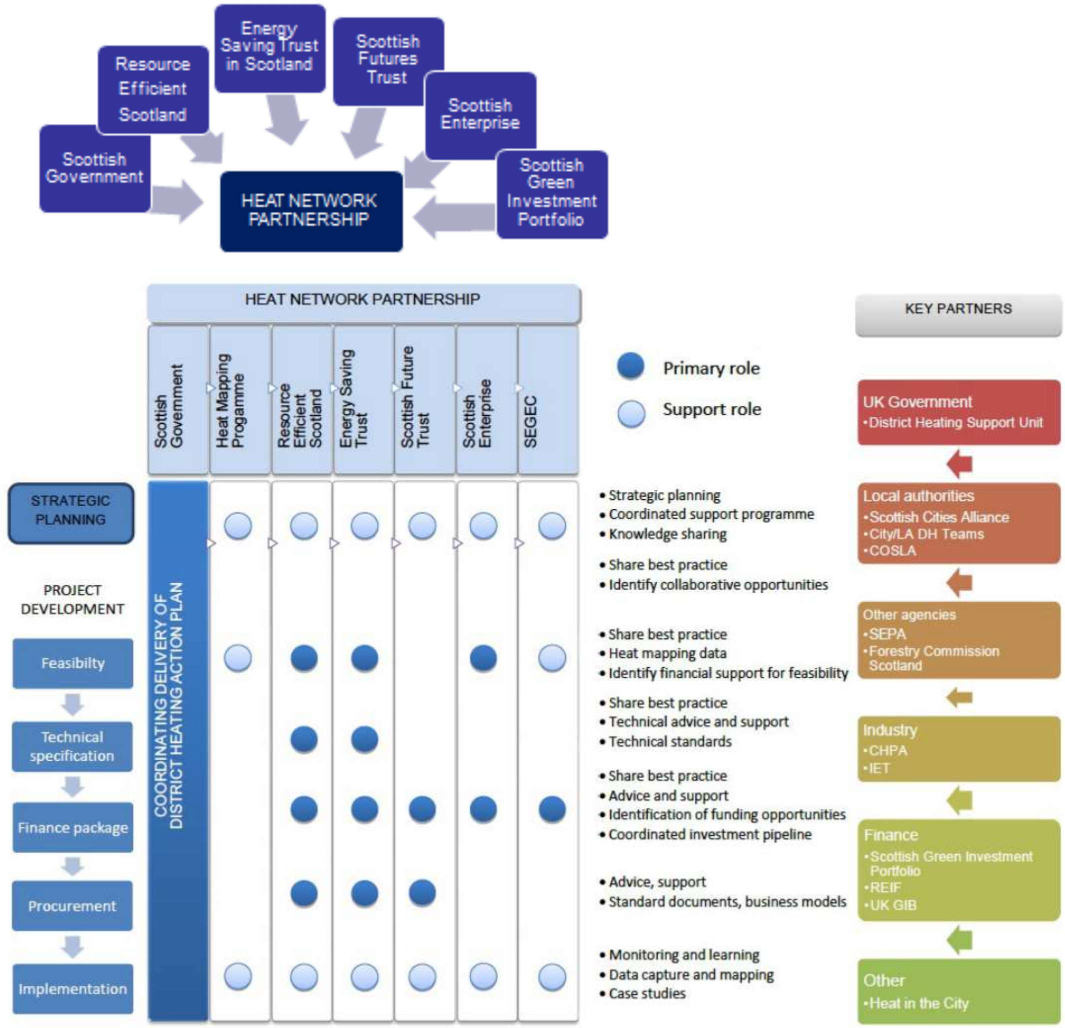
8.4.3 Scotland – Heat Network Partnership

The main body of support for Heat networks in Scotland is the Heat Network Partnership, which brings together the Scottish Government agencies who providing financial and technical support and guidance to businesses, the public sector, communities and households, working with a wider partnership of key stakeholders to deliver a step change in the scale of heat networks in Scotland.

The Heat Network Partnership was set up to co-ordinate support for district heating, best practice, guidance and knowledge-sharing to accelerate the uptake of district heating in Scotland. The information and guidance provided is under the headings of Leadership; Planning; Procurement; Finance and Technology.

[65] http://www.seai.ie/Publications/Renewables_Publications_/Bioenergy/The_Mitchels_Boherbee_Regeneration_Project.pdf
[66] Delivering UK Energy Investment: Networks. DECC. 2015.

Figure 33: Heat Network Partnership diagram describing activities and linkages



To support the aims the Scottish government's goal of 1.5 TWh of heat to be delivered by district heating by 2020, the Scottish Government has announced an increase in funding for the District Heating Loan Fund[67] by over £4 million, making a total of £8 million available over the two years 2014 to 2016.

The District Heating Loan Fund provides loans to help organisations implement district heating projects that benefit local communities. Loans up to £500k (or more in certain cases) are available as low interest (about 3.5%) unsecured loans, with repayment terms of either 10 or 15 years. The scheme is open to local authorities, registered social landlords, small and medium sized enterprises and energy services companies [ESCOs] with less than 250 employees.

Since 2011, over £8m has been lent to 38 projects in Scotland to support District heating, and three Warm Homes Fund projects have been awarded £2.2m, connecting 619 homes and providing a capacity of 3.3 MWth. For 19 projects up to summer 2014 the DH loan Fund has covered £4.4m of loans, providing a capacity of 5 MWth.

[67] http://www.energysavingtrust.org.uk/district-heating-loan

There is also financial support from schemes such as the Renewable Energy Investment Fund (REIF)[68], and organisations such as the Scottish Green Investment Portfolio (SGIP)[69], Community Energy Programme, LCITP and Local Energy Challenge fund.

Undertaking a District Heating Scheme is a big investment and will likely require several funding streams, large scale purchasing of equipment and a robust business model.

8.4.4 Denmark

Denmark has an active, long term energy policy, initiated in the 70's as a response to the oil crisis. In the mid 70's energy taxes on electricity and oil were introduced to promote energy savings. Fuels for electricity consumption were exempted, which encouraged the shift from heat only production to CHP, using surplus heat from power plants.

In 1979 it became a legal requirement that all local authorities produce heat maps by end 1982 at the latest, which was to be used for master planning of the local heat supply. This Heat Supply Act included four phases for local authorities to follow for regional development:

- Mapping – describing existing heat supply and demand
- Proposal – outlining future options for heat supply
- Planning – identifying least cost options, deciding on main projects to pursue
- Project – implementing planned and approved projects.

The entire country was divided into heat supply districts according to heat density and the options of heat supply from district heating to individual gas supply. To serve as a common basis for the planning process, a standard manual was drafted by a collaborative group with representatives from all major stakeholders within the energy sector (energy supply industries, public authorities, research institutes etc.), this included price information about various types of plant, efficiency ratings, and unit consumption.

The Heat Supply Act also sets the parameters for heat pricing, ensuring pricing on actual cost on a non-profit basis. The Act allows the municipalities to impose compulsory connection to the natural gas and DH grid, whereby consumers must take steps to be connected within a period of nine years. This can be compensated through subsidies under certain conditions, e.g. if heat prices rise as a result.

Until 2005, customers on the local distribution network have had an obligation to buy electricity from local CHP units; this ensured long term revenues to encourage investment. The electricity is now sold on the market and subsidised by tariffs and surcharges.

The above information concentrates mostly on policy to drive forward energy sector changes; there have also been a number of incentives to promote DH and CHP in the early 90's:

- Conversion of DH into CHP – DKK 50m/year over five years
- Investment grants for new district heating networks and rehabilitation of existing networks for compulsory connection to the grid.
- Subsidy for electricity sold to the grid from CHP (DKK 100/MWh)
- Investments subsidies for installation of central heating in DH areas to increase penetration – DKK 150m/year over 10 year

[68] http://www.scottish-enterprise.com/services/attract-investment/renewable-energy-investment-fund/overview
[69] http://scotgip.com/about.html

- Introduction of green taxes on trade and industry, with the full DKK 2.6bn yield returned as investment grants, of which approx. 40% is for CHP.

9. CONCLUSIONS

Based on the outputs of this study, the following conclusions can be drawn from the results:

1. The heat demand in Ireland predominantly low density in nature. The heat mapping and analysis of linear heat density demonstrates that around 90% of the heat demand is too low to make DH a viable proposition. In general, the low heat density areas are made up of rural areas, small towns and villages, and the edge of large towns and cities. These areas are unlikely to be viable for heat networks and are more appropriate for alternative low carbon technologies.

2. Based on the selected system boundaries, the potential for heat networks at 3,000 MWh / km and 5,000 MWh / km linear heat densities is negligible at less than 0.1% of the country's heat demand. Whilst there may be some small scale schemes which exist at these density levels, this means that the majority of Ireland's heat demand will not be suitable for district heating. Where further analysis is undertaken for low density areas, it will be important to use more detailed local information to identify the opportunities.

3. At 10,000 MWh / km linear heat density, an economic potential of around 300 GWh per year is identified with a cost benefit of around €33million NPV, largely based on a zone in Dublin resulting from the threshold analysis. This is equivalent to around 1.5% of Irelands heat demand, and therefore whilst small, still an appreciable potential. . However at 10,000 MWh/km, around half of the identified technical potential is economic, and so it is unlikely that the economic potential will increase at higher heat densities, due to the smaller target demand. If the heat density was lowered, the technical potential may increase, but the proportion which is uneconomic is likely to increase. The relatively small potential for heat networks will mean that CO_2 and primary energy savings at a national level will not be significant.

4. The economic potential appears to be based around two types of district heating schemes:

    a. Large scale schemes (in Dublin) which have a small cost benefit over the counterfactual technology options, and which are reliant on a source of waste heat from power stations for economic viability, although other heat sources are only marginally uneconomic.
    b. Small scale schemes (potentially outside of Dublin), where there is a much larger cost benefit in terms of levelised cost, but the overall heat provision potential is very limited. These types of scheme are likely to be located where more expensive counterfactual options exist (potentially off the gas network and probably on oil). The predominant heat source is boilers due to the small scale of the schemes.

5. In light of the small economic potential for heat networks, it is possible that a national scale programme of support is excessive. However if the specific opportunities are to be realised, appropriate programmes and support mechanisms will need to be put in place, either at a national or local level. It will be important for the public sector to take a lead if any of the schemes are likely to succeed. In particular, it is suggested that a detailed energy masterplanning assessment of Dublin be considered, making use of information from this report, and Dublin specific studies, with a view to identifying heat network areas for further feasibility testing.

6. In virtually all areas, alternative low carbon technology options can provide a more cost effective heat source than heat networks. This suggests that future priorities for Ireland should be generally concentrated around the deployment and incentivising of building scale technologies including small scale CHP.

7. Alongside the heat network and alternative low carbon technology options assessed in this report, there will be a range of other options for reducing CO_2 emissions and energy demand including energy efficiency. The results in this study therefore need to be viewed within the wider context of CO_2 reduction measures when identifying the most appropriate solutions.

APPENDIX 1 – CBA ASSUMPTIONS

This appendix provides details of the assumptions used in the CBA. For assumptions relating to costs and performance of technologies, please see Appendix 2.

Economic Evaluation Basis

These are the key parameters and assumptions used in calculating the present value of the costs and benefits of each scenario.

- Price Year: 2015
- Present Value Year: 2015
- Price escalation: Real terms
- Value Added Tax: Excluded
- Social Discount Rate: 5%
- Financial Discount Rate: 5%

VAT will be included in the Financial Appraisal only where it is non-recoverable. The discount rates are obtained from the DPER guidance for capital appraisal available at: http://www.per.gov.ie/en/project-discount-inflation-rates/

Appraisal Period

For the purposes of comparing scenarios and estimating the potential value of district heating it has been assumed that the necessary infrastructure is in place in ten years, after a three year construction and implementation period. Costs and benefits have been forecast over a twenty year appraisal period in line with standard DPER guidance.

- Implementation commences: 2022
- Operation commences: 2025
- Appraisal period end: 2044

Shadow Pricing

It is assumed that the heat network will have to be provided from public funds. In line with standard DPER guidance these public funds incur a "shadow price" and these costs are increased by 30% in the CBA. This reflects the costs to the economy of raising tax revenue. It is assumed that the economy is at or near full employment at the time of construction, so that the labour cost of the scenarios represents an opportunity cost to the economy rather than the use of a resource that would otherwise go to waste.

- Shadow price of public funds: 1.3 / 130% (used for heat network costs)
- Shadow price of labour: 1 / 100%
- Assumed labour proportion 20%
- Shadow price of carbon: N/A (included in carbon pricing)

Ramp-Up

It is assumed that a ramp up period is needed to allow users to adopt the new technology

- Implementation period: No users
- Opening year: 25% of heat users connected
- Year 2: 50% of heat users connected
- Year 3: 75% of heat users connected
- Year 4+: 100% of heat users connected

Heat Sources

- Heat source load factor: See technical assumptions
- Primary heat source availability: 80%
- Source of back up/peak heat: Back-up boiler installed on heat network

The primary heat source availability is the maximum availability of all stand-alone heat sources on a network. The remaining 20% of heat is assumed to come from back-up boilers. A lower heat source availability will be assumed during construction and heat uptake period of 50% to account for the impact of the construction process on plant phasing. The source of back up and peak heat will be gas or oil boilers depending on fuel availability.

Capital Cost

- Capital costs See technical assumptions
- Renewal costs Capital cost and real increase
- Capital cost reductions See technical assumptions
- Expenditure profile See technical assumptions
- Real cost escalation 1%
- Heat network costs UK ETI Macro DE study

Capital costs will be the initial costs of establishing the new heating systems in the early part of the appraisal period. Renewal costs will arise later in the period where capital equipment has to be replaced because standard O&M activity is not enough to keep it operational for the full appraisal period. Capital cost reductions are capital costs that would otherwise be encountered in the baseline scenario e.g. new boilers in homes. Note that in some cases these cost reductions may be included as a benefit as opposed to a negative cost. As the overall measure is NPV, this will only be a presentational issue. The estimate of real cost escalation is based on the AECOM Ireland Annual Review 2015 which forecast capital inflation of 3%, with long term nominal price inflation of 2%. This is conservative compared to official forecasts which only cover the shore to medium term. The Department of Finance expects nominal inflation to be 1.7% until 2018, and for investment prices to increase by only 1.4% per annum over the same period.

O&M Costs (excluding fuel)

▪ O&M New Infrastructure	See technical assumptions
▪ O&M Existing Infrastructure (For example, power stations that are modified to supply heat via a district heating network)	See technical assumptions
▪ O&M Reductions (For example maintenance of domestic boilers. Please note that in some cases these cost reductions may be included as a benefit as opposed to a negative cost. As the overall measure is NPV, this will only be a presentational issue)	See technical assumptions
▪ Real cost escalation	0% (Based on assumed labour content of less than 50% (see http://www.per.gov.ie/en/project-discount-inflation-rates/)

Residual Value

▪ Residual value	Based on depreciated capital cost.

This is based on the standard approach to estimating residual value used in DPER and European Commission Guidance.

Counterfactual stranded asset costs

▪ Redundant heat supply capital cost	Based on depreciated annual capital

Environmental

- Cost of carbon

Year	Price (€/tCO2 – 2013 prices)[70]	Price (€/tCO2 – 2015 prices)
2020	10	10.04
2025	14	14.06
2030	35	35.14
2035	57	57.23
2040	78	78.31
2050	100	100.40

[70] Source: EU Energy, Transport and GHG Emissions, Trends to 2050, Reference Scenario 2013 http://ec.europa.eu/transport/media/publications/doc/trends-to-2050-update-2013.pdf ; adjusted to 2015 prices using 0.2% per year (European HICP).

- Carbon intensity of electricity

Year	Carbon Intensity (gCO_2/kWh)[71]
2013	468.9
2020	335.2
2025	335.2
2030	335.2
2035	335.2

- Carbon intensity of other fuels

Fuel type	Carbon Intensity (gCO_2/kWh)
Natural gas	0.205
LPG	0.229
Oil (fuel oil)	0.274
Coal	0.341
Biomass	0

- Other environmental damage

Technology	Environmental damage[72] (€/MWhth – 2012 prices)	Environmental damage (€/MWhth – 2015 prices)
CHP-Bio (Heat)	3	2.77
CHP -Natural gas (Heat)	4	4.36
CHP - Hard coal (Heat)	11	11.52
CHP - Waste (Heat)	5	4.57
Domestic natural gas - fired boiler	6	5.61
Domestic wood pellet boiler	8	8.10
Domestic heat pump	6	6.29
Domestic solar thermal	8	7.73
Industrial fuels for heat	13	12.93
Electricity	17	16.75

[71] Source: SEAI projections. Assumed constant after 2020.
[72] Source: Table A3-7 and A3-9, Annex 3, Subsidies and Costs of EU Energy (Alberici et al., 2014) https://ec.europa.eu/energy/sites/ener/files/documents/DESNL14583%20Final%20report%20annexes%201-3%2011%20Nov.pdf Prices uplifted to 2015 based on 0.2% per year average (European HICP)

Primary Energy

Fuels [73]

Fuel	Primary energy factor
Natural gas	1.1
LPG	1.1
Oil (fuel oil)	1.1
Coal	1.1
Biomass	1.1

Electricity

Year	Primary energy factor
2020	1.9
2025	1.9
2030	1.9
2035	1.9

[73] Source: SEAI http://www.seai.ie/Your_Business/Public_Sector/FAQ/Calculating_Savings_Tracking_Progress/What_are_the_conversion_factors_used_to_calculate_TPER.html Source: SEAI http://www.seai.ie/Your_Business/Public_Sector/FAQ/Calculating_Savings_Tracking_Progress/What_are_the_conversion_factors_used_to_calculate_TPER.html Electricity values post 2020 assumed constant based on SEAI recommendation.

Energy prices (normalised to € / MWh used in modelling)

Fuel	Source cost	€/MWh	Real Growth
Electricity: Market price	€75 per MWh[74]	75.00	1.0%
Electricity: Domestic price	€0.19 per kWh[75]	250.00	1.0%
Electricity: Commercial price	€0.12 per kWh[76]	100.00	1.0%
Gas: Wholesale price	€29.10 per MWh[77]	29.10	1%[78]
Gas: Commercial price	€0.0347 per kWh[79]	45.90	1%
Gas: Domestic price	€0.0559 per kWh[80]	75.00	1.0%
Oil: Wholesale price	€86.10 per barrel[81]	48.60	1.7%[82]
Oil: Commercial price	€0.787 per litre[83]	69.50	1.7%
Oil: Domestic price	€0.86/0.81 per litre[84]	81.00	1.7%
Coal: Wholesale price	€72.20 per tonne[85]	10.10	1.5[86]
Coal: Commercial price	€123.34 per tonne[87]	17.20	1.5%
Coal: Domestic price	€490 per tonne[88]	68.60	1.5%
LPG :Commercial price	€0.086 per kWh[89]	86.00	1.0%
LPG: Domestic price	€0.099 per kWh[90]	99.00	1.0%

[74] Based on review with the SEAI. With constraints and capacity payments, the wholesale price is in the region of €70/MWh – €80/MWh.
[75] SEAI EPSSU http://www.seai.ie/Publications/Statistics_Publications/Electricity_and_Gas_Prices/Price-Directive-2nd-Semester-2014.pdf
[76] SEAI EPSSU http://www.seai.ie/Publications/Statistics_Publications/Electricity_and_Gas_Prices/Price-Directive-2nd-Semester-2014.pdf
[77] Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[78] Based on Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[79] SEAI EPSSU http://www.seai.ie/Publications/Statistics_Publications/Electricity_and_Gas_Prices/Price-Directive-2nd-Semester-2014.pdf
[80] SEAI EPSSU http://www.seai.ie/Publications/Statistics_Publications/Electricity_and_Gas_Prices/Price-Directive-2nd-Semester-2014.pdf
[81] Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[82] Based on Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[83] SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Commercial_Fuel_Cost_Comparison.pdf
[84] SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Domestic-Fuel-Cost-Comparisons.pdf
[85] Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[86] Based on Fossil Fuel Price Projections (DECC, Sept 2014) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360598/DECC_2014_fossil_fuel_price_projections.pdf
[87] SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Commercial_Fuel_Cost_Comparison.pdf
[88] SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Domestic-Fuel-Cost-Comparisons.pdf
[89] SEAI Fuel Cost Comparison . Based on bulk delivery of 0 – 3 tonnes http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Commercial_Fuel_Cost_Comparison.pdf
[90] SEAI Fuel Cost Comparison based on bulk delivery http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Domestic-Fuel-Cost-Comparisons.pdf

Biomass prices

	€/tonne	€/MWh	Real Growth	Domestic use	Commercial / public sector	DISTRICT HEATING NETWORK / industrial
Domestic bulk pellets 2015	€290 per tonne[91]	60.42	1.0%	100%		
Commercial bulk pellets 2015	€273 per tonne[92]	56.88	1.0%		50%	
Commercial wood chip 2015	€129 per tonne	40.31	1.0%		50%	100%

Biomass energy density

	kWh / tonne	Type
Biomass domestic	4,700 kWh / tonne[93]	Pellets
Biomass commercial	3,700 kWh / tonne[94]	Wood chip

Industrial heat prices

	£ / MWh	€/MWh	Real Growth
Average heat production price	35[95]	49	1.0%

Price inflation and conversion (used to present € at 2015 values)

Factor	Value
2015 index (MM2 Producer Price index)	110[96]
Average annual increase (calculated from MM2)	2%
2015 Euro conversion (£/€)	0.71140[97]

91 SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Domestic-Fuel-Cost-Comparisons.pdf

92 SEAI Fuel Cost Comparison http://www.seai.ie/Publications/Statistics_Publications/Fuel_Cost_Comparison/Commercial_Fuel_Cost_Comparison.pdf

93 Typical for pellets. Used for domestic and commercial scale applications. http://www.seai.ie/Renewables/Bioenergy/Sources/Wood_Energy_and_Supply_Chain/Wood_Pellets/

94 Typical for wood chip at 30% moisture content. Used for industrial, and district heating networks applications. http://www.seai.ie/Renewables/Bioenergy/Sources/Wood_Energy_and_Supply_Chain/Wood_Chips/

95 https://www.gov.uk/government/publications/the-potential-for-recovering-and-using-surplus-heat-from-industry

96 Index based on mix from MM2 Producer Price Index (2010 =- 100) http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-377137 A UK index is selected due to the majority of technology costs being sourced from UK references. Indexes from the CSO (http://www.cso.ie/en/statistics/prices/) are slightly lower (typically around 107), but less applicable to the UK-sourced cost information used.

97 https://www.ecb.europa.eu/stats/exchange/eurofxref/html/eurofxref-graph-gbp.en.html

APPENDIX 2 – TECHNOLOGY ASSUMPTIONS

This appendix provides details of the technology costs, performance, and applicability used in the modelling.

Technology cost and performance

Technology	**Sector**	**CAPEX**	**OPEX**	**Lifetime**	**Efficiency (thermal %)**	**Efficiency (electrical %)**	**Load factor**	**Minimum capacity**	**Ref**
		€/kW	€/kW/yr	yr	%	%	%		
GSHP	Domestic	1864	10	23	350	0	18.5		1
GSHP	Commercial - large	1415	1	20	392.5	0	35		1
GSHP	Industrial - large	1415	1	20	412.5	0	35		1
ASHP	Domestic	2403	14	20	262.5	0	13.5		1
ASHP	Commercial - large	961	2	20	400	0	35		1
Biomass Boilers	Domestic	676	20	15	85	0	9.5		1
Biomass Boilers	Commercial – large	568	26	15	81	0	32.5		1
Biomass DH	Industrial – large	1448	33	35	73	0	20		1
Nat Gas Boiler	Domestic	192	13	15	94	0	6.5		1
Nat Gas Boiler	Commercial – large	91	1	15	94	0	20		1
Nat Gas Boiler	Industrial - large	66	5	15	94	0	51		1
"Off-grid" (LPG & Oil) Boiler	Domestic	192	13	15	80	0	7.5		1
"Off-grid" (LPG & Oil) Boiler	Commercial - large	91	1	15	80	0	20		1
Electric Heating	Domestic	244	0	15	90	0	7		1

Electric Heating	Commercial - large	309	0	15	100	0	20		1
mCHP - low H:P (e.g. fuel cell)	Domestic	6030	302	15	43	43	45		4
mCHP - high H:P (e.g. Stirling)	Domestic	812	41	15	73	12	34		4
Small gas engine CHP	Building / DH	733	68	15	52	28	50	250	2
Large gas engine CHP	DH	936	68	15	42	38	50	1000	2
Waste heat from power stations	DH	18	0	40	630		90	10000	3
Waste heat from industry	DH	0	0	NA	100	0	90	100	8
Medium biomass steam turbine CHP	DH	1488	34	20	63	17	50	29,000	2
Geothermal - CHP mode	DH	3586	146	25	1000	500	90	5000	5 & 6
Geothermal Heat only mode	DH	2451	146	25	1000	0	90	5000	5 & 6
Small gas turbine	Industrial	945	73	15	46	34	90	13500	7

Notes:

- All values presented in Euros and include a price uplift from year of publication so that they represent 2015 costs. The sources used for capital costs originate from UK analysis so the uplift is based on UK indices as given in Appendix 1.
- Where a range of values are provided in the reference, central values have been used here.

Sources:

1. The UK Supply Curve for Renewable Heat. NERA & AEA. Study for the Department of Energy and Climate Change (DECC). 2009.
2. The potential and costs of district heating networks. Pöyry and Faber Maunsell (AECOM). Report to the Department of Energy and Climate Change (DECC). 2009.
3. A study into the recovery of heat from power generation in Scotland. AEA. Report to the Scottish Government. 2011.
4. Decarbonising Heat: Low-Carbon Heat Scenarios for the 2020s. NERA & AEA. Report for the Committee on Climate Change (CCC). 2010.
5. Deep Geothermal Review Study. Atkins. Study for Department of Energy and Climate Change (DECC) 2013.
6. Geothermal Potential and Great Britain and Northern Ireland. SKM. 2011.
7. Electricity generation cost model - 2011 Revision. PB Power. Report for the Department of Energy and Climate Change (DECC). 2011.
8. Industrial waste heat costs are based on a levelised cost of heat capture and provision. See footnote 95.

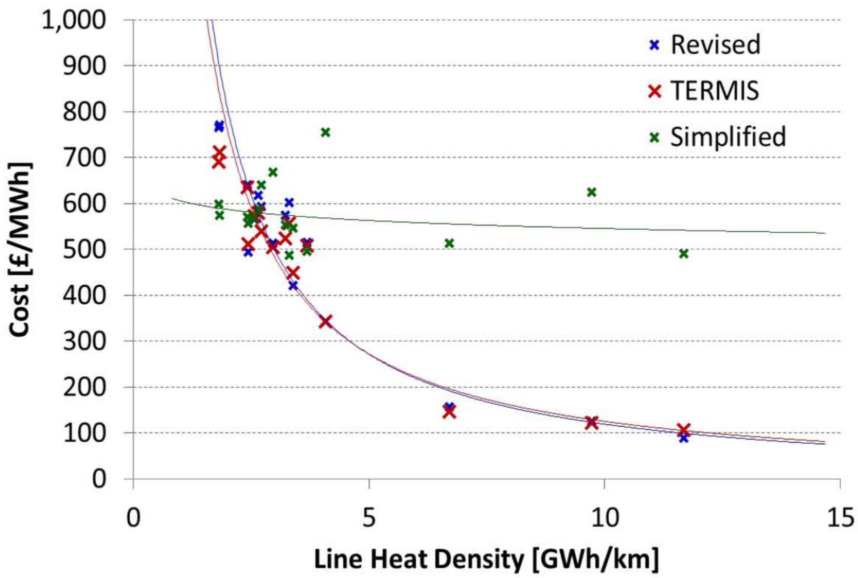
Alongside the above sources, the cost source WIKI used in the UK's 2050 modelling, and wider IEA Energy Technology Systems Analysis Programme (ETSAP) was referred to[98]. This includes the references listed above.

Heat network costs and performance

Heat network costs are based on published data by the UK Energy Technologies Institute (ETI) taken from the macro DE study into which AECOM provided technical support[99] . The costs are estimated from extensive modelling of a range of areas in the UK and characterise heat network costs through linear heat density (MWh / m) and cost per unit of energy (€ / MWh). The analysis used TERMIS, commercial software used for the design, analysis, and simulation of district heat networks. The cost calculation algorithms developed in the study were tested against detailed network models and cost models, and demonstrated a high level of consistency. The costs include all elements of the distribution network and building connections, and provide a detailed but efficient way to calculate heat network costs on a national scale study.

[98] http://2050-calculator-tool-wiki.decc.gov.uk/cost_sources/58
[99] http://www.eti.co.uk/wp-content/uploads/2014/03/ETI_Macro_Distributed_Energy_Report_-21_March_2013_2.pdf

Figure 34: ETI Macro DE cost data - includes all pipework and building connections - with the final cost curve ("Revised"), and an earlier cost curve using simplified analysis ("Simplified") which was disregarded.



Transmission pipe costs for connecting different zones and connecting energy sources to zones are based on the JRC guidance range of €1000 - €2000, with a central value of €1500 used.

Other factors used for modelling the heat networks are shown below:

Factor	Value	Comments
Thermal store capacity	0.015 m^3 per MWh annual demand	Based on UK analysis for DECC[100].
Thermal store cost	€1,352 per m^3	See footnote 100.
Energy centre building capacity	0.050 m2 per MWh	Based on an indicative 1000m^2 energy centre for a 20,000 MWh scheme.
Energy centre building costs	€2000 per m^2	Indicative building cost.
Network lifetime	50 years	
Pumping energy requirement	2% of heat demand by kWh	CIBSE Code of Practice[101].
Thermal losses	10%	Indicative of large networks.
Operation costs	1% of capital expenditure	
Max thermal supply from primary heat sources	80%	Indicative of an optimised scheme without oversizing primary plant.
Minimum thermal supply from peak boilers	20%	Linked to max thermal supply from primary heat sources.

[100] Costs and Performance of Heat Networks. AECOM. Report for DECC. 2015
[101] Heat Networks: Code of Practice for the UK. CIBSE. 2014

Maximum heat uptake penetration	80%	Used for central case modelling.
Annual export of electricity from	75%	Assumes 25% can be sold to local customers directly.

Heat network connection suitability

The following factors are used to indicate the suitability of different building types for connection to a heat network.

Sector	% suitable for connection (water based systems)	% suitable for connection (electric heating systems)
Domestic		
Flat	100%	50%
Terraced	100%	50%
Semi Detached	100%	50%
Detached	100%	50%
Commercial		
Healthcare	75%	25%
Hospitality	75%	25%
Leisure	75%	25%
Office	75%	25%
Retail	50%	25%
Warehouse	25%	25%
Education	25%	25%
Other	75%	25%
Public sector		
Education	75%	25%
Healthcare	75%	25%
Office	75%	25%
Retail	50%	25%
Restaurant/public house	75%	25%
Warehouse and storage	25%	25%
Industrial		
Low temperature	25%	25%

Alternative technology applicability

The following factors are used to indicate the suitability of different building types for connection to alternative heating technologies.

House type	GSHP	ASHP	Biomass boiler	mCHP - low H:P (eg fuel cell)	mCHP - high H:P (eg Stirling)	% Electric homes suitable	Upgrade costs to water system [102]
	%	%	%	%	%	%	€
Flat	0%	45%	0%	80%	5%	50%	£3,940
Terraced	50%	75%	83%	90%	20%	50%	£5,516
Semi Detached	72%	80%	88%	90%	50%	50%	£7,092
Detached	72%	80%	88%	90%	80%	50%	£7,092

Sector	GSHP	ASHP	Biomass boiler	Gas engine CHP	Small gas turbine	% Electric buildings suitable
Commercial						
Healthcare	55%	63%	80%	80%		0%
Hospitality	55%	63%	80%	80%		0%
Leisure	50%	58%	58%	58%		0%
Office	45%	53%	53%	53%		0%
Retail	45%	53%	53%	53%		0%
Warehouse	50%	58%	58%	58%		0%
Education	50%	58%	58%	58%		0%
Other	45%	53%	53%	53%		0%
Public sector						
Education	50%	58%	58%	58%		0%
Healthcare	55%	63%	80%	80%		0%
Office	45%	53%	53%	53%		0%
Retail	45%	53%	53%	53%		0%
Restaurant/public house	45%	53%	53%	53%		0%
Warehouse and storage	50%	58%	58%	58%		0%
Industrial low temp	0%	0%	85%	85%	0%	
Industrial high temp	0%	0%	0%	0%	50%	

These values are based on applicability assumptions used by the SEAI in existing analysis of Renewable Heat Potential in Ireland[103]. The SEAI study does not include gas CHP, and so commercial gas CHP values are based on the applicability of biomass boilers, assuming that similar base-load requirements are needed. In the domestic sector, it is assumed that low H:P mCHP (fuel cells) can be viewed as a boiler replacement, but that high H:P ratio mCHP (Stirling Engine) requires a larger baseload.

[102] The potential and costs of district heating networks. Pöyry and Faber Maunsell (AECOM). Report to the Department of Energy and Climate Change (DECC). 2009.
[103] Renewable Heat in Ireland to 2020. SEAI. 2015.

APPENDIX 3 – HEAT MAPPING

Methodology and assumptions used in the development of the Heat Map

The development of an Ireland-wide heat map is the starting point for this study. This forms the basis for the assessment of district heating network potential and high efficiency CHP potential. Key components of the heat map development are:

- Description of current heating and cooling demand covering the domestic, commercial, public, and industrial sectors.
- Forecast of how this demand may change over the next 10 years.
- Mapping of heating and demands, and mapping existing and planned heat supply schemes.

For calculating the energy demands two complementary approaches have been applied:

- Bottom up. Calculating demands based on characteristics of the heat users.
- Top down. Using measured energy consumption data. National statistics have been used to help verify the bottom up assumptions where comparable data is available.

Stage 1: **Production of heat mapping dataset**

The heat mapping dataset produced describes at a Small Area level:

- heat demands for domestic and non domestic buildings. These are annual heat demands (both for 2015 and 2025), and linear heat density.
- industrial demands and waste heat availability for EU ETS sites.
- the location of industrial sites within the Large Industry Energy Network group.
- road lengths used for the calculation of linear heat density
- key energy supply technologies including power stations

Other data are included within the dataset to support the CBA following GIS analysis.

Stage 2: **Presentation of heat map and identification of areas**

The heat map data is presented as a GIS map with a Small Area resolution. Small Areas are areas of population comprising between 50 and 200 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi). Small Areas were designed as the lowest level of geography for the compilation of statistics in line with data protection and generally comprise either complete or part of townlands or neighbourhoods. There is a constraint on Small Areas that they must nest within Electoral Division boundaries[104].

The GIS system was used to set up scenarios for analysis of high efficiency heating potential. This allowed the filtering of the heat map by linear heat density to select Small Areas that meet the criteria for the selection of zones to conduct the technical assessment of heat network potential.

The contiguous areas made up of Small Areas are grouped and form a zone. Any zones which are made up of one or more Small Areas, and which have a distance of 2km or less between them, are joined to form a larger zone, in line with the JRC guidance. The connection distances are logged to allow assessment of

[104] http://www.cso.ie/en/census/census2011boundaryfiles/

district heating interconnects. These combined zones are then used as the basis for the national CBA assessment.

It is important to note that the baseline is defined as the data set obtained through the heat map modelling to estimate the heat demands per sector in 2015. The CBA modelling is based on the forecast 2025 demand obtained through the heat map modelling.

Stage 3: **Assessment of DH and technology options, and national CBA**

This stage is used to conduct the technical assessment. For each zone, the following calculations take place:

- Assessing the baseline / counterfactual heating systems and costs, based on the number and size of buildings, and the existing fuel types.
- Assess alternative heating system costs using building scale technologies.
- Calculate the capital cost of installing heat networks across each zone based on linear heat density.
- Assess the cost of heat network schemes based on a number of appropriate supply technologies.

For the counterfactual, alternative low carbon technologies, and heat network schemes, the average levelised costs of heat are calculated across the zone, alongside the NPV.

Data sets

Data have been collected from different sources and analysed using benchmarks and other defaults and assumptions to estimate heat demands for different sectors: domestic, commercial, public sector and industrial. The following sections describe the data and methodology for each sector.

Domestic sector

Data sources	Type of data	Comments
CSO Small Area (SA)	Household types and numbers at Small Area level together with fuel sources distribution	• Provides information on housing form and heating / fuel type at Small Area level.
Geodirectory	Address points	• Provides exact geographic location of each address and associated Small Area at building level.
BER	577,000 BERs with address, dwelling type and BER rating	• Limited BER data for around 1/3 of the housing stock. • Data available with Eircodes (but no conversion to location/Small Area)
"Unlocking The Energy Efficiency Opportunity" report, June 2015	Energy benchmarks by house type	• Provides energy benchmarks for different house types and different energy efficiency packages. • Contains benchmarks for different efficiency specifications.
NRA	Population Growth	• Estimates of population growth per county

	Estimates	and CSO_DED level from 1986 in 5 year intervals.
SEAI Final Energy Demand statistics, 2013	Ireland consumption by fuel type for Residential sector	• National level consumption statistics broken down by fuel type. • Based on national import data with model supporting fuel split • Not available at a disaggregated geographic level.

The Domestic heat demand has been modelled based on the Small Areas set out in the CSO Census data of 2011. This identifies a total of 18,488 Small Areas in the Republic of Ireland to allocate heat demand to.

Household types

The CSO Census data provides the total number of houses and apartments (over 1.6 million households) in each Small Area (98%, with 2% allocated to *Other* or *Unknown* types) with a distribution overall of 11% *Apartments* and 87% *Houses*. In order to estimate the heat demand of these dwellings, benchmarks of annual kWh per household were used from the "Unlocking The Energy Efficiency Opportunity" report, June 2015. This study identifies different benchmarks for different house types (detached, semi-detached and terraced) and therefore, there is a requirement to understand the specific distribution of each type of house within each Small Area out of the total number of houses provided by the CSO data set.

To estimate this spread per Small Area, the BER data has been used to provide a representative sample of different house types in each Small Area.

The BER data provides the following house types which have been in turn allocated to each of the three main benchmark categories:

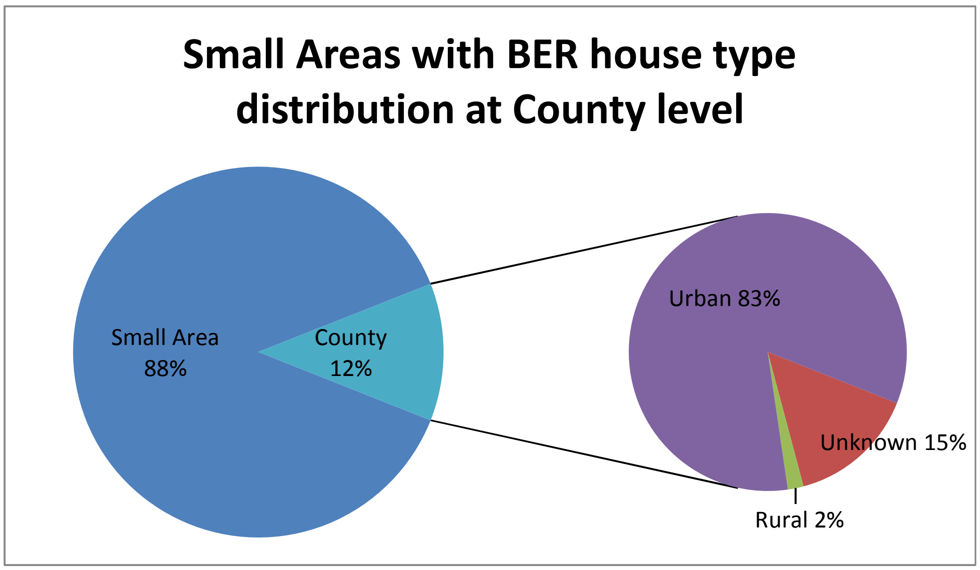
BER CATEGORIES	BENCHMARK TYPES
Apartment	Apartment
Basement Dwelling	Apartment
Detached house	Detached house
End of terrace house	Semi-D House
Ground-floor apartment	Apartment
House	Semi-D House
Maisonette	Apartment
Mid-floor apartment	Apartment
Mid-terrace house	Terraced House
Semi-detached house	Semi-D House
Top-floor apartment	Apartment

In order to quantify the numbers of each house type from BERs in each Small Area, the address recorded in each BER was matched against the GeoDirectory of Ireland postal addresses to identify the Small Area for each, and thus the number of benchmark house types in each Small Area. Using a number of algorithms on an Access database, out of the ~ 576,000 BERs with addresses (considered for the purpose of this study to correspond to unique buildings and not include more than one BER for a given building), over 340,000 (59%) were matched to a postal address with a 90% match score or higher. About 320,000 (94% of matches) were matched to a 100% accuracy level, with the reminder matched to a level of 90%

and above. Not all addresses in the Geodirectory have a Small Area and therefore, although addresses were found for 340,000 BERs, only about 330,000 of these have a Small Area. This is the number of BERs finally used to provide approximations for distribution of house types and energy benchmarks.

The representativeness of the BER distribution of house types varies across Small Areas. In cases where no BERs were identified for a given Small Area, a BER County level distribution of house types and energy benchmarks was used as a default approximation. This was applied to 2,221 Small Areas (12%). 83% of these are identified as Urban Small Areas, with the rest being Rural or Unknown.

Figure 35 - Small Areas with BER house type distribution at County level



For the 88% Small Areas for which at least one BER was identified:

- 26% of them have house type distributions corresponding to BERs for less than 10% total houses (excluding apartments).
- 53% of them have BERs identified for between 10% and 30% of total houses, and
- 21% with BERs identified for more than 30% of total houses.

No significant differences in these levels were identified for Urban or Rural Small Areas.

Figure 36 - Small Area with BER house type distribution at SA level

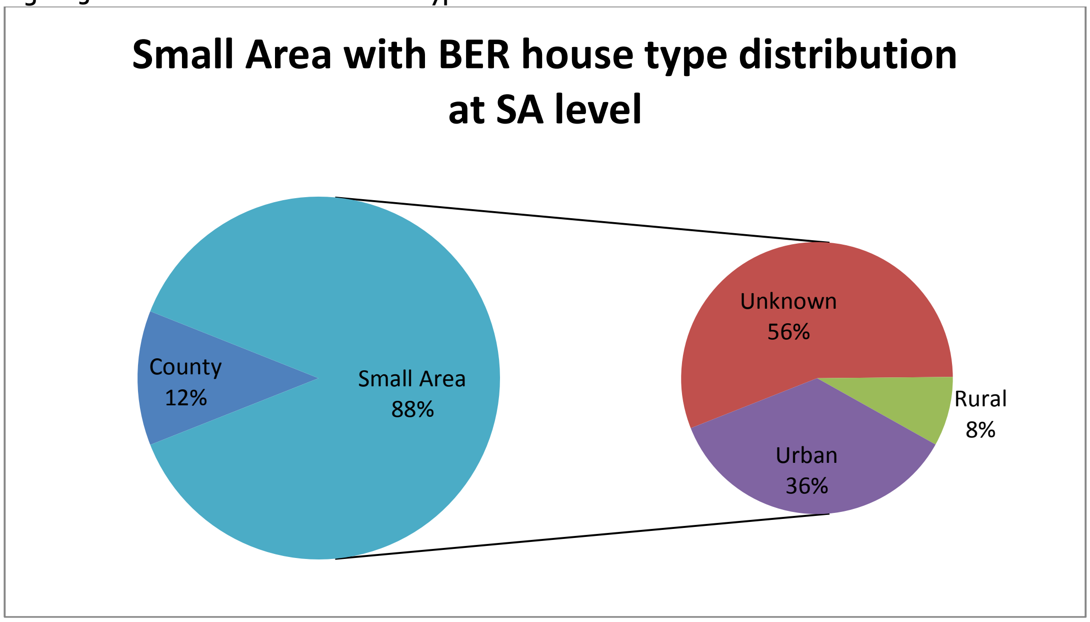
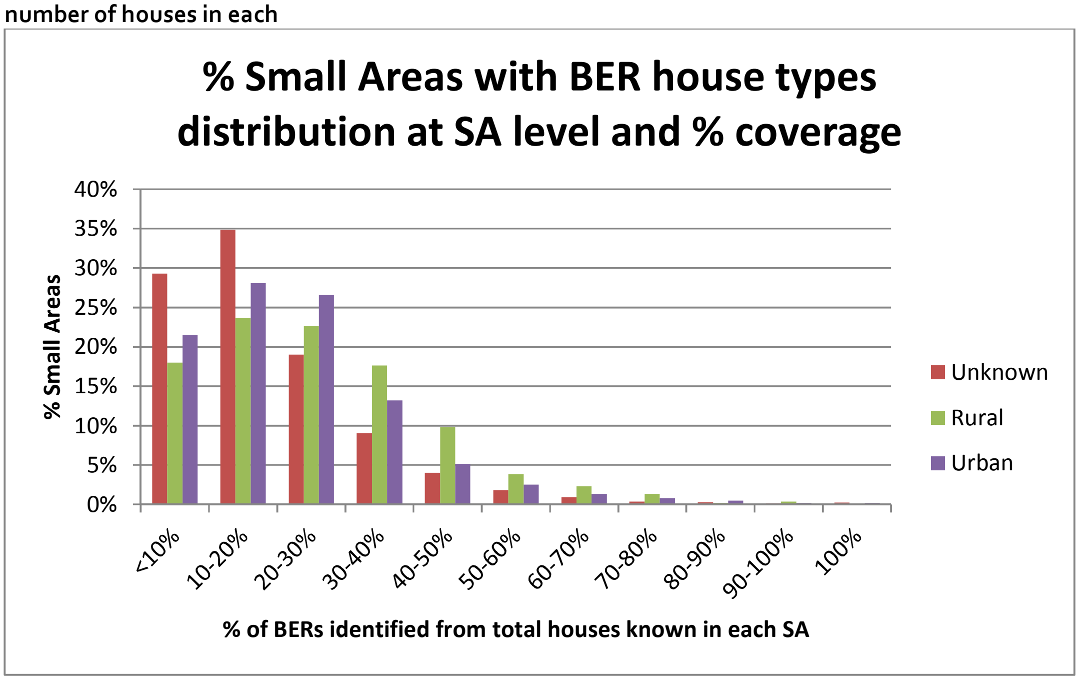


Figure 37 - % Small Areas with BER house types' distribution at SA level and % BERs coverage of total number of houses in each



A final distribution of household types was derived per Small Area. The aggregated country-wide distribution looks as follows:

Apartment	11%
Detached House	33%
Semi-D House	41%
Terraced House	13%

Energy consumption benchmarks and heat demands

For each Small Area, the number of BERs per Rating (A1 to G) and household type was identified, and an average, composite energy consumption benchmark was produced for each from the Initial (baseline) benchmarks identified in the "Unlocking The Energy Efficiency Opportunity" report. The benchmarks used correspond to Natural Gas heating fuel for Natural Gas consumption as follows:

	INITIAL (MWh per building)						
	A1-B2	***B3-C1***	***C2-C3***	***D1-D2***	***E1-E2***	***F***	***G***
Apartment	5	6	7	9	10	12	13
Detached House	11	14	16	19	24	27	37
Semi-D House	7	9	11	14	18	21	29
Terraced House	6	7	8	11	13	15	20

A counterfactual efficiency for heat of 85% was used to estimate annual heat demand for each household type per Small Area providing a total country-wide baseline of about 20.2 million MWh.

Energy efficiency was then introduced by re-calculating the heat demand baseline using the same methodology as above but applying the "Unlocking The Energy Efficiency Opportunity" report benchmark for Medium Installed energy efficiency package. This includes cavity wall and roof insulation, draught proofing, energy efficient lighting, energy efficient appliances and heating controls.

	MEDIUM INSTALLED PACKAGE (MWh per building)						
	A1-B2	***B3-C1***	***C2-C3***	***D1-D2***	***E1-E2***	***F***	***G***
Apartment	5	5	7	8	9	10	11
Detached House	11	13	15	17	20	22	27
Semi-D House	7	9	10	12	15	17	20
Terraced House	6	6	8	9	11	12	15

The annual country-wide aggregated energy efficiency heat demand of existing households is estimated to be in the region of 17.3 million MWh.

Finally, estimated heat demand for 2025 (10 year projection) was calculated by adding estimated growth of households per Small Area to the energy efficient estimated heat demand of existing buildings. The growth was calculated using population growth estimates (from 2011, year of the census data, to 2026) at CSO_DED[105] level (or county level if no Small Area identified) spread equally amongst the Small Areas for each and applied to the current volume of household types. One of the weaknesses of this approach is that, for those Small Areas with no recorded households of a specific type (e.g. no apartments), no growth of such household type is predicted. For estimating the heat demand of the growth, energy benchmarks from the "Unlocking The Energy Efficiency Opportunity" report for Medium Installed package and rating of A1-B2 are allocated to each house type:

[105] CSO_DED level is a geographical level intermediate between County and Small Area – population growth estimates were available at this level of disaggregation.

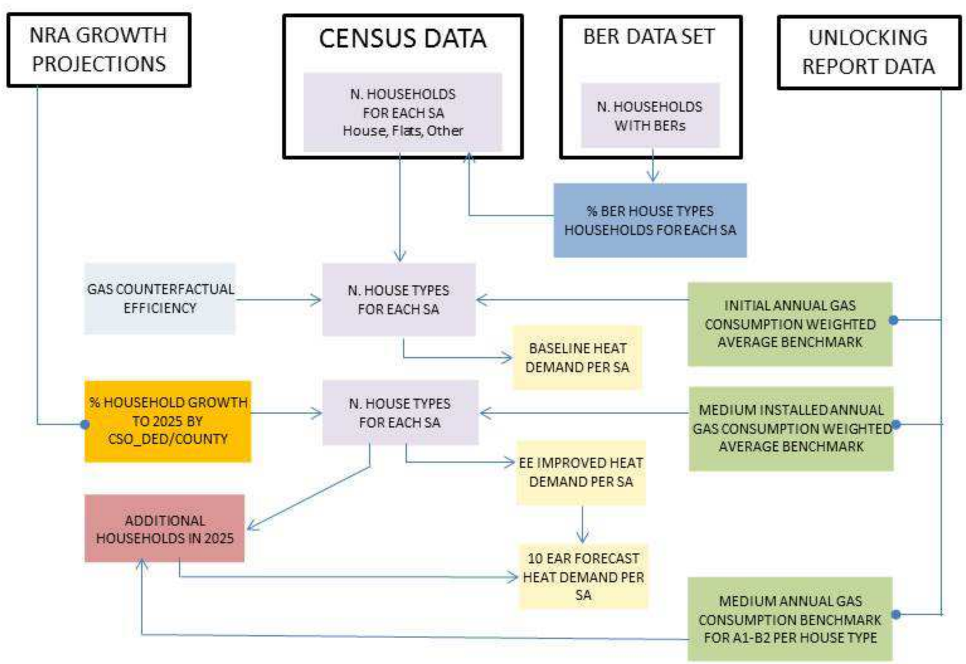
	MEDIUM INSTALLED PACKAGE (MWh per building) *A1-B2*
Apartment	5
Detached House	11
Semi-D House	7
Terraced House	6

The annual country-wide aggregated 10 year projection is estimated to be around 18.4 million MWh.

Calibration

To sense check the results obtained, the Energy Balance[106] figures for Residential Consumption by Fuel Type for 2013 were obtained. These national energy balance figures are themselves based on models (due to lack of metered fuel use in every house) and therefore provide a useful comparison, but may not be robust enough for "calibration" purposes. In terms of estimated heat demand, overall results obtained from the heat map domestic model fall within less than 9% difference from those shown by the Energy Balance, with a very similar distribution per fuel type. Following this check, a decision was taken not to adjust the results obtained by the model.

Figure 38 - Domestic data set methodology



[106] http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=SEI01&ProductID=DB_SEI&PLanguage=0

Public Sector

Dataset	Type of data	Comments
Public Sector Energy Efficiency Performance submissions	Energy consumption by Public Bodies for 2014	• Contains details of total energy consumption per fuel source for each Public Body, thus aggregated (one PB could include multiple locations/buildings) • Gas Meter data • Gas Meter description (free text field) which may include address of Gas Meter in a free text format
Geodirectory	Address points	• Provides exact geographic location of each address and associated Small Area at building level.
"Unlocking The Energy Efficiency Opportunity" report, June 2015	Energy demand benchmarks by sector for different size and building use types with energy efficiency	• Provides energy demand benchmarks for public sector buildings of different use types, building sizes, and HVAC systems. • Contains benchmarks for different efficiency specifications. • Based on analysis of the BER dataset and survey data.
NRA	Population Growth Estimates	• Estimates of population growth per county and CSO_DED level from 1986 in 5 year intervals.

Buildings and Small Areas

The Public Sector EE Performance submissions provide annual gas consumption reported to SEAI by the meter operator for 3,625 gas meters. This data includes hospitals and schools. Each gas meter contains a free text description field which in many cases, contains the address or partial address information for the meter. For each, the Public Body ID and name are identified. A first stage of processing required data cleaning, followed by an identification of separate address parts from the description, followed by a matching procedure using the Geodirectory to identify Small Areas for each gas meter. 497 gas meters were excluded due to lack of data (no consumption or blank address). 39 meters with negative consumption reported were excluded as well as some duplicated entries. A visual inspection and match of the remaining with the ETS dataset allowed the discard of another 25 meters (to avoid duplication – this involved 4 entities with consumption reported in this data set as well as via the ETS). A few entries were also discarded as they had the potential to being included in the VO dataset part of the Commercial data. Following this, 3,062 gas meters remained (84% of original).

The following assumptions were then used to identify unique, individual buildings (where several gas meters appear to feed one building a at a single address): looking sequentially at gas meters by County and Public Body ID, 1st line of Address and then use type, when combination same or similar, a unique building is assigned to multiple GPRNs. In this way, 2,718 potential unique buildings were identified. Small Areas were identified for 1,472 of them (54% of unique buildings).

Energy consumption benchmarks and heat demands

The weather corrected gas consumption reported for each building in each Small Area forms the baseline for this dataset. A counterfactual efficiency for heat of 85% was used to estimate annual heat demand

In order to evaluate the energy efficiency potential for these buildings, a 13% reduction on reported consumption has been applied. This is based on information provided in section 2.5 of the "Unlocking The Energy Efficiency Opportunity" report, June 2015. Assumptions of measures taken by Public Sector buildings include:

Primary Energy saving per measure in TWh	
7-Draught proofing	0.1
8-Cavity Wall Insulation	0.06
10-Roof insulation	0.21
13-Solid wall insulation	0.08
15-EE glazing	0.47
TOTAL	***0.92***

With primary energy consumption in this sector identified in 2013 as 7 TWh, the above savings amount to 13% which is applied to the Public Sector buildings consumption provided by the gas meters.

Estimated heat demand for 2025 (10 year projection) was calculated by adding estimated growth attributed to each public sector building evaluated, to the energy efficient estimated heat demand of existing buildings. The growth in buildings was calculated using population growth estimates (from 2011, year of the census data, to 2026) at county level.

To estimate the heat demand of the growth, energy benchmarks from the "Unlocking The Energy Efficiency Opportunity" report were used. The heat consumption figure for new buildings is estimated as growth of existing consumption (without energy efficiency) then calibrated to the new building benchmarks as follows:

- Large or small building is assumed depending on whether baseline consumption is above or below average for the use type.
- An assumption is made that baseline buildings are 50:50 split of ventilation type.
- An assumption is made that baseline buildings are 50:50 split of quality (good/poor).
- A composite energy benchmark for each use type is calculated as above as the baseline benchmark (using the Initial benchmarks) on which current consumption would be based.
- A composite benchmark for each use type is calculated for new buildings based on all being of good quality, 50:50 split of ventilation type, and for the Medium Energy Efficiency package. This includes cavity wall and roof insulation, draught proofing, energy efficient lighting, heating controls, energy efficient office equipment and refrigeration and more efficient boilers.

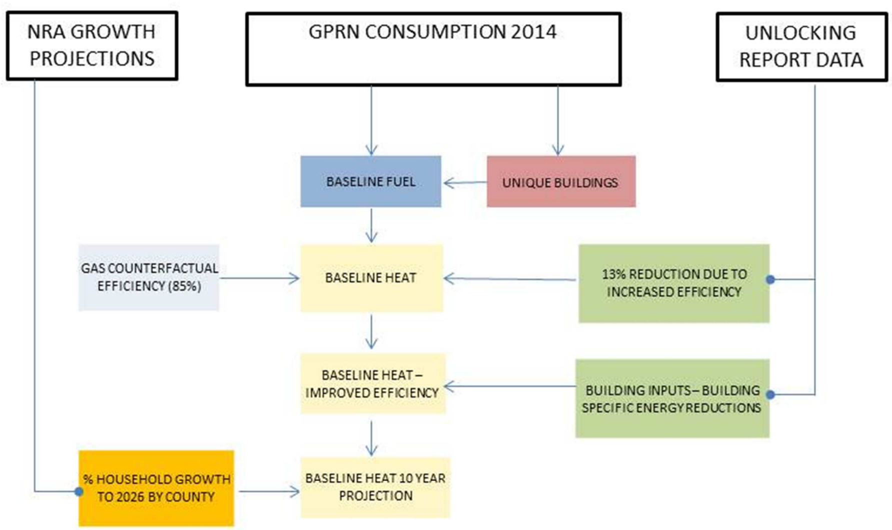
A calibration factor is applied to the consumption growth based on the difference between initial and new buildings composite benchmarks for large versus small buildings. In this way, adding up the energy efficient heat demand of existing buildings with energy efficiency measures plus the growth heat demand provides the future 10 year forecast heat demand.

The main weakness of this dataset is that this it represents a very small percentage of the overall Public Sector buildings in Ireland.

To apply relevant benchmarks to each building use type, the types provided in the gas meter data have been converted to the types available in the "Unlocking The Energy Efficiency Opportunity" report as follows:

Gas meter building type	"Unlocking The Energy Efficiency Opportunity" report building types
Education Building	Education
Healthcare Building	Healthcare
Office Building	Office
Other	Office
Other Building	Office
Other Processing	Retail
Restaurant/public house	Restaurant/public house
Transport	Warehouse and storage
Unknown	Office

Figure 39: Public sector data set methodology



Commercial Sector

Dataset	Type of data	Comments
Valuation Office (VO)	Floor areas by building and Small Area	• List of Valuation Office Rateable properties with Use Type, and Small Area • Provides floor areas for most properties in Dublin, Limerick and Waterford. No floor areas available for other locations.
CIBSE TM 46 energy benchmarks	Energy demand by sector per m2	• Benchmark dataset developed for UK DECs. Covers a number of different sectors (use types).
Geodirectory	Address points	• Provides geographic location of each address and associated Small Area at building level.
Non Domestic BER	41,718 BERs with address, use type, heating type, floor area and BER rating	• Data available with Eircodes (but no conversion to location/Small Area)
"Unlocking The Energy Efficiency Opportunity" report, June 2015	Energy demand benchmarks by sector for different size and building use types with energy efficiency	• Provides energy demand benchmarks for public sector buildings of different use types, building sizes, and HVAC systems. • Contains benchmarks for different efficiency specifications. • Based on analysis of the BER dataset and survey data. • Provides distribution of building sizes and performance levels per type
NRA	Population Growth Estimates	• Estimates of population growth per county and CSO_DED level from 1986 in 5 year intervals.

Buildings and Small Areas

A first stage of processing required VO data cleaning, excluding not applicable entries (e.g. yards, car parks,), and separating commercial from industrial entries. Re-classification of VO use types to CIBSE sectors was also produced to enable benchmarking. The Geodirectory is used to identify the county for each Small Area in the VO data set. There are VO entries for 12,904 Small Areas (70%). In total, there are 153,260 VO premises in the commercial data set. 30% of these (all in Dublin, Limerick and Waterford) have floor areas.

The BER records were matched using the Geodirectory to obtain the Small Areas for each. 66% of BER records were matched to a Small Area.

In order to allow the calculation of heat demand, CIBSE benchmarks were used which correspond to kWh per m^2. Therefore, the aim of this stage is to estimate floor areas for all known commercial buildings (VO entries) for which no areas are available (70% of VO premises).

When the number of BER buildings in a Small Area is higher than 50% of the VO buildings with no floor area then the BER average floor area for the use type/sector for the Small Area is used to estimate the missing floor areas. Otherwise, a BER county floor area average for the use type/sector is used to approximate the missing floor areas.

Energy consumption benchmarks and heat demands

For the total floor area of commercial buildings calculated, the CIBSE use type/sector fossil-thermal benchmarks were used to obtain heat demands using a counterfactual efficiency for heat of 85%. This forms the baseline heat demand for the heat map for commercial buildings.

To estimate the energy efficient heat demand of the existing commercial building stock, energy benchmarks from the "Unlocking The Energy Efficiency Opportunity" report were used for each use type/sector. An energy efficient benchmark was calculated for each as follows:

- An assumption was made that baseline buildings are distributed in size as follows[107]:

Building size distribution	Small	Large
Hotel	75%	25%
Office	95%	5%
Restaurant/public house	100%	0%
Retail	93%	8%
Warehouse	86%	14%

  For other building types, the overall building distribution is used (93% small / 7% large).
- An assumption was made that baseline buildings are 50:50 split of ventilation type.
- An assumption was made that baseline buildings are Good or Poor depending on their percentage distribution of double/triple glazing (80% or over for Good, the rest are considered Poor)[70]:

Building performance level	Poor	Good
Hotel	9%	91%
Office	22%	78%
Restaurant/public house	46%	54%
Retail	46%	54%
Warehouse*	72%	28%

  **Warehouse figures estimated from Figure 22 in the Extensive survey of the commercial buildings stock in the Republic of Ireland*

  For other building types, the overall building distribution is used (64% Good / 36% Poor).

- A composite energy benchmark for each use type was calculated as above as the baseline benchmark (using the Initial benchmarks) on which current consumption would be based. In a similar way, a composite energy benchmark for each use type is calculated as above using the Medium package benchmarks. A factor between the two is obtained which is applied to the current heat demand Based on CIBSE energy benchmarks) to obtain the estimated energy efficient heat demand of current building stock.

[107] http://www.seai.ie/Publications/Energy_Policy_Publications/Energy_Modelling_Group_Publications/Extensive-Survey-of-Commercial-Buildings-Stock-in-the-Republic-of-Ireland.pdf

Finally, estimated heat demand for 2025 (10 year projection) was calculated by adding estimated building growth per Small Area to the energy efficient estimated heat demand of existing buildings. The growth was calculated using population growth estimates (from 2011, year of the census data, to 2026) at CSO_DED[108] level (or county level if no Small Area identified) spread equally amongst the Small Areas for each and applied to the energy efficient heat demand. One of the weaknesses of this approach is that, for those Small Areas with no recorded buildings, no growth of such building type is predicted. This assumes that new commercial buildings have a similar heat demand as current buildings with energy efficiency.

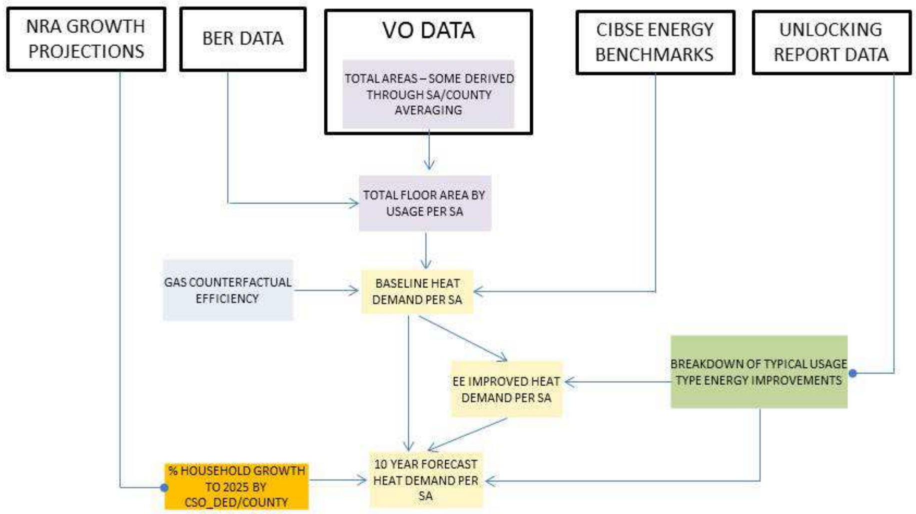
Calibration

For the % distribution of fuel type per Small Area approximated by the County level BER distribution, a calibration has been introduced to adjust the electricity % allocation per sector as per the % shown in the "Unlocking The Energy Efficiency Opportunity" report, with the remaining fuels adjusted accordingly.

The "Unlocking The Energy Efficiency Opportunity" report identified the annual volume of oil and gas used for heating in the Commercial sector (2.3TWh). This figure was used to provide a check on the heat demand estimates obtained through the model. Heat demand obtained from the commercial heat map model was identified to be very high in relation to this. This is believed to be mainly due to the approach taken to the allocation of floor area estimates for the VO entries in locations outside Dublin, Limerick and Waterford (see above). For Small Areas where no sufficient BER data allowed for estimates to be provided at this level, overall county level estimates were used. As BER data is believed to be greatly skewed towards new buildings rather than existing ones, and these are highly likely to contain bigger commercial buildings than probably are present in many of the locations involved (more rural areas in general with lesser likelihood of this type of building sizes), a reduction factor of 90% was applied when approximating unknown floor areas using the county level BER averages. This provides a good match between the modelled gas and oil data and figure from the Unlocking The Energy Efficiency Opportunity" report.

[108] CSO_DED level is a geographical level intermediate between County and Small Area – population growth estimates were available at this level of disaggregation.

Figure 40: Commercial data set methodology



Industrial Sector

Dataset	Type of data	Comments
Valuation Office (VO)	Floor areas by building and Small Area	• List of Valuation Office Rateable properties with Use Type, and Small Area • Provides floor areas for most properties in Dublin, Limerick and Waterford. No floor areas available for other locations.
EU ETS	Energy use and CO_2 emissions for each ETS site	• Contains details of facility (Name, site location and industrial sector, NACE code) • Energy consumption by fuel type • No information on end use of energy.
CSO POWSCAR	Location of employment	• Contains number of jobs per Small Area and sector
LIEN	Locations of LIEN sites	• Site location of LIEN facilities (many of which will be covered under EU ETS). • No information on energy demand per facility due to confidentiality reasons.
Energy Consumption in the UK: Industrial Sector data tables	Energy demand by industrial sector, fuel type, and process type	• Can be used as a proxy for Irish industry. • Allows a breakdown of input energy into different types of processes by industrial sector.
Reference paper: Spatial Modelling of Industrial heat loads and recovery potential in the UK. McKenna and Norman. Energy Policy 38 (2010)	Research paper examining heat recovery potential	• Research paper aiming to identify technical recoverable heat potential from UK industry. • Suggests that min target is heat recovery from exhausts. • Around 50% of exhaust heat can be recovered. • Suggests exhaust fractions are around 5 – 10% of total input thermal energy in most efficient systems. A figure of around 10% appears representative across many sectors shown. • This therefore suggests that approx 5% of total input thermal energy used for combustion processes can be recovered. • Additional heat recovery may be possible from the processes, but is not quantified.

There are three subsets of this dataset as follows:

Industrial sector space heat demands

A first stage of processing required VO data cleaning, excluding not applicable entries (e.g. yards, car parks,…), and separating commercial from industrial entries. The Geodirectory is used to identify the county for each Small Area in the VO data set.

There are 4,618 VO industrial premises covering 2,142 Small Areas. An evaluation is made to assess whether in each Small Area, the floor areas for all buildings are available or not. If this is the case, the number of jobs in each Small Area (provided by an extract from the CSO POWSCAR) is identified. The average number of jobs per m^2 floor area (from the VO entries) of industrial buildings in each Small Area is then calculated. This provides an overall country-wide average of jobs per m^2 floor area (eliminating outliers showing averages of more than 0.5).

For each VO premise where the area is not known, an estimate is produced of the number of jobs per building (from total number of buildings in each Small Area in the VO data) in each Small Area. This is used in to estimate the missing total floor area for each VO premise (by multiplying the jobs per building in each by the total average jobs per m^2 floor area).

The baseline heat demand is then calculated, excluding those premises present in the ETS dataset (see below), applying the CIBSE benchmark for workshops and a counterfactual efficiency for heat of 85%.

The 10 year forecast heat demand is calculated using a percentage growth from FED Industrial 2011[109]. This accounts for efficiency improvements and growth. Forecast data for heating is based on total energy demand, not broken down by fuel type

ETS – Heat Types

113 ETS industrial entities are included in this dataset. Power generation sites are excluded since they form part of the power generation dataset in the heat map.

Using *Table 4.05: Industrial final energy consumption by end use (different processes), 2014*, part of the Energy Consumption in the UK, Industrial sector data tables, 2015 update, the ETS entries were matched via the NACE codes to the SIC codes in the table to estimate the energy use at each site by end process[110]. This allowed the application of the % of reported consumption which could be attributed to high temperature process, low temperature process, drying/separation and space heating.

The total potential heat for district heating is estimated as the total allocated energy to low temperature process, drying/separation and space heating with a counterfactual efficiency for heat of 85%.

This dataset assumes 100% of the above end uses are suitable for DH connection (this is reduced in the national CBA modelling).

ETS – Waste Heat Potential

113 ETS industrial entities are included in this dataset. Power generation sites are excluded since they form part of the power generation dataset in the heat map.

Using *Table 4.05: Industrial final energy consumption by end use (different processes), 2014*, part of the Energy Consumption in the UK, Industrial sector data tables, 2015 update, the ETS entries were matched via the NACE codes to the SIC codes in the table to estimate the energy use at each site by end process. This allowed the application of the % of reported consumption which could be attributed to low temperature process, drying/separation and space heating.

For processes listed under combustion only (all of the dataset in this case), the following assumptions are used by relevant sector to determine magnitude of potential waste heat recovery:

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[109] http://forecasts.seai.ie/chart.php?ref=FED11

[110] The use of UK data here is considered justifiable since Ireland specific data is not available, and the data is used to split demand by process type for each industry sector. Whilst the fuel use may differ for Ireland, the end use is unlikely to differ from UK industry.

Assumption	Source
Typically half of the sensible heat in an exhaust stream might be technically recoverable	Section 2.3 of McKenna and Norman 2010 article - Spatial modelling of industrial heat loads and recovery potentials in the UK
Fraction of total input energy contained in exhaust gases - Low heat fraction typically 5-10%, High heat fraction typically 10-20%	Table 3 of McKenna and Norman 2010 article - Spatial modelling of industrial heat loads and recovery potentials in the UK
Gives proportion of exhaust heat that is already recovered and used in processes for each industry	Page 58 Appendix for the final report for The potential for recovering and using surplus heat from industry, Element Energy,2014

Energy from which waste heat can be potentially recovered is estimated from that allocated to high temperature process, low temperature process, and space heating. A waste recovery factor is then applied to each premise according to its NACE/SIC type to obtain the accessible waste heat. The waste heat recovery factor is calculated for each premise as follows:

Exhaust heat fraction X (1- proportion of heat recovery realised) X 50% (typically half of the sensible heat in an exhaust stream might be technically recoverable)

Fraction of input energy in exhaust:

	low exhaust fraction	high exhaust fraction	average exhaust fraction
CHP	0	0	0
Boilers and steam systems	0.05	0.1	0.075
Aluminium	0.05	0.1	0.075
Cement	0.1	0.2	0.15
Ceramics_bricks	0.05	0.1	0.075
Chemicals_ammonia	0.05	0.1	0.075
Chemicals_carbon black	0.05	0.1	0.075
Chemicals_general	0.05	0.1	0.075
Chemicals_stream cracker	0.05	0.1	0.075
Food and drink_breweries	0.05	0.1	0.075
Food and drink_distilleries	0.05	0.1	0.075
Food and drink_maltings	0.05	0.1	0.075
Food and drink_sugar beet	0.05	0.1	0.075
Food and drink_sugar cane	0.05	0.1	0.075
Glass_flat	0.1	0.2	0.15
Glass_container	0.1	0.2	0.15
Glass_other	0.1	0.2	0.15
Lime	0.1	0.15	0.125
Gypsum	0.05	0.1	0.075
Mineral/rock wool	0.1	0.2	0.15

If any building does not fit into one of the categories listed above, the default exhaust heat fraction is 9% (Fraction of total input energy contained in exhaust gases - Low heat fraction typically 5-10%, High heat fraction typically 10-20%).

Proportion of heat recovery already realised:

	Heat realised	heat remaining
Cement	65%	35%
Ceramics	38%	62%
Chemicals	67%	33%
Food and Drinks	44%	56%
Glass	58%	42%
Iron& Steel	50%	50%
Oil refining	63%	38%
Paper and pulp	25%	75%

If any building does not fit into one of the categories listed above for the heat realised, the average factor (51%, which gives the proportion of exhaust heat that is already recovered and used in processes for each industry) is applied as the proportion of heat recovery realised.

Figure 41: Industrial data set methodology