National Heat Study

District heating and cooling: Spatial analysis of infrastructure costs and potential in Ireland

Appendix B - Heat Network Costs and Deployment

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Contents

I. Introduction

I. Introduction

The National Heat Study aims to provide a rigorous and comprehensive analysis of the options to reduce CO_2 emissions associated with heating in Ireland. The Sustainable Energy Authority of Ireland (SEAI) commissioned Element Energy and Ricardo Energy and Environment to work with SEAI on the study. The project was carried out in close collaboration with the Department of the Environment, Climate and Communications.

As well as contributing to national policy, the findings also supported Ireland's second submission to the EU of a National Comprehensive Assessment of the Potential for Efficient Heating and Cooling, as required by Article 14 of the Energy Efficiency Directive. The data, assumptions and outcomes of the National Heat Study are detailed in eight technical reports. The concluding report is *Net Zero by 2050*, which outlines the study's key insights across scenarios that achieve net-zero emissions from heating and cooling.

The present slide deck is an appendix to the *District Heating and Cooling: Spatial Analysis of Infrastructure Costs and Potential in Ireland* report.

Official Journal of the European Union, 2012. 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

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I. Introduction

The purpose of the 'Heat network costs and deployment' task was to produce a database containing the costs associated with constructing a district heating network. The data have then been used to model the capital cost of district heating schemes as part of the National Heat Study. The first objective of this task was to understand how cost is affected by:

I. Pipe diameter
II. Trenching – the cost to physically dig space underground for the network to be laid
III. Soft or hard digging – how the terrain affects trenching
IV. 2 or 4 pipe network – if the system provides a flow and return for just hot water, or if cooling is also provided
V. Year of Construction – 2020, 2030, 2040 and 2050

This data was then to be paired with the heat demand for the 18,641 small areas that make up Ireland, to model the cost of implementing a district heating network for each small area.

Alongside this, tailored stakeholder questionnaires and a literature review were conducted to understand the existing and future district heating networks within Ireland.

II. Background information & literature review

II. Background information & literature review

Key Studies reviewed	Description
A guide to district heating in Ireland (2016)	*A guide to district heating in Ireland* was a report produced as a collaboration between Codema and BioXL in 2016 on behalf of the Irish Bioenergy Association (IrBEA), funded by the SEAI National Energy Research, Development and Demonstration programme. This is a key piece of literature for reviewing the state of district heating in Ireland.
Cost benefit analysis of the potential for high-efficiency cogeneration and efficient district heating & cooling in Ireland (2015)	As part of the 2015 National Comprehensive Assessment of Ireland, AECOM developed a model for assessing the district heating potential throughout Ireland. Findings were presented in *Cost benefit analysis of the potential for high-efficiency cogeneration and efficient district heating & cooling in Ireland*.
Scheme specific case studies	Search of literature on specific studies related to DH schemes was also undertaken (e.g. Tralee District Heating System, Elm Park district heating scheme, Stewarts Care heat network, Cloughjordan Ecovillage).

Gartland D., and Bruton T., Codema & BioXL, 2016. A guide to district heating in Ireland. Available at: Guide_to_DH_in_Ireland_Final.pdf (codema.ie)
AECOM, 2015. Cost benefit analysis of the potential for high-efficiency cogeneration and efficient district heating & cooling in Ireland. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/20151221%20SEAI%20EED%20ART14%20-%20Final.pdf

II. Background information & literature review - Generations of heat networks

3rd Generation (3GDH): Developed from the 1970s onwards. Based on water with temperatures <100°C and incorporates pre-fabricated, pre-insulated pipes which are buried directly beneath the ground. They are the most common district heating (DH) systems today.

4th Generation (4GDH): Supplies lower temperatures than 3GDH, with flow at 45-55°C and return at 15-25°C. This reduces installation costs and heat losses to the ground. 4GDH works with a higher contribution of renewable energy, such as geothermal, solar thermal and heat pumps, and waste heat for decarbonisation purposes. Requires buildings with higher insulations standards than 3GDH. Needs supplementary boost for domestic hot water (DHW) unlike 3GDH. The annual heat supply costs for 4th generation are lower than 3rd generation as shown in the table below. It is evident the economic benefit to operating DHN at lower temperatures is more pronounced for modern solutions (geothermal and heat pumps) whereas for traditional technologies such as waste CHP and biomass CHP the benefit is not so apparent.

	Annual Heat Supply Costs [M€]	
Operational mode	**3GDH**	**4GDH**
Waste CHP	–9.9	–10.7
Biomass CHP	5.1	3.4
Biomass boiler	12.7	11.2
Geothermal	10.8	3.3
Geothermal investment	11.0	6.0
Industrial excess heat	17.4	11.6
Heat pump	15.9	8.9
Heat pump investment	15.1	10.5
Solar thermal investment	14.5	10.2

Notes: CHP: combined heat and power; 3GDH: third generation district heating; 4GDH: fourth generation district heating.

Table 1: Example of annual estimated heat demand costs for 3rd generation versus 4th generation heat networks (Averfalk and Werner, 2020)

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BEN UK. Fourth generation district heating networks. Available at: https://www.benuk.net/Fourth-Generation-District-Heating-Networks.html
Jones P. et al., 2019. A roadmap to achieve 5th generation heat networks in the UK. 5th International Conference on Smart Energy Systems, Copenhagen. Available at: https://smartenergysystems.eu/wp-content/uploads/2019/09/17-3_PhilJonesSESAAU2019.pdf
Averfalk H. and Werner S., 2020. Economic benefits of fourth generation district heating, Energy 193.. https://doi.org/10.1016/j.energy.2019.116727

II. Background information & literature review - Generations of heat networks

5th Generation (5GDH): Can provide cooling and heating from the same network, unlike 3GDH and 4GDH which require separate cooling networks. 5GDH utilises an ambient ground temperature distribution circuit. On the network, each building uses a heat pump to transfer heat into the building (heating) or out of the building (cooling). It is effectively a heat sharing network - providing cooling increases the temperature of the circuit to benefit those needing heat and vice versa. 5GDH is also known as 'cold district heating'.

The advantages of 5GDH include:

- Lower installation and running costs
- No on-site GHG emissions because there is no combustion mechanisms
- Modular expansion of networks possible
- No need for separate cooling network
- Negligible heat losses
- Does not require an energy centre since each building has a heat pump

Both 4th and 5th generation DH can deploy smart grid principles, such as demand side response controls that interact with the electricity market.

At present, the majority of district heat networks are 3rd generation. To meet carbon targets associated with heating, 4th and 5th generation networks are expected to become commonplace across Europe over the coming decades.

Buffa S. et al., 2019. 5th Generation district heating and cooling systems: A review of existing cases in Europe, Renewable and Sustainable Energy Reviews, 104, 504-522. https://doi.org/10.1016/j.rser.2018.12.059
Jones P. et al., 2019. A roadmap to achieve 5th generation heat networks in the UK. 5th International Conference on Smart Energy Systems, Copenhagen. Available at: https://smartenergysystems.eu/wp-content/uploads/2019/09/17-3_PhilJonesSESAAU2019.pdf

II. Background information & literature review - Stakeholder consultation questionnaire

A tailored stakeholder questionnaire was put together and sent to organisations/sites that operate a district heating network in Ireland. The intention was to gain an insight into the technical operation of the system and how much the construction of the network costs. A screenshot of the first page of the questionnaire is shown in Figure 1. Three responses were received, of which two have provided details associated with DH pipework costs. More details of existing/planned district heating networks in Irelands are available in the *District Heating and Cooling: Spatial Analysis of Infrastructure Costs and Potential in Ireland* report.

Outcomes of the Consultation: Whilst the costing information received from the surveys is useful, it is not comprehensive enough to complete the level of modelling required. Therefore, an alternative source of data was used to develop the pipe cost database. Instead, the questionnaire data was used to verify the database generated was accurate and ready for use in modelling.

National Heat Study

Heat and other networks (WP4) / Stakeholder consultation

We would be grateful if you could provide the information listed in the tables below based on your experience with district heating/cooling in Ireland. The input you provide will be used for the National Heat Study to develop ambitious but realistic trajectories for the uptake of low carbon heating systems and to make recommendations on policy to support low carbon heating.
In the below tables, where relevant, we have included data based on UK projects; these are provided as a 'baseline' and we would like to update them with data from Ireland if possible. If information is available in reports or other documents, please do not hesitate to refer to these in the below tables and please send a copy on to us if they are not available publicly – we are happy to discuss data confidentiality with you. We thank you in advance for your contribution.

Part 1 – General network information / Supply and End-uses	
Network location and name	
What useful end uses are supplied by the network?	a) Space heating b) Water heating c) Process heating d) Space cooling *(please delete as appropriate)*
Is cooling served by a chilled water network or a heat network serving individual absorption chillers?	
Number of customers connected to the heat network in each sector and ideally sub-sector	a) Housing (e.g. Detached, semi-detached, terraced, bungalows, flats) b) Public sector (e.g. Health, education) c) Commercial (e.g. Retail, leisure, offices) d) Industrial (e.g. Food and drink, chemical industry)
What fuel types are used?	*(e.g. Gas, biomass, etc)*
What central heat/cooling plants are connected to the network? And what is their capacity?	a) Oil boiler / Capacity: b) Gas CHP / Capacity: c) Biomass boiler / Capacity: d) Electric heat pump / Capacity: e) Electric chiller / Capacity: f) Absorption chiller / Capacity: *(please delete as appropriate)*
Fuel input in MWh for each plant	
Annual heating and cooling supply in MWh	Annual heating supply (MWh): Annual cooling supply (MWh):
Annual heating and cooling supply to consumers in MWh	Annual heat supply to consumers (MWh): Annual cooling supply to consumers (MWh):
Thermal storage type (hot water/other), capacity (MWh and volume), and temperature	Type: Capacity (MWh and volume): Temperature:
Annual heating/cooling losses	Heating losses: Cooling losses:

Figure 1: Screenshot from the stakeholder questionnaire

II. Background information & literature review – Examples of cost of district heating

Table 2 compares the levelised cost of district heating in various countries. When compared to the UK, the cost of Irish projects is higher, particularly for gas boiler DH. When compared to Denmark, market leader in district heating, Irish projects tend to be less expensive, with the exception of geothermal heating which is more expensive in Ireland.

Table 2: Cost of heat from different DH schemes for low energy buildings

	Cost of heat [€/kWh]							
	Inner city				Outer city			
Country	Gas boiler	Biomass boiler	Geothermal plant, low temperature	CHP surplus / waste	Gas boiler	Biomass boiler	Geothermal plant, low temperature	CHP surplus / waste
Bulgaria	0.091	0.109	0.142	0.066	0.097	0.117	0.155	0.069
Denmark	0.126	0.109	0.144	0.066	0.137	0.117	0.157	0.069
Finland	0.106	0.106	0.143	0.066	0.114	0.114	0.156	0.069
Ireland	0.099	0.108	0.146	0.066	0.106	0.116	0.160	0.069
Italy	0.094	0.097	0.149	0.066	0.100	0.104	0.163	0.069
Latvia	0.092	0.104	0.145	0.066	0.098	0.112	0.158	0.069
Lithuania	0.103	0.102	0.145	0.066	0.110	0.110	0.158	0.069
Portugal	0.097	0.095	0.145	0.066	0.104	0.101	0.158	0.069
Slovakia	0.100	0.107	0.146	0.066	0.108	0.115	0.160	0.069
Slovenia	0.112	0.106	0.144	0.066	0.121	0.114	0.157	0.069
Sweden	0.117	0.110	0.143	0.066	0.126	0.118	0.156	0.069
United Kingdom	0.086	0.106	0.145	0.066	0.092	0.114	0.158	0.069

Gudmundsson O. et al., 2013. Cost analysis of district heating compared to its competing technologies. WIT Transactions on Ecology and the Environment. 176. 3-13.
Available at: https://www.witpress.com/Secure/elibrary/papers/ESUS13/ESUS13009FU1.pdf

II. Background information & literature review – Capital cost case study: Proposed Clongriffin District Heating Network

The proposed district heating network at Clongriffin is estimated to have a 23-25% primary energy saving and 38% carbon dioxide saving compared to a scenario with individual gas boilers. Two gas CHP units would be in place along with a 1325 m pipe network. The pipework system would have a flow temperature of 85 °C and return 45-50 °C.

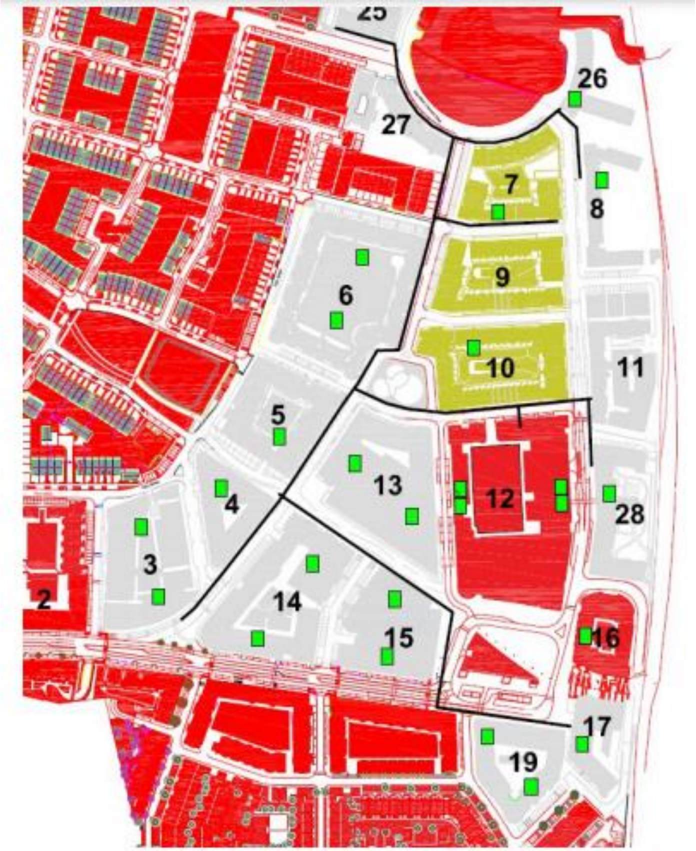

Figure 2: Illustration of proposed district heating network in Clongriffin

Table 3: Cost breakdown for proposed city district heating network at Clongriffin

Annual capital & funding cost.	Equipment	Unit Cost [€]	Total Cost [€]
District heating pipe work	1325 m	750	993,750
CHP units 2x500kWe n=85%	2 items	455,000	910,000
Boiler plant	1 item	50,000	50,000
Primary distribution & pumping	1 item	75,000	75,000
Acoustic treatment	1 item	32,500	32,500
Secondary distribution	1 item	62,000	62,000
Civil pipe work	1325 items	150	198,750
Civil plant	1 item	85,000	85,000
Electrical & data distribution	1 item	135,000	135,000
Thermal store	1 item	45,000	45,000
Controls	1 item	65,000	65,000
Engineering	1 item	135,000	135,000
	Capital cost		€ 2,787,000
	Operating Cost		€ 662,645

DK Partnership, 2019. Proposed mixed use development at Clongriffin – City district heating network. Available at: http://www.pleanala.ie/publicaccess/EIAR-NIS/305319/Clongriffin%20SHD%202/M&E/Clongriffin%20City%20District%20Heating%20Network%20Report.pdf

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II. Background information & literature review

Further details of the literature reviewed and existing and planned district heating networks in Ireland, are available in the main report (Appendix A).

III. Pipework cost database

III. Pipework cost database

The cost of purchasing, trenching and installing the pipework for a district heating network is a major component in the overall capital cost. Hence, it is important that an accurate set of cost data is established before modelling can begin.

The pipework database was constructed using the following methodology:

I. Source data: steel pipe diameter vs pipe cost (£) – was taken from *Heating Supply Options for New Development - An Assessment Method for Designers and Developers*. This data reflects 2019 cost of 2-pipe. It includes equipment, installation and trenching costs, as well as the maximum capacity of heat a given pipe size can provide.

II. These costs were then inflated to 2020 using Consumer Price Index (CPI), and converted from GBP to EUR (€1.12 per £)

III. Conversion factors were used to account for network location, e.g. additional 25% for inner city development, where trenching cost is larger (EU Commission data)

IV. Rule of Six Tenths was used to estimate costs for 4-pipe systems – where hot and cost water is provided in parallel (Sinnott, R. K., 2005)

V. Projection of costs for 2030, 2040 and 2050 were then estimated using data from the European Commission *Long-term (2050) Projections of Techno-Economic Performance of Large-Scale Heating and Cooling in the EU*

VI. Data sense checked versus multiple sources including UK Government data

The full data set is shown in Tables 6 & 7, whilst Figures 3-6 graphically plot key trends found in the data.

Scottish Building Standards Agency, 2009. Heating supply options for new development - An assessment method for designers and developers. Available at: Heating supply options for new development - an assessment method for designers and developers, Scottish Building Standards - Publication Index | NBS (thenbs.com)
European Commission, 2017. Long-term (2050) projections of techno-economic performance of large-scale heating and cooling in the EU. Available at: https://ec.europa.eu/jrc/en/publication/long-term-2050-projections-techno-economic-performance-large-scale-heating-and-cooling-eu
Sinnott, R. K. 2005. Chemical Engineering Design. Coulson & Richardson's chemical engineering series, Vol. 6. Elsevier Butterworth-Heinemann.

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III. Pipework cost database

Figure 3 shows the relationship between pipe diameter and pipe cost. It is clear that as the diameter increases so does the cost. However, the rate of increase is lower than expected, which suggests that the pipe length is perhaps the more significant cost driver. Due to the additional trenching requirements, the cost of inner-city pipes is greater than outer city. The cost of 4-pipe systems is greater than 2-pipe systems, but since the *Rule of Six Tenths* has been applied, they are less than twice as expensive for any given diameter.

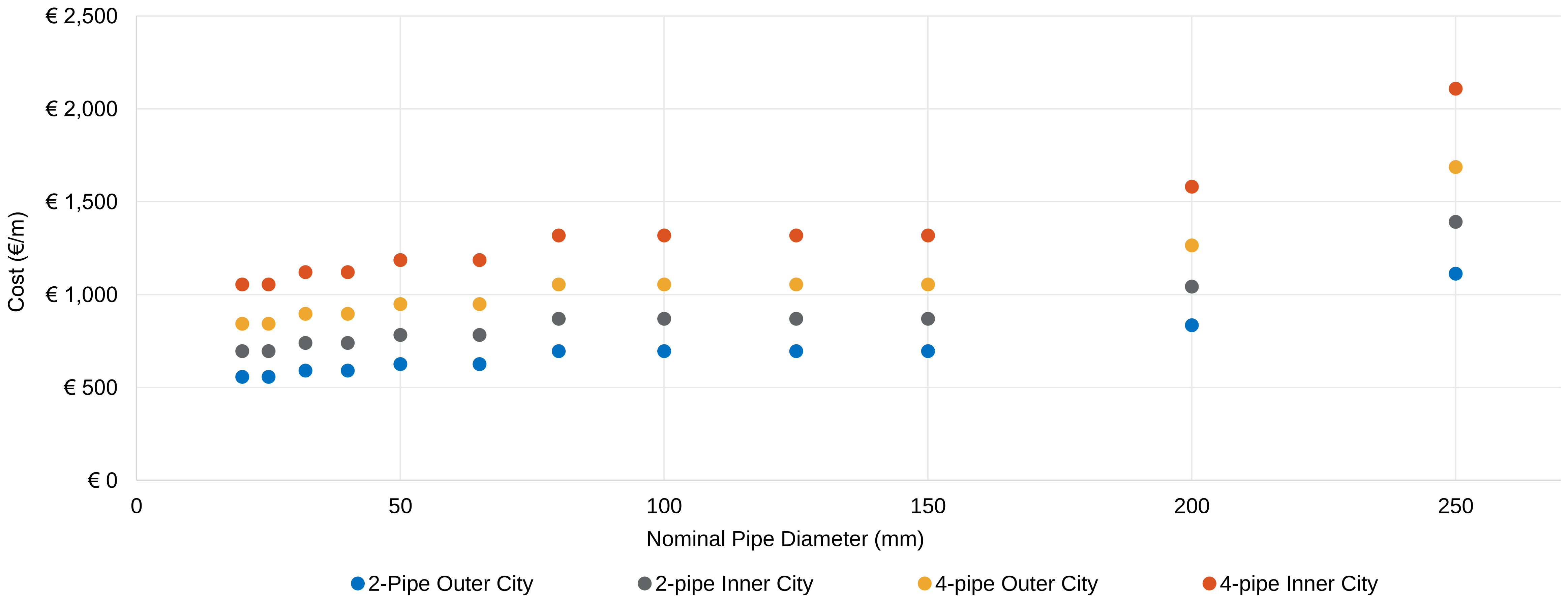

Figure 3: Cost per meter trench length for DH pipes of various sizes in Ireland (2020)

III. Pipework cost database

Figure 4 shows the relationship between pipe diameter and the maximum capacity. As the pipe diameter increases a larger volume of hot water can be transported, and hence the maximum capacity also increases.

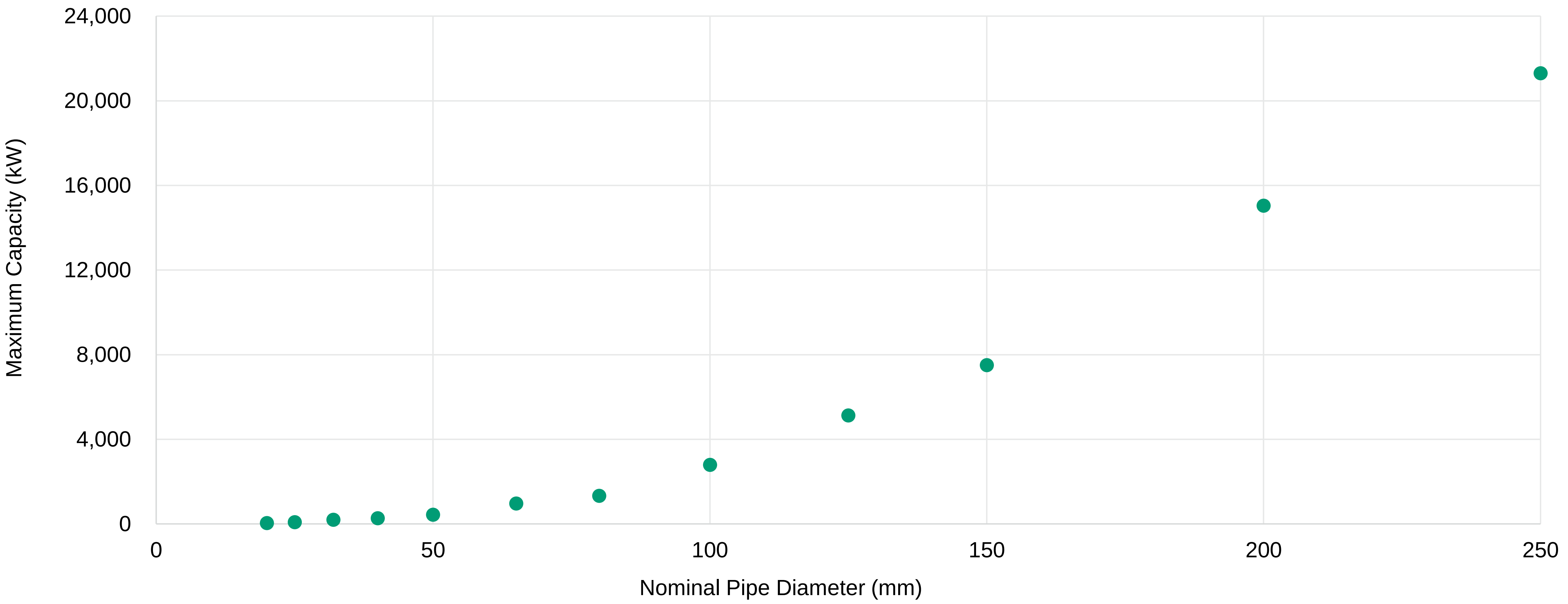

Figure 4: Maximum capacity for each pipe diameter up to 250 mm

III. Pipework cost database

For illustration purposes, the cost projection for 20 mm and 100 mm 2-pipe systems for Ireland in an inner-city location are shown below in Figures 5 & 6. This shows an expectation for the pipe cost to decrease marginally in the coming decades. Each other pipe size follows the same trend.

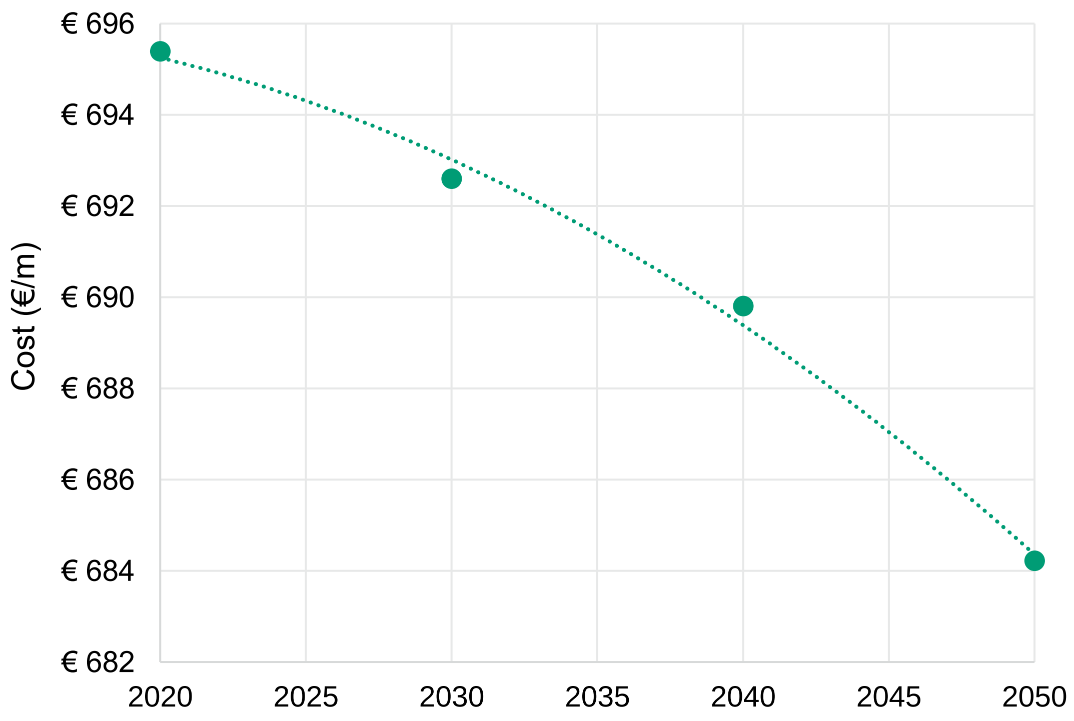

Figure 5: Cost projection for 20 mm 2-pipe DH for Ireland inner city from 2020 to 2050

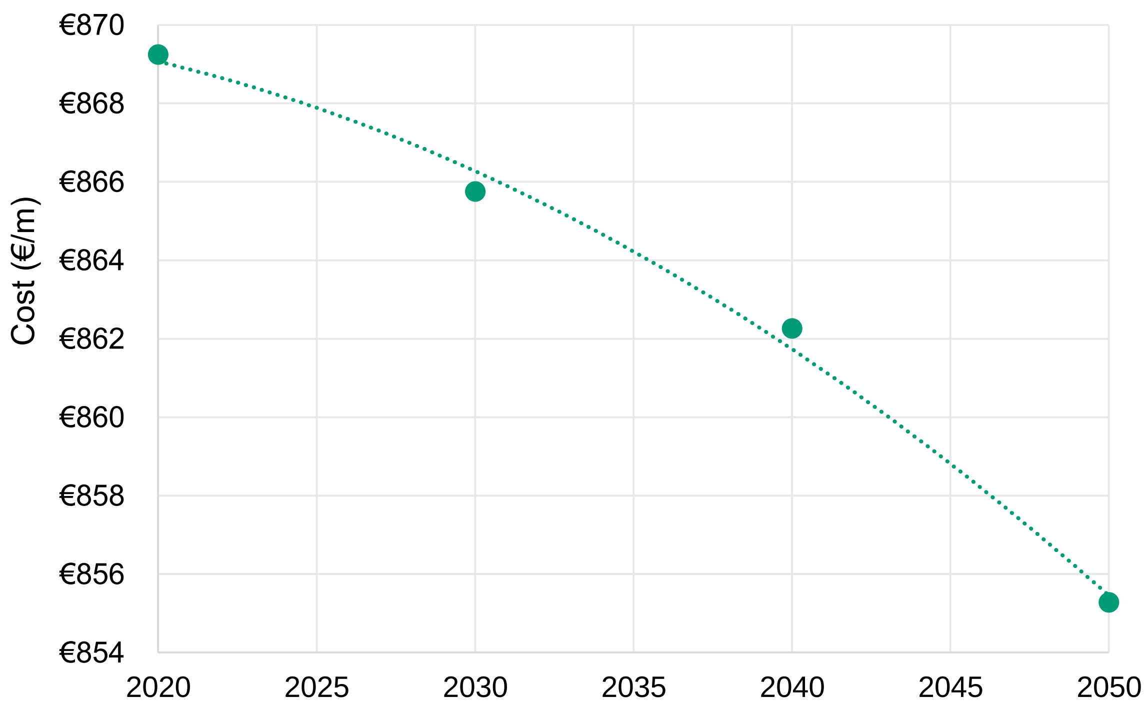

Figure 6: Cost projection for 100 mm 2-pipe DH for Ireland inner city from 2020 to 2050

Table 4: Two pipe systems

Plastic Pipes	Max Capacity [kW]	Pipe Cost [€/m]							
Nominal diameter [mm]		2020		2030		2040		2050	
		Outer City	Inner City	Outer City	Inner City	Outer City	Inner City	Outer City	Inner City
20	46	€ 556	€ 695	€ 554	€ 693	€ 552	€ 690	€ 547	€ 684
25	79	€ 556	€ 695	€ 554	€ 693	€ 552	€ 690	€ 547	€ 684
32	202	€ 591	€ 739	€ 589	€ 736	€ 586	€ 733	€ 582	€ 727
40	272	€ 591	€ 739	€ 589	€ 736	€ 586	€ 733	€ 582	€ 727
50	434	€ 626	€ 782	€ 623	€ 779	€ 621	€ 776	€ 616	€ 770
65	962	€ 626	€ 782	€ 623	€ 779	€ 621	€ 776	€ 616	€ 770
80	1,325	€ 695	€ 869	€ 693	€ 866	€ 690	€ 862	€ 684	€ 855
100	2,792	€ 695	€ 869	€ 693	€ 866	€ 690	€ 862	€ 684	€ 855
125	5,129	€ 695	€ 869	€ 693	€ 866	€ 690	€ 862	€ 684	€ 855
150	7,506	€ 695	€ 869	€ 693	€ 866	€ 690	€ 862	€ 684	€ 855
200	15,044	€ 834	€ 1,043	€ 831	€ 1,039	€ 828	€ 1,035	€ 821	€ 1,026
250	21,300	€ 1,113	€ 1,391	€ 1,108	€ 1,385	€ 1,104	€ 1,380	€ 1,095	€ 1,368
300	30,672	€ 1,252	€ 1,565	€ 1,247	€ 1,558	€ 1,242	€ 1,552	€ 1,232	€ 1,539
350	41,748	€ 1,391	€ 1,738	€ 1,385	€ 1,731	€ 1,380	€ 1,725	€ 1,368	€ 1,711
400	54,528	€ 1,599	€ 1,999	€ 1,593	€ 1,991	€ 1,587	€ 1,983	€ 1,574	€ 1,967
450	69,012	€ 1,738	€ 2,173	€ 1,731	€ 2,164	€ 1,725	€ 2,156	€ 1,711	€ 2,138
500	85,200	€ 1,947	€ 2,434	€ 1,939	€ 2,424	€ 1,931	€ 2,414	€ 1,916	€ 2,395
550	103,092	€ 2,303	€ 2,879	€ 2,294	€ 2,867	€ 2,285	€ 2,856	€ 2,266	€ 2,833
600	120,977	€ 2,364	€ 2,955	€ 2,355	€ 2,944	€ 2,345	€ 2,932	€ 2,326	€ 2,908
700	163,952	€ 2,712	€ 3,390	€ 2,701	€ 3,376	€ 2,690	€ 3,363	€ 2,668	€ 3,336
800	211,511	€ 2,990	€ 3,738	€ 2,978	€ 3,723	€ 2,966	€ 3,708	€ 2,942	€ 3,678
900	267,527	€ 3,199	€ 3,999	€ 3,186	€ 3,982	€ 3,173	€ 3,966	€ 3,147	€ 3,934
1,000	329,981	€ 3,770	€ 4,713	€ 3,755	€ 4,694	€ 3,740	€ 4,675	€ 3,710	€ 4,637
1,100	412,368	€ 3,770	€ 4,713	€ 3,755	€ 4,694	€ 3,740	€ 4,675	€ 3,710	€ 4,637

Table 5: Four pipe systems

Plastic Pipes	Hot Line - Max Capacity [kW]	Pipe Cost [€/m]							
Nominal diameter [mm]		2020		2030		2040		2050	
		Outer City	Inner City	Outer City	Inner City	Outer City	Inner City	Outer City	Inner City
20	46	€843	€1,054	€840	€1,050	€836	€1,046	€830	€1,037
25	79	€843	€1,054	€840	€1,050	€836	€1,046	€830	€1,037
32	202	€896	€1,120	€892	€1,115	€889	€1,111	€882	€1,102
40	272	€896	€1,120	€892	€1,115	€889	€1,111	€882	€1,102
50	434	€949	€1,186	€945	€1,181	€941	€1,176	€933	€1,167
65	962	€949	€1,186	€945	€1,181	€941	€1,176	€933	€1,167
80	1,325	€1,054	€1,318	€1,050	€1,312	€1,046	€1,307	€1,037	€1,296
100	2,792	€1,054	€1,318	€1,050	€1,312	€1,046	€1,307	€1,037	€1,296
125	5,129	€1,054	€1,318	€1,050	€1,312	€1,046	€1,307	€1,037	€1,296
150	7,506	€1,054	€1,318	€1,050	€1,312	€1,046	€1,307	€1,037	€1,296
200	15,044	€1,265	€1,581	€1,260	€1,575	€1,255	€1,568	€1,245	€1,556
250	21,300	€1,686	€2,108	€1,680	€2,100	€1,673	€2,091	€1,659	€2,074
300	30,672	€1,897	€2,372	€1,890	€2,362	€1,882	€2,352	€1,867	€2,333
350	41,748	€2,108	€2,635	€2,100	€2,624	€2,091	€2,614	€2,074	€2,593
400	54,528	€2,424	€3,030	€2,415	€3,018	€2,405	€3,006	€2,385	€2,982
450	69,012	€2,635	€3,294	€2,624	€3,281	€2,614	€3,267	€2,593	€3,241
500	85,200	€2,951	€3,689	€2,939	€3,674	€2,928	€3,659	€2,904	€3,630
550	103,092	€3,491	€4,364	€3,477	€4,346	€3,463	€4,329	€3,435	€4,294
600	120,977	€3,584	€4,480	€3,569	€4,462	€3,555	€4,444	€3,526	€4,408
700	163,952	€4,111	€5,138	€4,094	€5,118	€4,078	€5,097	€4,045	€5,056
800	211,511	€4,532	€5,665	€4,514	€5,643	€4,496	€5,620	€4,459	€5,574
900	267,527	€4,848	€6,061	€4,829	€6,036	€4,810	€6,012	€4,771	€5,963
1,000	329,981	€5,715	€7,144	€5,692	€7,115	€5,669	€7,086	€5,623	€7,029
1,100	412,368	€5,715	€7,144	€5,692	€7,115	€5,669	€7,086	€5,623	€7,029

IV. District heating modelling

IV. District heating modelling

A small area is a land area typically containing 80 to 120 dwellings. These areas are sized at the lowest level of geography to allow for detailed statistical analysis, whilst ensuring compliance with data protection. Ireland contains 18,641 small areas, which were created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSI).

Each small area in Ireland has a corresponding heat demand for the domestic, commercial and public sectors. This data was calculated as part of the *Heating and Cooling in Ireland Today* report, where heat and cool demand maps were generated. These three sectors were summed to provide the total thermal demand of each small area (MWh/year). The model was designed to evaluate the cost of implementing a district heating network in each of these small areas. The *Heat Networks: Code of Practise for the UK* states that it is best practise for network heat losses to not exceed 10% of the annual consumption. Hence, the heat losses for each network was set as 10%.

$$Network\ Heat\ Output\left[\frac{MW_{th}h}{year}\right] = \frac{Small\ Area\ Heat\ Demand}{0.9}$$

The total road length (km) in each small area was taken from the existing SEAI 2015 heat map. Note that whilst the purpose of the *Heating and Cooling in Ireland Today* analysis was to update the heat demand per small area, updating the road length was not required. It was assumed that the total network length equalled the total length of road, as this is the path the DH pipes would likely follow.

CIBSE, 2020. Heat networks: Code of practise for the UK. Available at: CIBSE - Building Services Knowledge

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IV. District heating modelling

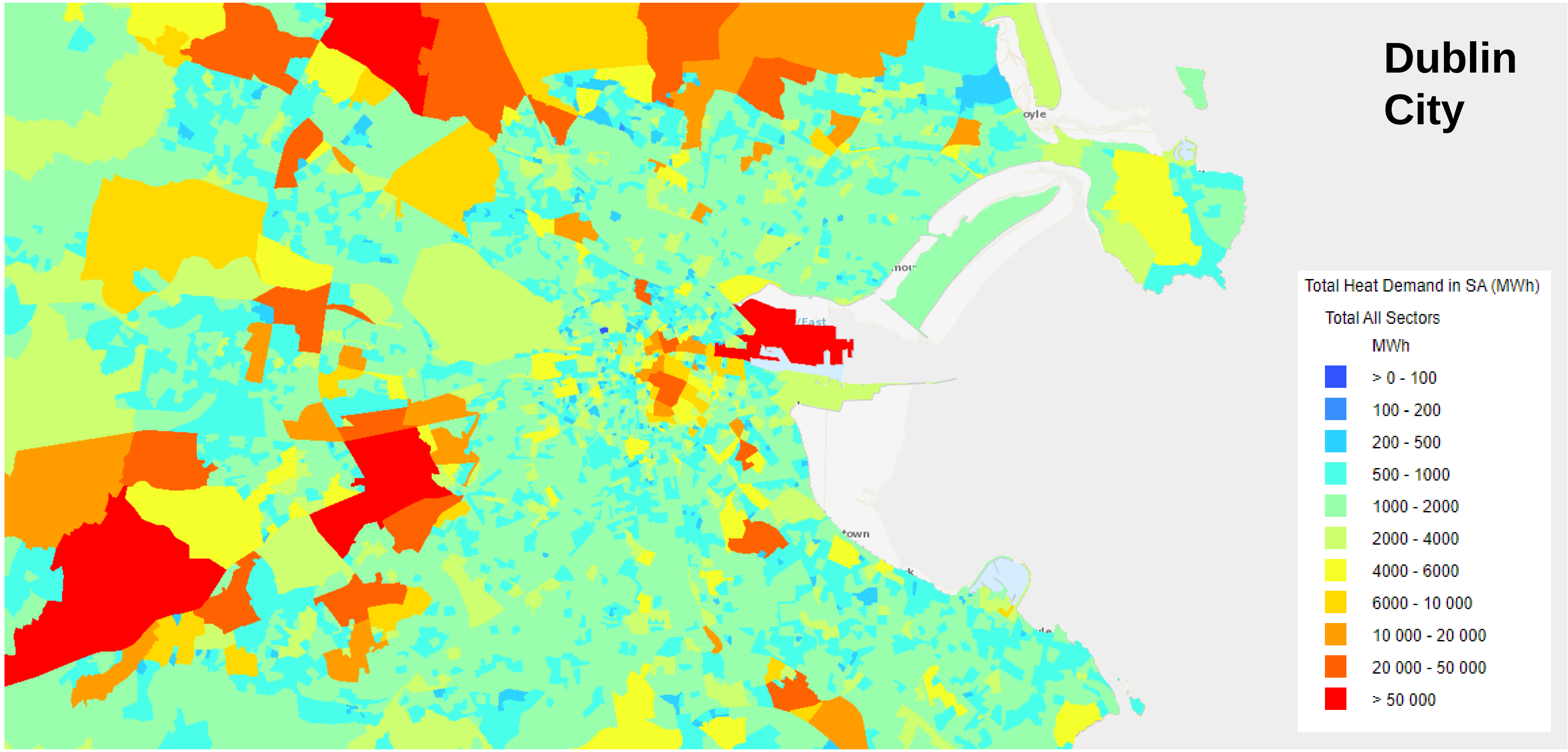

Figure 7: Small area heat demand in Dublin

Sustainable Energy Authority of Ireland. Heat Demand Map. Available at: Map Of Heat Demand In Ireland | SEAI GIS Maps | SEAI (Accessed: 01/02/2020)

IV. District heating modelling – Pipeline cost

Pipeline cost

A DH pipe network has a shrinking branch structure, with the pipes closest to the energy centre being largest. As the network spreads to each consumer, the number of pipes increases, but the diameter of each becomes smaller. An exact pipeline structure is specific to each network and requires greater detail than available during this modelling. As an estimate, the peak capacity was halved, and this value was assessed against the DH cost database previously discussed, to determine the pipe size (mm) required for each network. This is a commonly used method for assessing network pipe cost.

For example, if the small area has a peak capacity of 0.8 MWth, then a 50 mm pipe is required (400 kW rounds up to 434 kW), which costs €782/m. However, if the heat demand is 7 MWth, then a 125 mm pipe is needed instead, costing a total of €869/m. In this example, costs were taken for an inner-city region in 2020.

The pipeline cost (€/m) was then multiplied by the total road length in each small area to calculate the cost of purchasing and constructing the pipe network (€). Where the small area existed within a city, an increased pipe cost was used to account for the increased trenching cost in urban areas.

$$\boldsymbol{Total\ Pipeline\ Construction\ Cost}\ [€] = (\boldsymbol{Pipeline\ Cost})(\boldsymbol{Road\ Length})$$

Department of Energy & Climate Change (DECC) UK, 2015. National comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK – Report for DECC.
Available at: The national comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK - GOV.UK (www.gov.uk)

IV. District heating modelling – Energy centre cost

Energy centre cost

As previously discussed, there are a range of technologies that can be used to generate the hot water at the energy centre. For the purposes of this model, six options were compared:

- Option 1 – Waste heat recovery – industrial sites, power stations and data centres.
- Option 2 – 100% the heat demand was provided by one biomass boiler.
- Option 3 – 75% of the heat demand was provided by a biomass CHP (load factor = 63.75%), and a backup biomass boiler was also installed. As a security, the backup boiler was designed to be able to meet 100% of the demand.
- Option 4 – 100% the heat demand was provided by one air source heat pump (ASHP).
- Option 5 – 100% the heat demand was provided by one ground source heat pump (GSHP).
- Option 6 – 75% of the heat demand was provided by a gas CHP (load factor = 63.75%), and a backup biomass boiler was also installed. As a security, the backup boiler was designed to be able to meet 100% of the demand.

Information concerning the performance and capital/operating cost of technology Options 2-6 were taken from datasets generated as part of the *Low Carbon Heating and Cooling Technologies* report. The waste heat recovery costs are discussed in more details in the *District Heating and Cooling: Spatial Analysis of Infrastructure Costs and Potential in Ireland* report and Appendix C.

Alongside the generating plant, a thermal storage tank is also required to control for fluctuations in heat demand. As previously discussed, the thermal store capacity for each small area [MWh] was sized whilst flattening the heat profiles. Thermal store capital cost data was taken from the *Assessment of the Costs, Performance, and Characteristics of UK Heat Networks*, inflated to 2019 and converted to Euros (Department for Energy and Climate Change UK, 2015).

For example, under Option 2, if the small area has a peak capacity of 0.8 MWth, then a 1 MW biomass boiler is required, which has a capital cost of €385/kWt. Alternatively, if the small area has a heat demand of 7 MWth, then a 10 MW boiler is needed, with a cost of €330/kWth.

$$\boldsymbol{Total\ Energy\ Centre\ Cost}\ [€] = (\boldsymbol{Boiler\ cost} + \boldsymbol{Thermal\ Storage\ Cost})(\boldsymbol{Peak\ Capacity})$$

Department of Energy & Climate Change (DECC) UK. 2015. Assessment of the costs, performance, and characteristics of UK heat networks. Available at: Assessment of the costs, performance and characteristics of UK heat networks - GOV.UK (www.gov.uk)
Department of Energy & Climate Change (DECC) UK, 2015. National comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK – Report for DECC. Available at: The national comprehensive assessment of the potential for combined heat and power and district heating and cooling in the UK - GOV.UK (www.gov.uk)

IV. District heating modelling – Installation costs

Consumer Property Installation Cost

In order to connect the consumer to the DH network there are three additional costs to consider: the heat interface unit (HIU), the heat meter, and installation of pipe to connect that particular property to the overall network. The HIU allows energy to be taken out of the network and transferred into the consumer's property, for example this could be a heat exchanger. Costs vary depending on if the consumer has a domestic or non-domestic property.

Domestic Installation

The domestic property size does not vary greatly, and so an average was taken that covers the combined cost of the HIU, heat meter and piping in one figure (€/dwelling). Hence, the total cost of connecting every domestic property in a small area can easily be calculated by multiplying this index by the number of residential properties in that small area. This data was taken from *The Potential and Costs of District Heating Networks*, inflated to 2019 and converted to Euros. Note, stock is a term used to describe the total number of buildings within a defined group.

$$\textit{Total D Installation Cost}\ [€] = (\textit{Cost per Dwelling})(\textit{D Stock})$$

Pöyry Energy Consulting & Faber Maunsell (AECOM), 2009. The potential and costs of district heating networks – A report to the Department of Energy and Climate Change, London.

IV. District heating modelling – Installation costs

Non-Domestic Property

Conversely, the size of non-domestic properties varies considerably, and so the cost of the HIU, the heat meter, and piping also vary accordingly. The average heat demand per non-domestic property (in each small area) was calculated by dividing the combined commercial & public peak heat demand by the number of non-domestic properties. Data was taken from *The Potential and Costs of District Heating Networks* and the *Biomass Heat - A Practical Guide for Potential Users*, inflated to 2019 and converted to Euros.

$$Average\ ND\ Demand\left[\frac{MW}{Property}\right] = \frac{\sum Commercial\ \&\ Public\ Heat\ Demand}{ND\ Stock}$$

This average heat demand was then used to size and cost the HIUs, heat meters, and piping. Finally, the total cost of connecting every non-domestic property in a small area can be determined by summing these three components.

$$HIU\ Cost\ [€] = (HIU\ Cost\ per\ MW)(Average\ ND\ Demand)(ND\ Stock)$$

$$Heat\ Meter\ Cost[€] = (Heat\ Meter\ Cost\ per\ Property)(ND\ Stock)$$

$$ND\ Pipe\ Connection\ Cost\ [€] = (Pipe\ Cost\ per\ m)(Assumed\ 20\ m\ connection)(ND\ Stock)$$

$$Total\ ND\ Installation\ Cost\ [€] = HIU\ Cost + Heat\ Meter\ Cost + ND\ Pipe\ Connection\ Cost$$

Total District Heating Cost

Finally, the total capital cost of constructing and implementing a district heating scheme in each small area is equal to the sum of the pipeline cost, energy centre cost, domestic installation and non-domestic installation costs.

$$\boldsymbol{Distict\ Heating\ Network\ Cost\ [€] = Total\ Pipeline\ Cost + Total\ Energy\ Centre\ Cost + Total\ D + Total\ ND}$$

Pöyry Energy Consulting & Faber Maunsell (AECOM), 2009. The potential and costs of district heating networks – A report to the Department of Energy and Climate Change, London .
Carbon Trust, 2009. Biomass heat - A practical guide for potential users

IV. District heating modelling – Operational costs

In addition to the capital cost, the operating costs associated with each technology was also calculated within the model. The operating costs were scaled based on the demand in each small area (€/year/kWh). Only the operating cost of the central generating plant was considered. This did not include the cost of fuel which will be accounted for separately in the scenario modelling (see *Net Zero by 2050* report).