New District Heating Cities

Overcoming barriers to deployment of districs heating

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Preface

This thesis is prepared as a completion of the Master Programme Sustainable Cities, in the Department of Development and Planning at Aalborg University Copenhagen. The work has been carried out from February to June 2016.

This thesis seeks to uncover existing barriers to district heating diffusion in countries with low district heating penetration and to propose ways to overcome some of these barriers to enable the diffusion of district heating in new district heating cities. In order to do so, interviews have been carried out with actors from Ireland, UK and Denmark.

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We would also like to thank our interviewees:

Andrew Crips, John O'Shea, Alexia Gonin, Victor Coe & Seamus Stora, Xavier Dubuisson, Olivier Gailliot, Birger Lauersen, Morten Duedahl, Jakob Bjerregaard, Anders Dyrelund & Søren Ørsted.

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Abstract

Currently more heat is being wasted in Europe than the amount required to heat all buildings. By means of district heating, some of the heat losses can be captured and recycled to provide heating to 50% of all buildings in Europe. This thesis applies a two-step methodological approach to investigate barriers to development of district heating in new district heating cities and suggests possible ways of overcoming some of these barriers.

First, a conceptual framework is applied to identify barriers in relation to the five elements of technology; technique, knowledge, organisation, product and profit. Through qualitative interviews this framework is used to identify perceived barriers among people involved in delivering new district heating systems and the people sharing their experiences. From the interviews six main barriers are identified, which reveals some interesting alignments and mismatches. Secondly, a feasibility study is used on a specific case, Dublin, to quantify these main barriers. Based on the feasibility study nine recommendations are made to overcome the barriers.

Table of Contents

Part 1: Barriers to district heating deployment

Part 2: Feasibility Study

1 Introduction

In the context of climate change, continued urbanization processes and large amounts of energy wasted in the energy sector, there is a need for enhancing energy efficiency and renewable energy penetration in EU energy systems. By means of district heating, some of the heat losses can be recycled to provide heating to buildings and improve the overall efficiency of the EU energy system. Furthermore, this will add flexibility to the energy system and allow higher penetrations of renewable energy. With a big potential for increasing the district heating share in Europe, these benefits are ready to pick. However, much of the potential has not been utilised, indicating that there exist some barriers. In this thesis, diffusion of district heating is studied from a local planning perspective, with the aim of uncovering the main barriers for implementing district heating in new district heating cities. So far, little is known about the practical and technical limitations for developing and implementing district heating in inexperienced countries perceived by the practitioners involved and the experts supporting. The main objective is therefore to uncover practical and technical challenges, as perceived by the people involved in delivering new district heating systems and the people sharing their experiences and to propose suggestions for how these can be overcome.

1.1 Towards a smart, efficient and sustainable heating and cooling sector

In December 2015, world state leaders were gathered at COP 21 in Paris, which culminated in a historic global agreement. Never before have so many state leaders been able to create consensus on the necessity of fighting climate change. Involving 196 nations worldwide, the 'Paris Agreement' covers more than 96% of global emissions, with a long-term goal of keeping global temperature rise below 2°C and a reaffirmation of the promise from the industrialized countries to contribute with $100 billion annually to developing countries climate efforts beyond 2020. The primary aim of the 'Paris Agreement' is to begin levelling off fossil fuel emissions, which is seen as a crucial action in order to prevent the irreversible effects of climate change. This agreement is an important step towards a global society with significantly reduced CO2 emissions, which is strongly signalling the imperative need to act.

In Europe, the European Union, including 28 member states, have ambitious energy policies, with the main objectives of ensuring security of supply, sustainability and competitiveness (European Commission, 2015). Achieving this goal requires a fundamental restructuring of the European energy systems. To pursue and fulfil these objectives the European Commission has adopted EU wide targets and policy objectives for 2020 and 2030. Already by 2020, EU aims to reduce its GHG emissions by at least 20%, increase the share of renewable energy to at least 20% of total energy consumption and achieve energy savings of at least 20% (European Commission, 2010), often referred to as the 20-20-20 target. Furthermore, EU countries have committed themselves to a 40% cut in greenhouse gas emissions by 2030 compared to 1990 levels (European Commision, 2014). On the longer term the European Council has committed to decarbonize the European energy system with a target of 80 to 95%

cut in emissions by 2050 compared with 1990 levels (European Commission, 2011a). To ensure the fulfilment of these targets, the EU has set out a set of binding measures, which will help EU countries enhance energy efficiency in the building sector (EE Directive), improve the energy performance of buildings (Energy Performance of Buildings Directive) and increase the penetration of renewable energy sources (Renewable Energy Source Directive).

Some progress has been made towards these goals. With a projected share of 15,3% renewable energy in 2014 gross final energy consumption the member states are on track regarding the interim target defined in the RES Directive (Ecofys et al., 2014), while only a few countries have appeared insufficient to trigger the required RES volumes. Even though this seem promising for the decarbonisation of the European energy systems, the transition is still adapting too slowly (European Commission, 2010). While the EU Member States are on track to reach the 20% renewable target, they far from achieving the energy efficiency objectives (European Commission, 2011b), which is one of the central objectives for the 2020 targets and a key factor in achieving the long-termed energy and climate goals. This calls for national and local authorities to intensify their work and to implement adequate policies, especially regarding energy efficiency.

Today, Europe wastes a lot of energy. As Figure 1-1 reveals, approximately half of the primary energy supply (PES) is lost in conversion before reaching the end user. This highlights the potential for increasing the efficiency of the energy sector. Special attention should be given to the building sector, which currently accounts for 50% of the EU's annual energy consumption, as can be seen in Figure 1-1. This calls for making the sector smarter, more efficient and sustainable and thereby contribute to the aim of the European Union (European Commission, 2010), by reducing the dependency on energy imports, cut energy costs and reduce emissions. Much of this can be obtained with the diffusion of district heating, which will allow a higher utilisation of renewable energy sources and recycling of waste heat.

With the release of the very first collective heating and cooling strategy prepared by the European Commission in February 2016, district heating is acknowledged as a key technology in the decarbonisation (European Commission, 2016). The overall vision of the heating and cooling strategy is the decarbonisation of the building stock by intensifying energy efficiency and renewable energy while creating synergy between the heating and electricity sector through means of efficient district heating.

1.2 Role of district heating

District heating systems are collective infrastructures, which distribute centrally produced heat to individual customers. By connecting suitable heat demands with decentralised heat supplies, demands can be met by use of fewer resources than conventional heat supplies, such as individual gas boilers. The fundamental idea of district heating is to use local heat sources, which would otherwise have been wasted, by utilising a local distribution network. The benefit is, that once the network is established, all types of energy sources, both fossil fuels and renewables, can be used to supply heat in a cheap and reliable way. District heating systems should thus be considered as urban energy efficiency infrastructures, which can be employed to enhance efficiency in heat supply by increased excess heat recoveries. The key benefits of district heating are that:

- It improves the efficiency of the energy system
- It enables additional renewable energy sources to be utilised, e.g. wind and solar
- It adds flexibility to the energy system by introducing thermal storage
- It increases security of supply for the heating sector

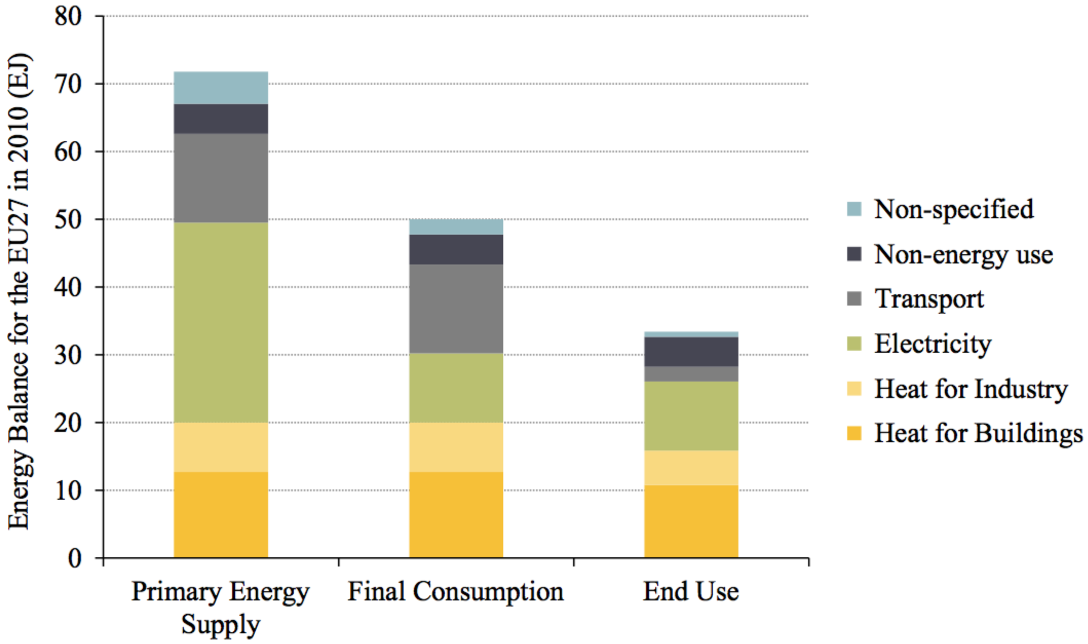

Figure 1-1: EU 27 energy balance in 2010 presented in three steps (D. Connolly, Lund, Mathiesen, Werner, Möller, et al., 2014). The first bar reflects the primary energy supply into the European energy system. The second bar shows the total final consumption of energy.

The role of district heating have been overlooked in many reports concerning the decarbonisation of the EU energy supply, including the EU Energy Roadmap 2050 released in 2011 (European Commission, 2011a), which predicted no growth in district heating between 2010 and 2050. Heat Roadmap Europe was the first study to emphasize the role of district heating and to quantify the potentials and benefits of district heating from an EU perspective (D Connolly et al., 2013). The study showed that increasing the share of district heating to 50% in 2050 can achieve the EU objectives more cost-effective than by means of heat savings in buildings (D. Connolly et al., 2012; D. Connolly, Lund, Mathiesen, Werner, Möller, et al., 2014). Furthermore, the study showed that exploiting this potential will lower the energy consumption, reduce carbon emissions and energy costs while increasing the renewable energy share and creating new jobs (D. Connolly, Lund, Mathiesen, Werner, Möller, et al., 2014).

In 2010, 73% of the 507 million EU 27 residents lived in urban areas and it is expected that this will increase to 84% in 2050 (United Nations, 2009). This, itself, is a substantiated basis and strong argument for utilising district heating in Europe. However, as Figure 1-2 reveals, the diffusion of district heating varies significantly all over Europe, with a total heat market share of 13%. The figure illustrates that many countries have already implemented large shares of district heating, especially the northern and eastern European countries, while other countries still have very low shares of district heating.

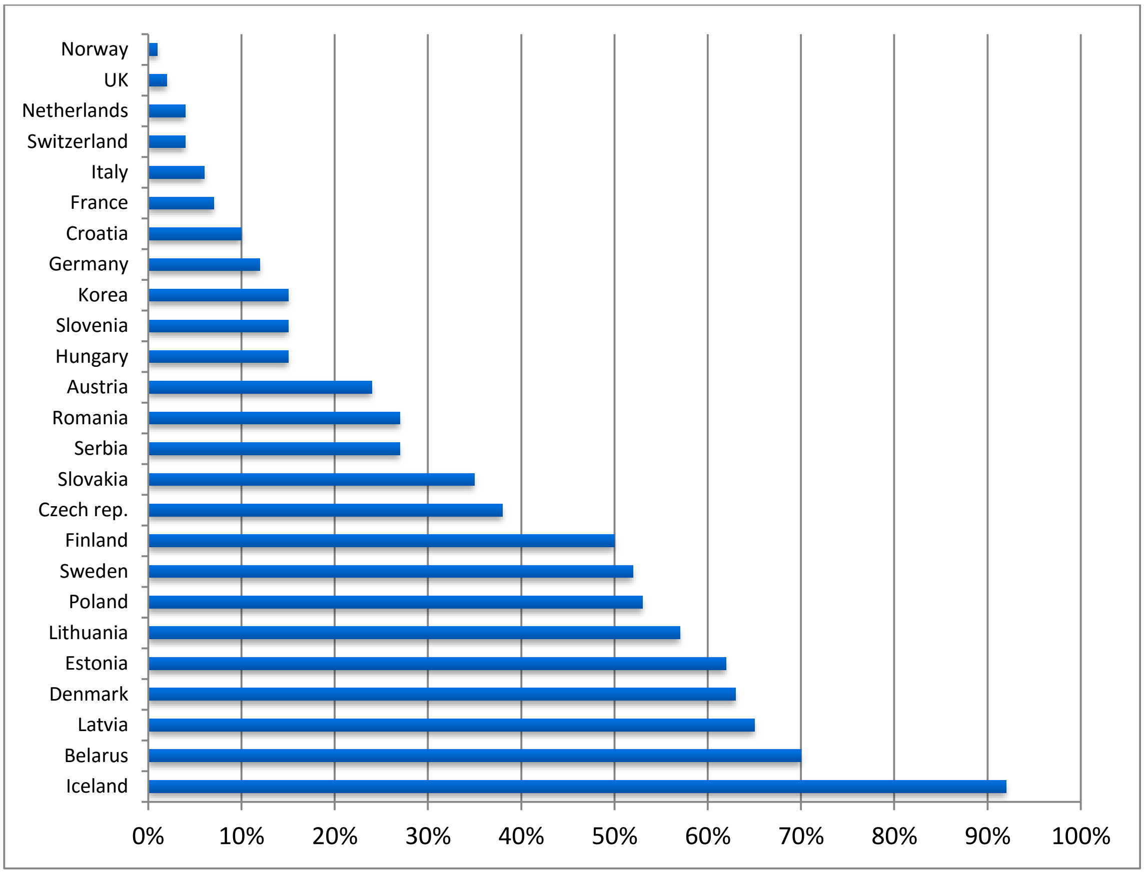

Figure 1-2 Share of population served by District Heating in 25 countries (Euroheat and Power, 2013).

Previous research have showed that there is a sufficient heat demand for district heating in many cities in Europe (D. Connolly et al., 2012; Urban Persson & Werner, 2011; Werner & Constantinescu, 2006). Currently, the European heat market share for district heating is 13% (D. Connolly, Lund, Mathiesen, Werner, Möller, et al., 2014), indicating that much of this potential has not been deployed. Furthermore, EU is wasting more energy in terms of heat than the total heat demand in buildings, due to losses in conversion as illustrated in Figure 1-1, which potentially could replace all gas for heating in buildings. This present an opportunity for increasing efficiency of buildings in Europe, by substituting individual boilers and enhance waste heat recovery by means of district heating in high density areas. Increasing the share of district heating from 13% today to 50% in 2050 is technically feasible and will save energy and carbon dioxide emissions, increase security of supply and renewable energy penetration, while also reducing costs and creating approximately 220.000 new jobs (D. Connolly, Lund, Mathiesen, Werner, Möller, et al., 2014).

A basic premise is that district heating can be developed in all areas with a sufficiently high heat density, meaning that all demands beyond a given threshold value potentially could be supplied at lower costs compared to individual heating solutions. By experience, a typical threshold value, which can be considered directly feasible for district heating, is 140-180 TJ/km^2 (Frederiksen & Werner, 2013). This heat density can be found in most cities in EU. For example, the district heating level in London is currently less than 5%, but as illustrated by the red and purple squares in Figure 1-3, most of London city has a heat density over 100 TJ/km^2 with some areas above 300 TJ/km^2, indicating that a big part of London could be supplied with district heating.

Figure 1-3 Calculated heat demands in London represented in a spatial resolution of 1 km^2. The figure reveals high heat densities in London city centre (Heat Roadmap Europe, 2016).

This is not only evident in northern European countries with low average temperatures, as is often assumed to be the case. For example (David Connolly et al., 2015) identified that the potential district heating level for Italy is 60% of the heat demand compared to 40% of the heat demand in Czech Republic, which is further north. This demonstrates that the district heating potential is not only linked to the outdoor temperatures, but also has to do with the proximity of buildings to one another and the standard of the building envelopes.

1.3 Unexploited potential

District heating is a well-proven technology, which has existed for more than a century. In Europe, approximately 6.000 district heating systems can be found covering a distance of almost 200.000km (Euroheat and Power, 2013). This seems to have given a widespread acceptance that technically district heating can be done. District heating can be found many places, in water-rich places such as in the Netherlands to hilly areas in Sweden and Finland - in both old and newly built city areas. District heating can be developed more or less anywhere there is a sufficiently high heat density, but despite its many valuable merits, district heating is still a niche technology in many parts of the world (Frederiksen & Werner, 2013). As illustrated in Figure 1-2, the national heat market shares vary significantly within EU, with heat market shares above 50% in some Scandinavian and Baltic member states, while district heating systems only cover approximately 13% of the total European heat market. Many reasons can be proposed to explain this variety, such as national climates, urban densities and available energy resources as well as differences in energy policies, regulatory frameworks and heat planning traditions (State of Green, 2016).

From a pure technical and economical point of view, district heating has the potential to increase significantly towards 2050 and contribute to the decarbonisation of the European energy systems (D. Connolly et al., 2012; Urban Persson & Werner, 2011). This has already been demonstrated in the established countries like Denmark and Sweden, where district heating is covering 63% and 52% of the heat demand. In these countries there are well-tested and established ways of delivering district heating, i.e. to develop feasibility studies and bring them forward through financing, economic assessment, organisation and procurement to actually constructing the network and deliver hot water to the customers. They have know-how within planning and implementation of district heating and have gained lots of experiences in all parts of the process – simply because they have done it many times in multiple projects. The only thing other countries have to do is to copy these experiences. They do not have to invent it all again, but simply replicate what is already done in the experienced countries. So what stops the development?

Many textbooks and handbooks have been written in the very experienced countries like Denmark and Sweden, and only exist in national languages. Only a few books, which comprehensively address the subject (e.g. Frederiksen & Werner, 2013), have been published in English, since district heating is still a minor technology in countries like United Kingdom, Ireland and USA. No doubt, this has made it very difficult for inexperienced countries to exploit the benefits of district heating and has led to a rising demand for knowledge sharing. The request for the Danish energy model and the experiences within district heating has been so big, that the Danish Energy Agency initially has been necessary to select a few countries to focus on (Danish Energy Agency, n.d.). However, much effort has been done to export experiences between countries. In Denmark a major effort has been made to provide consulting and advisory on the delivery of district heating from Danish embassies, district heating organisations, private consultancies and companies and research institutions.

1.4 Thesis objective

This thesis seeks to understand what barriers that impact the deployment of district heating in inexperienced countries to suggest possible ways of overcoming some of these barriers. From a theoretical point of view, the introduction of district heating is framed as a radical technological change as described by Lund (2010) arguing that assessment of technological change must be understood based on five elements; *Technique, Knowledge, Organization, Product and Profit*. This conceptual framework is adapted to fit to the characteristics of district heating systems and applied in an empirical approach to understand the challenges that occur in the deployment of district heating. The introduction of district heating in undeveloped countries is identified in an empirical approach to provide planners and policymakers with knowledge about possible pitfalls in the context of delivering district heating systems in order to suggest ways to overcome some of these. This is framed by the following research question:

What are the barriers when introducing district heating to European countries with low district heating market penetration and how can these be overcome?

To answer the research question, a two-step analytical framework has been developed. The first part of the thesis investigates challenges for the practical implementation of district heating in new district heating cities. To do so, a series of interviews were carried out to explore and uncover perceived challenges related to the planning process among inexperienced countries and experienced countries. These outputs are used to outline the key reasons for the slow diffusion of district heating in new district heating cities.

Secondly, a case study is used, i.e. Dublin, to explore ways in which some of these challenges may be overcome. The study is carried out for a large-scale district heating scheme in Dublin city, to demonstrate the process of designing and assessing a potential district heating scheme, including technical and economic factors.

1.5 Report content

Chapter 2 presents the theories used to frame the analysis. Chapter 3 presents the overall research design. The analysis is divided in two parts reflecting the two-step methodological approach.

<u>Part 1: Identification of barriers</u>

Chapter 4 describes the application of literature review and interviews, while chapter 5 presents the main barriers identified in the interviews.

<u>Part 2: Feasibility study</u>

The second part starts by outlining the approach of the feasibility study. Chapter 6 presents the background of district heating in Ireland, and describes the specific case area, Spencer Dock, which is used for the feasibility study. In chapter 7 two scenarios used in the feasibility study is designed and the assumptions are presented. Chapter 8 presents the results of the feasibility study. In Chapter 9 the findings of the two analyses are discussed and recommendations are formed. Chapter 10 presents the conclusions.

2 Theory

Technology theory, as described by (Lund, 2010), is concerned with societal changes of technologies in the energy sector. Technologies are defined to embrace a combination of the five elements: technique, knowledge, organisation, products and profit. The basic assumption is that if any of these five elements are substantially changed with the introduction of a new technology, others will have to follow (Lund, 2010). If society makes a fundamental change in a technique without making equal changes in the knowledge and the organisations related to this technique, this new technique will not be implemented. Therefore, creating a fundamental change of technology will require that more of these five elements change, which can be defined as a radical technological change (Lund, 2010). Here it is argued that introducing district heating in countries and cities with low district heating penetrations will enforce major change in the way heating currently is provided and can be understood as a radical technological change. Shifting from individual heating solutions to a collective heat system like district heating systems will have influence on how heat is being distributed, organised and planned. Thus introducing district heating to undeveloped countries will imply major changes in the existing heat sector in, which can be defined as a radical technological change (Lund, 2010). Such a radical technological change will face resistance within the existing regime and will require fundamental changes in multiple dimensions of the energy system. Multiple organisations will have to redefine their role in this new system, roles will be changed, profits will be redistributed, new organisations and institutions will be formed and new knowledge will have to be obtained. Recognising that district heating is a radical new technology for some EU countries can thus be used to identify the barriers that occur in the diffusion of district heating in countries with low market penetration. By identifying the content of the different elements the barriers that lies within them can be articulated and accommodated. Here the technology theory is adapted as a conceptual framework that will be used to assess district heating as a technological system, consisting of elements of knowledge, organisation, technique, product and profit (Blarke & Jenkins, 2013; Lund, 2010). A successful implementation of a district heating network, must target the possible challenges in all elements. Applying this framework will be helpful in order to find relevant societal factors that go beyond merely technical challenges.

2.1 Understanding barriers to technological change – a conceptual framework

In order to identify and analyse the challenges for developing and deploying district heating the technology theory as described by (Lund, 2010) is used as conceptual framework as presented in Table 2-1.

Table 2-1 Conceptual framework for analysing challenges to deployment of district heating

Technology Components	Changes with the introduction of District Heating Systems
Knowledge	Practical: Local authorities will play a central role, which will challenge the existing planning practice and capacity of skills and knowledge Technical: Introducing new technologies and equipment requires knowledge and skills embedded in the technology Awareness: Familiarity with the potentials and benefits of district heating among planners, researchers, companies and private consumers
Technique	New technologies will be introduced in a district heating system, primarily in the distribution grid, which will require new techniques and planning practises, as described in knowledge (see above).
Organisation	Engagement: Organising and facilitating district heating systems requires engagement with several actors, e.g. suppliers, end-users and prospect system owners and operators. Regulation: Establishment of rules and framework for district heating at different levels such as legislation, taxation and incentives.
Economy	Profit: Profits will be redistributed, which might not support the interest of existing organisations Risks: Several risks will occur in the development, which might challenge the organisation and delivery of district heating. Finance: District heating is an investment-based technology, meaning that upfront capital costs are high, while operation and maintenance costs are considerably lower than existing heating systems. District heating therefore relies on finance to cover upfront investment costs.
Product	The fundamental purpose of district heating is to provide broad societal benefits, i.e. benefits for the customers, businesses and society. Characteristics: - Local control: reduces external dependence - Flexibility: allow introduction of renewable energy source - Efficiency: reduce conversion losses and allow utilisation of waste heat - Cost efficiency

With respect to *technique*, district heating is based on some physical elements that make up the system such as pipes, substations, heat exchangers, valves, supply technologies and raw materials in the form of fuel and manpower.

Within this research the *technique* element is understood as the physical parts of the installation; pipes and raw materials in the form of heat and manpower. The technical element is highly depended on the knowledge. A district heating network would require a huge amount of technical installations in the ground as well as at the heat producing facilities.

Whereas *technique* represents the raw materials and physical installation, the *knowledge* element is related to know-how and know-why (Jespersen & Liengaard, 1993). Within the aim of identifying challenges and solving these, the understanding of *knowledge* (or the lack thereof) is not solely related to the practitioners, but also related to the societal discourse of the matter, politically and publicly, and the awareness of the possible benefits. This understanding is applied in the interviews.

Knowledge also represents preceding research and development, which continuously is renewed. In the case study, new research and knowledge is applied in the specific context to create awareness about alternatives. This step is crucial in order to accommodate the technique elements. There is a good possibility of building bridge to more experienced actors.

With respect to *organisation*, it can be interpreted as both the planning practice and the execution of the working process with the design and establishment of the infrastructure, as well as the planning and operation of the network in the future. It contains power structures, decision-making and engagement and inclusion of stakeholders, on both supply and demand side. Another aspect of *organisation* is the institutional structures surrounding the district heating network. A district heating network would be placed in settings where existing rules and regulation will play a decisive role, which is framed in the socio-technical regime (Geels, 2004). Thus introducing district heating will require changes in the institutional setup and the regulative framework, as rules often don't exist already.

The product in this case is the sum of the other elements, which should result in a grid-based heating system, with a central heat source that is not depending on gas at the individual housing. The product should be both more environmentally friendly, cost efficient, as well as providing flexibility to the system.

Hvelplund (2005) add the element of profit as the decisive part of technological change. Introduction of a new technology, which district heating is, will likely redistribute the profits. It would be argued that a premise for a successful implementation of district heating is that the product will withdraw benefits for users, businesses and the society. The way to examining this is by applying the premises of institutional economy in the calculation.

The profit however, does not come without risks. In this report, the element of profit would be seen in a broader economic sense, connected to initial investment, financial insecurity, funding schemes and liability on actually having a market to support. In this manner, the profit is influenced by the organisational and institutional landscape, where changes in rules and regulation would have a huge influence on the feasibility and viability of the project. Furthermore, by applying the concept of institutional economy, and aiming at an alternative that can be profitable at individual, business and societal level; a strong argument for charging the legislative framework can be obtained.

2.2 Technological change and the creation of alternatives

As stated before, a radical technological change requires that more than one of these technology aspects change. Geels (2004) argues that when new technologies emerge and find a place in the market, the socio-technical regime would have to adapt. However, the scope of this report is just to identify key elements within the technology itself, which can be touched upon by the practitioners and not by society in a broader sense.

But identifying the key elements of the technology will not suffice, therefor the Choice Awareness theory developed by professor Henrik Lund (2010). The theory will be used to describe how the current settings will affect the implementation of a district heating network in Ireland. The theory also suggests a methodology for creating counter strategies for how the society can create alternatives to raise choice awareness in an environment where the existing institutions and organisations are not being supportive to a radical technological change. First step according to (Lund, 2010) is to design a technical alternative to existing technology, proving the potential and thereafter to conduct an economic feasibility study. These two steps will be carried out when analysing district heating in Ireland, as a way to explore possible ways to overcome some of the challenges.

3 Research design

This thesis seeks to uncover existing barriers to district heating diffusion in countries with low district heating penetration and to propose ways to overcome some of these barriers to enable the diffusion of district heating in new district heating cities. To do so, a two-step methodological approach has been applied.

First, qualitative interviews are used to explore the perceived challenges of district heating delivery from a planning perspective. In order to gain a deep understanding of the barriers related to new district heating cities interviews were carried out with ‘inexperienced’ district heating organisations, primarily from Ireland and United Kingdom (UK), as well as ‘experienced’ district heating organisations, primarily from Danish organisations with a focus on exporting district heating to other countries. Lot of experiences, best practices and knowledge can be gained from Denmark, which have utilised district heating since the early 70’ies. By doing so, it is possible to combine the perspectives from those that are currently exporting district heating with those that want to start implementing district heating, which reveals some interesting alignments and mismatches.

After identifying the key barriers for new district heating cities, a feasibility study is conducted to help overcome some of the barriers identified for new district heating cites. A specific case is used here, which is Dublin in Ireland, but the methodology could be repeated in any district heating city. The overall objective of the feasibility study is to quantify some of the barriers identified in the interviews, which in line with the choice awareness theory, then makes it easier to propose alternatives and solutions to overcome these barriers.

Finally, the findings from both the interviews and the feasibility study are used to propose suggestions for how to overcome some of the identified barriers, which can inform both policymakers, planners and district heating promoters forward with the diffusion of district heating.

Part 1: Barriers to district heating deployment

This first part of the study seeks to understand and identify barriers to developing and deploying district heating in the UK and Ireland. In chapter 4 the methodology of the analysis is introduced. Here the data collection process, applied methods and data processing will be described. In chapter 5 the results are presented based on the empirical data from the interviews and the literature study.

4 Methodology

4.1 Data collection

The aim of the qualitative research was to collect detailed information about experiences with district heating development, including state of progress, challenges and barriers and possibilities for future development. These qualitative data were collected through interviews and literature review.

4.1.1 Sample

The two countries, UK and Ireland, were selected with the aim of getting an in-depth understanding of the challenges of delivering district heating in cities in Europe with low levels of district heating and which have a potential to increase this share. This research aim was used as a framework and applied in a purposive sampling process (Bryman & Bell, 2011; 492), i.e. to select which countries to include in the research. Based on the categorisation developed in (U. Persson, Møller, & Werner, 2014) as shown in Table 2-1, these countries include Belgium, Ireland, Luxemburg, Netherlands and United Kingdom (UK). In terms of capability and available resources it was chosen to focus the research on Ireland and UK. Furthermore, these countries were selected due to their convenience and the access to gatekeepers (Bryman & Bell, 2011; 428), which was used to get access to organisations within the UK and Ireland and with experts from Denmark.

Table 4-1 Five general categories reflecting the current district heating penetration on EU27 member state heat markets. Adapted from (U. Persson et al., 2014).

Country category	Member states	DH market penetration
Consolidated	DK, EE, FI, LT, LV, SE	Very High
Refurbishment	BG, CZ, HU, PL, RO, SK	Medium or High
Expansion	AT, DE, FR, IT, SI	Medium
New development	BE, IE, LU, NL, UK	Low or Medium
Other	CY, EL, ES, MT, PT	No or Low

The informants were selected by use of the gatekeepers, which had connections in organisations and companies involved in delivering district heating in the two target countries. During conversations and dialogues with the gatekeepers some informants were strategically selected to give a broad perspective on the challenges in inexperienced countries. This way people involved in the delivery of district heating at different levels (consultants, advisors, city and regional planners and private companies) were approached, based on a convenience sample (Bryman & Bell, 2011; 489).

Within the aim of identifying challenges to deployment of district heating in UK and Ireland, it was of particular interest to have inputs about the barriers to district heating deployment from Danish trade organisations involved in the promotion and export of Danish district heating experiences and solutions. Denmark is one of the most experienced countries when it comes to district heating, from both a technological and planning perspective. Thus, getting an in-depth understanding of the challenges and opportunities from their perspective was used to clarify, why delivery persons have difficulties in delivering district heating systems. Having inputs of the challenges and opportunities of district heating deployment in UK and Ireland from these two perspectives furthermore enable discovering inconsistency between the barriers that were considered to have the biggest impact.

In total 12 interviews have been performed. Of these, 8 interviews were performed with district heating delivery persons from Ireland and UK, while 4 interviews were performed with Danish district heating experts involved in the promotion of district heating in undeveloped countries. The final interview sample is presented in Table 4-2.

Table 4-2 Interview sample breakdown

Sample group	**Inexperienced**		**Experienced**	**Number of interviews**
	UK	IE	DK	
Local Authority	0	2	0	3
Consultant	3	2	1	6
Trade organisation	0	0	3	3
Total	3	4	4	**12**

Furthermore, 5 supplementary interviews have been performed to provide knowledge about the planning process, give technical insight into district heating technologies and to frame the aim of the research. Detailed information about the interviewees is presented in Table 4-3.

Table 4-3 Presentation of interviewees

	Organisation	Profession & title	Reference	Purpose
Inexperienced Country				
UK	AECOM	Regional Director, Sustainable Development Group	Andrew Crips	Engaged in a project investigating how to reduce the cost of district heating in UK.
UK	Rambøll UK	Sustainable Energy Engineer, Energy Systems - District Energy	John O'Shea	Involved in master planning and feasibility studies in UK. Mainly involved in identification of prospect DH schemes, provisional network designs, techno-economic modelling and risk assessments.
UK	Rambøll UK	Consultant, Energy Systems	Alexia Gonin	Working with projects in UK and is former district heating consultant from France.
IE	Dublin City Council (DCC) – District Heating Committee	Senior Executive Engineer, Environment and Transportation & Senior Executive Engineer, Docklands Unit	Victor Coe & Seamus Storan	Part of DCC district heating committee, which is responsible for the provision of DH in Dublin City.
IE	CODEMA – Dublin Energy Efficiency Agency	Strategic Sustainable Energy Planner	Donna Gartland	Have produced detailed heat mappings and assessments for Dublin City and South Dublin pointing out prospect DH areas. Carried out a market assessment for district heating in Dublin City on behalf of DCC. Involved in the provision of DH in Dublin City.
IE	XD Consulting	Founder and CEO	Xavier Dubuisson	Provides advice and support in renewable energy projects and energy efficiency. Is involved in the European Project, SmartReFlex, which supports the development of DH in 6 regions in 4 countries (DE, IE, IT, ES) by providing capacity

				building and knowhow transfer.
IE	RPS consulting	Associate Consulting Engineer	Olivier Gailliot	Was involved in Dublin WtE project and was project manager for Dublin District Heating Project in RPS. Have previously worked as consultant in France investigating the potential of Combined Heat and Power (CHP) and biomass.
Experienced Country				
DK	Danish District Heating Association (DDHA)	Manger International Affairs in DDHA & Vice president at Euroheat & Power	Birger Lauersen	Works with promotion of district heating in both Danish and EU policy and encourage collaboration between stakeholders.
DK	Danish Board of District Heating (DBDH)	Business Development Manager	Morten Duedahl	Responsible for the promotion of DH in UK, Germany and France through facilitation of partnerships and export of Danish knowhow. Was Head of Secretariat in the Danish District Energy Partnership under DI Energy, which specifically focused on the promotion of DH in UK and Scotland.
DK	Embassy of DK in USA (DK Embassy)	Senior Advisor, District Energy	Jakob Bjerregaard	Promotes and export Danish knowhow and expertise and encourage networking between Danish and American industries.
DK	Rambøll Denmark (DK)	Senior Market Manager, Energy Planning and Production & Head of Department, Energy Systems Divisions	Anders Dyrelund & Søren Ørsted	Supports the development of DH in both Denmark and EU in general. Involved in all stages of DH project development: heat mappings and analyses, network design, techno-economic assessments and construction and supervision.

4.1.2 Qualitative interviewing

The nature of qualitative interviews is that they are formed to capture the interviewees perspectives on a given topic, giving space to cover things that the interviewees sees as relevant and important (Bryman & Bell, 2011). The aim of the qualitative interviews was to collect detailed information about the barriers that was perceived to have an impact on the deployment of district heating and to address possible ways of overcoming these.

The interviews were performed as unstructured interviews (Bryman & Bell, 2011) that served to explore and gain an genuine understanding of the interviewees perceptions. Using an aide-mémoire a brief set of topics and themes were covered during the interviews. This way the interviews had the form as informal conversations where a single question was asked, and the interviewee could answer freely, from where questions were raised to cover points that seem worthy of being followed up. It was pursued to carry out the interviews face-to-face. However, due to practical reasons telephone interviewing (or skype) have been used for the hard-to-reach groups.

The interviews were audio recorded where possible to enable accurate collation and analysis of the findings. In cases where audio recordings were not possible notes were taking during the interviews and summarised after the session. The recordings can be found on the attached USB and the takeaways are presented in chapter 5.

4.1.3 Literature review

In addition to interviews, a thorough literature review has been conducted to gain a thorough understanding of the district heating development in UK and Ireland, including national policy documents, reports and assessments of potentials and barriers, research of best-practice district heating planning, state-of-the art descriptions, technical and planning guidelines, magazines and articles. This literature has been reviewed during the research and used as preparation for interviews and as supplementary input in the analysis. The literature is used throughout the report so it is referenced wherever it is relevant.

4.1.4 Other data collection methods

As part of the research the case country, Ireland, was visited as a means to obtain data and investigate the case area for constraints and possibilities regarding the analysed district heating scheme. During the study trip three of the interviews were conducted where maps and information about the case area were obtained. Furthermore, during the trip we attended two talks. One of these were held at the Electricity Supply Board[1] (ESB) headquarter in Dublin City, where David Connolly, Associate Professor at Aalborg University Copenhagen, presented his research about a “100% Renewable Ireland”. Approximately 50 employees from different divisions of ESB attended the talk, where the participants discussed the future role

[1] ESB owns and operates three large power generation plants in Dublin City.

of district heating in Ireland afterwards for approximately one hour. As attendees, this discussion provided valuable knowledge and insight into the real market dynamics, which could not have been gained anywhere else. It also gave access to ask question about their interest and opportunity for participating in a prospect district heating system. Secondly, a talk held at Irish International Energy Affairs was attended, where David performed the same presentation (David Connolly, 2016). At this talk several energy sector stakeholders from Ireland were present, such as NGO's, regional and local authorities and private companies. Again, the future role of district heating in Ireland was discussed for approximately one hour, providing valuable knowledge for the research.

4.2 Data compilation and analysis

Due to a very tight schedule and time available for the research it was not possible to produce full transcripts of all interview recordings. Instead, it was chosen to do a pragmatic transcription process, where sections or portions of the interviews were transcribed (Bryman & Bell, 2011), leaving out sections or parts of the interviews that did not cover the research topic or where the conversation went out of a tangent. However, this was also a process of exploring and discovering, what was interesting to include in the research and to give a good insight to the perceived issues and possibilities for district heating. For those interviews where no audio recordings were made, the notes taken through the process was gathered and organised in one document to get an overview of the main inputs and to ensure consistent reporting of the findings from all interviews.

All data from the interviews, meetings and talks (transcriptions, notes and minutes) have been organised and arranged in order to discover main challenges and issues. This was done in a process of 'tidying up' the data as a way to make sense and give an overview of the data before analysing them (Esterberg, 2002). Hereafter, the data was analysed in a two-step coding process, which is a process of analysing qualitative data in order to find commonalities, differences, patterns and structures (Esterberg, 2002). First, an open coding procedure was performed, where all the data were studied systematically and reduced to inductively derived themes. This open coding process was guided by the research question, but without pre-established codes, allowing key themes to emerge from the data material, which were continuously revised and adapted in an iterative process.

After the open coding the key themes identified were used to cook down the important parts of the data in a focused coding process (Esterberg, 2002). Line by line the data was studied and a category system for discussed topics was developed and applied to the textual data. This way the key barriers and enablers were identified and highlighted, which enabled commonalities and differences to be identified across the interviews. Both of the coding processes were carried out in word using the comment function, which was a simple way to identify and search for themes and topics. The key themes and categories that emerged from the qualitative coding process are presented in the result section (see chapter 5).

In the analysis references to interviews are presented by the surname, e.g. (Gartland, 2016). Detailed information about the interviews can be found in Table 4-3.

5 Barriers to development and implementation of District Heating

This chapter presents the challenges and barriers to the deployment of district heating in UK and Ireland primarily based on inputs from the interviews supplemented by inputs from the reviewed literature.

Table 5-1 summarises the inputs from the interviews in relation to the conceptual framework. The main topics that were discussed as barriers to the deployment of district heating relates to organisation, economy and knowledge, while some topics were discussed in relation to technique and product.

Table 5-1 Main challenges discussed in the interviews

	Reference	Technique	Knowledge	Organisation	Economy	Product
IE						
CODEMA	Gartland, 2016	✓	✓	✓	✓	✓
DCC	Coe & Storan, 2016	✓	✓	✓	✓	✓
RPS	Gailliot, 2016	✓		✓	✓	
WD Consulting	Dubuisson, 2016	✓	✓	✓	✓	✓
UK						
Rambøll UK	O'Shea, 2016; Gonin, 2016			✓	✓	
AECOM	Cripps, 2016		✓		✓	
DK						
DBDH	Lauersen, 2016		✓	✓	✓	✓
DDHA	Duedahl, 2016		✓	✓	✓	✓
DK Embassy	Bjerregaard, 2016		✓	✓	✓	
Rambøll DK	Dyrelund & Ørsted, 2016		✓	✓		

The subsections below present the empirical findings organised in relation to the conceptual framework. During the interviews it appeared that there were several overlaps between the discussed topics relating to *technique* and *knowledge*. These are addressed together in the first following section.

5.1 Technique, knowledge and skills

Several aspects were discussed concerning experience, knowledge and competences related to the actual planning and implementation of district heating. From the Danish experts' perspective district heating were not considered as 'rocket science' and they experienced that the technology itself is well known in most cities. One expert experienced that most people have a good sense about pipe sizes and temperatures and in general about designing networks (Duedahl, 2016), while others experienced that the technical side of district heating were not considered as the most complicated part and that the technical aspect of district heating not is causing that projects stall (Lauersen, 2016; Bjerregaard, 2016). In their perspective, other aspects should have greater emphasis, such as establishing the necessary framework and setup for district heating.

In contrast, the Irish interviewees expressed a need for more technical knowledge and in general to be more familiar with district heating, arguing that they currently have no experience with district heating. In Ireland, very few organisations and project developers have been involved in district heating projects, which according to Dubuisson (2016) means that they do not have the technical and practical skills to develop and implement district heating schemes. Typically project developers will have to start from a blank page when they face new projects, causing that projects progress very slowly. Likewise, The European project, SmartReFlex, identified a lack of technical knowledge and experience relating to the different steps of district heating project development among local stakeholders in Ireland (SmartReFlex, 2015). A research study of barriers and challenges related to the deployment of district heating in UK commissioned by the Department of Energy and Climate Change (DECC) have found that especially local authorities lack knowledge to initialise district (BRE, 2013). It appeared from the interviews that technical knowledge relating to the initial processes of the development, such as creating a basic network design and deciding on pipe sizes and routes were something that was needed.

> *"What size of pipe is needed for a house this big? I don't know. If you are going to put in a network here, what size of pipe is needed? What are the losses? What are the heat losses in a pipe network? […]. So I don't have that expertise. I am sure it can't be that difficult"* (Coe & Storan, 2016; 29:20).

> *"What size of pipe need to be is obviously an issue. Trying to plan little parts of the picture without knowing exactly how the big picture fits in, so exactly what size of pipes and pressures and temperatures are involved."* (Gartland, 2016a; 5:00).

> *"Are there limitations on if you have a small area on the backbone at the start in terms of then, in terms of spreading the district heating system into other areas? So what should you design your water storage for? Just the small development or should the water storage be designed at the start to have the expansion in mind. Those kinds of things."* (Gartland, 2016a; 16:10).

From the perspective of the Irish interviewees, there are lots of experiences with other types of urban infrastructure like water, sewage water and public lighting, stressing that the groundwork and installation is not new, but concerning the specific experience with district heating it is something that lack in general (Coe & Storan, 2016; Gartland, 2016a, 2016b). Another perspective was that that even engineers and consultancies lack this kind of knowledge, as the district heating market within Ireland still is immature and very few schemes exist (Gartland, 2016a; Dubuisson, 2016). The market penetration in Ireland is virtually zero, and with very few small-scale district heating schemes in Ireland, there does not exist best-practice examples from an Irish context to copy and no guidelines to gain knowledge and assistance from. Therefore, the interviewees requested guidance and support to upskill persons involved in the project developments, which can generate the necessary capacity to initialise district heating projects. This need for capacity building has been acknowledged in SmartReFlex, which has trained and educated key stakeholders at both national and regional level, among other technical staff and city planners from municipalities (SmartReFlex, 2016).

During the discussion of network designs, it also appeared that getting the needed information about end-user's installations and consumption is an issue. One Irish interviewee noted that obtaining information about exact customer demands and type of space heating is an issue in terms of establishing a network design (Gartland, 2016a). Another interviewee experienced that the same information deficit appeared in UK and noted that lots of efforts have to be put at the marketing to collect this information, which can be labour intensive and difficult, as most people are reluctant to provide that information (O'Shea, 2016). In comparison, project developers and local authorities in Denmark can access actual consumption data and building information from the Building and Housing Register (BBR), which ease the process of getting adequate information at building level. However, even when marketing is completed successfully and adequate data is obtained, one interviewee experienced an inability of determining what inceptions and refurbishment are necessary, to make the end-user district heating enabled and to determine what the costs of the adoption would be (Gartland, 2016a, 2016b).

Concerning the implementation and installation of district heating networks, another aspect that was discussed was the supply chain and the lack of skilled and competent civil contractors. In UK, it is evident that the diffusion of district heating is hampered by a lack of qualified civil contractors (BRE, 2013; Pöyry & AECOM, 2009). One of the UK interviewees faced that very few contractors have the competencies and skills to do excavation of trenches and perceived that there is a need to break the knowledge gap that occurs among the contractors (Cripps, 2016). This lack of experience is caused by the low market penetration in UK, which according to Lauersen (2016) will be rectified with the diffusion of district heating schemes and the maturity of the market. The lack of local experience and established supply chain also occurs in USA, which according to Bjerregaard (2016) experience the same hurdles with contractors that lack competencies to do excavation and welding of district heating pipes mainly because they do not have experience with it. In general, this was perceived as a considerable challenge in relation to the tendering process and construction costs, which were considered to hamper the overall economy of the projects, as discussed in section 5.3.

5.2 Organisation

Several aspects were discussed concerning project delivery in terms of engaging stakeholders and developing business plans. Aligning stakeholders, getting them to come to terms and structuring the ownership of the network were seen as central issues. One expert mentioned that many feasibility studies in UK ends up collecting dust, as the project developers do not have the knowhow and experience to convert it in to a business model in terms of deciding who should own, finance and operate the system (Duedahl, 2016). The lack of experience and ability to convert the feasibility studies in to a business case have occasionally stalled the projects in UK (BRE, 2013). It is a challenge that has been addressed by DBDH, which in a recently published magazine stated that it is a challenge that not only occur to newcomers, but appears in many countries (DBDH, 2015). In general, the Danish experts considered the organisation of systems and alignment of stakeholders to be the essence and key element of delivering district heating. For instance, Lauersen (2016) expressed that engaging the variety of stakeholders that should come to terms in a district heating network is the complicated part. You have to find someone that has some heat to supply, authorities that provides the needed permissions and you need to identify and secure a customer base that are willing to pay for the heat. In his perspective, getting all these different actors to align and agree on the same conditions is what makes the process complex and new to many cities. Furthermore, when this is settled, the next question that arises is how the benefits, risks and responsibilities should be distributed among different partners in the business model, which poses the real hurdle (Lauersen, 2016). The Irish interviewees, who felt that they did not have any knowledge about and experience with how to develop business models and push projects forward, supported this argument. In Dublin they have been working on a feasibility study for a while, but finding out who should own and run the network and how it should be structured is one of the main challenges they still have to overcome (Gartland, 2016a; Coe & Storan, 2016).

> *"The department is at the moment looking at a business case model, so what would suit the council best in terms of what part they should own, should they just own the pipelines and maybe rent this district heating facility, would that be the best option for them or. […] You know will the customers trust the utility enough to connect or should it be a municipality run district heating system. So that kind of business is a little bit of complication."* (Gartland, 2016a; 2:30).

Another concern was whether the municipality would have the resources and ability to own a district heating network, as they do not have any experience with running utility. Also in terms of trust and legitimacy, one interviewee expressed a concern for the customers' willingness to accept the utility depending on who should own the district heating network (Gartland, 2016a).

From the Danish district heating expert's perspective, a big part of the Danish district heating success has been 'the Danish model', which is based on effective regulation and planning. The heating sector in Denmark have been regulated since the establishment of the first Heat Supply Act in 1979 and continuously developed and strengthened in to a strong planning approach, which by many are regarded as one of the most effective in the world (Chittum & Østergaard, 2014; IEA, 2011). Besides the regulation of the heating sector, the Danish model comprise a stable energy policy, municipal planning and a tradition for cooperation (Chittum

& Østergaard, 2014). As such, the elements comprised in this model have created a setup and framework that have made it possible to integrate high shares of district heating in the Danish energy system. According to the Danish district heating experts, the absence of such a framework is a barrier for the organisation and delivery of district heating and is one of the main reasons why district heating faces a slow diffusion in many countries (Lauersen, 2016; Duedahl, 2016; Bjerregaard, 2016). The planning framework is in their perspective necessary to make district heating compatible and to protect both suppliers and customers from other heat supply sources. District heating is a natural monopoly, which means that when first established it can provide heat at a considerably lower cost than a competing alternative supply due to the *economy-of-size* (Frederiksen & Werner, 2013). More elaborated, a natural monopoly should not be exposed to competition to ensure economy-of-scale and thus to protect the interest of both consumers and investors. In Denmark the principle in the Heat Supply Act is to ensure that the supply alternative with the best socio-economy is to be implemented and after that it is made to a monopoly, where nothing else is allowed to compete with it. It is a principle, which has been adopted in the Energy Efficiency Directive (EED) Article 14, where it is stated that:

> *Member States shall carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling […].* (European Parliament, 2012; Article 14/1)
>
> *Member States shall carry out a cost-benefit analysis covering their territory based on climate conditions, economic feasibility and technical suitability […]. The cost-benefit analysis shall be capable of facilitating the identification of the most resource-and cost-efficient solutions to meeting heating and cooling needs.*(European Parliament, 2012; Article 14/3)
>
> *Where the assessment referred to in paragraph 1 and the analysis referred to in paragraph 3 identify a potential for the application of high-efficiency cogeneration and/or efficient district heating and cooling whose benefits exceed the costs, Member States shall take adequate measures for efficient district heating and cooling infrastructure to be developed and/or to accommodate the development of high-efficiency cogeneration […].* (European Parliament, 2012; Article 14/4)

This principle has had great success in Denmark and by adopting it in the EED, the European Commission have strived to make the Member States adopt it. However, making other Member States adopt this principle is not that easy, and so far it has had little impact (Lausersen, 2016). A way to enhance the promotion of district heating is to make it mandatory for Member States to implement district heating in areas where the comprehensive assessments (as required by Article 14 in the Energy Efficiency Directive) show that district heating is the socio-economic best solution, which might be something that will come from EU as a follow-up on the Heating and Cooling Strategy (Lausersen, 2016).

Neither Ireland nor UK has any regulation on district heating, which both UK and Irish interviewees considered as a challenge to the diffusion of district heating. The Irish interviewees mentioned that it is a barrier that they can't require the customers to connect due to the lack of regulation (Coe & Storan, 2016). Also that it is difficult to secure a customer base without regulation (Gartland, 2016a, 2016b). In UK, one interviewee mentioned that the unregulated pricing of heat often makes consumers nervous about getting tied to contracts where the price of heat can rise rapidly (O'Shea, 2016). This transparency in the heating price have earlier been deemed as an important factor to convince customers to connect to district heating in both UK and Ireland (BRE, 2013) (SEAI, 2015a). All district heating companies in Denmark are established under a non-for-profit principle, which means that the company is not allowed to earn money (Danish Energy Agency, 2015). Thereby, the price that customers pay reflects the actual price of producing and delivering the heat plus some additional legal expenses, which are defined in the Heat Supply Act (Danish Energy Agency, 2015). More elaborated, it means that the customers are first of all protected from sudden price increases, which are not reflecting the marginalized costs. Secondly, they directly benefit from any savings that may occur.

In combination with the regulation and planning the political stability and commitment in Ireland was mentioned as a barrier. At the moment the oil and gas prices are low and there is a need for incentives to promote district heating. One interviewee referred to the discussions about a Renewable Heat Incentive (RHI), which have been much debated in working groups and policy documents in Ireland, as the incentive that can make district heating bankable, similar to the RHI that is enforced in UK (Crown, 2015). Recently, a national White Paper have been published in Ireland stating that this RHI will be introduced in 2016 (DCENR, 2015b), however the interviewee were sceptical, as it is not outlining how and when it will be introduced (Dubuisson, 2016). The Sustainable Energy Authority of Ireland (SEAI) has supported the need for national political stability. In their assessment of the potential for district heating in Ireland they state that no prior national assessments have been carried out (however one thorough study have been carried out by Dublin), and that it is important for the Irish Government to identify how the policy should support district heating in the future (SEAI, 2015a). It is also considered that the absence of national policy is a barrier and as part of that suggests providing incentives to allow district heating enter the heat market. However, at the moment district heating is not on the political radar and the political commitment is considered to be more or less absent (Coe & Storan, 2016), even though the National Renewable Energy Action Plan has recognized the potential benefits of district heating (DCENR, 2009). In UK, district heating have got more political attention and several actions have been proposed to increase the diffusion of district heating (DECC, 2013a, 2013b, 2014). For example, a national heat map has been commissioned by DECC to support the planning and deployment of local low-carbon energy projects in England (DECC, 2012), which has provided information and increased awareness of available heat demands and supply assets

(O'Shea, 2016). Furthermore, a national Heat Network Delivery Unit (HNDU) have been set up by DECC to provide grant funding and guidance to local authorities (DECC, 2015), recognising the capacity and capability challenges they identified in a previous study (BRE, 2013).

The role of local authorities and their ability to push district heating projects forward was another discussed aspect. In general, it was considered that the local authorities should play a central role in the development of projects, acting as a 'local champion' (Gaillot, 2016) and 'enthusiast' (Duedahl, 2016). The municipalities were seen as particularly significant actors, and as a key element in developing district heating, as they both are in a good position and possess valuable knowledge. In Denmark, part of the district heating success have been the role of municipalities in Denmark, which effectively acts as local regulators and project facilitators in cooperation with district heating companies (Chittum & Østergaard, 2014). Part of this is that they have been enabled and empowered to have this role, with the decentralised heat planning power and responsibility provided by the Danish Government. However, taking on this role was considered a barrier between both UK and Irish interviewees and has similarly been found to be a barrier in much literature (D. J. C. Hawkey, 2009; D. Hawkey, Webb, & Winskel, 2013; Pöyry & AECOM, 2009; SEAI, 2015a). One interviewee observed a lack of skills and competencies within local authorities in Ireland and a lack of empowerment, which he considered as a central barrier (Dubuisson, 2016). Another interviewee explained that district heating has lower priority than other services and further stated that it caused a resource deficit, which was the main reason why a project stalled (Coe & Storan, 2016). It was also noted that the internal coordination in the public authority is a shortage, which have to be addressed (Dubuisson, 2016). In UK the cities face the same issues (BRE, 2013; Pöyry & AECOM, 2009), aside from London, where the former City Mayor had the power and willingness to push projects forwards, by allocating resources and force customers to connect (O'Shea, 2016), which might change with the enforcement of the new mayor. However, outside London the cities are depending on the local council to make district heating appetizing (O'Shea, 2016), but as in Ireland district heating seems to be prioritized lower than other public sector services, such as health and education (Pöyry & AECOM, 2009).

The projects that actually are realized are typically small-scale projects that emerge in 'campus-settings', typically small arrangements with very few, often public, customers. In these projects the developer (either private or public) are keen to put efforts into realizing the project, as they have one large or very few customers and thus no difficulty in structuring it (Bjerregaard, 2016; Duedahl, 2016). These types of projects can be found in most of UK and USA and a few exists in Ireland. However, when you get outside these campus-settings and begin to look at large-scale district heating schemes, it can be difficult to find someone to mobilise the projects. It was mentioned that private developers usually do not have an appetite for these projects, as they are perceived to carry higher risks (Bjerregaard, 2016;

Duedahl, 2016). In these cases, the local authority could very well take the role as project facilitator, but they often lack both resources and competencies to do so (Bjerregaard, 2016).

Another problem that occur in UK is the jurisdiction that does not allow district heating companies to sell heat to private entities like hospitals and universities, which means that a municipal company will drag a pipe over housing associations, hotels and hospitals, even though they would be both willing and beneficial to connect (Duedahl, 2016). Due to these jurisdictional limitations, many small isolated systems emerge, each with their own small heat unit. This prevents collaboration between the system owners and thus coordination of system investments, which means that they are not able to pick the benefits of economy of scale, which is one of the key challenges in the UK district heating situation (Duedahl, 2016).

5.3 Economy

The economy was raised as a central barrier to deployment of district heating by all interviewees. Especially three aspects of economy were discussed; costs, risks and finance.

In relation to costs, some interviewees faced that the capital investment needed for the heat network contests the competitiveness of district heating schemes. An Irish interviewee involved in a scheme development in Dublin faced that there is lacking experience with pipe costs and suffered from the absence of Irish cases to get the information from. He explained that the price of installing an ordinary pipe would be €1000 per meter, as the city centre is highly congested with existing pipes, and perceived that the cost of installing district heating pipes would be twice as high (Coe & Storan, 2016). In UK, it is evident that network development costs are significantly higher compared to other markets (BRE, 2013; Pöyry & AECOM, 2009), caused by the immaturity of the market, as was discussed in section 5.1. Contractors in UK are perceived to lack competencies and knowhow, which is reflected in high risk premiums being added to the costs (Pöyry & AECOM, 2009; Cripps, 2016). This is an obstacle that has got increased intention in UK. For example, a UK consultancy, AECOM, is engaged in investigating why the installation of district heating pipes seem to bear more costs and why UK contractors seem to be up-skilling slower than other countries (Wiltshire & Cripps, 2016). Another reason relates to the market immaturity and the absence of domestic district heating unit and pipe manufactures (BRE & Centre for Sustainable Energy, 2013; Cripps, 2016), which cause higher prices on network equipment. These challenges also occur in USA, where the market size for district heating is low as well. However, this market immaturity may be rectified when district heating gets more commercially mature (Lauersen, 2016; Bjerregaard, 2016; Pöyry, 2009).

It is also evident that some costs drivers are of a more structural nature. A rule of thumb is that areas with heat densities over 140 TJ/km^2 can be considered feasible (Frederiksen & Werner, 2013), while the cost effectiveness of a prospect district heating scheme depends on the plot ratio for the specific area (Nielsen, 2014). A report carried out for DECC In UK found that the mix of the housing stock leads to increased costs of building the network compared to a country like Finland (Pöyry & AECOM, 2009). Similarly, an assessment of the potential for district heating in Ireland found that the heat demand is low density in nature, with less than 10% of the national heat demand deemed feasible for district heating (SEAI, 2015a). Prior to this, it was stated in the National Energy Efficiency Plan (NEEAP) of Ireland that the cost effectiveness of district heating is contested by the population dispersal, the nature of the housing stock, temperate climate and low availability of biomass (DCENR, 2014). The NEEAP further states that the district heating market is contested by the deflated construction industry and a perceived low cost effectiveness of retrofitting district heating:

> *"[…] the cost effectiveness of retrofitting District Heating is clearly a considerable challenge having regard to (a) the drive towards near zero energy buildings with accompanying low heat demand and (b) capital cost and logistics, both weakening the business case for District Heating."* (DCENR, 2014; 46)

In relation to investment costs, there was a perception of high risks and uncertainties. In this regard several risks where perceived to be a barrier for making a return on the investment, which often gets a strong focus (DBDH, 2015). In Dublin, the City Council is hesitant to make investments due to the uncertainty about the size of investment related to establishment of the heat network, as the scheme in their perspective already have small financial gains (Coe & Storan, 2016). This is a risk that influence whether the scheme will be realized, as the city council not is willing to gamble with public money, as reflected in the quote:

> *"We haven't found out what those costs are and we need to be made sure that we can actually have a return on the money and the investment that DCC have invested to build this. So we don't know what that is yet. Obviously Dublin City Council is spending public money, so we want to be sure that we are not putting ourselves us self at risk. So we need to know what is the cost, or the reports says it is going to cost 34.6 or 21.5 million depending on which report you read. And we need to know if we connect all these properties here that we are going to get a return on our 43.6 or 21.5 million. But what if it costs 100 million? Then we will never get a return on it and we have asked the taxpayers in Dublin to spend 100 million that they are never going to get a return on. That is not good governance."* (Coe & Storan, 2016; 31:15).

Besides merely cost related risks it was perceived that the lacking regulation of district heating poses a coordination problem. It was mentioned that project developers do not have the ability to make district heating mandatory, and thus have to handle this obstacle by signing optional customer contracts (Gartland, 2016b; Coe & Storan, 2016; O'Shea, 2016). Furthermore, it was perceived as a barrier for the project developer's ability to engage with heat suppliers, who are unwilling to participate if long termed contracts have not been agreed (O'Shea, 2016). According to Duedahl (2016), private companies are not willing to expose themselves to unnecessary risks, which is legitimate and understandable seen from a stockholders' point of view. The lacking regulation was also perceived as a barrier in terms of engaging customers and getting their acceptance. One interviewee expressed that the lacking familiarity with district heating among customers coupled with the insecure pricing makes customers nervous about uncontrollable heat prices (O'Shea, 2016). Also the fact that district heating schemes are not protected from competition from other alternative supply (as discussed in 5.2 on page 22) was by a Danish expert perceived as a risk to the project developer (Lauersen, 2016).

In general, it was perceived that district heating projects are subject to several types of risks; lack of knowledge, inability to coordinate, inconsistent pricing and customer protection, protection from competing energy sources and lacking maturity of supply chain. These risk coupled with the high upfront capital costs makes district heating an uncertainty investment, which affect project developers' appetite to develop the projects. According to a Danish expert it all comes down to a discussion of risks and returns (Bjerregaard, 2016).

> *"So it's all about risk and return in the end. When you start to plan something like this, if you then think that there is 50% chance that it [the project] will come to nothing, then you would have 50% profit on it [...]. And that assessment of what type of profit and what type of risk you have, that is so vital for private companies, as they only enter projects where they can see that there might be a 'return on investment' on let's say 20-30%. Since there is a risk that it does not succeed they will require this return to even bother to develop the project."* (Bjerregaard, 2016; 7:00)[2]

As reflected in the quote, private investors are motivated by the prospect of a profit, thus projects that are perceived to contain risks will be re required to have a high return on investment. Another interviewee experienced that private investors in UK typically looks for an internal rate of return of 12-15%, while public authorities require 8-10%. These hurdle rates are in his perspective reflecting their risk willingness, where public authorities often will accept a bit more uncertainty (O'Shea, 2016).

Sourcing finance and obtaining funding were considered as a principal impediment to deployment of district heating. District heating is still a niche technology in both Ireland and UK, which means that mayor investments are required. Locating finance to realize these investments is maybe the biggest barrier (Dubuisson, 2016). In Ireland, there is no national funding or grants to cover capital costs and private finance can be difficult to get, if projects have low rates of return (SEAI, 2015a). As such, the capital costs need to be covered by the municipality (Gartland, 2016). Obtaining long termed bank loans is a challenge, as they do not have any experience with district heating and thus perceive district heating projects to contain high risks (Dubuisson, 2016). In 2013, a national Energy Efficiency funding mechanism

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[2] Own translation: *"Altså det hele handler om risk og return i sidste ende. Når man begynder at planlægge sådan noget her, hvis man så tror, at der er 50 % chance for at det ikke bliver til noget, så skal man gerne have 50 % profit på det […]. Og den vurdering af, hvilken type profit og hvilken type risiko man har, det er den, der er så afgørende for at få private selskaber til at gøre det, for de vil kun gå ind i projekter, hvor de kan se, at der måske er en 'return on Investment' på, lad os sige 20-30%. Fordi med den risiko, der er for, at det ikke bliver til noget, der skal de derop for at de gider at udvikle projektet."*

was set up, allocating €35 million to private and public energy efficiency projects (SEAI, 2013). However, the funds are mainly designated to retrofitting or end use reductions, which can cover the investments in e.g. heat exchangers or the connection to an established district heating scheme, but not the pipe costs (Gartland, 2016b). This is a major challenge, as the costs related to the heat network are a significant part, covering maybe 60% of all capital costs (O'Shea, 2016). Considering that some projects can have long termed revenues and low returns on investments, long termed funds with favourable low rates may be a prerequisite for projects to be bankable. In Denmark, public authorities can obtain long termed loans at a favourable rate through KommuneKredit (The Credit Institution for Local and Regional Authorities in Denmark). In UK, sourcing funds and making projects bankable have until recently been a challenge as well (BRE, 2013), but in November 2015, DECC made £300 million available for project funding in order to support project owners in project delivery (Ashfords, 2015). Furthermore, the HNDU have been established to support the development of projects from heat mapping to the detailed feasibility and viability study and delivery of business models. The initial preparation of a scheme is usually a long and costly process and sourcing appropriate finance to this first phase of the scheme development can itself be a barrier for the mobilisation of projects (Bjerregaard, 2016). For the same reason the HNDU also provide grant funding to local authority projects, covering up to 67% of the of eligible costs.

5.4 Product

The societal priority objectives for district heating over conventional heat supply, such as natural gas, includes factors as energy efficiency, independence from external fuel supply, increased renewable energy penetration and local jobs. These are priority objectives that have been incorporated in the European heating and cooling strategy (European Commission, 2016) as a means to comply with the overall European Union objectives of ensuring security of supply, sustainability and competitiveness (European Commission, 2015). The deployment of district heating is not yet mandatory, but the European Commission will most like follow up on the heating and cooling strategy with an attempt to increase the diffusion of district heating across the EU MS's. However, the diffusion of district heating in Ireland and UK are facing a challenge in terms of competition with established market interests (Duedahl, 2016). Both countries have high shares of natural gas covering up to 70% of the total heat demand in both countries (DECC, 2013b; Howley, Holland, & Dineen, 2014), reflecting a well-established gas sector. District heating is a competing technology and does not fit the priority of the existing gas sector, which protects their interest through lobbyism (Duedahl, 2016). Therefore, the market uptake of district heating will need to be supported politically to be able to compete with the gas sector (Lauersen, 2016). In UK, district heating penetration in the building sector have reached 2% (DECC, 2014), while the district heating level in Ireland is approximately 0% (SEAI, 2015a). The difference is possibly enforced by political awareness and support of district heating, which recently have encouraged and enabled the entry of district heating through fiscal incentives, allocation of resources and enhanced awareness of the possibilities for district heating (O'Shea, 2016). The political attention to district heating in Ireland has not reached the same levels yet (Dubussion, 2016; Coe & Storan, 2016), but is beginning to get attention in political documents (DCENR, 2015b). However, district heating has got a central role in the fulfilment of the Covenant of Mayors in Dublin, where the priority objectives are a better environmental footprint, increased possibility for RES and efficiency gains (CODEMA, 2010). As part of this, Dublin City has committed to the development of district heating in Dublin as a means to reduce carbon emissions, utilise excess heat and promote Dublin as a sustainable city (Coe & Storan, 2016). However, the familiarity with district heating among the public and their acceptance of a collective heat supply pose a challenge. The district heating network is developed to be supplied with heat from a Waste to Energy (WtE) facility, which have been met negatively by the public and generated bad press (Coe & Storan, 2016; Gaillot, 2016). Though, the plant is going to be commissioned in 2017, the council have not been able to sign contracts with any customers, and the public acceptance of the WtE facility and willingness to connect are thus posing a considerable challenge to the realization of the project (Gartland, 2016). This is considered to require a change in mind-set, as connecting to a collective system like a district heating system almost is a cultural barrier for citizens in UK and Ireland, which tend to prioritize independency and freedom to choose (Dubuisson, 2016; Duedahl, 2016). The gas sector in UK have, according to Duedahl (2016), persuaded citizens to prioritize natural gas over district heating, in the believe that it provides independency and freedom to choose over own supply.

5.5 Main barriers

Overall, the results show that there are several barriers that have to be overcome to enable the development of district heating in the new district heating cities. However, some barriers stand out from the rest. The results show that several barriers are hampering the deployment of district heating in Ireland, which relates to all of the technology elements, while the district heating development in UK slowly is beginning to mobilise making the barriers more specific and mainly related to organisational and economic aspects of the development. The main findings of the analysis are summarized in Table 5-2.

Table 5-2 : Overview of main barriers

	Technique	Knowledge	Organisation	Economy	Product
IE	✓	✓	✓	✓	✓
	Designing and dimensioning prospect DH networks	Preparing business case and defining business model Skilled consultancies and contractors	Ability and resources to mobilise and facilitate projects Coherent planning and internal coordination Political stability Regulation of heat networks	High capital costs High risks and uncertainties Funds and grants to cover upfront capital costs	Public acceptance
UK		✓	✓	✓	
		Skilled consultancies and contractors	Regulation of heat networks	High capital costs Longevity and reliability of customer demands Market maturity	Public acceptance
DK		✓	✓	✓	✓
		Lacking ability to organise and establish business models	Regulation of energy sector Integrated planning framework	High capital costs High risks and uncertainties Funds and grants to cover upfront capital costs Market maturity	Public acceptance Competition and lobbyism from the gas sector

There is a deficient practical and technical knowledge related to the design and development of district heating networks in Ireland, while UK seem to have gained a little more experience and knowledge within this field. Interestingly, a misalignment was found between the inexperienced and experienced countries' perception of the technical barriers. The experienced interviewees did not recognise this parameter as a main barrier, as they did not consider district heating to be rocket science and they had confidence in the engineers' competences to overcome most obstacles. A capacity building through training and insight to best-practice showcases could be a way to overcome the restraints in the inexperienced country.

Though the perceived barriers were found to differ among the experienced and inexperienced interviewees the results show that there is some degree of convergence indicating that the barrier is to enable and empower local authorities to develop and implement district heating. The local authorities have a key role to play, in terms of facilitating and organising the project, both in relation to identifying and engaging possible stakeholders and end-users, as a well as to organise a business model. There is a challenge relating to the question of how to distribute the benefits, risks and responsibility in the business model. Thus, from a theoretical point of view it is not only an organisational challenge, but also a question of providing knowledge and developing in-house skills in the public sector that enable them to develop and deliver district heating projects.

From the perspective of the experienced interviewees the regulative and political support is a determining factor. A strong political commitment and support is needed to generate momentum for district heating. The last couple of years several political actions have been initialised in UK, which among others include a national support unit and allocation of national funds. This indicates a strong and clear political commitment, extended beyond the long-termed strategies and good intentions. The political commitment could also help creating a higher degree of security of the investment and create a stable setting for district heating. The high capital costs and risks suggest that it is important to establish this long-term stability in order to secure returns on investments.

Table 5-2 outlines there is a consistency in the perceived challenges. Denmark has a proven concept and the inexperienced countries are striving for inputs, so much to a degree where the demand is higher than the supply. The Danish expert organizations accommodate this demand, by providing their support where they see fit. For organizations such as DDHA and DBDH, the main focus has been to assists overcoming regulative and organizational barriers. This has been done by showcasing good Danish practices of engaging the supply side with the city planners. Thus, DBDH and DDHA are attempting to open up new market arenas and are acting proactive by providing knowledge that enhances the local capacity. When it comes to technical challenges, they can refer to Danish companies like Logstor and Danfoss, who have specialized expertise related to meet the concrete technical challenges related to district heating projects. Rambøll on the other hand, as a consultancy offer their services in all stages of planning, design O&M and managing. The have the skills to realize and commission the concrete projects. Put simple, Rambøll is delivering the product, while the trade organizations are creating the market. An up-qualification of the local actors could prove beneficial in order for them to identify new potential projects, as seen in SmartReFlex.

In conclusion, the following six main barriers can be highlighted:

1. Lack of technical and practical knowledge among local stakeholders, such as public sector city planners and technical staff
2. Incapability of engaging stakeholders and arrange business models
3. Lack of regulation and political stability
4. High capital costs and sensitivity to long-term risks
5. Lack of funding to cover long-term capital costs
6. Lacking understanding of the benefits of district heating among individual consumers

In part 2, a feasibility study will be used to investigate some of the main barriers that have been highlighted here in more detail. First, the feasibility study will be used to demonstrate how a rough network design, including route mapping and pipe dimensioning can be carried out, which address the technical barrier identified above. Secondly, an economic assessment of the designed network will be used to quantify the magnitude of the investment in the pipework and the risks and uncertainties, which address the economic barriers. Thirdly, the feasibility is used to investigate, how a district heating network can be organised and which stakeholders could be involved, which address the knowledge and organisation barriers. Fourthly, the feasibility study is used to quantify the benefits of a district heating system from a socioeconomic, business economic and consumer economic perspective, which address the product barrier. Thereby, the feasibility study will investigate all of the six barriers highlighted above.

Part 2: Feasibility study

In line with the choice awareness theory described in chapter 2, a 3-step methodology is used here to investigate and quantify some of the main barriers identified in part 1, as illustrated in Figure 5-1. First, a technical alternative will be designed, which will demonstrate how to design a district heating network. Secondly, this technical alternative is compared with a reference scenario and evaluated from a societal, business and consumer economic perspective. Here the capital costs, risk and uncertainties and benefits will be quantified and the organisation of the district heating network will be investigated. In the third and last step, the results of the feasibility study and the identified barriers from part 1 are discussed. Overall, the feasibility study will serve as a social learning tool (Lund, 2010), that can be used to suggest solutions for the identified barriers and furthermore create awareness of the possibility for developing district heating in Dublin.

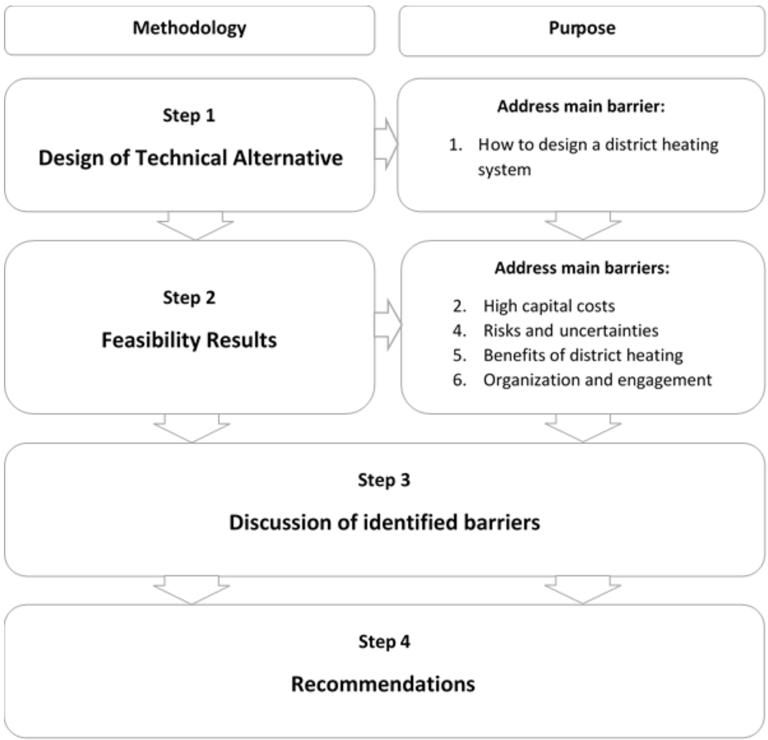


Figure 5-1 Flow chart of feasibility study

Ireland is used as case country, but the methodology could be repeated in any district heating city. Ireland is chosen due to the availability of data required for the feasibility study and further due to the institutional context, which was easy to understand and gain knowledge from. The fact that the district heating level in Ireland is virtually 0% was furthermore a motivation for quantifying the barriers to introducing district heating. The first chapter gives a short description of the potential for district heating in Ireland and introduces the specific case area, Spencer Dock, which is used for the feasibility study.

6 Background of district heating in Ireland

District heating has had very limited development in Ireland. Only a few small-scale district heating networks exist, powered by small CHP's or boiler systems. The biggest system is in Tralee Town in Kerry County Council where 100 residential units and a few public buildings are supplied with hot water and heat from two 500 kW wood chip boilers (Sustainable Energy Authority of Ireland, n.d.). One feasibility study has been conducted for a large scale district heating in Cork, while two feasibility studies have analysed the potential for large scale district heating in Dublin. The District Heating Association of Ireland carried out the first study in 1975, but still after 40 years there have been no breakthrough for district heating. A couple of reports have stated that the low heat density, temperate climate and access to cheap heat sources are barriers to the development of district heating in Ireland (Ecoheat4EU, 2011; SEAI, 2015a; WS Atkins Consultants, 2002). However, it will be argued that these are half-true statements (Lund, 2010).

In 2015, a comprehensive assessment of the potential for cogeneration and district heating showed that around 90% of the total Irish heat demand is located in low heat density areas (SEAI, 2015a), while around 1,5% of the heat demand, mainly located in Dublin, was found to be in high density areas with a sufficiently high viability (SEAI, 2015a). A detailed spatial energy demand analysis of the heat demands in Dublin, found that over 75% of the total heat demand in the city is located in high-density areas (i.e. have heat densities above 150 TJ/km^2), and could be classified as suitable for district heating (Codema, 2015b). The study also indicated that there are several potential waste heat sources within short range, such as breweries, cement factories, waste water treatment plants and power generation plants (Codema, 2015b). As illustrated in Figure 6-1, three power plants are located within 2 km from the high heat density areas, which currently not harness any of the waste heat generated from the electricity generation processes. It has been argued that the excess heat from these power stations alone, if turned into CHP mode, could supply all of Dublin City's heat demands, by means of district heating (David Connolly, 2016). Another potential supply source, which has not yet been mapped in (Codema, 2015b) is Dublin Waste-to-Energy (WtE) facility, which is currently under construction on Poolbeg Peninsula in Dublin City. The WtE facility is to be completed in 2017 with a thermal capacity of 150MW, expected to produce heat enough to cover the heat demand of 50.000 households (DWtE, 2014). These potential waste heat sources would be an ideal input for district heating systems, as it can utilise the excess heat as a low cost domestic energy source (Frederiksen & Werner, 2013).

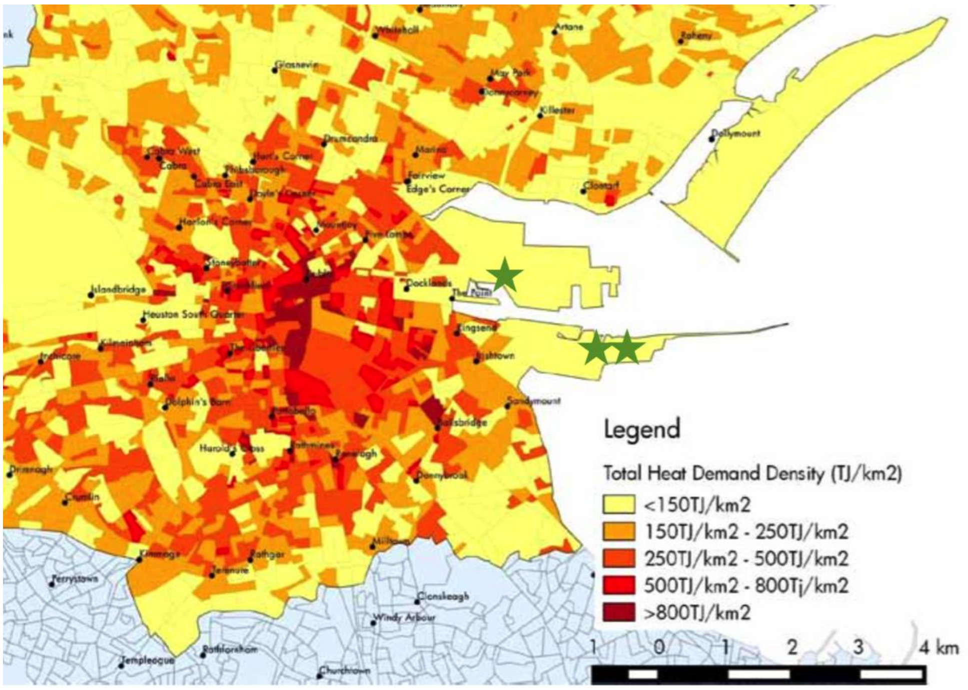


Figure 6-1 Heat densities in Dublin City (Codema, 2015b)

It can be concluded that even though the potential for district heating is found to be low in most of Ireland, over 75% of the heat demand in Dublin could potentially be supplied with district heating. Furthermore, it is shown that there are excess heat sources within short range, which potentially could cover all of the heat demand in Dublin City. Arguing that Ireland is not suited for district heating in terms of heat density and cheap supply sources are thus not true.

To quantify the barriers to district heating in Ireland, Dublin will be used as a case in the feasibility study. The next section presents the specific area in Dublin, Spencer Dock, which is the focus of the study.

6.1 District heating in Dublin

In 2009, the Lord Mayor of Dublin signed up to the Covenant of Mayors, which imply that Dublin City has to go beyond the EU objectives set by EU for 2020. In the Sustainable Energy Action Plan (SEAP) from 2010 it is stated that the development of a district heating system is necessary to reach this target (CODEMA, 2010).

> *"It is […] clear from the technical analysis that energy efficiency alone is not enough to keep Dublin's emissions trajectory on track through to 2020 and beyond. A significant investment is required in: 1) Dublin District Heating project, 2) Transport 21 - public transport and 3) Renewable energy. And, critically, the investment must start without delay."* (CODEMA, 2010; 26)

Dublin City Council has since 2008 planned the development of a district heating system in Dublin Docklands (see Figure 6-2). Docklands is a Strategic Development Zone (SDZ), in which several new developments are currently at a planning stage conditioned to be district heating enabled (DCC, 2013).

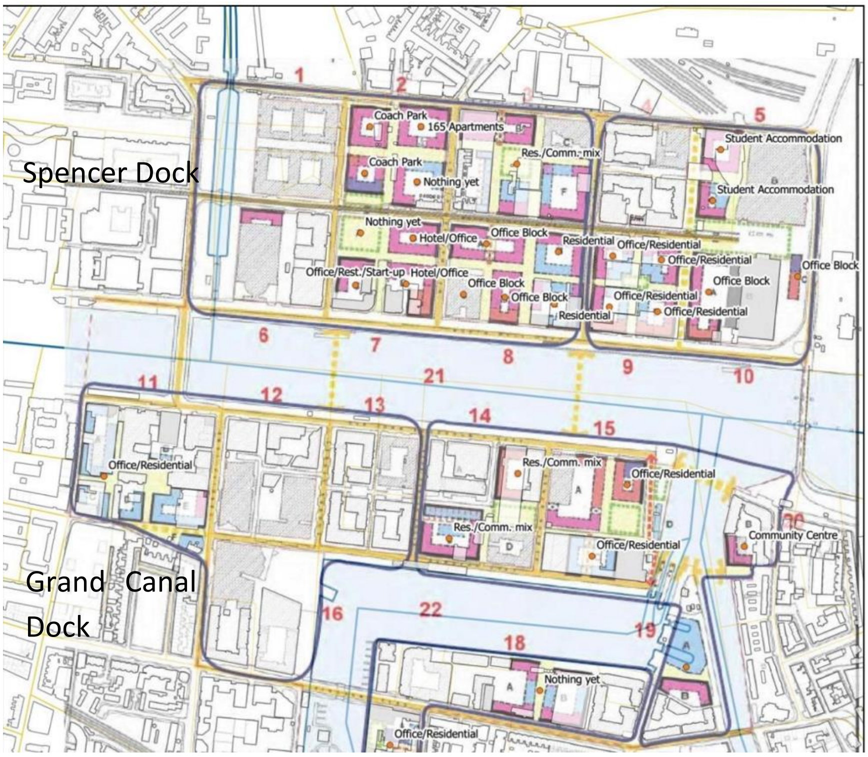


Figure 6-2 New developments in Dublin conditioned to be district heating enabled (Gartland, 2015)

The new developments, Spencer Dock and Grand Canal, are planned at each side of the river (Liffey). Grand Canal Dock on southern side of Liffey, consist of several existing commercial buildings, while only a few existing premises are found in Spencer Dock, where several new apartments and offices are planned to be completed within the next two years. Most of the existing buildings in Spencer Dock are district heating enabled and the new developments are conditioned enabled as well, which means that Spencer Dock easily can be connected to a future district heating system. A waste to energy (WtE) facility is under construction at Poolbeg Peninsula (Figure 6-3), less than 3 km from Spencer Dock and due to be to commissioned in 2017 (DWtE, 2014), which is planned to supply the district heating system.

The focus of this feasibility study is to analyse the feasibility of a large scale district heating system in Spencer Dock supplied by heat from the WtE, in line with plans of Dublin City Council. Spencer Dock is a good place to start, as most buildings are district heating enabled. The location of Spencer Dock and the WtE facility is showed in Figure 6-3.

Spencer Dock covers 300.000 m^2 with a total annual heat demand of 62 GWh in existing and future buildings (Codema, 2015b). This corresponds to a heat density of 520 TJ/km^2, which is considerably higher than the threshold value of 140 TJ/km^2, as previous described. The area consists of relatively few users, mainly commercial and with big annual demands, which can be considered as essential anchor loads for a prospect district heating system. Most of the existing buildings are already district heating enabled and Dublin City Council has conditioned "*all proposed developments be district heating-enabled in order to provide an environmentally* *sustainable source of heating and cooling*" (Gartland, 2015; 4). This suggests there is a local commitment to a district heating scheme in the area. Dublin City Council have already installed some district heating pipes in the area including a district heating tunnel under Liffey, which will enable the WtE facility to supply heat to Spencer Dock. The proximity to the new WtE facility is in favour for a district heating system in Spencer Dock.

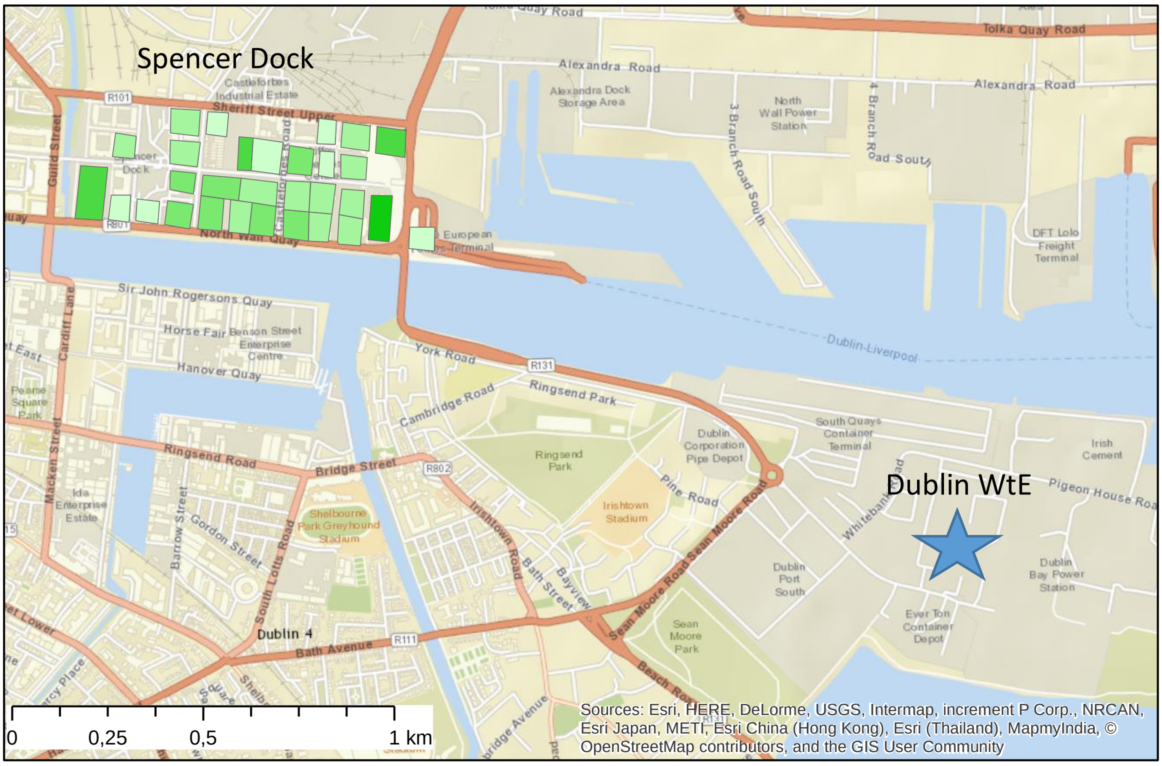


Figure 6-3 Location of case area and heat supply source

In summary, Spencer Dock has numerous advantages relating to be the backbone of a future district heating system in Dublin:

a) High heat density
b) Few entities with high demands
c) Proximity to heat source
d) New developments
e) Political commitment

7 Design of technical alternative

The basic principles of district heating systems are illustrated in Figure 7-1. District heating systems consists of three main elements; supply facilities (heat plant), a distribution network (district heating pipes) and demand side interchanges (heat exchangers). More detailed, the distribution network can be further divided into transmission lines, distribution pipes and branch pipes. These system elements have been used here to investigate the costs of a district heating system in Spencer Dock.

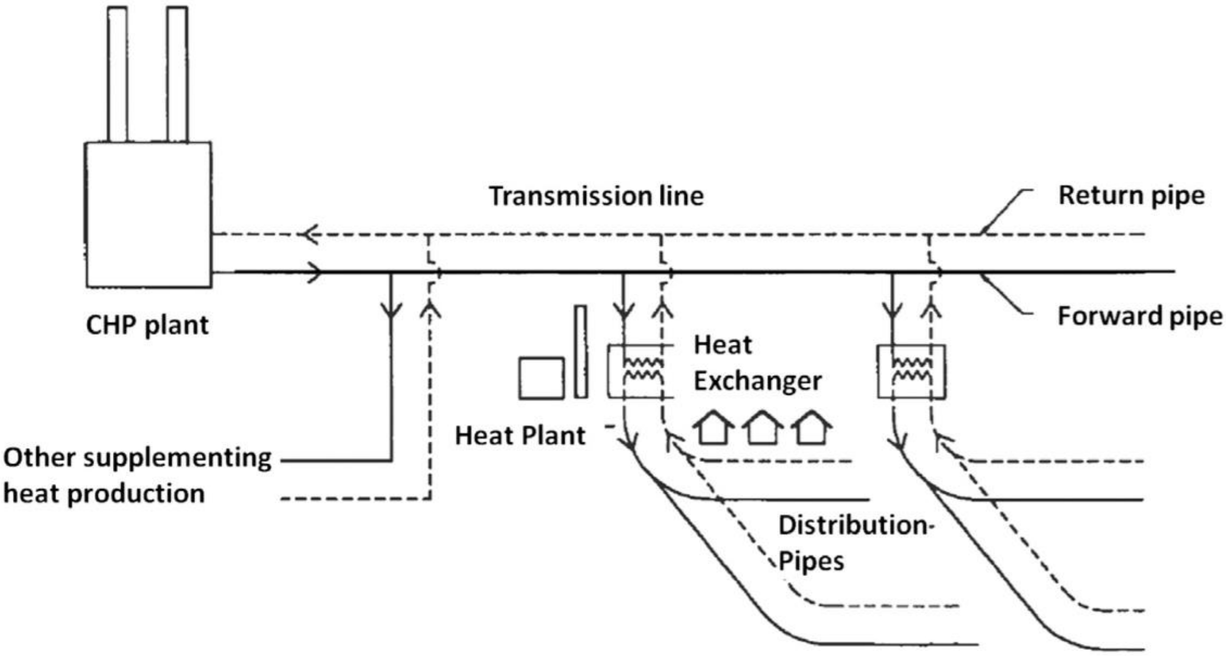


Figure 7-1 Principles of district heating systems (Lauritsen, 2015).

The following sections will chronological go through the steps of the design, starting out with identifying the heat demand. The heat demand is vital for the design of the network, as it is used to dimension the heat exchangers and design the distribution network. By knowing the heat demand, it is possible to derive estimates of pipe sizes and capacity of heat exchangers, which can give insight to the potential cost of the system. The heat plant will not be designed here, but the supply costs are included in the calculations. The design and basic principles used in this chapter is primarily based on (Frederiksen & Werner, 2013) and (Nielsen, 2014).

7.1 Annual heat demand

The information on annual heat demands used in the feasibility study is based on Dublin City Spatial Energy Demand Analysis (Codema, 2015b) and Codema's Analysis of Heating Demands in Docklands Area (Gartland, 2015), where the annual heat demands for existing buildings and new developments have been estimated based on building standards and benchmarks from UK's Chartered Institutions of Building Services Engineers (CIBSE). The heat consumption information is the most important information used to estimate the size of heat exchangers in the buildings, as it is essentially impossible to dimension these without information on the size of heat demand. Similarly, the consumption information is vital to design the distribution network, as the consumptions are used to determine the size of the district heating pipes (Nielsen, 2014). This means that the level of detail of consumption information is vital for the system design. Whereas detailed data on current supply and annual heat consumption on building level are available in Denmark in the Danish Building Register (BBR), there is no such database for Ireland. So the estimated annual consumption information from Codema (Codema, 2015b) is the most accurate data available for the analysis. However, a previous district heating project in Tralee (Tralee, 2014) showed that there is a high considerable amount of uncertainty related with this estimation method. In Tralee, the difference in the metered energy data and the benchmark data showed to be 47% off (Tralee, 2014). However, these are the best available data and will be used for the analysis.

The total annual heat demand for Spencer Dock is shown in (Table 7-1). The demands are increasing from approximately 32MWh to 62MWh between 2018 and 2020 in accordance with the commissioning of new developments, as described in the development plan for Spencer Docks (Dublin City Council, 2011). The heat density for the area increases correspondingly from 381 TJ/km^2 to 748 TJ/km^2 as showed in **Fejl! Henvisningskilde ikke fundet.** which shows that the area most likely can benefit from a district heating system (a thumb rule is that heat density areas above 140TJ/km^2 are economically suitable for district heating (Frederiksen & Werner, 2013)).

Table 7-1 Annual heat demand at Spencer Dock

	2018	2019	2020 –
Annual heat demand	31.752 MWh/y	40.964 MWh/y	62.305 MWh/y
Heat density	381 TJ/km^2	492 TJ/km^2	748 TJ/km^2

The information on heat demands used is divided by type of usage and not for each building. In order to find the annual heat demand for buildings with more than one usage (for example an office domicile) the heat demands are aggregated. The heat demands for buildings located end to end within the same area are aggregated, as it is assumed that they will be heated with one centralised boiler. This way 30 clusters are created with a total annual heat demand between 90MWh and 15.000MWh as showed in Figure 7-2.

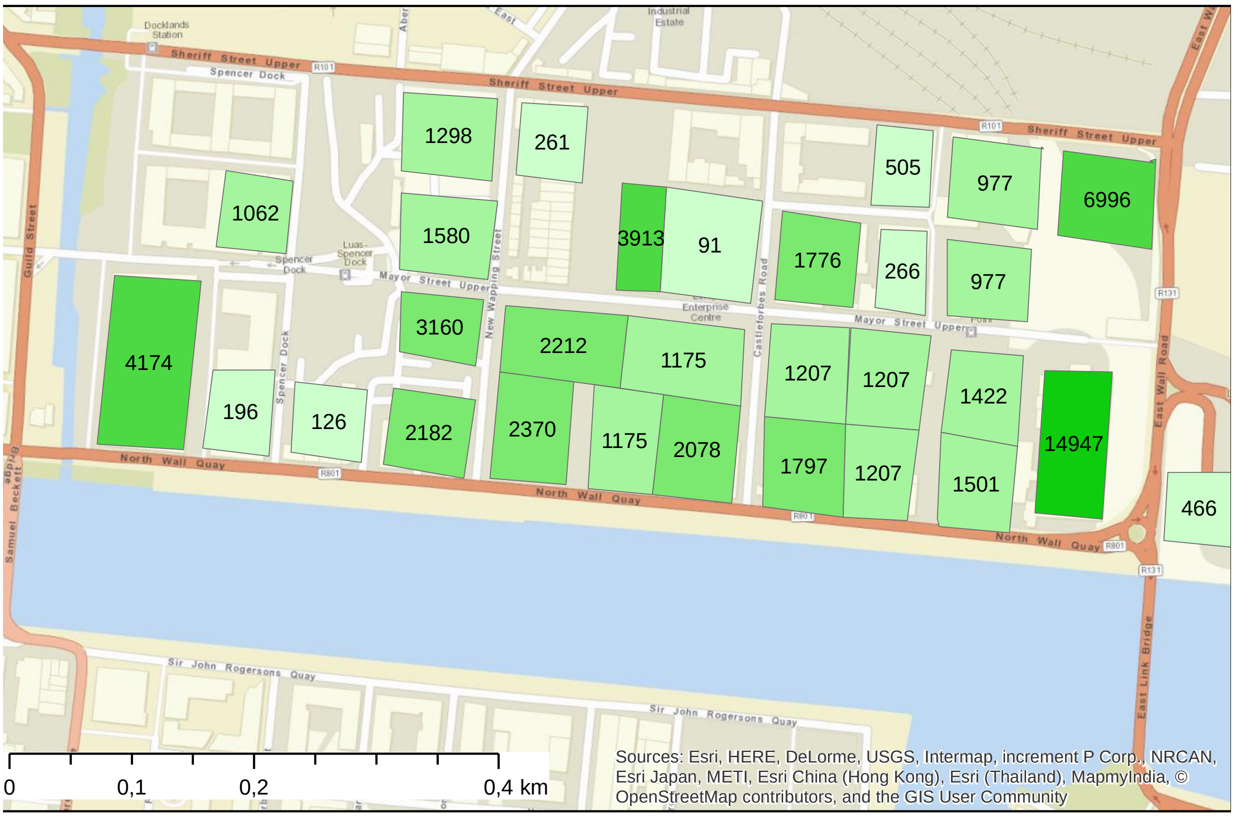


Figure 7-2 Aggregated annual heat demands by cluster (MWh/year). The colours indicate the size of the heat demand, where light green is low and dark green is high.

These heat demands are the starting point for the analysis and define the heat demands that have to be satisfied in both the business-as-usual reference scenario and the alternative district heating scenario. In both scenarios one heat unit is assigned to each cluster to satisfy the heat demand.

7.2 Heat load

The heat demands are not constant, but vary according to seasonal and daily variations (Frederiksen & Werner, 2013). The seasonal variations is a result of the fact that winters are colder than summers, i.e. that the outdoor temperature changes, which result in higher demands during winter periods than in the summer period. Besides the seasonal variations, the daily variations originate from human behaviour, i.e. higher heat demands during specific periods of the day and lower demands during the night. These daily variations are small (5%) compared to the seasonal variations, which means that rather little heat storage are necessary to even out this difference (Frederiksen & Werner, 2013). The heat load is the heat power that is needed to satisfy the customers heat demand at all times during the year, which is used here to find the needed capacity of the heat exchangers and the pipes in the distributions network (which is described in section 7.4. The heat load for the buildings has been calculated by using Danish figures of the relation between annual heat demand and heat load for different types of buildings (see Appendix A – Technology data). Using this to estimate the heat load, is cause to uncertainties due to the climatic differences and differences in the building stock between Ireland and Denmark, however it is adequate for this analysis. The difference will result, that the heat load might be a little overestimated. The specific heat load for each cluster can be seen in Figure 7-3.

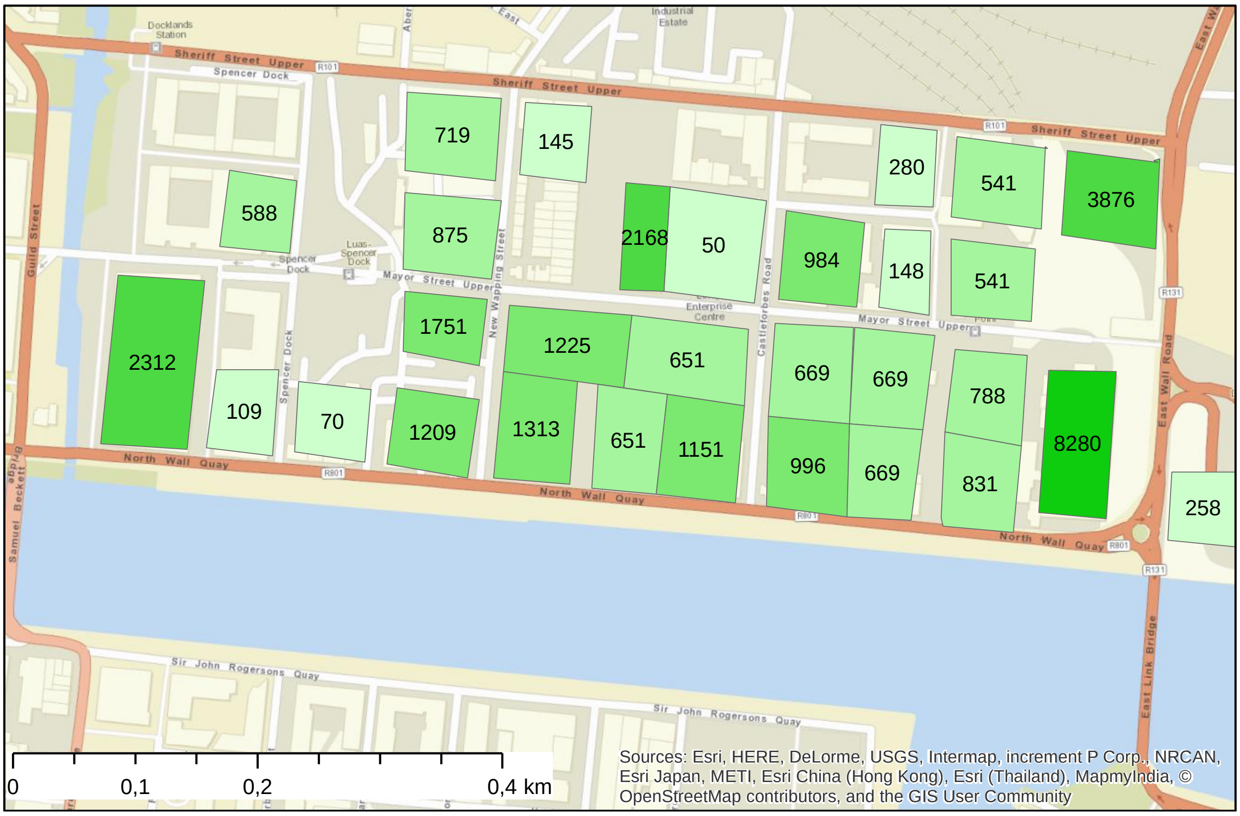


Figure 7-3 The specific heat load (kW) for the heat clusters at Spencer Dock

The heat exchangers needed for the buildings are designed based on the heat load capacities showed in Figure 7-3.

7.3 Design of distribution network

The routing of the network is based on pragmatically by drawing the lines aclong the existing roads. The urban structure of the area is grid-based, which proves to be efficient to a simple design of the network. The distribution grid is connected to the existing tunnel with transmission pipes under Liffey (Miller, 2013) (as shown in figure 7-4), which supply the distribution grid with heat. A transmission line, which follows the southern boundary of the Spencer Dock area along the North Wall Quay will supply the area with heat. Five perpendicular streets from North Wall Quay will function as distribution line (4 at the moment, the last in a planning process) (Codema, 2015a). The design principle is illustrated in Figure 7-4.

The transmission pipes are going from the WtE plant at Peninsula and connects to the established tunnel on the south side of Liffey. The network design at Spencer Dock presented above is similarly connected to the tunnel at North Wall Quay on the north side of Liffey.

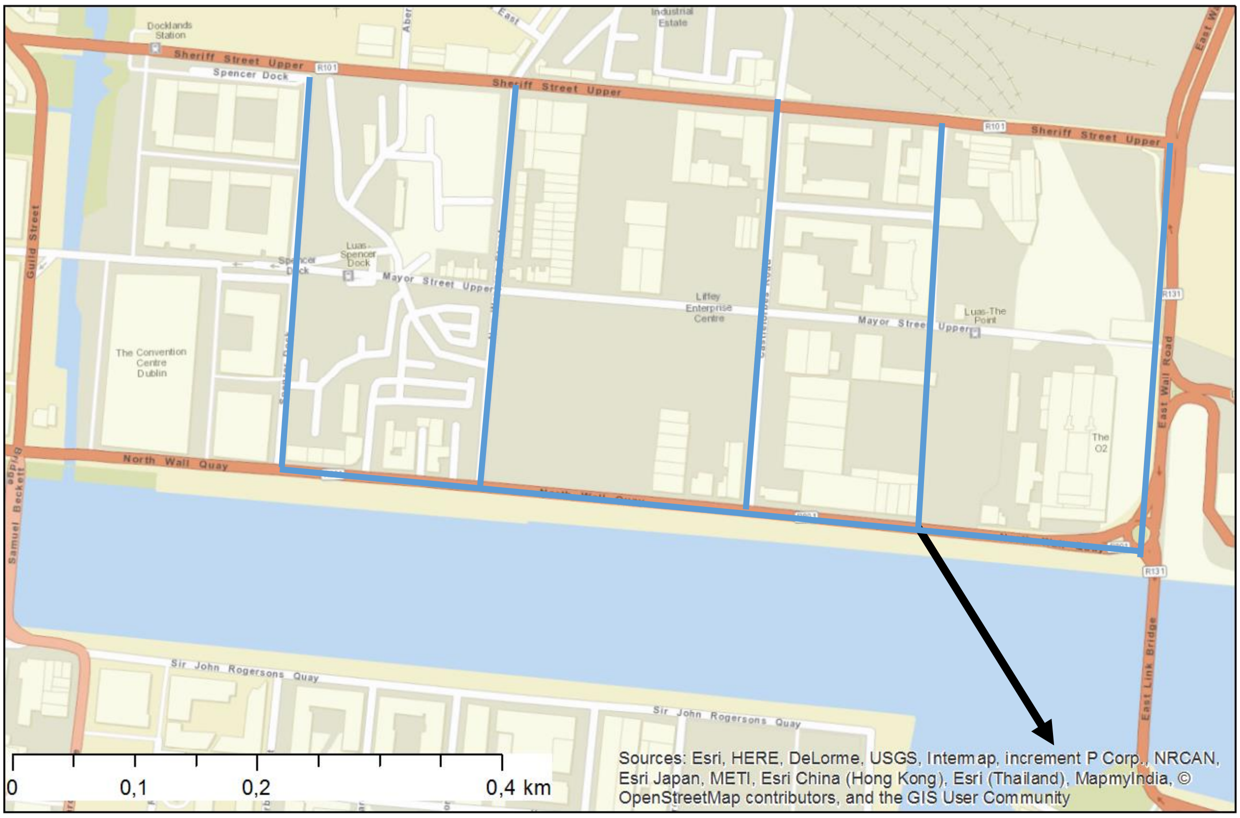


Figure 7-4 The future transmission (black) and distribution (blue) pipes for Spencer Dock

7.4 Pipe sizes

The capacities of the district heating pipes are directly linked to the aggregated heat loads of each street. So to dimension the pipes, the heat loads have been aggregated to determine the sum of capacity connected to the pipe. When designing the pipes a simultaneity factor have been multiplied to the sum of connection capacity, which is used because the consumers do not consume heat at the same rate during the day. The diversity and multiplicity of the end-users cause that the maximum demand is not acquired at the same time (Frederiksen & Werner, 2013). In order to take this into account, a simultaneity factor is applied for the distribution and transmission pipes. For the distribution pipes serving the branch pipes a simultaneity factor of 90% is applied. The simultaneity factor is set relatively high, compared to Danish experiences (Lauritsen, 2015) due to the homogeneity of the functions of the buildings along the five distribution lines. For the transmission pipes, the simultaneity factor is set to 75%.

The capacities of the pipes have been used to determine the diameter (DN standards), heat loss and investment costs using data from (Nielsen, 2014; 356), which is based on Swedish District Heating Association’s cost catalogue (Svensk Fjärrvärme, 2013). The costs for projecting, field work, pipe work and excavation are included in the investment costs (Nielsen, 2014). The relation between diameter, capacity, heat loss and investment costs can be seen in Figure 7-5.

Technical aspects such as the forward and return temperatures, as well as pressure have not been included in the study. In reality, higher details are needed to determine pipe sizes and routing, where pipe lengths and sizes for a new district heating network will be determined using an advanced optimization software, such as Termis, which will design the network based on simulations of water flow, temperature and pressure. However, in this study the purpose is not to make a detailed design and optimisation of the network, but to estimate the economic feasibility of a new network taking into account actual city design.

The delimitations mentioned about pressure and temperature, as well as price estimates based on Swedish experiments are creating some degree of uncertainty. However, the costs estimated in this study is comparable to the costs found in a previous feasibility study carried out for Dublin by COWI and RPS (RPS, 2008), with slightly higher costs for the pipes smaller than 406,4 mm, and equally lower costs for the wider pipes.

Diameter (mm)	Capacity (MW)	Heat loss (W/m)	Investment (EUR/m)
48.3	0.04	7.8	281
60.3	0.08	9.8	334
76.1	0.16	12.3	376
88.9	0.29	14.4	422
114.3	0.54	18.5	508
139.7	0.83	22.6	600
168.3	1.61	27.2	718
219.1	2.76	35.4	848
273	4.53	44.2	907
323.9	9.14	52.4	1011
406.4	16.28	65.8	1145
508	25.99	82.2	1317
609.6	47.17	98.6	1522
711.2	85.04	115.1	1749
812.8	136.52	131.5	1946
914.4	204.34	147.9	2162
1016	289.47	164.4	2429

Figure 7-5 Pipe sizes and investment costs from (Nielsen, 2014; 356).

Figure 7-6 shows the diameter of the pipes and placement of the pipes. The transmission pipe from the WtE plant is connected through the existing tunnel (DN508) under the river Liffey. As the excact place for delivery is unknown, the distribution pipes are extended to cover the entire area, creating a buffer for the investment.

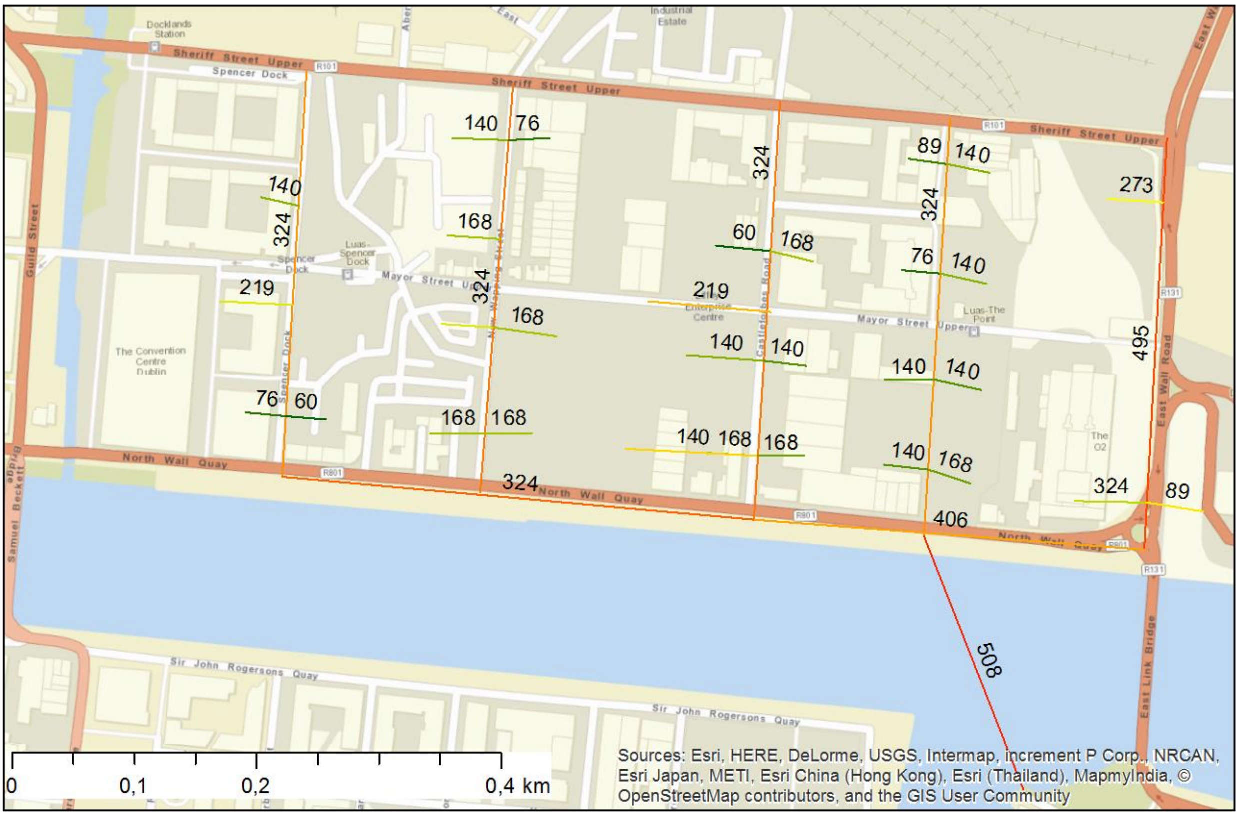


Figure 7-6 Pipe diameter and placement

7.5 Supply

The district heating network will be supplied by heat from the Waste to Energy (WtE) plant being built at Poolbeg Peninsula, which is to be completed in 2017 and with commencement of operation by the end of 2017 (dublinwastetoenergy.ie; 2014). The WtE plant at Poolbeg have a heat production capacity of 150 MW and an annual heat production of 111.000 MWh (DWtE, 2014), which is assumed to be sufficient for satisfying the heat demand at all times. However, a simulation of the heat supply and demand balance would be needed to examine the full extent of the coverage. The WtE facility will be operating as a Public Private Partnership between Dublin City Council and Covanta, the world's largest WtE company, and is fully funded by Covanta (DWtE, 2014). The revenue from electricity sales will primarily finance the facility, but DCC will have a two-folded interest in the sale of the heat to the district heating network.

The heat delivered to the district heating network will solely be based on heat purchased from the WtE plant, with a price fixed at 7 €/MWh, based on the strategic business plan for Dublin District Heating Company (Austin & Baghdasaryan, 2010).

7.6 Reference scenario

As already discussed, the costs of the district heating system will be compared with the business as usual reference scenario. In the reference scenario the heat demands will be covered with natural gas supplied by individual natural gas boilers. The investment costs for gas boilers are based on data from the Department of Energy and Climate Change in UK, which are assumed to be applicable for Ireland. The assumptions are showed in Appendix A – Technology data.

The gas price is based on the business gas price for the 1st semester of 2015, and is settled at 39 €/MWh excluding VAT (SEAI, 2015b; 45). No forecast has been used relating to the future gas price. In reality the gas price will change over time, however this has not been included in the study.

7.7 Economic calculations

The feasibility study is considering three different types of economics; socio-economy, business economy and the consumer economy. Table 7-2 shows which costs are included for each group. The investment costs of the socio- and consumer economy, have been annualised as the equivalent annual costs (EAC), as expressed in the formula below. This serves to address the long-term investment benefits of an investment. The discount rate is set to 5%, which is used for public sector projects in Ireland (Government of Ireland, 2015)

$$\text{EAC} = \frac{Total\ investment\ x\ Discount\ rate}{\left(1 - \frac{1}{(1 + Discount\ rate)^{Lifetime}}\right)}$$

In the business economy section, the excel formulas for net present value (NPV) and internal rate of return (IRR) have been used.

Table 7-2 Overview of costs for the different feasibility calculations

	District heating scenarios			Reference scenario		
	Investment	**Viable costs**	**Fuel costs**	**Investment**	**Viable costs**	**Fuel costs**
Socio-economy	Transmission – Distribution – Branch pipes Heat exchangers	O&M – Network O&M - Consumer	Heat price from WtE	Gas boilers	O&M consumers	Gas price
Business economy	Transmission – Distribution – Branch pipes	O&M Network	**Cost**: Heat price from WtE - **Income**: Heat sale to network	-	-	-
Consumer	Heat exchangers	O&M Consumer	Heat price from network	Gas boilers	O&M consumer	Gas price

7.8 Delimitations

This study gives an overview of the installations and components needed for the network and does not represent the final design. The design of the network is carried out as a rough design, with no regards to temperature and pressure in the system. A more detailed design would be needed for the actual implementation, where pressures, supply and return temperatures, flow velocity and additional pumps would be determined using optimisation software like Termis. Neither has the electricity demand for the system been taken into account. In reality a backup boiler would be needed for the system, but this has not been included in the study.

A few distribution pipes have already been installed in Spencer Dock (Coe & Storan, 2016), which means that these investments could have been excluded from the study. However, it is chosen to include the investments to secure that the investment is not underestimated. The pipe sizes determined in this study are set to fit with the existing pipe installations. In 2007, a service tunnel under the River Liffey was constructed, including a DN508 mm pipeline for district heating (Miller, 2013). The investment costs for this tunnel is not included in the feasibility study.

Finally, the building specific installations for distributing the heat inside the buildings (e.g. radiators, etc.) have not been accounted for in this model, but is assumed to be cost neutral compared to conventional heating systems (RPS, 2008). In some existing buildings, additional costs may be required here to retrofit district heating into each building depending on the current methods for distributing heat internally.

8 Results

The presentation of results is divided into investment costs; socio-economic feasibility, business economic feasibility including sensitivity analyses and consumer economy. The main results are summarised in the end of the chapter.

8.1 Investment costs

Table 8-1 shows the investment costs for the service pipes, the distribution pipes, and the transmission pipe from the WtE facility and the heat exchangers. The total investment cost is €7,9 million. The pipes alone represent 85% of the total investment (€6,776 million), while the biggest investment in the district heating system are the transmission pipes (€ 3,424 million).

Table 8-1 Total investment costs for the district heating infrastructure: see Figure 7-4 o see the pipes defined as transmission and distribution. Branch pipes are those that connect each building to the distribution network.

Investments	1000€
Branch pipes	842
Distribution pipes	2.510
Transmission pipes	3.424
Heat exchangers	1.182
Total	**7.958**

Table 8-2 shows the pipe sizes, length and the costs of pipes in the district heating system. The transmission pipe allocated for the area represents 50% of the total pipe investment. However, it should be noted that this transmission pipe could be used for many other developments in the future, e.g. Grand Canal, Poolbeg Peninsula and Dublin Port.

Table 8-2 Breakdown of pipe size, length and investment costs

Diameter	Length (Meters)	Cost 1.000€	Diameter	Meters	Cost 1.000€
DN60	80m	27	**DN219**	180m	153
DN76	120m	45	**DN273**	586m	626
DN89	131m	55	**DN324**	1069m	1.083
DN140	430m	258	**DN406**	544m	725
DN168	300m	215	**DN508 (Transmission)**	2600m	3.424

Figure 8-1 shows the physical location of investments of each pipe in the distribution network. The map shows how big an investment is needed to connect each building to the distribution network. The distribution pipes are dimensioned to go to the end of the street, so the investment needed to connect the buildings is actually lower.

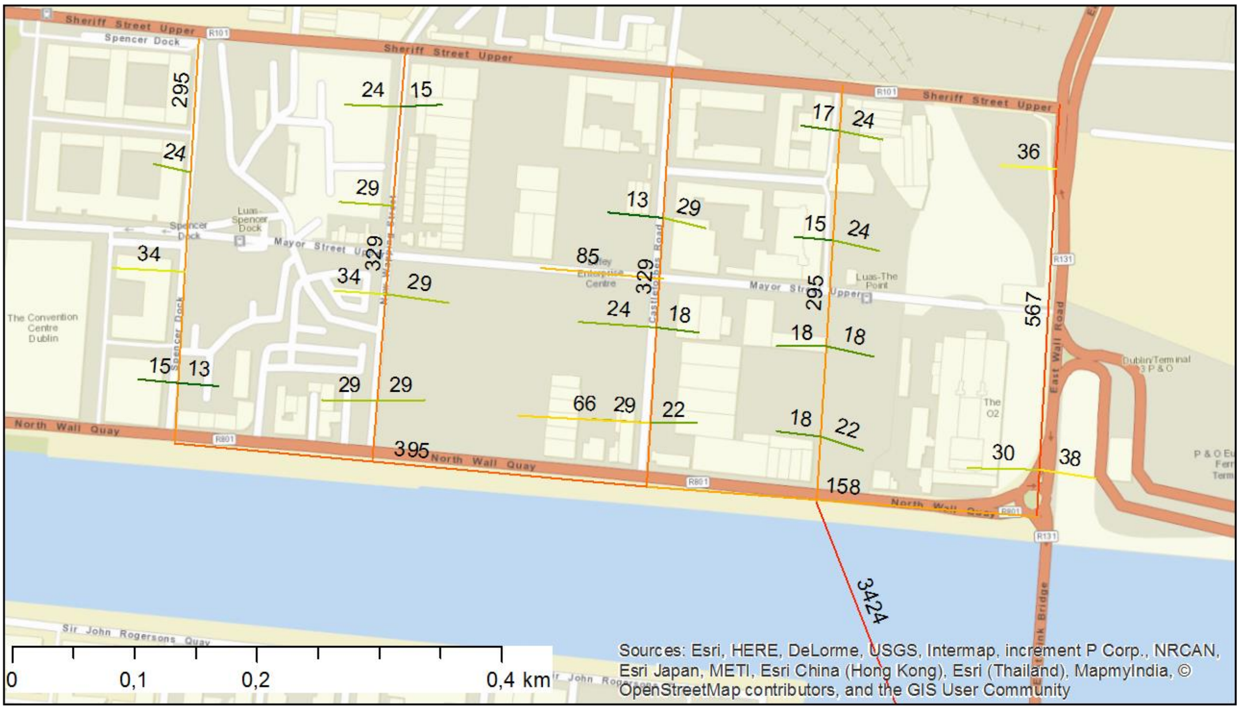


Figure 8-1 Breakup of investment cost for each separate pipe (1000€)

8.2 Socio-economy

The socioeconomic feasibility is calculated as annual equivalent costs including fuel and operation and annual investment cost and a discount rate on 5%. The district heating pipes is assumed to have a technical lifetime of 30 years (Danish Energy Agency, 2013).

Figure 8-2 shows the annual costs of the district heating scenario and the reference scenario. Compared to the reference scenario, the district heating scenario converts fuel costs into investment costs and has lower annual costs. This makes the district heating scenario more robust to fluctuating fuel prices and less depended on fuel import.

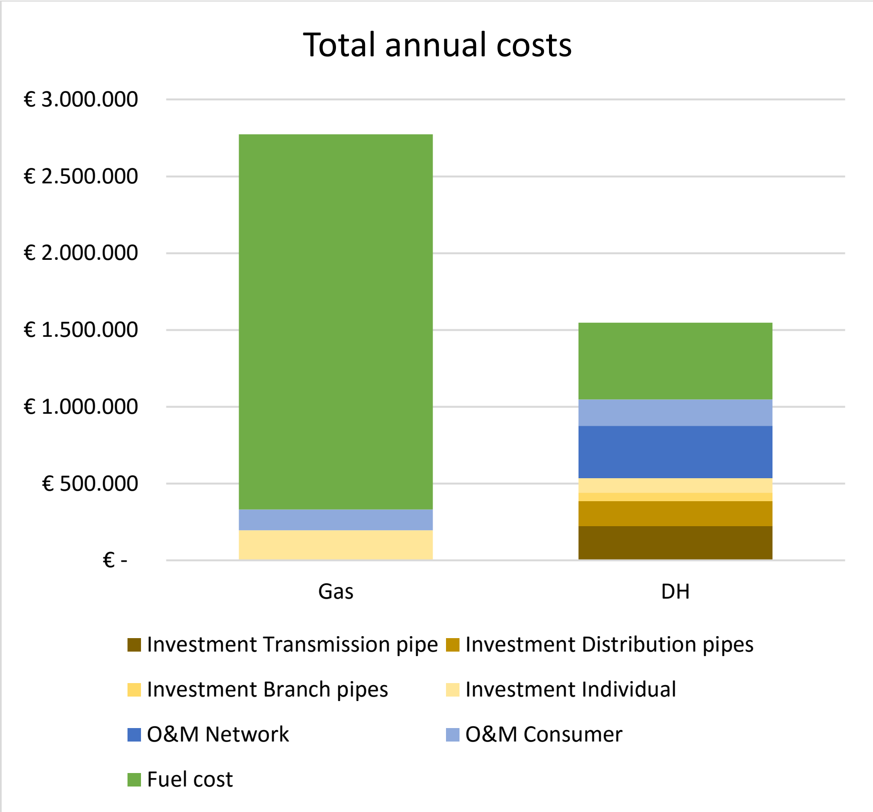


Figure 8-2 Total annual costs

The total annual cost for the reference scenario is €2,77 million, while the annual cost of the district heating scenario is €1,55 million. This gives a marginal heat price for respectively gas and district heating of 44,5 €/MWh and 24,9 €/MWh. With an annual saving of €1,2 million, the district heating investment has a simple payback time of 6,5 years.

The district heating scenario is sensitive to changes in the fuel cost. The fuel cost in the district heating scenario is set to 7 €/MWh based on the assumptions from Dublin City District Heating Company (Austin & Baghdasaryan, 2010), but any deviation from this will affect the feasibility. A sensitivity analysis made on the district heating price show that the price has to be kept below 24,1 €/MWh to keep district heating competitive if the gas price is kept at the same level.

8.3 Business economy

The business economic feasibility is calculated as the investment of the district heating network and the initial planning and consultancy cost, an annual cost for O&M and the heat purchase price from the WtE facility and the income from the heat sales. The prices are calculated exclusive of taxes, including Value Added Tax (VAT). The total investment costs are shown in Table 8-3 and the annual costs are showed in Table 8-4.

Table 8-3 Investment costs

Investment	*€ Million*
Pipes	6,7
- *Transmission pipes*	*3,4*
- *Distribution pipes*	*2,5*
- *Branch pipes*	*0,8*
Planning and consultancy	0,3
Total investment cost	*7,1*

Table 8-4 Annual costs

Cost	*€ Million*
O&M	0,3
Fuel	0,5
Total annual cost	*0,8*

The annual business income depends on how the customer price is determined. The two basic pricing principles are cost-based or market-based (Frederiksen & Werner, 2013). A cost-based price is determined based on the total activity expenses, i.e. a price level reflecting the total annual costs and optionally a certain return on invested capital (cost price). Market-based prices are determined using a price formula containing the market prices, where the price is adjusted according to competing market alternatives, which in this case is natural gas (market price). The design of price model will reflect the major goal of the company and the owners (Frederiksen & Werner, 2013). So for example, a non-for-profit company could determine a price that reflects the marginal costs of producing the heat (cost price), while a company that requests a profit could determine a price that would be compatible with natural gas (market price). In the following these two pricing principles have been used to assess the business economy. The cost price, which reflects the total expenses will result in a heat sales price of 24 €/MWh (based on the results in Figure 8-3). The market price is adjusted to be 10% lower than the gas price in order to keep it competitively more attractive, which results in a heat sales price of 35,1 €/MWh. Figure 8-3 shows that the design of the price model affects the return on investment, where the cost price gives an IRR on 5%, while the market price gives an IRR on 15%.

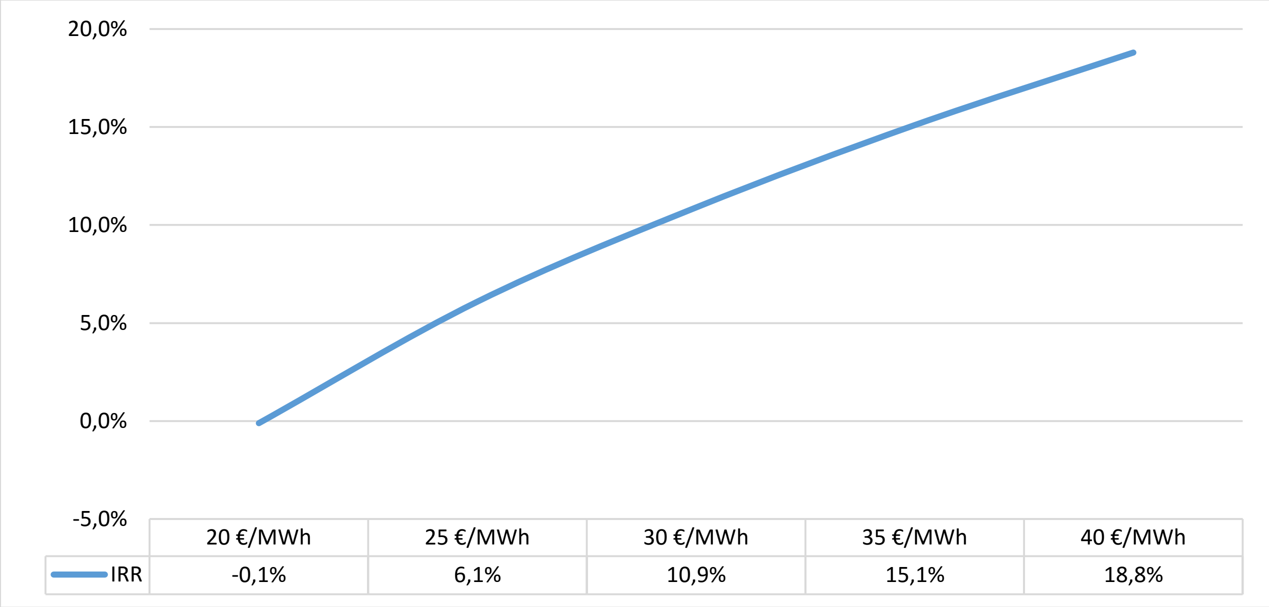


Figure 8-3: Relation between heat sales price and internal rate of return (IRR).

The business economic result based on the two different price models is showed in Table 8-5. The net income is obviously higher with the market price, which gives a shorter simple payback time and higher internal rate of return (IRR) compared to the cost price.

Table 8-5 Business economic results for two price models: cost price (24 €/MWh) and market price (35,1 €/MWh).

	Cost price	***Market price***
Heat sales price	24 €/MWh	35,1 €/MWh
Annual heat net income (2020-)	€0,65 million	€1,36 million
Simple payback time	13,1 years	7,3 years
IRR (20 years)	5%	15,3%
IRR (10 years)	-8,6%	6%
NPV (2036)	0	€20,1 million

Figure 8-4 shows the annual cash flow based on the two different price models. It shows the initial investment costs for the planning and consultancy costs in 2016 and the capital investment in the heat network in 2017. The income starts from 2018 and increases towards

2020 associated with the commissioning of the new developments in Spencer Dock (i.e. higher heat demands).

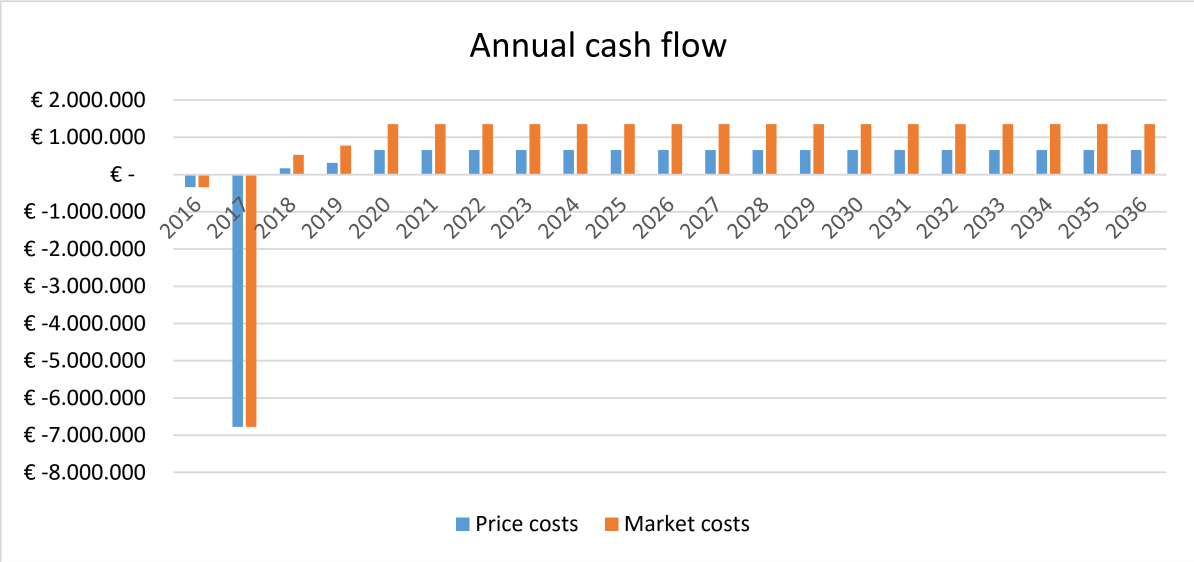


Figure 8-4: Annual cash flow for two price models

The development of the net present value for each price model is shown in Figure 8-5. The cost price gives a neutral NPV after 20 years, as the return is used to cover the loan (5%). The market price will result in a NPV of €20,1 million in 2036.

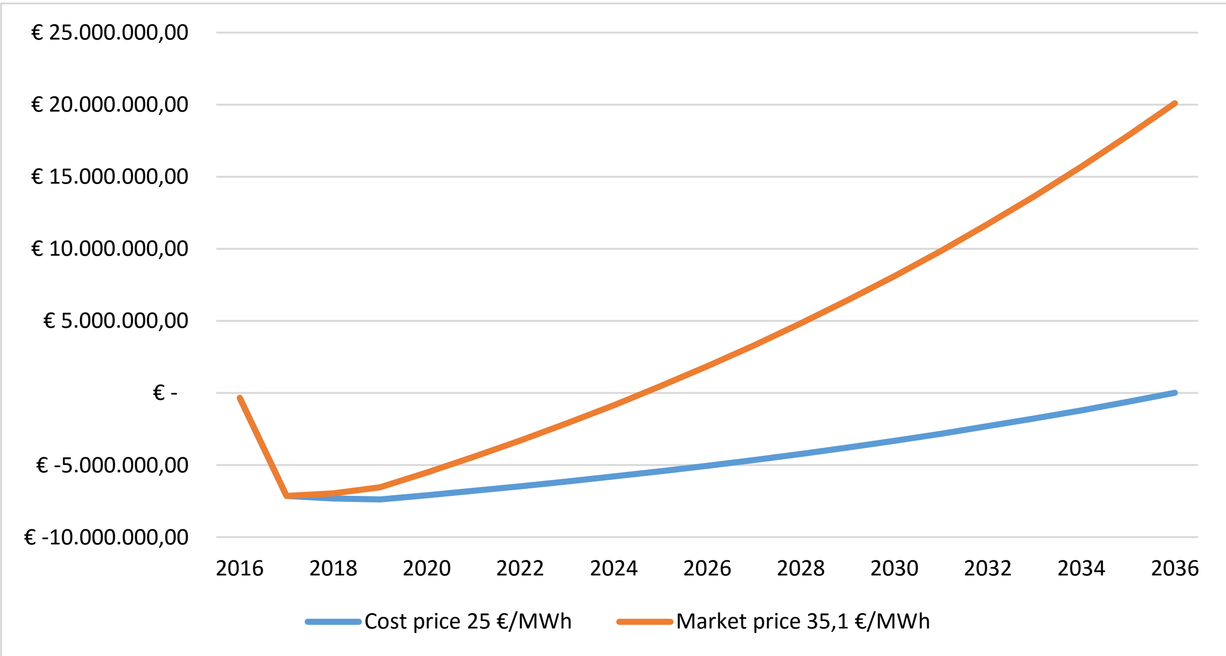


Figure 8-5: The development of the NPV for each price model

The business economy based on the cost price is very sensitive to two factors: one is the magnitude of the investment costs and the other is the total heat sale. Consequently, any increase in investment or decrease in consumption would give a negative NPV after 20 years, which requires that the company raise the IRR requirement. On the contrary, the market price makes the business less sensitive to risks, which will be analysed in the following subsection.

8.3.1 Sensitivity analysis

In order to account for uncertainties in the calculations different sensitivity calculations has been carried out. The parameters that will be examined are based on insecurities expressed in Part 1, which are subject to the biggest uncertainties and thus have the biggest influence on the net present value (NPV). These include:

- Increased investment costs
- Decreased consumer penetration
- Increased heat purchase price from the WtE

The sensitivity calculations have been made for each parameter separately and will be presented with a graph showing the development of the NPV and a table with the key figures of the IRR.

8.3.1.1 Higher investment costs

Although the model is based on validated investment costs, the cost is subject to a number of insecurities. Figure 8-6 shows the relation between the NPV and the investment costs of respectively 10%, 25% and 50%. Table 8-6 shows that even with an increase in investment cost of 50%, the project would remain economically viable with an IRR of 10%, and with a simple payback time of 10 years. Again, it shall be noted that the transmission pipe could be used for many other developments in the future, so there is a chance that the income will increase with the propagation of the network.

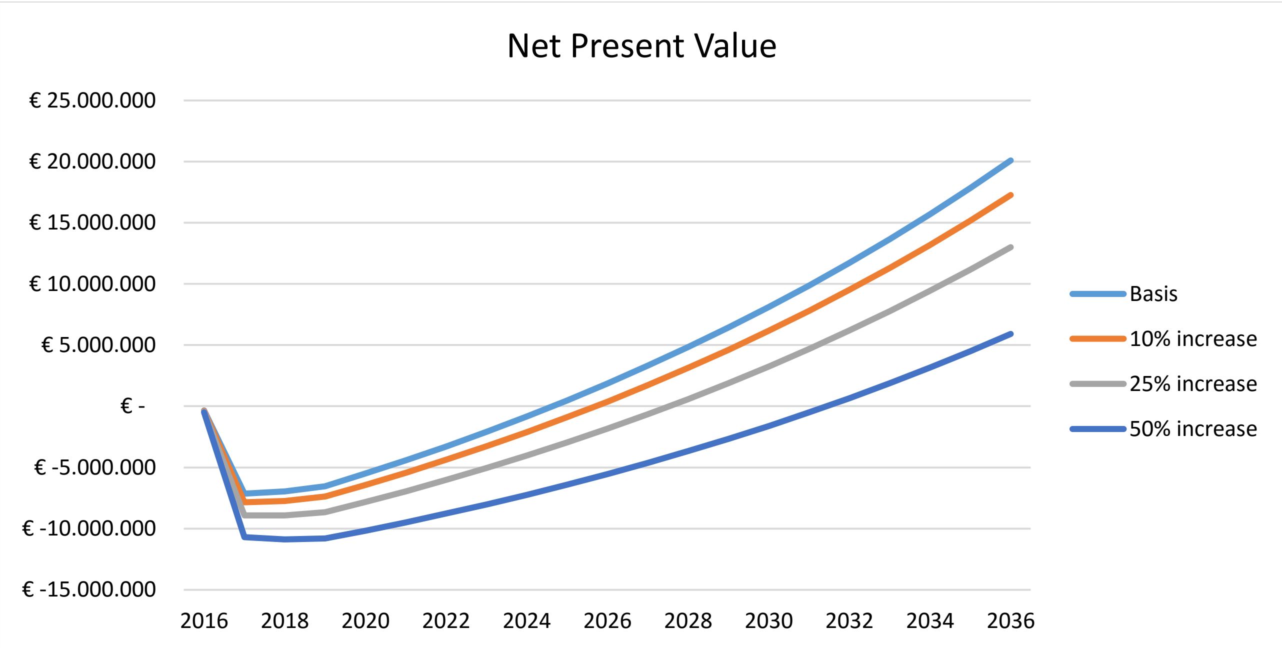


Figure 8-6 NPV at increased investment costs

Table 8-6 Impact of higher investment costs

	Basis scenario	10% increase	25% increase	50% increase
IRR (10y)	6,0%	4,3%	-0,3%	-5,2%
IRR (20y)	15,3%	14,1%	10,7%	7,0%
Simple payback	7,6	8,3	9,4	11,6
NPV (20y)	€ 20.100.236	€ 17.263.160	€ 13.007.545	€ 5.914.855

8.3.1.2 Decreased consumer penetration

The results of the interviews showed that deficient consumption information and decreased consumer penetrations was perceived to be a barrier. Consequently, sensitivity analyses have been made for a decrease in consumption of 50%, 25% and 10%, which reflects the effect that inaccurate consumption data and decreased consumer penetration will have on the business economy. Figure 8-7 shows that the NPV is positive in all cases, but that the payback time varies from 17 years (50%) to 10 years (90%). In the most extreme case (50% reduction) the NPV will be reduced with €18,3 million compared to the basis. However, the IRR after 20 years would still be positive according to Table 8-7.

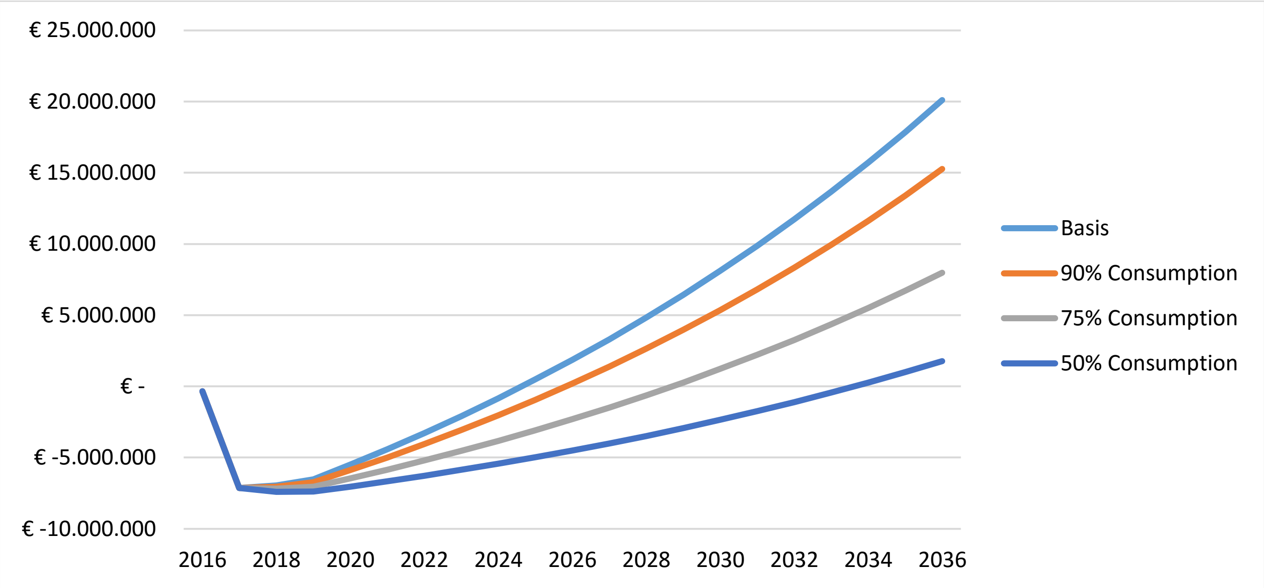


Figure 8-7 The NPV at reduced heat consumption

Table 8-7 Impact of decreased consumption

	Basis scenario	90% consumption	25% consumption	50% consumption
IRR (10y)	6,0%	3,0%	-2,0%	-7,1%
IRR (20y)	15,0%	13,0%	9,5%	5,7%

Simple payback	7,6	8,4	10,1	12,6
NPV (20y)	€ 20.100.236	€ 15.253.136	€ 7.982.486	€ 1.770.068

8.3.1.3 Price for acquiring heat from WtE

The heat purchase price is another uncertain factor, as the company has to make a price contract with the WtE plant. The heat purchase price is estimated to be 7 €/MWh (Council, Strategic, & Plan, 2010), but Dublin City Council is currently negotiating this price with the WtE company (Storan & Coe, 2016). Consequently, sensitivity analyses have been made on increased heat purchase prices. Figure 8-8 shows the impact an increase in the heat purchase price will have, given that the heat sales price remain at 34 €/MWh. With a heat purchase price of 15 €/MWh, the IRR after 20 years would be 7% and the NPV positive. However, if the heat purchase price is increased to 20 €/MWh, the investment will result in a deficit on €6,5 million as showed in Table 8-8.

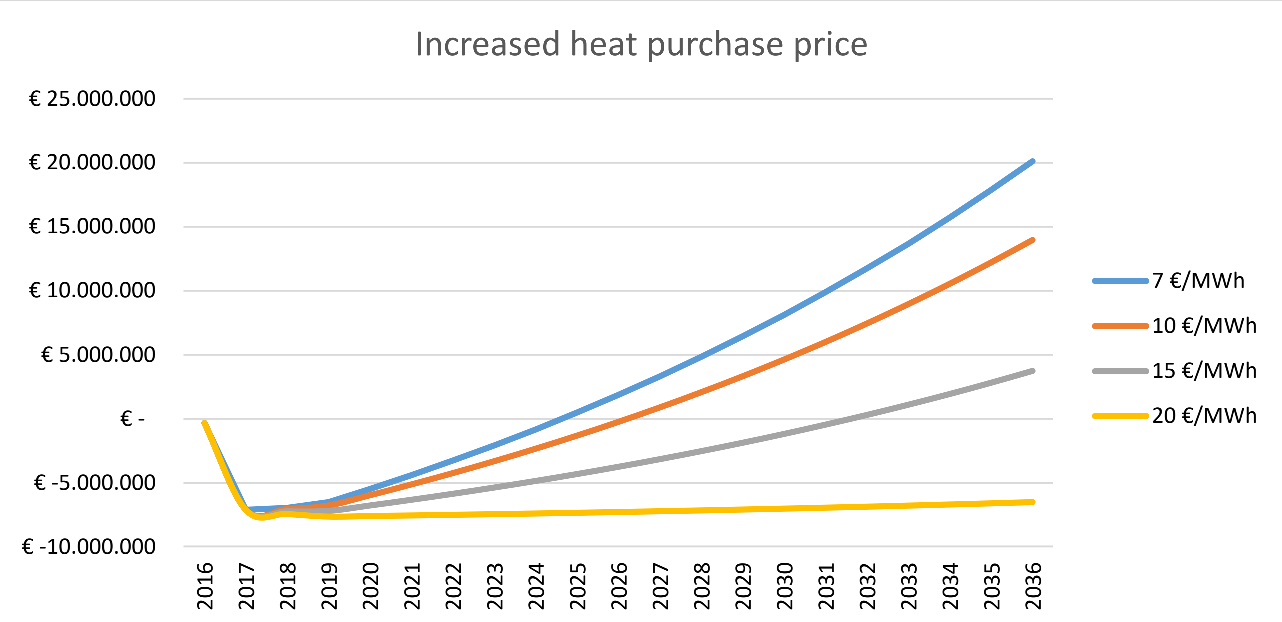


Figure 8-8 – Accumulated financial result for various heat purchase prices.

Table 8-8 Impact of higher heat purchase prices

Heat bought	7 €/MWh	10€/MWh	15 €/MWh	20 €/MWh
IRR (10y)	6%	2%	-5%	-16%
IRR (20y)	15%	12%	7%	0%
Simple payback	7,29	8,63	11,24	19,30
NPV (20y)	€ 20.100.236	€ 13.958.270	€ 3.721.661	€ -6.514.948

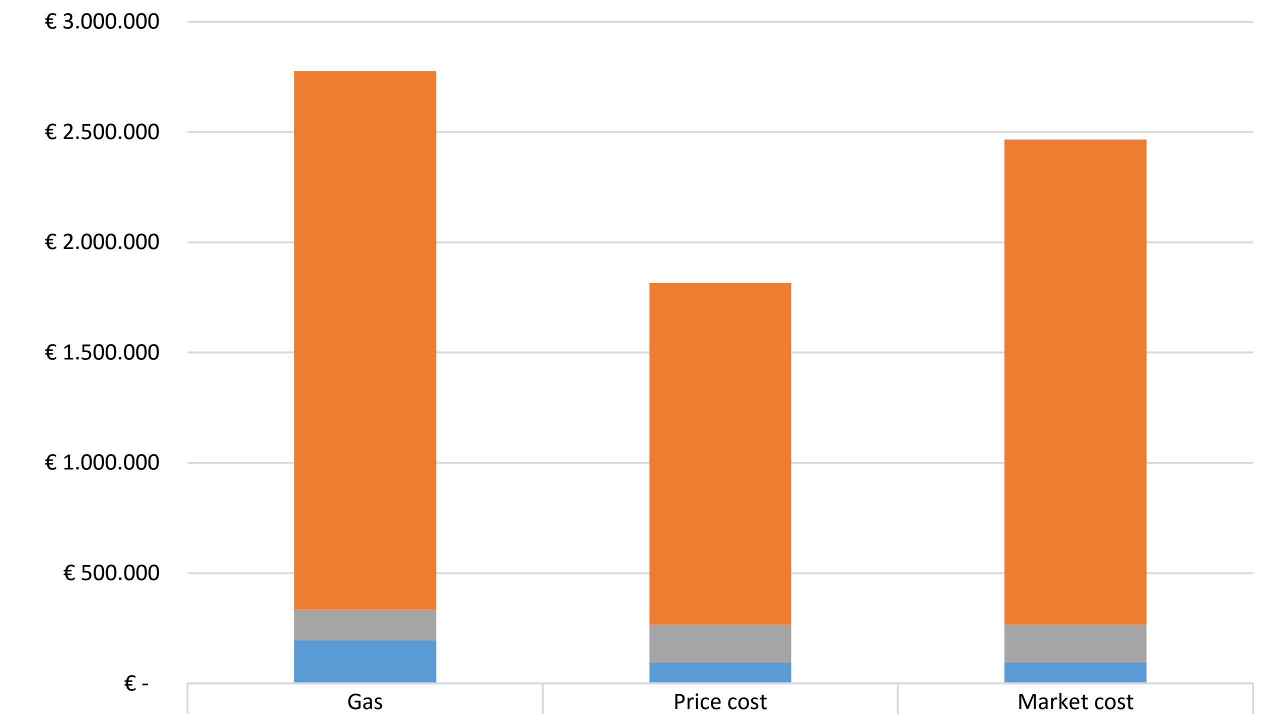
8.3.2 Assessment of business economy

The sensitivity analysis shows that the business economy based on a market pricing principle proves to be feasible, even with variation in one of the assessed parameters of 50%. The results indicate that the business economy is more sensitive to an increased heat purchase price than increased investment costs, cf. the spread in variations in Figure 8-6 and Figure 8-7. The heat purchase price from the WtE facility is a vital factor, which can affect the business economy greatly. Figure 8-3 proved a wide range of negotiation possibilities, depending on the internal rate of return.

8.4 Consumer economy

The consumer economy is calculated as annual costs including fuel, investment and operation and maintenance. The total investment cost for heat exchangers is €1,2 million. The heat price will vary according to the price model. In the previous section, two different models were presented: a cost price and a market price.

Figure 8-9 shows the total annual costs for the consumers for the entire network for the 3 different scenarios. It shows that the reference has higher investment and fuel costs compared to the district heating scenarios. The cost price of 24€/MWh results in an annual saving in fuel expenses of €893.490 compared to the reference scenario, and €382.825 compared to the market price. The market price would reduce the annual fuel costs for the consumers with €510.665 compared to the reference scenario, and give a total annual saving of €308.463.



	Gas	Price cost	Market cost
Fuel	€ 2.442.110	€ 1.548.620	€ 2.197.899
O&M	€ 138.305	€ 172.571	€ 172.571
Investment	€ 196.019	€ 94.837	€ 94.837

Figure 8-9 The total annual cost for the consumers for supplied by natural gas and district heating based on two different price models

Table 8-9 shows the savings for an average consumer. As can be seen, both district heating price models would provide a considerable saving for the average consumer.

Table 8-9 Consumer savings

	Gas	Cost price	Market price
Cost pr. MWh	€ 44,6	€ 29,1	€ 39,6
Savings		35%	11%

Naturally, the consumers with the highest demand get the highest savings. This can be seen in Figure 8-10 that shows the potential annual savings at cluster level. With a demand varying from 91 MWh to 15 GWh, the annual savings varies from €1.407 to €72.365. The average annual saving is €10.282 per year. In reality, the price model would consist of more price bands related to the size of the customer's demand, which would allocate the benefits more even. Even though the big consumers are the backbone of the system, the high difference of annual savings between consumers with high and low demands would be flattened by designing the price model with size based charges (Frederiksen & Werner, 2013).

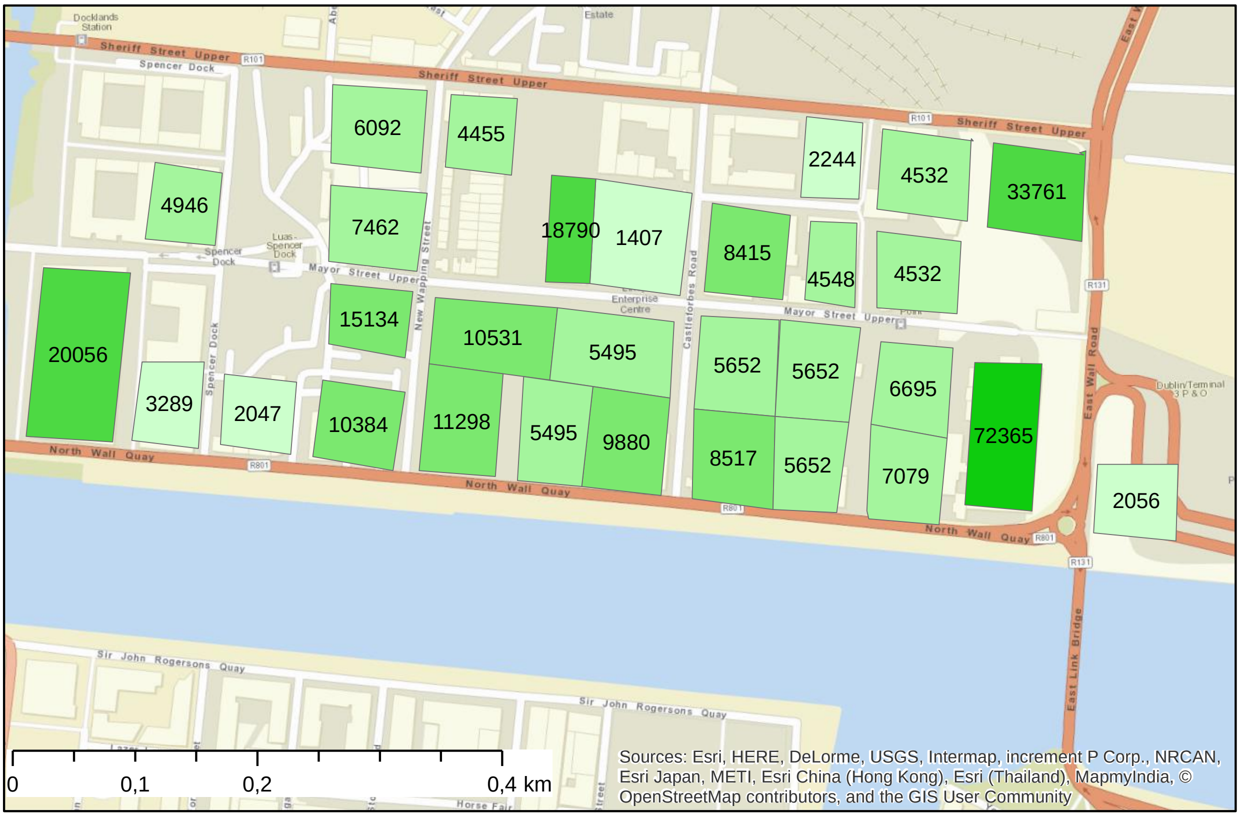


Figure 8-10 – Potential annual savings (€) for each cluster.

8.4.1 *Consumer finance of branch pipes*

Figure 8-10 shows that the average consumer saving is relatively big compared to the needed investment in branch pipes, as showed in Figure 8-1 in section 8.1. The total investment in the branch pipes accounts for €0,8 million, while the total annual consumer saving with cost priced district heating is €308.463 per year. This means that the consumers savings could finance the investment in the branch pipes, which would give a simple payback time of 2,7 years. However, due to the big variation in the individual savings, the payback time at the individual clusters vary from 18,7 years, to only 0,4 years, see Figure 8-11.

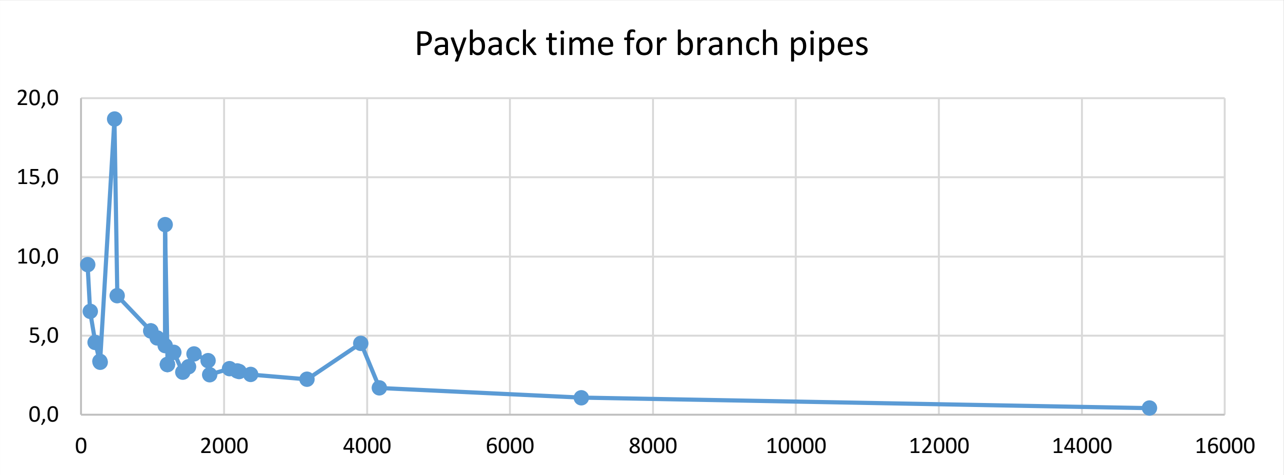


Figure 8-11 The simple payback time for the investment in the branch pipes if paid by the consumer savings

8.5 Summary and discussion of results

The socioeconomic results show that a district heating scheme in Spencer Dock supplied with excess heat from the WtE facility is competitive with traditional individual gas heating. Compared to the reference scenario, the district heating scenario is 45% cheaper than the gas scenario, so it will result in annual savings of €1,2 million. Additionally, the structure of the costs show that the reference scenario primarily is fuel based, so most of the costs are based on imported fuel, since Ireland currently imports 96% of the natural gas (DCENR, 2015a). In contrast, the district heating scenario is primarily based on investments and O&M, so more money is spent locally, which imply lower fuel dependency and potentially more local jobs.

The business economic results show that the district heating company can have a short term (10 years) IRR of 6% and a long term (20 years) IRR on 15,3% based on a market price on €35,1. This will result in a NPV on €20,1 million over 20 years. In contrast, a cost price on €24 will result in a short term (10 years) IRR on -8,6% and a long term (20 years) IRR on 5% resulting in a neutral NPV after 20 years. This shows that the district heating company's operational profit depends on the design of price model, i.e. the heat sales price. It indicates that there are several opportunities in terms of developing a business case that can deliver the district heating scheme. Here it is shown that a company, which operate as non-for-profit and regulate the price according to the cost price, could aim at allocate the benefits to the consumers. However, it will result in a long payback time, which will require access to long-term funding mechanisms and low-cost loans. The sensitivity analyses show that the business economy is influenced by the magnitude of the investment, the heat purchase price from the WtE and the customer penetration rate. Here it is shown that a company that require a high IRR (15% is here used as example) will be robust to additional, unforeseen costs or a decreased customer penetration. This indicates that there is a need to reduce the risks to allow lower IRR's.

The sensitivity analysis showed that the network would be feasible even with a 50% reduction in demand, indicating that 50% of the total heat load could bear the system. According to the heat demand information (see figure 7-2: annual heat demands), this indicates that the five biggest customers are enough to secure the viability of the network. With the potential for expanding the network to other areas, it is likely that the viability of the system will increase. Additionally, the results showed that the heat purchase price should be settled below €20/MWh, in order to keep district heating compatible with natural gas. The average purchase price form heat supply plants in Denmark is €50/MWh. Considering that the heat purchase price here is set to €7/MWh it is very likely that the price will be doubled. This suggests that it is very important to negotiate the price, as it impose a quite big risk. Interestingly, the sensitivity analysis also shows that a decreased consumer penetration poses a higher risk than an increased investment costs. The results show that a 10% decrease in demand has a higher impact on the feasibility of the project than a 10% increase in investment cost. It indicates that encouraging consumers to connect to district heating pose a bigger challenge than the magnitude of the investment costs.

The results show that the consumers will benefit from district heating, even if they are invoiced a high unit price (€35,1/MWh). However, the importance of securing a high consumer penetration suggests that it should be pursued to design an economically attractive price model.

9 Discussion

One of the identified barriers for introducing district heating to new district heating cities, is the lack of technical and practical knowledge. The Irish and UK interviewees expressed that they lacked familiarity with district heating planning and knowledge to carry out basic network designs. Here a case has been used to demonstrate how a rough design can be made based on relatively simple information and some basic thumb rules and used to give estimates about costs and potentials that can serve as a starting point for more detailed assessments. This methodology and many of the basic principles can be used in other new district heating cities in order to make the first cost calculations of prospect district heating networks. Knowledge about this kind of rough estimates of the feasibility and viability of a project can be useful for local authorities in order to assess suitable district heating areas, which can be the first step towards a further deployment of district heating. Heat atlases, like the ones provided by Heat Roadmap Europe (Heat Roadmap Europe, 2016), serve as a useful tool for designing a heat distribution system and the corresponding costs. This kind of knowledge can help create awareness of the possibility for district heating. However, district heating is relatively complex and requires experienced expertise to fully implement, so it should not be expected that every municipality can encompass the technical skills and knowledge to execute detailed network designs and feasibility studies. But provided with this kind of knowledge, they can assign experienced companies, like Rambøll or RPS, who can assist with the detailed technical planning. It is our believe that municipalities should have some basic energy planning competencies to identify the potential, which can be used to uncover what expertise is needed to develop the projects further. Knowledge about supply and demand will have an influence in designing the network, and the acquisition of accurate data at a building level is essential for designing the optimal network. In this process the critical mass and central actors can be identified and special effort should be paid in approaching them. In the feasibility the 5 biggest customers alone accounts for approximately 50% of the consumption. The feasibility study is based on the best available data, but is relying on estimates based on benchmarks and potential demand of proposed developments, which create a high degree of uncertainty. If the municipality is deciding to be more proactive in heat planning in the future, it would be beneficial if they could obtain better data.

The interviewees from the Danish trade organisations had much confidence in the capabilities of the engineers, as they did not recognize technical installations to be a barrier. Instead they pointed to the lack of knowledge of the organisational context the project is planned in. In their perspective the real barrier is merely relating to the municipalities ability to organise the different actors and elements, which is to constitute the system. In chapter 5.2 it was stated that the first step "*is to find some heat to supply, and to identify authorities that provides the needed permissions and you need to identify and secure a customer base that are willing to pay for the heat.*" (Lauersen, 2016). These are all some prerequisites that have to be taken into account when doing the design of the system, and would require local coordination. This kind of organisation will typically require local knowledge, which the experts might not be in possession of. So the combination of technical knowledge and ability to organise might constitute the real barrier.

It was mentioned that project developers do not have the ability to make district heating mandatory, and thus have to handle this obstacle by signing optional customer contracts (Gartland, 2016b; Coe & Storan, 2016; O'Shea, 2016). Furthermore, it was perceived as a barrier for the project developer's ability to engage with heat suppliers, who are unwilling to participate if long termed contracts have not been agreed (O'Shea, 2016). According to Duedahl (2016), private companies are not willing to expose themselves to unnecessary risks, which is legitimate and understandable seen from a stockholders' point of view. The lacking regulation was also perceived as a barrier in terms of engaging customers and getting their acceptance.

This leads to the question of how the benefits, risks and responsibilities should be distributed around the different stakeholders. Many municipalities do not have experience with owning or operating a district heating network; let alone heat planning. Therefore, it would require new capacity building to increase the role and responsibility of the municipality, if they are to be in charge of the district heating network. In the case of Dublin, the feasibility study suggests that there is a potential for a great economic gain. However, it would require a considerable investment accompanied by risks. These investments and risks can also be distributed differently, depending on the business model chosen.

The feasibility study touches upon different factors and risks that can influence the economic viability of the proposed district heating system; the price for supplied heat, a decrease in consumption and an increase in the investment costs. The results of the feasibility study show the importance of the right balance between the prices for purchasing heat at the WtE facility and the sales price at the demand side. This indicates the huge importance of coordination between the two, if the system is to be economic viable. The estimated purchase price for the system is low compared to Danish experiences, and the likelihood of an increase is imminent. This emphasizes the importance of negotiating a long-termed, suitable, and favourable price that could minimize the risk. The sensitivity analysis also suggests that the viability of the project is highly depended on the maintaining a high consumption. With the lack of existing regulative measures, it is likely that not all potential customers will be willing to be enrolled in the network. However, only the ~5 biggest consumers are needed to maintain this 50% (Figure 7-2: see annual heat demand figure). Beside from that, there is a lot of room to expand, just to put this in context! In the feasibility study, the new WtE facility has been identified as the supplier of heat. If the proposed district heating network is to be expanded in the future, there would be a need of either to build extra thermal capacity, or to approach alternative sources of heat. In the immediate vicinity of Spencer Dock, ESB has 3 power plants that could be possible providers of excess heat for a future system.

There were more interviewees that had the perception that the capital costs needed for developing district heating networks are high, and especially that the costs of establishing the pipework erase the competitiveness of district heating. This may be true for areas where the capital costs for establishing the network exceeds the revenue that can be gained, which can be the case for areas with low heat densities (i.e. lower than 140TJ/km^2), which leads to a higher levelized cost of the network. However, local circumstances might also influence the cost effectiveness of the investment, such as the construction costs of the pipes, which in inner city areas typically are higher than in green or outer city areas (Frederiksen & Werner, 2013) where the construction is more complicated. For example, one interviewee mentioned the cost of installing large district heating pipes in Dublin were considered to be in the range of €1000 to €2000 per meter due to the congestion of the ground, which corresponds very well to the Swedish experiences as shown in Figure 9-1. These kinds of local circumstances can naturally influence the cost effectiveness of the network. However, for inner city areas the heat density will typically also be higher, which might as well outline the extra costs. Heat density maps are therefore a good tool to make the first estimation of pipe sizes needed and the related capital costs, which can be used to assess the magnitude of the investment and thereby the feasibility of the network.

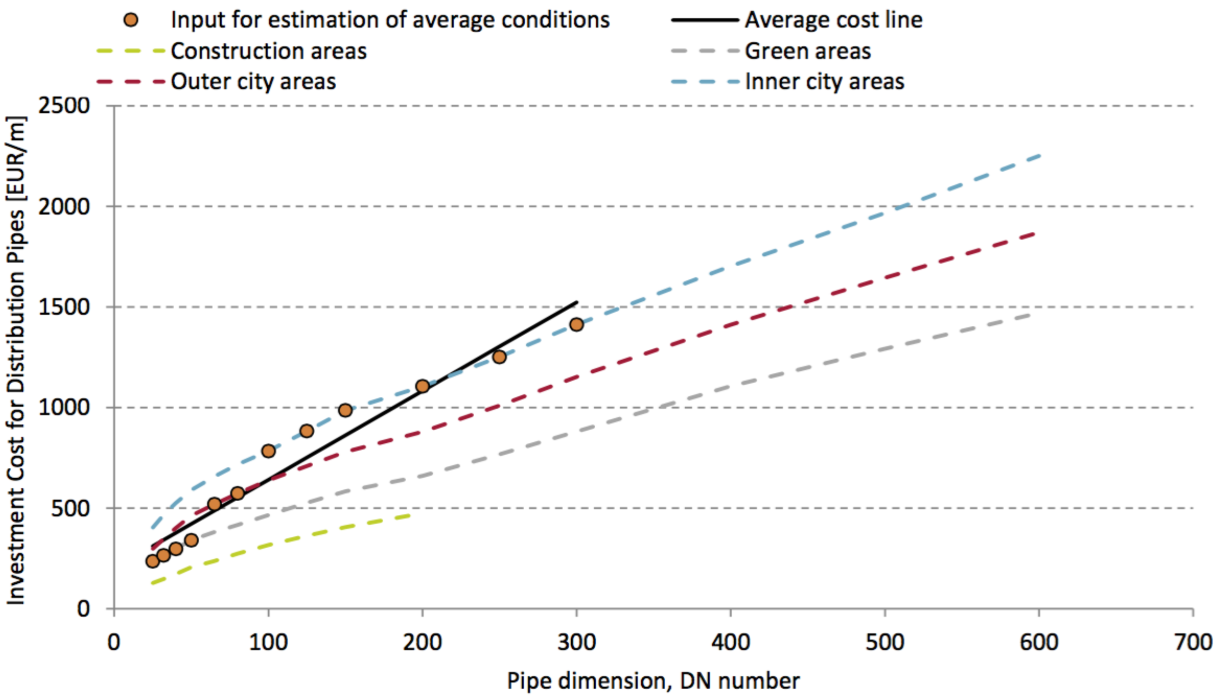


Figure 9-1 Typical construction investment costs for district heating pipes per route length and ground conditions based on Swedish experiences (Moller, 2015).

There is no doubt that the upfront capital cost needed for establishing district heating is considerably high compared to other heating solutions, mainly due to the costs of establishing the district heating network, which typically constitutes more than 50% of the total investment. However, comparing the capital costs isolated like this distort the picture, as district heating have other benefits in terms of lower fuel costs and long lifetime. Considering the capital costs over a long-term period will give a totally different picture. Here the feasibility study can serve as an example. The cost breakdown of the district heating network in Dublin (see Figure 8-2 on page 51) shows that the district heating pipes only represents one third of the total annualised district heating costs, while the last two thirds are equally shared between O&M and fuel. Furthermore, it can be seen that the annualised investment costs are considerably lower than the annualised fuel costs in the district heating scenario (approximately 80%).

Funding was another perceived barrier, especially in Ireland where no national funding mechanisms exists. Considering that district heating has a high capital outlay and relatively long-term revenue the lack of funding can be a barrier. It is possible that projects with high rates of return can attract funding from private investors or commercial banks. However, for municipalities and other public sector stakeholders, the aim might not be to generate a return, but instead provide efficient and sustainable energy supply and low energy costs for consumers. In UK, the Government have accommodated this by allocating €300 million to fund district heating capital investments, which provide a guarantee for needed loans. In Denmark, the municipalities have access to guaranteed low-cost loans through the nationally organised credit institution, which supports the development of district heating networks. Something similar could be applied in Ireland as a Governmental support to municipal development of district heating. This will reduce the risks, as mentioned above, and allow that interest rates to be reduced.

9.1 Recommendations

Based on the findings in this study the following recommendations have been made in order to overcome some of the barriers for the deployment of district heating in new district heating cities:

1. **Develop heat maps**
   Heat maps can serve as a good tool to identify potential areas suitable for district heating. By identifying the areas with the highest heat densities, an initial network design and corresponding cost estimation can be made. These heat maps can both illustrate the geographical location of heat demands and potential waste heat supply assets. Heat maps can be made on a national scale as in UK (DECC, n.d.) and on regional or city scale as in Dublin (Codema, 2015b).

2. **Approach key stakeholders**
   Normally a few buildings with high energy demands will be crucial for the viability of district heating projects. These anchor loads should be considered first and thereafter fit smaller heat users in around these. If the large heat loads can be secured at an early stage it is easier to design the physical structure around them. Similarly, the potential heat suppliers can be approached, which can be easier if the marked is secured.

3. **Active municipalities**

The municipalities should play an active role and act as local champions to develop district heating networks. Municipalities can play various roles and support the development of district heating in several ways, e.g. collect and gather heat and supply information (heat maps), provide planning consents (planning authority), disseminate benefits of district heating to the general public, be a district heating consumer and act as a role model and own and operate district heating systems.

4. **Compare alternatives by the annualised costs**
   District heating is an investment-based technology, meaning that upfront capital costs are high, while operation and maintenance and fuel costs can be considerably lower than traditional heating supply. Therefore, alternatives should be compared by annualised costs, which will accentuate the long-termed benefits of district heating.

5. **Establish national funding schemes**
   National funding mechanisms can act as support to the deployment of district heating systems. Provision of low-cost loans to municipalities for large infrastructure projects will enable projects to provide broad societal benefits.

Based on the findings from the feasibility study, the following recommendations can be made for Dublin:

1. **Develop district heating in Spencer Dock**
   It is recommended to establish a district heating system serving Spencer Dock with surplus heat from Dublin WtE facility. Here it is shown that district heating can deliver heat to the whole area at a lower cost than traditional individual natural gas boilers. The results indicate that the overall cost reduction will be about €24 million by 2036, if district heating is implemented compared to the natural gas reference. This corresponds to a relative cost decrease of 45%.

2. **Start by approaching the critical mass**
   Typically district heating projects will be based on a few anchor loads, which is critical for the viability of the business case. In these cases, it is desirable to obtain prior confirmation that these customers are willing to connect. Here it is shown that five of the biggest customers in Spencer Dock constitutes around 50% (see annual heat demand in Figure 7-2) of the total heat demand, which is enough to make the project viable. Therefore, as a first step it is recommended to encourage and assist these customers to accommodate district heating in the buildings. However, it should also be ensured that information on the potential benefits of district heating are disseminated to other developers and the general public, to raise the awareness of

district heating. Eventually, this can raise the possibility of increasing the district heating penetration in Dublin.

3. **Settle the heat purchase price**
   The heat purchase price from the WtE plant is important to settle, as it influence the profitability of the project. Here it is shown that it has a severe impact if the heat purchase price is settled at 20€/MWh. It is recommended that Dublin City Council negotiate this price, which will remove the risk associated with it.

4. **Expand the network continuously**
   Once the transmission line for Spencer Docks is established, it is likely that it can be used to serve many other areas with district heating in the future. It is recommended to consider expanding the network to new development areas such as Grand Canal, Dublin Port and the Irish Glass Bottle Site. Furthermore, it is likely that existing developments could be connected in the future when existing heating equipment is retrofitted. Housing areas such as East Wall, Ringsend and Irish Town could avail of the cheap energy from the WtE facility, which could accommodate fuel poverty. Additionally, with a potentially higher connection rate in the future, i.e. higher demand, it is likely that other available heat sources, such as the three power generation plants in Dublin City, could provide heat to the district heating system. When the district heating market is established, it might increase an incentive for these power plants to be connected.

10 Conclusion

This thesis has combined interviews with 'inexperienced' district heating organisations from UK and Ireland and 'experienced' district heating organisations from Denmark to identify perceived barriers to development of district heating. This combination has revealed interesting alignments and inconsistencies between perceived barriers. In conclusion, the following six main barriers can be highlighted:

1. Lack of technical and practical knowledge among local stakeholders, such as public sector city planners and technical staff
2. Incapability of engaging stakeholders and arrange business models
3. Lack of regulation and political stability
4. High capital costs and sensitivity to long-term risks
5. Lack of funding to cover long-term capital costs
6. Lacking understanding of the benefits of district heating among individual consumers

Through a feasibility study for Spencer Dock in Dublin, some of the perceived barriers were quantified. The major findings from the interviews and the quantitative results, revealed some recommendations to overcome some of the barriers. The feasibility study suggested that a district heating network in Spencer Dock would be feasible and viable, from both a socioeconomic. In order to overcome some of the barriers that occur in new district heating cities, the following five recommendations are made:

1. Develop heat maps
2. Approach key stakeholders
3. Active municipalities
4. Compare alternatives by the annualised costs
5. Establish national funding schemes

Specifically, the findings of the feasibility study lead to the following four recommendations for Dublin:

1. Develop district heating in Spencer Dock
2. Start by approaching the critical mass
3. Settle the heat purchase price
4. Expand the network continuously

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12 Appendices

Appendix A – Technology data

The technology data for the natural gas boilers used in the reference scenario is based on data from the Department of Energy and Climate Change in UK (Pöyry & AECOM, 2009).

Natural gas boiler	
Capital costs	59€/kW
O&M	4€/kW
Technical lifetime	15 years
Efficiency	91%

The technology data for the district heating exchangers in the district heating scenario is based on Danish Energy Agency's Technology Sheet (Danish Energy Agency, 2013). The costs are estimated based on data from Danfoss.

District heating exchanger	
Capital costs	40€ x thermal capacity (kW) + 2611€
O&M	0,2€/kW
Technical lifetime	20 years
Efficiency	100%

The estimate of heat load for different building functions is based on Table 12-1 from the Danish Varme Ståbi (Lauritsen, 2015).

Table 12-1 Heat demand and heat load for different building types (Lauritsen, 2015; 275)

Kategori og boligstørrelse		Årsvarmebehov Pr. 100 m² [MWh]	Årsvarmebehov Pr. boligenhed [MWh]	Tilslutningseffekt Pr. 100 m² [kW]	Tilslutningseffekt Pr. boligenhed [kW]
Parcelhus, BR 10 - 2020	140 m²	2,0	2,8	1,1	1,6
Parcelhus, BR 10 - LE 2015	140 m²	4,0	5,2	2,2	2,9
Parcelhus, BR 10	140 m²	6,9	9,0	3,8	5,0
Parcelhus, BR 08 - LE 1	140 m²	4,6	6,0	2,6	3,3
Parcelhus, BR 08 - LE 2	140 m²	6,6	8,6	3,7	4,8
Parcelhus, BR 08	140 m²	9,2	12,0	5,1	6,7
Parcelhus, nyere	*135 m²*	*11,4*	*15,3*	*6,3*	*8,5*
Parcelhus, ældre	*140 m²*	*15,3*	*21,4*	*8,5*	*11,9*
Tæt-lav, nyere	*95 m²*	*10,6*	*10,0*	*5,9*	*5,6*
Tæt-lav, ældre	*110 m²*	*14,7*	*16,1*	*8,2*	*9,0*
Etagebolig, nyere	*70 m²*	*9,4*	*6,7*	*5,2*	*3,7*
Etagebolig, ældre	*85 m²*	*14,2*	*11,9*	*7,9*	*6,6*
Kontor, butik m.v., nyere		*13,9*		*7,7*	
Kontor, butik m.v., ældre		*18,9*		*10,5*	
Industri, nyere		*9,4*		*5,2*	
Industri, ældre		*12,2*		*6,8*	
Institution, hospital m.v., nyere		*20.0*		*11,1*	
Institution, hospital m.v., ældre		*26,4*		*14,7*	

Kategorier og data med kursiv er delvis ifølge /8.7/.
Nyere og ældre byggeri refererer til byggeri før og efter 1982.

Fig. 8.20. Årsvarmebehov og tilslutningseffekter for forskellige bygningskategorier.