Barriers to district heating development in the Netherlands: a business model perspective

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Summary

The current fossil fuel based energy system in the Netherlands is not sustainable and changes are needed. Moreover, if humans do not reduce CO_2 emissions drastically within this century the consequences can be disastrous for the livability of many species on this planet. For the heating sector, which is 40% of the total energy need, The Dutch government promotes the use of district heating networks (DHNs) to replace the gas network. DHNs are a local network of pipes transporting heat from the source to industrial, commercial and residential buildings. The main benefit of DHNs is that cleaner heat sources that are often not available for individual users, such as geothermal heat, industrial waste heat, biomass and waste incinerations, can be utilized through a large scale DHN.

The switch from a fossil fuel system to clean and renewable alternatives is, however, a challenging task. The extensive and highly competitive gas network in the Netherlands has created “a carbon lock in” for the Dutch heating sector, which makes it difficult for other heating alternatives, such as DHNs, to compete. Many local governments in the Netherlands who have attempted to replace fossil fuel systems with DHNs in recent years seem to stumble upon barriers that causes their projects years of delays, to go over budget or to not come to fruition at all. Furthermore, to be truly sustainable, DHNs have to be able to create environmental, societal as well as economic value. How businesses create, capture and deliver value is reflected by the business model they employ. Therefore, the purpose of this thesis was to study the barriers of DHN development in the Netherlands and the potential solutions to these barriers in order to ***determine how district heating companies can configure their business model to overcome the barriers of sustainable DHN development***. The focus in this study was specifically on DHNs that operate on a city-level aiming to deliver heat to as much buildings as possible as opposed to block heating or industrial heat exchange.

Based on a literature review the following definition was adopted for business models: a business model is the way that organizations create, deliver and capture value, resulting from strategic choices relating to their value proposition, architecture, value network and financial structure. The business model framework that was used in this study consisted of the following four components: value proposition, value architecture, value network, and value finance. The first step was to use this framework to develop an overview of the current business model configuration in the Netherlands and the barriers that are found in the literature. For a more in-depth analysis of the business models of DHNs, four case studies in the Netherlands were reviewed to determine what the barriers are with the current business models and what the potential solutions might be. These cases have gone through the process of developing a DHN in recent years and accumulated a great deal of insight and experience into the barriers, success factors and pitfalls of establishing a DHN over the years. To tap into this source of knowledge, this study reviewed documentation of these four cases and performed interviews with employees within the district heating companies and various stakeholders of the DHNs within these cases.

Besides the more obvious financial barriers that come with large infrastructural projects, the findings in the case studies showed that there are key organizational and network related issues in the business model of DHNs that are not covered in the current literature of DHNs. These issues include a lack of knowledge and experience within local government institutions with the inherently complex process of developing a DHN in the Netherlands and a lack of support due to conflicting interest with the stakeholders. To overcome the lack of knowledge, this study proposes municipalities to seek public private partnerships (PPPs) with network operators and energy companies. Network operators and energy companies bring the experience and expertise, while the municipality can cover the financial gap in the business case. Furthermore, to attract private partners more easily, a key strategy is to unbundle network operations and heat delivery activities into two legal entities, because private companies prefer to invest in the operations they can control best.

As for the network related issues, large scale customers are hesitant to undergo long-term energy contracts, while heat suppliers do not want to commit to a DHN when there are no solid guarantees on heat demand. To break this stalemate, stakeholders of the DHNs stressed the importance of having a strong-willed initiator to mediate the process and an experienced process manager with the ability to create trust willingness and support from stakeholders. The municipality is the most suited for this role, because they often have a strong ambition to develop a DHN to reduce CO_2 emissions, but also the time and patience to see a long-term project through. Furthermore, municipalities are well connected with the local stakeholders and the municipality can function as an impartial mediator in the negotiation between the private parties. The findings also showed that especially in the initial stages the relationship with key stakeholder is more important than value propositions towards end customers, since key stakeholders such as large-scale building owners, developers and housing companies are the ones that make the decision to connect to a DHN.

Lastly, there are large financial barriers due to high initial investments in the infrastructure, payback periods of 20+ years, and large uncertainties about future heat demand and gas prices. Gas prices are of particular importance for the revenues of DHNs, because Dutch DHNs are not allowed to charge higher heat prices for dwellings than in the case of a gas connection. This creates a large financial constraint on DHN projects, which provides little margins for mistakes or misfortunes. A useful strategy to prevent a high initial investment when there is not sufficient heat demand, is to develop small decentralized projects throughout the city whenever the opportunity arises to connect customers. When there are sufficient decentralized projects, the district heating company can make the large investment in the primary network to form one large DHN. Beside this strategy, DHN development relies heavily on public funds from national, provincial and municipal subsidies. These public funds are crucial for the long-term development of DHN in the Netherlands.

Preface

This thesis is my final assignment to acquire the master Business Administration degree at the University of Twente. After my bachelor Civil Engineering I was not certain about which career to pursue so I decided to broaden my knowledge by pursuing a master in Business Administration next to a master in Civil Engineering. Looking back at it, I can say that especially the master thesis project was a challenging experience with its ups and downs. It has taught me a lot that I think will benefit me greatly in my future endeavors.

This result was not possible without the help of others. That is why I would like to take this opportunity to thank some people. First, I want to thank my supervisors from the University of Twente: Klaasjan Visscher and Joop Halman. Their feedback sessions have helped me tremendously to bring more depth and structure within this thesis. It has been a long journey for me and I also thank them for their time and patience throughout the process.

For this thesis, I emerged myself in the world of district heating networks and I had the pleasure to take part in an internship with Warmtenet Hengelo. I would like to thank the organization of Warmtenet Hengelo and the Municipality of Hengelo for opening up their resources and connections for me. I would like to especially thank Ineke Nijhuis and Raymond Frank for taking their time to guide and teach me more about district heating networks. I also want to thank all the other employees of Warmtenet Hengelo for making the whole process more enjoyable with numerous coffee breaks, chats, and sometimes nonsense.

Thirdly, I want to thank all interviewees within this study for their cooperation and openness. Their insight in the district heating network world has truly made the findings of this study worthwhile for other parties who are trying to develop a district heating network in the Netherlands.

Finally, I take this opportunity to express my gratitude to my family for their love, patience and unfailing support. This thesis would not be possible without them.

I hope you will enjoy reading this thesis and be able to move forward from the presented results.

Enschede, July 2017

Nejat Osman

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List of abbriviations

Abbriviation	Meaning
ACM	Authority for Consumers and Markets
CBS	Centraal Bureau voor de Statistiek
CHP	Combined Heat and Power
DH	District Heating
DHN	District Heating Network
DHC	District Heating Company
NMBP	Nationaal Milieu Beleidsplan
PPP	Public Private Partnership
SVP	Stadsverwarming Purmerend
WNH	Warmtenet Hengelo

1. Introduction

This report is the result of the master thesis program of Business Administration (BA) at the University of Twente. The central topic of the study is District Heating Networks (DHNs): an underground system of piping to distribute thermal energy from one or more central energy sources to industrial, commercial and residential users. This chapter will continue with the Research background (Section 1.1), Research problem (Section 1.2), Research objective (Section 1.3), Research questions (Section 1.4), and Outline of thesis (Section 1.5).

1.1 Research background

Humanity faces serious energy and environmental problems at present. The environment is threatened, for instance, by increasing greenhouse gas (GHG) emissions, which have contributed to concentrations in the atmosphere having already reached concerning levels in terms of their potential to cause climate change (Arroyo, 2006; Rezaie & Rosen, 2012a). Furthermore, it is apparent to both energy experts and oil companies that the end of fossil fuels is coming (Dobbelsteen, Broersma, & Stremke, 2011; Shafiee & Topal, 2009). Despite these threats, Western societies still heavily rely on fossil fuels. The Netherlands for instance obtains less than 6 % of its energy by means of sustainable sources, the rest is fossils and a little of imported nuclear energy (CBS, 2017).

Many policymakers have recognized these problems and targets have been set by many countries to reduce greenhouse emissions (United Nations, 2015) and to use renewable energy sources (The European Parlement and Council, 2009). However, current energy systems seemed to be somewhat protected by the institutional alignment, which favors the old technology over the new one (Jacobsson & Bergek, 2004; Unruh, 2000). This especially becomes clear in the Dutch heating sector, where over 88% of the domestic space heating need is delivered by natural gas (CBS, 2015a)

This means that stabilizing greenhouse gas concentrations and shifting to renewable energy sources will require a disruptive change in our energy system (Arroyo, 2006; TNO, 2013). Recently, policymakers are trying to implement this change with bottom-up initiatives on a local level, such as DHNs, using efficient and renewable energy technologies. The fundamental idea of this shift is that communities have to search for local (renewable) possibilities that would avoid demand from alien energy in the first place (Dobbelsteen et al., 2011). Consequently, this will lead towards local resources being optimally seized before any demand is posed upon other areas. Besides stabilizing greenhouse emissions, this transition will have other benefits as well, including improved competitiveness, energy security, air quality, public health, and job creation (Zervos, Lins, & Muth, 2010).

DHNs have the ability to provide heat from a wide variety of renewable energy sources to homes and businesses using a network of pipes. As a result, they are often characterized as a clean and sustainable alternative for the heating sector. Although the environmental potential is evident, developing feasible business cases for sustainable DHNs remains a difficult task, particularly in the Netherlands where there is an extensive gas network in place throughout the country. One of the key barriers for sustainable DHNs is to configure their business models in a way that enables the stakeholders to capture economic value for itself while delivering social and environmental benefits for the region they serve. Therefore, this study will take a business model perspective to investigate the barriers and potential solutions to these barriers for the business models of sustainable DHNs.

1.2 Research problem

As stated before, DHNs are a local network of pipes transporting heat from the source to customers. It has been shown that district heating can be an energy and (exergy) efficient way to provide for the heating demand of an area, while reducing CO2 emissions and the use of fossil fuels (Bloomquist, 2003; Faninger, 2000; Joelsson & Gustavsson, 2009; Rezaie & Rosen, 2012a). Renewable energy sources such as biomass, sewage heat and geothermal heat can be economically exploited in large DHNs (Ghafghazi, Sowlati, Sokhansanj, & Melin, 2010). Furthermore, DHNs can have access to a wider range of (renewable) energy sources compared to decentralized systems (Ghafghazi et al., 2010) and benefit from economies of scale from a large power plant over small residential systems (Marinova, Beaudry, Taoussi, Trepanier, & Paris, 2008). It can be particularly advantageous for dense urban districts where heat losses in the distribution network are small.

However, in areas of low heat density, milder climates or where the value of fuel savings is low, DHNs may not be the least-cost option (Gocenuri, 2001). Furthermore, the feasibility of DHNs relies highly on local characteristics, such as local available energy sources, energy users and geographical properties, which makes it difficult to imitate or scale successful business cases of DHNs (Lund, Möller, Mathiesen, & Dyrelund, 2010; Reidhav & Werner, 2008). Therefore, many investors in the Netherlands are hesitant to invest in DHN projects claiming that the substantial front-end investment with a long payback period is not cost effective (Bernard Oattes, 2011; Huisman, 2010). Also the dominant energy companies in the Netherlands are unwilling of changing the current energy system for now, as they perceive little incentive to cannibalize their market share by introducing new technologies (Goijen, 2013; Rigby, Christensen, & Johnson, 2002).

On the other hand, the European Union as well as the Dutch national and regional government support the expansion of DHNs in order to increase the share of renewable energy sources and reduce CO2 emissions (SER, 2013; EU Parlement and Council, 2009). However, politicians are burdened with the task to balance various conflicting political and economic interests that seem to prevent them to fully commit themselves to large-scale sustainable DHN programs. Therefore, the responsibility of new sustainable DHNs are passed down to local governments (such as municipalities) and initiatives of local communities (Kousky & Schneider, 2003; Tachet, 2009). Often a separate division or entity is created which operates as a District Heating Company (DHC) within these communities (Advokaat, 2011).

These DHCs often struggle to compete with other heating alternatives, such as individual gas fired boilers. The root of the difficulties that sustainable DHNs face, originate from "industrial economies that have been locked into fossil fuel-based energy systems through a process of technological and institutional co-evolution driven by path-dependent increasing returns to scale" (Unruh, 2000). This "carbon lock-in" is also visible in the Dutch heating sector that is dominated by natural gas. The Dutch possess substantial gas reserves have held the sustainable development back in the last couple of decades compared to countries with more progressive environmental policies (Eurostat, 2012). The share of DHN connections for Dutch dwellings is merely at 7% (ACM, 2016). Moreover, some of these DHNs still use natural gas as the primary heat source with large gas-fired boilers or power stations (CE Delft, 2009), while the true benefit of DHN is that clean heat sources can be utilized. With regard to these considerations, the main problem for this study is defined as follows:

District Heating Networks have the potential to reduce CO2 emissions and increase the use of renewable energy sources, however, district heating companies in the Netherlands do not seem to be able to seize this potential.

1.3 Research objective

In order for DHNs in the Netherlands to break the carbon lock in the heat market and increase the share of renewable energy sources, the barriers for DHNs and potential solutions to these barriers have to be explored. Logically one would assume that the key to breaking the carbon lock is to develop value propositions for sustainable DHNs that outperform other heating options in the region they serve. However, this is easier said than done, as the development of DHNs depend on the cooperation of various local stakeholders. For instance, waste heat supply has to be secured from an industrial partner, support or at least approval has to be obtained of the Municipality Council to develop the DHN infrastructure, and for the heat demand commercial building owners and housing associations have to be persuaded to connect to the DHNs. Hence, DHCs cannot simply create value on their own, rather value as to be co-created with and for these local stakeholders. Besides this, to be truly sustainable, DHNs have to be able to create environmental, societal as well as economic value (Bond & Morrison-Saunders, 2009; Drexhage & Murphy, 2012; Sutton, 2004).

How businesses create, capture and deliver value is reflected by the business model they employ (Osterwalder & Pigneur, 2009). Therefore, choices on the business model components seem to be of crucial importance to the success of sustainable DHNs. Especially, since academics come to understand that business models can serve as a useful tool to determine strategic choices that are key to the success of a particular business case (see e.g. Magretta, 2002; Masanell & Ricart, 2011; Shafer, Smith, & Linder, 2005). These choices for instance include what customer segments to target, what partnership to undertake, and how to create revenue. Furthermore, for new ventures, arranging the business model components beforehand can be a helpful exercise for businesses to unravel the value creating logic and check for inconsistencies within their strategic choices (see e.g. Chesbrough, 2010; Magretta, 2002; Osterwalder, Pigneur, & Tucci, 2005).

In the past ten years, research on business models has also spilled over to the field of sustainable development. In particular, business models in this field are used as an instrument to explore innovative ways to capture economic value while delivering social and environmental benefits (see e.g. Bocken, Short, Rana, & Evans, 2014; Schaltegger, Lüdeke-Freund, & Hansen, 2011). Since DHNs in the Netherlands seem to struggle with creating a sustainable value creating logic, the business model perspective can bring a useful perspective on the issues of DHNs and how they can potentially be solved. Furthermore, a study that comprehensively and explicitly focuses on the business models of sustainable DHNs in the Netherlands is missing in the academic literature. Therefore, the objective in this study is to:

Determine how district heating companies can configure their business model to overcome the barriers of sustainable DHN development *by capturing the expertise and experience of DHNs in the Netherlands through interviews with experts and stakeholders of DHNs, and translating the findings into a set of guiding principles to configure business models of sustainable DHN.*

Certain aspects of this objective need some clarification. First, the objective of this thesis is not to seek one ‘best’ way to configure the business model of DHNs. Since there are many ways to set up DHNs, depending on contextual factors such as the available energy sources, stakeholders and geographical properties of the designated region. This also means that there will be various ways to configure the business model successfully based on these contextual factors. Nevertheless, we do believe that there might be some guiding principles to configure the business model of sustainable DHNs. The purpose of this is thesis is to explore what these guiding principles are.

Second, the objective of this thesis focuses on *business models*. This is a contested concept that is explored by means of a literature review in Chapter 2. Third, the objective states that the focus in this study will be on <u>sustainable</u> DHNs. For the objective of this thesis it is important to understand that sustainability comprises an integration or balancing of environmental, social and economic issues (see e.g. Bond & Morrison-Saunders, 2009; Drexhage & Murphy, 2012; Gibson, 2006; Kelly, 1998; Kemp & Martens, 2007).

Lastly, it is important to specify the term DHN, because the definition of DHN covers a wide area of different types of DHNs. In legal terms a DHN in the Netherlands is defined as “a local network of pipes transporting heat from the source to customers". This might be a network with 20.000 buildings or block heating for a single apartment building or industrial companies delivering steam through a pipeline with a neighboring company. However, in this study we are specifically focused on the DHNs that operate on a city-level aiming to deliver heat to as much buildings as possible. The distinction between different DHNs is further specified in Section 4.1.

1.4 Research questions

The research objective is translated into a main research question, which in turn is divided into three sub-questions:

How can district heating companies configure their business model to overcome the barriers of district heating network development?

1. What business model configurations do district heating companies currently use to develop district heating networks in the Netherlands?

The purpose of the first question is to establish a taxonomy of business model configurations (i.e. value network, value propositions, technology and revenue model) for DHNs that are currently employed in the Netherlands and describe the context in which the business models are employed. Furthermore, issues that are found with the current business model configurations are also identified.

2. What are the barriers that district heating networks currently face and what solutions do district heating companies provide?

In order to develop successful business models, one first has to know what pitfalls to avoid. The purpose of the second question is to explore the barriers that DHNs currently face and potential solutions to these barriers through case studies including interviews with stakeholders and experts of sustainable district heating networks. Based on the interviews, an overview will be developed of what the customer and key partners value, and the discrepancies with the offerings of the current business models.

3. How can district heating companies configure their business model to develop sustainable district heating networks in the Netherlands?

The goal of the third question is to develop a set of guiding principles to configure the business models of sustainable DHNs based on the solutions that experts and stakeholders have provided with found on the barriers that are found within the current business models.

1.5 Outline of thesis

This thesis consists of four parts (see Table 1). The first part is the Research design, which includes the introduction to the research topic in this chapter, a literature review on business models to develop a theoretical framework for this thesis in Chapter 2 and the Research strategy in Chapter 3. The second part is a desk study on the business models currently used for DHNs in the Netherlands in Chapter 4, alongside a discussion in Chapter 5 of the barriers of DHN development in the Netherlands as found in the literature. Part III is a multiple case study review of four DHNs in the Netherlands including interviews with experts and stakeholders of DHNs, which are described in a within case study analysis in Chapter 6 and a cross case analysis in Chapter 7. The thesis ends with a Research synthesis in part IV, which consists of Recommendations (Chapter 8), Discussion (Chapter 9) and Conclusion (Chapter 10).

Table 1: Thesis outline

Thesis Parts	
Part I: Research design	Chapter 1: Introduction
	Chapter 2: Literature review
	Chapter 3: Research strategy
Part II: Desk study	Chapter 4: Development of DHNs in the Netherlands
	Chapter 5: Barriers and success factors of DHNs
Part III: Multiple case study	Chapter 6: Within case analysis
	Chapter 7: Cross case analysis
Part IV: Research synthesis	Chapter 8: Recommendations for business model syntheses of DHNs
	Chapter 9: Discussion
	Chapter 10: Conclusion

2. Literature review on business models

The purpose of the literature review is to form the theoretical framework for the main objective of the study and to bring the reader up-to-date with current state of knowledge on the topic of business models. Especially in the last two decades, the amount of scientific literature on business models has grown exponentially. Alongside original publication, scholars performed many systematic literature reviews to make sense of business model theory and establish the core logic of the concept. Since these literature reviews already incorporate an analysis of earlier work, comparing the literature reviews in this chapter enables us to capture broad parts of the existing literature. Therefore, a systematic literature study into these secondary sources was used to provide a framework to analyse the business models of DHNs.

This chapter starts with a discussion on the origins of the business model concept in Section 4.1. Then, in Section 4.2 a definition and theoretical framework is presented based on a set of selected literature reviews. Section 4.3 elaborates on the relevance of the business model concept to the sustainability of DHNs. Finally, a conclusion is presented in section 4.4.

2.1 Origin of business models

Business models are an inherent element of every business. Whenever a business enterprise is established, it either explicitly or implicitly employs a particular business model based on a variation of the generic value chain underlying all businesses: make and sell something (Magretta, 2002). Despite this, interest in business models is relatively recent, with much of the research appearing since the mid-1990s as shown in Figure 1. Initially, the development of the concept was primarily associated with drivers of the "New Economy" (Wirtz, 2011). These drivers include the emergence of the internet, increasing globalization, faster innovation cycles and developments in IT making it possible for businesses to do things they simply never could before (McGrath, 2010; Teece, 2010).

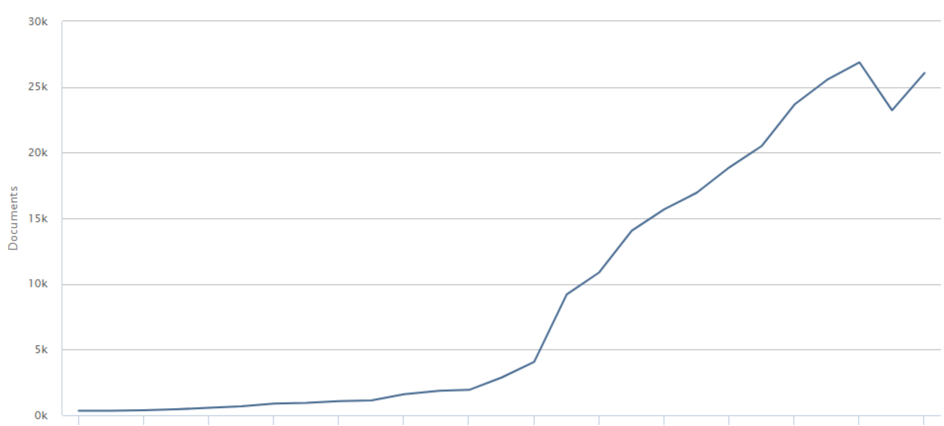

Figure 1: Business model articles found in Scopus between 1990 and 2016

In particular, “the way in which companies make money nowadays is different from the industrial era, where scale was so important and the capturing value thesis was relatively simple i.e. the enterprise simply packed its technology and intellectual property into a product which it sold” (Teece, 2010). Nowadays, it has become increasingly difficult to attach the success of a company to a single product or business unit. Instead, the success of a company might lie in its set-up of network partners, forming a symbiosis along the value chain (Resch, 2011). These developments provided managers with exciting new business opportunities and new ways to think about their value creating logic. However, the problem was that some of the developments within the “New Economy“ were difficult to capture with the predominant perspectives on business analysis at that time (Bettis, 1998; Boehnke, 2007; Stähler, 2002), such as the market based view (see Porter 1980) and the resource based view (see Barney, 1991). These traditional perspectives were based on assumptions from the “Old Economy” and less relevant to explain business that were operating within the “New Economy” (Bettis, 1998; Boehnke, 2007; Stähler, 2002; Zott & Amit, 2004). Therefore, business models emerged as a complementary unit of analysis to analyze and communicate how businesses operate in the “New Economy” (Hedman & Kalling, 2003; Stähler, 2002).

2.2 Business model definitions and components: a theoretical framework

Although the first definitions of business models came into being at the end of the 1990s, the term *business model* is not used consistently or precisely in either practice or academia (Wirtz, 2011). In fact, publications that review the literature on business models regularly comment on the lack of a construct definition (George & Bock, 2011). The large pile up of definitions is not because scholars disprove earlier definitions, rather scholars redefine the concept according their phenomena of interest or purpose of study. As a result, many of the proposed definitions have overlapping elements, however, due to a lack of a unified understanding of the business model concept cumulative research progress is hampered (Zott, Amit, & Massa, 2011)

Academics have tried to counter this by conducting extensive systematic literature reviews to establish the common elements and core logic of the concept. For the purpose of this thesis, these reviews provide an efficient and useful way to capture the essence of business models. Therefore, a literature study into these secondary sources will be used to establish a better understanding of the business model concept and provide a framework to analyse the business models of DHNs. To focus our search, while obtaining a complete and up to date overview of business model literature at the same time, three search criteria were used:

1. The publications had to present a systematic and reproducible method for their literature reviews.

2. Earlier literature reviews were disregarded if the publication was incorporated in a more recent literature review.
3. The publication must refer to the business model as a concept related to business firms (as opposed to, e.g., economic cycles).

Eventually three publications were found that satisfied these criteria: Al-Debei & Avison, 2010; Wirtz, 2011; Zott et al., 2011. These three publications together provide us with 32 definitions of business models from the period 1996 until 2011. Although most definitions differ from each other to some extent at first glance, there seems to be a common underlying intention that a business model describes how organizations create and distribute value in a profitable manner (see e.g. Amit & Zott, 2001; Byers, Dorf, & Nelson, 2001; Casadesus-Masanell & Ricart, 2010; Demil & Lecocq, 2010; Osterwalder, Pigneur, & Tucci, 2005; Teece, 2010). Furthermore, the review of Zott et al. (2011) showed that researchers have begun to converge on the four following themes that characterize business model research:

1. The business model is emerging as a new level and unit of analysis;
2. business models emphasize a system-level, holistic approach toward explaining how firms "do business";
3. activities performed by the focal firm as well as by partners, suppliers, and even customers play an important role;
4. business models center on the logic of how value is created for *all* stakeholders, not just how it is captured by the focal firm.

Also, the business model literature shows overlap with respect to the business model components. An analysis of Morris (2005) into business model components showed that the most frequently cited components in academic papers between 1996 and 2005 were the firm's value offering, economic model, customer interface/ relationship, partner network/roles and internal infrastructure/ connected activities. This is also reflected by various secondary sources who have provided syntheses of components of earlier work (see e.g. Al-Debei & Avison, 2010; Morris, Schindehutte, & Allen, 2005; Osterwalder et al., 2005; Shafer, Smith, & Linder, 2005; Stähler, 2002). Most recently, Al-Debei & Avison (2010) consolidated the common characteristics shared by the different definitions into a unified framework. Al-Debei and Avison (2010) performed a thorough and systematic content analysis into the business model literature between 1998-2008 and developed a framework with four dimensions by categorizing thematic indicators from the selected paper (see Figure 2).

The validity of the V4 framework is indicated through the coverage of its dimensions by other business model papers and its empirical demonstration (see Al-Debei, Panagiotopoulos, Fitzgerald, & Elliman, 2010; Joha & Janssen, 2012; Panagiotopoulos, Al-Debei, Fitzgerald, & Elliman, 2012;

Serrano, Serrano, & Al-Debei, 2010). Due to its grounding in business models research and empirical demonstrations so far, the V4 Business Model Structure is considered as an extensive and up-to date business model representation making it an appropriate framework to use in this thesis to analyse the business models of DHNs.

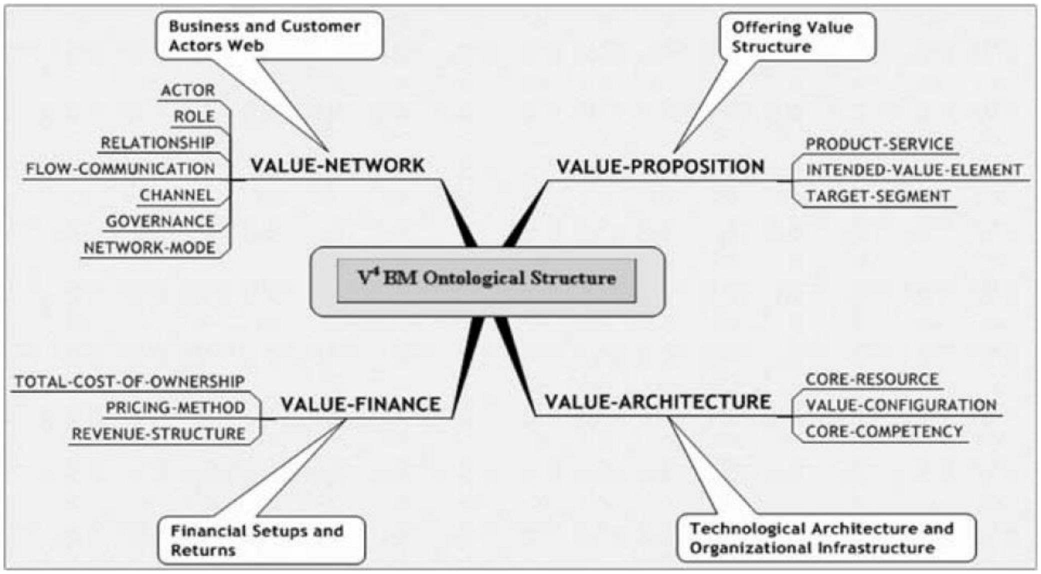

Figure 2: V4 Business model framework (Al-Debei & Avison, 2010)

The framework of Al-Debei and Avison (2010) consists of four dimensions as shown in Figure 2. The terminology used signifies that these fundamental dimensions are value-based: each aims to provide the market with desired values through the provision of services and products so as to capture economic values in return (Al-Debei & Avison, 2010). The first dimension is the value proposition. The value proposition includes a description of the product/services, value elements and targeted market segments. It solves a customer problem or satisfies a customer need. In this sense, the value proposition is an aggregation, or bundle, of benefits that a company offers customers (Osterwalder et al., 2005). The second dimension is the *value architecture*. The value architecture consists of its technological architecture, organizational infrastructure, and their configurations. This includes all the tangible and intangible organizational assets, resources, and core competencies. These resources allow an enterprise to create and offer a value proposition, reach markets, maintain relationships with customer segments, and earn revenues. The third dimension is the *value network*. The value network is a description of the position of an organization in the value system and its relationships with different stakeholders. This construct depicts the cross-company or inter-organization perspective towards the concept and has gained much attention in the business model literature (Al-Debei & Avison, 2010). Particularly, because the digital economy has provided firms with the potential to experiment with new forms of value creation, which are networked in the sense that value is created in concert by a firm and a plethora of partners, for multiple users (Amit & Zott, 2001; Zott et al., 2011). The last dimension is the *finance structure*. This dimension depicts information related to costing, pricing methods, and revenue structure. The business model concept is often confused with the financial component. Whenever a user refers to the business model, many people assume that the user is going to address financial arrangements with respect to revenue generation (Al-Debei & Avison, 2010). However, the business model is more comprehensive and that value finance represents only one dimension of the whole narrative (Al-Debei & Avison, 2010; Osterwalder et al., 2005; Shafer et al., 2005; Zott et al., 2011). Based on a synthesis of the definitions from the three literature reviews and the framework of Al-Debei & Avison (2010), the following definition is used in this thesis for the business model concept:

A business model describes the way that organizations create, deliver and captures value, resulting from strategic choices relating to their value proposition, architecture, value network and financial structure.

Business model reach

It is important to note the position of the business model in a firm, especially in relation with the strategy and business processes, since these concepts are closely related, but not the same. The most important difference is that strategy is considered more than the mere selection of a business model (Al-Debei & Avison, 2010; Casadesus-Masanell & Ricart, 2010; Magretta, 2002). Many scholars have argued that the business model is an intermediate theoretical layer between the business strategy and the business processes (e.g. Al-debei, El-Haddadeh, & Avison, 2008; Morris et al., 2005; Osterwalder et al., 2005). The business organization translates its broad strategy into specific business model components, thus bridging strategy formulation and implementation (Zott et al., 2011). In this way, business models provide a powerful way to understand, analyze, communicate, and manage strategic-oriented choices (Osterwalder et al., 2005; Pateli & Giaglis, 2004; Shafer et al., 2005). In a similar vein, both Shafer et al. (2005) and Casadesus-Masanell and Ricart (2010) view the business model as a reflection of a firm's realized strategy. Teece (2010), adds that business models are more generic than strategy, which means that coupling strategy analysis with business model analysis is necessary in order to protect whatever competitive advantage results from the design and implementation of new business models.

Business model function

The main function of a business model is to assist firms in describing their business activity (Wirtz, 2011). Osterwalder et al. (2005) describes it as a conceptual tool that can be used not only for illustrating but also for managing a company's core logic. Companies can then use this tool to understand and communicate the business logic to stakeholders (Al-Debei & Avison, 2010; Osterwalder et al., 2005; Wirtz, 2011; Zott et al., 2011). Al-Debei & Avison (2010) further specifies it as a conceptual tool of 'alignment' to fill the gap between corporate strategy and business processes, and to provide a crucial harmonization among these organizational layers. Furthermore, the business model concept can contribute in analyzing companies and compare them with each other, since it is a new unit of analysis (Al-Debei & Avison, 2010; Osterwalder et al., 2005; Wirtz, 2011).

2.3 Relevance of business models to the sustainability of DHNs

Now that the business model concept is developed, the next step is to describe the relevance of business models to sustainable DHNs. For this purpose, it is useful to understand the neoclassical economic standpoint on value creation. Neoclassical economic theory states that the primary obligation of the firm is to maximize profits for their shareholders and value is created whenever a manufacturing firm's supply meets demand (Key, 1999; Stubbs & Cocklin, 2008). According to Shrivastava (1995), this paradigm, is inherently limited in its ability to effectively address social and ecological degradation, and, accordingly, some scholars have called for new management paradigms to move beyond the "organization as an economic entity" (see e.g. Doppelt, 2009; Dunphy, Griffith, & Benn, 2003; Shrivastava, 1995; Stubbs & Cocklin, 2008). Business models represent a broader and holistic conceptualization of value creation that is more in line with the concept of sustainability and the notion that various stakeholders can play a crucial in the value creation potential of the focal firm (Stubbs & Cocklin, 2008).

Although the concept of sustainability is normative and subject to value judgements (Barrett & Grizzle, 1999; Bond, Morrison-Saunders, & Pope, 2012; Kemp & Martens, 2007), scholars have found consensus that sustainability equals the integration or balancing of environmental, social and economic issues (Sutton, 2004). As a result, the most common and general accepted method to operationalize sustainability is according the triangular concept with the three pillars "economy," "environment," and "society" (see e.g. Bond & Morrison-Saunders, 2009; Drexhage & Murphy, 2012; Gibson, 2006; Kelly, 1998; Kemp & Martens, 2007).

This is also where business model interlock with the problem of sustainable DHNs: in order for DHNs to increase their share of renewable energy sources, reduce CO2 emissions and be able to compete with fossil fuel alternatives, DHNs have to be cost efficient (1), environmental friendly (2) and accepted by the region they serve (3). Currently, the sustainability of DHNs vary significantly as most DHNs are able to somehow satisfy one or two of the requirements mentioned above, very few DHNs in the Netherlands satisfy all of them. Therefore, one of the key barriers is designing business models in such a way that enables the DHC to capture economic value for itself through delivering social and environmental benefits for the region they serve (Bocken et al., 2014; Schaltegger et al., 2011). Beside this, DHCs depend on various stakeholders for the development of DHNs, which means that the business models have to create win-win business situations to gain the cooperation of these stakeholders. Business model innovation offers a potential approach to enable the development of DHNs through re-conceptualising the value creating logic, and rethinking perceptions of value for DHNs (Bocken et al., 2014).

2.4 Conclusion

The purpose of this chapter was to carry out a literature review to form the theoretical framework for this thesis and describe the relevance of business models to the development of sustainable district heating networks in the Netherlands. To sum up, the business model concept presents a unique and practical tool to identify, analyse and improve business practices. The main function of the business model is to display what a firm's strategy is and how to execute this strategy. Business models can be especially useful in situation where the value creating logic is not straightforward, such as sustainable DHNs in the Netherlands. The development of sustainable DHNs are often characterized with complex settings such as a wide range of stakeholder interest, conflicting objectives and unfavorable institutional arrangements. Uncovering the right mix of value creating mechanism is therefore one of the challenging tasks for DHCs. In this light, the business model concept offers a promising perspective to conceptualise the value creating logic in order to overcome the barriers of sustainable DHNs.

Based on a literature review on secondary sources the following definition of business model was established: ***A business model describes the way that organizations create, deliver and captures value, resulting from strategic choices relating to their value proposition, value network, financial structure and technological architecture***. Furthermore, the V4 framework was introduced to study the business models of DHNs. This framework consisting of four dimensions of the business model concept: value proposition, value finance, value architecture and value network. The next chapter applies this framework to identify and categorize the business models currently used to develop DHNs in the Netherlands.

3. Research strategy

This chapter describes the Research strategy, starting with the overall research strategy in Section 3.1. Then, Sections 3.2, 3.3, and 3.4 elaborates on the research method for each sub question.

3.1 Overall research strategy

The overall research strategy is shown in Figure 3. The first stage consisted of the research design in which the research problem was discussed. Based on this problem a realistic and worthwhile research goal was formulated. The first stage also contains a literature review to elaborate on the elements of the research goal, define the scope of the research and to form a theoretical framework to study the business models of DHNs. Based on the research goal and the findings of the literature review a research strategy was developed and will be discussed in this chapter. The second stage consisted of a desk study to establish an overview of the current DHNs in the Netherlands and their business model configurations. Furthermore, the barriers found in the (grey) literature with the current business models of DHNs are also discussed in the second stage. The third stage consisted of multiple case study of four cases with in-depth interviews with experts and stakeholders of DHNs within these cases. The goal of these interviews was to develop an deeper understanding of the barriers, pitfalls and discrepancies of the business models to establish sustainable DHNs and subsequently find an answer to sub question 2. The last stage of the research addresses sub question 3, which is to develop guiding principles to help succeed business models of DHNs.

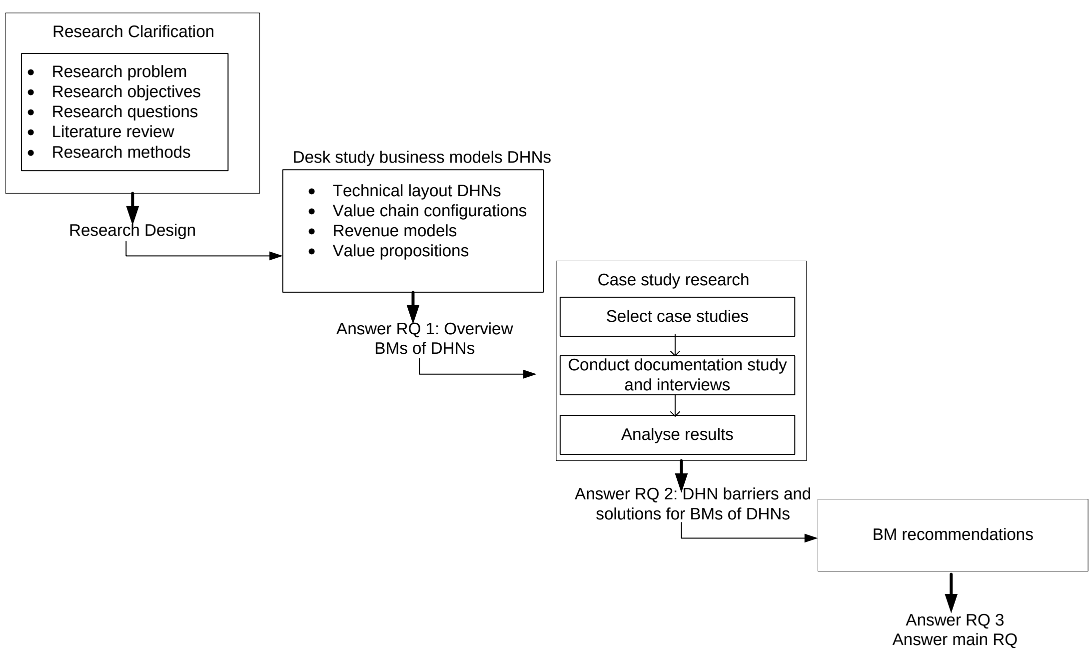

Figure 3: Research Strategy

3.2 Research method sub questions 1: Desk study

The first sub question, 'What business model configurations do district heating companies currently use to develop district heating networks in the Netherlands?' is addressed through a desk study. The first task of the desk study was to compile an overview of all district heating networks in the Netherlands. Then, the next step was to categorize the DHNs based on the business model dimensions (i.e. value proposition, network, technology and financial structure). For each dimension of the business model the various alternatives that occur in the Netherlands are clarified. For instance, within the technology dimensions all the energy sources and conversion technologies employed in the Netherlands are described. Then, the business model configuration consists of the combination of the business model dimensions that were found in practice. Furthermore, barriers for DHN development that were found in the literature are also described for the business model components.

3.3 Research method sub questions 2: Multiple case study review

The second sub question, 'What are the barriers that district heating networks currently face and what solutions do district heating companies provide?' is addressed by a multiple case study review. The purpose of the second sub question is to determine the barriers, pitfalls and discrepancies within the current business models of DHNs and the solutions that stakeholders of DHNs provide to these issues. A fruitful source of information to answer this question are the many DHCs in the Netherlands who have already gone through the process of developing a DHN. These DHCs and their stakeholders have accumulated a great deal of insight and experience into the barriers, success factors and pitfalls of establishing a DHN over the years. To tap into this source of knowledge, the researcher reviewed four cases of DHNs in the Netherlands and performed interviews with employees of DHCs and various stakeholders of DHNs in the Netherlands to determine what the barriers are of the current business models and what the potential solutions might be.

3.3.1 Case study selection

The case studies consist of a documentation study and semi structured interviews. The first step for the interviews is to select a sample size. Unlike quantitative research, there are no strict rules for sample size in qualitative research (King, 2004; M. Patton, 1990). In deciding how many participants to recruit, the amount of time and resource available is a critical factor (King, 2004). Beside this, the validity and insight generated from qualitative inquiry have more to do with information richness of the cases selected and the observational capabilities of the researcher than with sample size (Patton, 1990). Therefore, four cases were purposively selected based upon three criteria in order to provide a structural representation that matches the purpose of the study:

- The DHN needs to be developed in the past 15 years or have undergo major redevelopments in the last 15 years, because we are interested on how to develop DHNs in current times and DHNs developed in the past might not be relevant for new DHN development.
- The DHNs are being developed from a clear ambition to develop a cleaner heating alternative for the public. DHNs that still run on gas or coals with a combined heat and power (CHP)[1] installations from the 1980s or gas-fired boilers are excluded from the selection.
- As explained in Section 1.3. This study will focus on DHNs that operate on a city wide level aiming to deliver heat to as many buildings as possible. This excludes block heating or DHNs limited to exclusively industrial (single user restricted) networks (e.g. steam trading).

Another important criterium is the availability of data. The researcher had to examine the financial, technical and process reports of the participants, which they produced in the process of realizing a DHN. It was essential for the study that the DHCs for this study were willing to provide this information. Subsequently, semi-structured interviews were conducted with the participants of the case study to establish what their reasoning was behind certain decisions and what they experienced as barriers during the process.

From the stakeholder group of all the four cases one representative was approached for an interview. There were 18 interviews performed over the four cases (see Appendix B for a list of the interviewees).

3.3.2 Data collection case studies: Documentation study and interviews

The second step was to collect data by reviewing documents on the cases and conducting interviews with the stakeholders. Although, in general quantitative data is preferred in academic research, the data from the documents and interviews are of a qualitative nature (in the form of words). The main reason for this is the explorative character of this study to determine what the important variables are to set up a DHN in the Netherlands. Quantitative analyses on the other hand requires the researcher to determine the variables of the study beforehand. Therefore, the nature and availability of the information needed to answer the research questions correspond better with the qualitative approach of interviewing.

Furthermore, interviews provide an effective and efficient way to approach DHNs from the inside and to reconstruct the rules of practice or when a fresh perspective on a subject is sought (Stern, 1980). This applies to business models of DHNs, since academic literature has not yet provided a comprehensive research on the business models of DHNs. Furthermore, business model theory provides a fresh perspective to approach the problems that DHNs currently face in the Netherlands

[1] See Appendix A for more about CHP technologies.

(see Section 1.3). Eventually, the answer to this question will form the basis for the recommendation for the business models of sustainable DHNs. The remainder of this section describes the process of the interviews, including the measures the researcher took during the stages of the research to ensure the validity and reliability of the inquiry.

Overall, the data for the cases were gathered through the following sources:

- Interviews with stakeholders of the DHN.
- Municipality records on council meetings, proposals and decisions about the DHN.
- Newspapers and news websites. Local and national newspaper clippings were gathered via Lexus Nexus and Blendle.com. News websites were searched via google.

Besides interviews and news reports, company documentation were also studied to gather information on the cases. Company documentation can have valuable information to answer the research question, however, the validity and reliability of public company documentation must be questioned more than other sources, since it has been collected and processed for the purpose of legitimating a company (King, 2004). Confidential company reports and minutes usually correspond better with reality, however, companies are less willing to share this information with outsiders. The problems of company documentation are best overcome by qualitative interviewing (King, 2004). This does not mean that company documents were not analyzed, however, the analysis of documentary materials had a supplementary role of providing background information about an organization.

To perform the interviews, an interview guide was used, listing topics and questions, which the interviewer should attempt to cover in the course of the interview, and suggesting probes, which may be used to follow-up responses and elicit greater detail from participants (see Appendix C). The main sources for topics to include in the interview guide were based on the findings of the literature study and the desk study on the business model configuration in the Netherlands.

As opposed to selecting the interviewees across all DHNs randomly, concentrating the interviews on four DHNs enabled the researcher to verify the information from an interviewee with other stakeholders in the same DHN (i.e. data triangulation). Data triangulation involves using different sources of information to increase the validity of a study. To achieve this, different stakeholders from the 'supply chain' of DHNs (i.e energy suppliers, energy distributors and energy users) were interviewed. Furthermore, experts and stakeholders from different business model configuration were selected for the interviews. Additionally, the preliminary results after each interview are verified through an additional review of scientific, as well as, 'grey' literature (e.g. professional journals, roadmaps, and policy papers). The findings of these additional reviews were in some cases used to steer the following interviews.

The data of the interviews was collected with a digital recorder. Beside this, the researcher took notes during the interviews to facilitate the analysis of the data and serve as a backup in the event that a recorder malfunctioned.

3.3.3 Data analysis

Data analysis of the documents and interviews requires the researcher to reduce the volume of raw information, sifting trivia from significance, identifying significant patterns, and constructing a framework for communicating the essence of what the data reveal (Patton, 2002). In qualitative research, there is no clear distinction between data analysis and collection. Ideas for making sense of the data that emerge while still in the field constitute the beginning of analysis (Patton, 2002). This means that data analysis starts by making field notes and tracking analytical insight during data collection. The data analysis consisted of a within case analysis and a cross case analysis. Both are discussed in the subsections below.

Within case analysis

The interviewees were asked about barriers within the business model of their own case, but also about barriers on DHN development in general. The within case analysis focuses on the barriers and solutions provided to these barriers typical for the case. In the cross case analysis all factors that were mentioned by the interviewees were compared. The data of the within case analysis is presented in the following way:

- A brief history of DHN development
- The business models components of the DHNs
- The barriers experienced of the stakeholders during the development of the DHN
- The (potential) solution provided to the barriers during the development of the DHN

Since it is a qualitative study, it is difficult to measure the significance of the barriers and provided solutions. However, to provide meaningful results and safeguard against biases two criteria were used:

- Multiple interviewees within the case mentioned this factor as a barrier.
- The interviewee presents a valid and logical argument as to why the interviewee thinks this was a barrier for the case.

A third factor that helps the significance, is when the barriers and provided solutions mentioned by the interviewee, is also covered by media outlets (e.g. newspapers, websites, TV) or discussed in documents (e.g. council decisions, yearly reports). With most barriers and provided solution this was the case.

Cross case analysis

In the cross case analysis the data from the case studies were compared with each other through a coding process. These codes serve as a way to label, compile and organize your data. They also allow the researcher to summarize and synthesize what is happening in the data. In linking data collection and interpreting the data, coding becomes the basis for developing the analysis. The researcher formulated a pre-set list of codes before beginning data collection and the coding process. These initial codes are derived from the literature study and research questions. Based on the findings during the interviews, the coding scheme was refined, meaning, that coding categories were added, collapsed, expanded and revised.

After the coding process, a content analysis was performed to reduce the volume of data and to identify core consistencies and substantive meaning in the data. Uncovering substantive significance depends mainly on the judgment and quality of the researcher, since qualitative analyses does not have statistical tests to address the significance of the findings. Therefore, the researcher has to present an argument for substantive significance in presenting findings and conclusions.

3.4 Research method sub question 3: Business model syntheses

Through a content analysis of the interview data and an additional cross-checking with the literature, a list of barriers and provided solution to these barriers is compiled. These findings were used to assess the third sub question: How can district heating companies configure their business model to overcome the barriers to district heating network development? A large part of the findings for this question were addressed by the previous sub questions as the identified key success factors and barriers indicate where the focus of new business models of DHNs should lie (and were not). The purpose of this question is to translate these findings to a set of general guiding principles to configure the four dimension of the business model.

4. Business models of DHNs in the Netherlands

The literature review in Chapter 2 resulted in a theoretical framework to study the business models of DHNs. The purpose of this chapter is to utilize this framework in order to explore the following research question:

> What business model configurations do district heating companies currently use to develop district heating networks in the Netherlands?

To answer this question, each of the business model components for DHNs in the Netherlands are discussed in this chapter. However, to understand the development of DHNs better, this chapter starts with a discussion on the history and institutional context of DHNs in the Netherlands. Then, each of business model components are discussed in the following order: value proposition in Section 4.2, the value architecture in Section 4.3, the value network in Section 4.4 and the value finance in Section 4.5. Finally, the chapter ends in Section 4.6 with a conclusion.

4.1 History and institutional context of DHNs in the Netherlands

DHNs are not a new phenomenon in the Netherlands. The first DHN was built in 1923 in Utrecht. After the first DHN, there was for a long time little interest in DHNs in the Netherlands until a peak occurred during the '70s and early '80s (Fruyt van Hertog, 1982). The development of DHN during these periods was a direct response to the oil crisis's of the seventies in which fuel saving became a priority for the Dutch government (Doggenaar, 2015; Hylkema, 2008). DHN development in the form of combined heat and power (CHP) installations were deployed in various city across the Netherlands during this time (See Appendix D for an overview of large DHNs in the Netherlands).

With fuel prices stabilizing in the '80 and '90 interest in DHNs dwindled down. However, in the meantime concerns about global warming and greenhouse emissions came to the forefront of the global and national political agenda. Eventually this resulted in the Kyoto protocol in 1997, an international agreement between 192 participating nations to reduce greenhouse gasses that linked the United Nations Framework Convention on Climate Change, with internationally binding reduction targets on greenhouse gasses. For the Netherlands, the reduction target was to reduce CO2 emission by 6% compared to the CO_2 levels in 1990.

In order to reach the objectives of the Kyoto protocol, the Netherlands set up their plans in the fourth national environmental policy plan (National Milieubeleidsplan 4). Although earlier environmental policies plans included objectives to reduce CO2 emissions, NMP 4 was the first to lay down an important role for provinces and municipalities to reduce CO2 emissions (VROM, 2001).

As a result, a climate covenant was developed with municipalities in 2001 and budget was set aside to develop CO_2 reduction policies on a local level. During this time interest in DHNs was revitalized. As municipalities started to develop strategies to cut down CO_2 emissions, they found that DHNs were often more cost efficient to reduce CO_2 (euro/kg co2 reduction) compared to other alternatives (e.g. wind energy, photovoltaic). Although on paper they seemed a sound investment, many municipalities found that it was not easy to develop DHNs, which will be discussed in more detail with the case studies in Chapter 6.

4.2 Value proposition

The first component is the value proposition. The value proposition consists of the services/products to be offered, the targeted audience, and the value elements to be communicated to the defined target audience. Each of these elements are discussed in this section for DHNs in the Netherlands.

Product

The offering of DHC is straightforward: heat for the purpose of heating buildings and hot water needs. Beside heating, it is also possible to use DHNs for cooling buildings. However, due to the mild climate in the Netherlands the market for cooling is almost negligible compared to heating. Figure 4 shows the complete heat market in the Netherlands. 88% of the heat is generated on location, which is done mostly with individual gas fired boilers at dwellings, and industrial and commercial buildings. 12% of the heat is transported from the heat supplier with a network of pipes to the customer. More than three quarters of the transported heat consists of industrial DH. These are usually industrial companies transporting steam between each other.

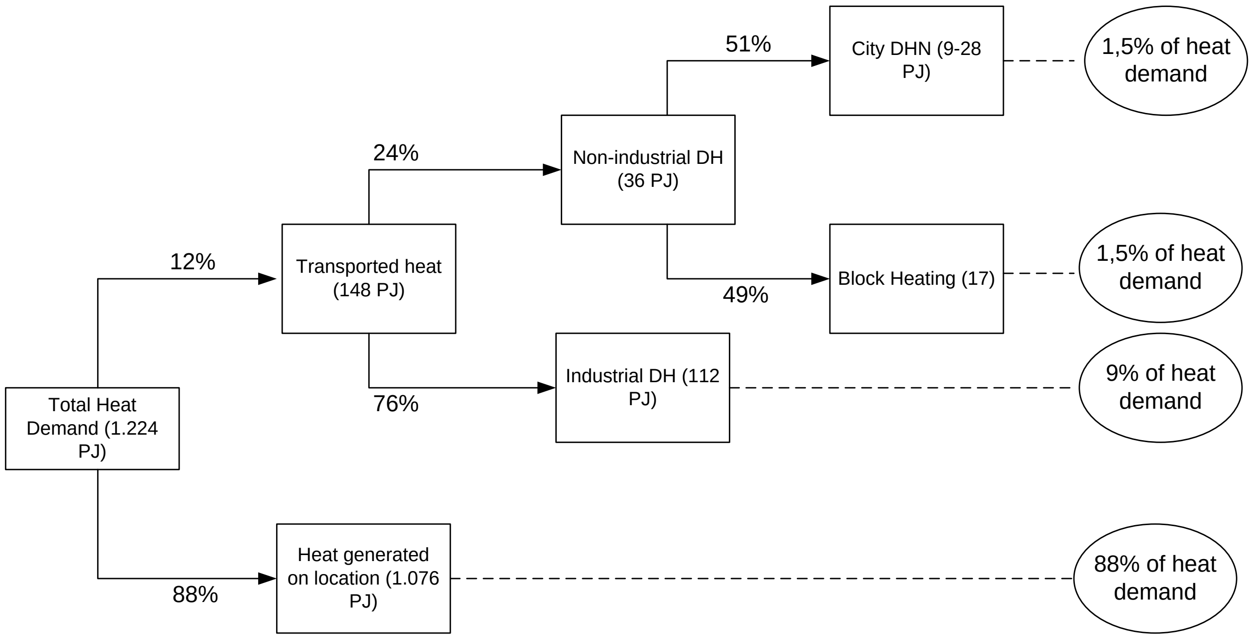

Figure 4: Overview of Dutch heat market (CBS, 2015; Haffner, Til, Jong, Mans, & Graaf, 2016). *There are some inconsistencies in the reported data about City DHNs due to different definitions and gathering methods (the bandwidth of the reported data is shown).*

Of the non-industrial DH, almost half consists of block heating. Block heating refers to heat generated via a central installation in a building or apartment building block (e.g. collective boiler) and delivered to the individual residential units through a network of pipes. The other half consists of city DHNs, which are the focus of this thesis. These DHNs amount to approximately 1,5 % of the total heat demand. In 2015 there were 762.569 connections to small scale user[2], which is around 7% of the total Dutch households (ACM, 2016). Data on the number of connections for large-scale users is not reported.

Target audience

The customers of DHNs are commercial building owners, housing companies, project developers, renters/home owners. For residential buildings, the DHN operator signs contracts with the housing companies or project developers to deliver heat to the dwellings, not the actual resident. These residents are restricted to the DHN for their heating purposes. However, the residents receive the heat and pay the bill directly to the DHN operator, therefore they are also the client. Table 2 shows the different type of customers of city DHNs as reported by the national department of statistics.

[2] According to the Dutch heat act a customer is considered small scale when the heat capacity <100kw. Heat suppliers have to report the number of connections to small scale users to the Autoriteit Consument &Markt (ACM).

Table 2: Customers of city DHNs in 2013 (CBS, 2015)

Customer type	Heat demand in PJ
Households	14
Commercial buildings (offices, hospitals etc.)	5
Greenhouses	4
Waste and water treatment plant	<1
Industrial	<1
Distribution losses	3,5
Total	28

Currently, 3% of the total building stock is connected to a DHN. CE Delft (2014) estimates that considering the heat plans of the cities in the Netherlands the total market potential for DHN can reach 18% in 2050. Based on their analysis there is a large market potential for DHNs to grow in the Netherlands.

Value element

As discussed earlier, individual gas boilers dominate the heating market in the Netherlands. Therefore, the value of DH is often communicated as a comparison with individual gas boilers. A scan of the websites of the three large DHN operators (Nuon, Eneco and Ennatuurlijk) show that they all communicate the same three benefits towards their consumers (Eneco, 2015; Ennatuurlijk, 2014; NUON, 2015):

1. Sustainable heating and the carbon savings they can deliver compared to conventional heating alternatives.
2. Convenience. The DHN is responsible for maintenance of the DHN and the customer does not have to worry about the heat delivery to their dwellings.
3. Comfort. The heat and warm water is instantly available at any time without any preheating time.

Other benefits often mentioned are the safety and the price. DHNs are safer compared to individual gas boilers, since there are no gas pipes in the dwellings. As for the price, the Dutch Heat Act (in Dutch: Warmtewet) regulates that the price of district heating cannot be higher than heating with an individual gas boiler, which DHN operators often emphasize. However, there is much controversy about this law, as many customers still believe that they pay more for DH compared to individual gas boilers. This topic will be further discussed in Section 5.1.

4.3 Value Architecture

The value architecture consists of a description of the lay out of DHN and the possible heating technologies. For DHN the technological architecture consists of three main subsystems: heat production, thermal distribution, and end users (consumers).

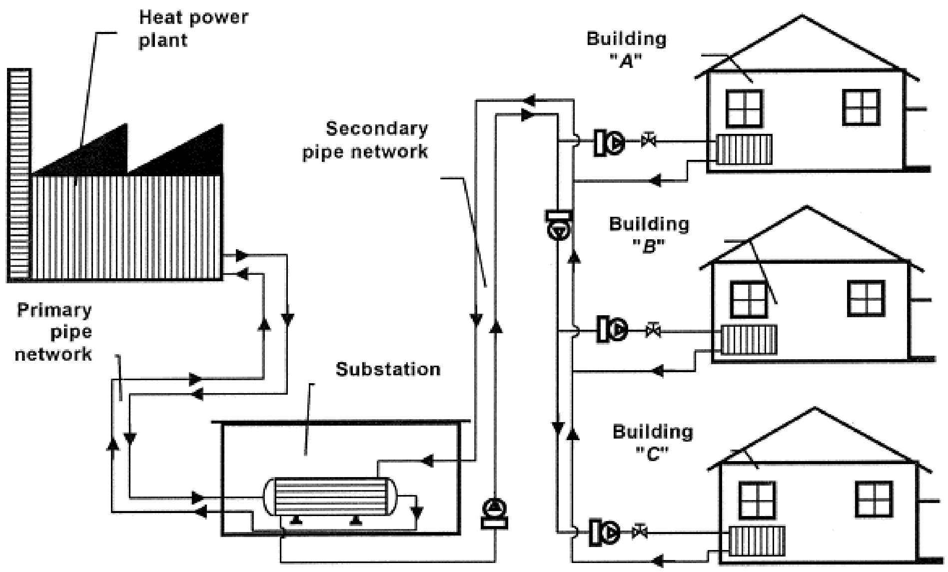

Figure 5: Schematic representation of a DHN

These three subsystems deliver heat to the clients in the following way (see also Figure 5):

- The process starts by an industrial plant producing the district thermal energy requirement by converting the energy content of fuel, electricity, or other primary sources of energy into heat.
- Then, a distribution system consisting of a network of insulated pipes transport the heat in the form of steam or hot or chilled water to several substations located near the end users, this is called the primary network.
- From the substation, a secondary network with smaller dimensions delivers the heat to several residential and commercial buildings. The substation also contain a back-up installation for peak demand.
- A heat exchanger in the buildings is used to convert the thermal energy that the system provides into heating for the end user, replacing the conventional equipment such as fired or electrical furnaces.
- A separate pipe returns water with most of the energy removed to the production plant for reprocessing.

Although DHNs can run directly on boilers using fossil fuels as the primary energy source (most commonly natural gas), the fundamental idea of district heating is recycling of heat that otherwise would be wasted (Persson & Werner, 2011). Common local energy resources to accomplish this are useful waste heat from thermal power stations (cogeneration); heat obtained from waste incineration; useful waste heat from industrial processes; natural geothermal heat sources; and biomass fuels, such as wood waste, peat, straw, or olive stones (Werner, 2004). A complete overview of the energy supply side, including the energy sources, conversion technologies, and the energy products delivered to the distribution system of the DHN are shown in Figure 6.

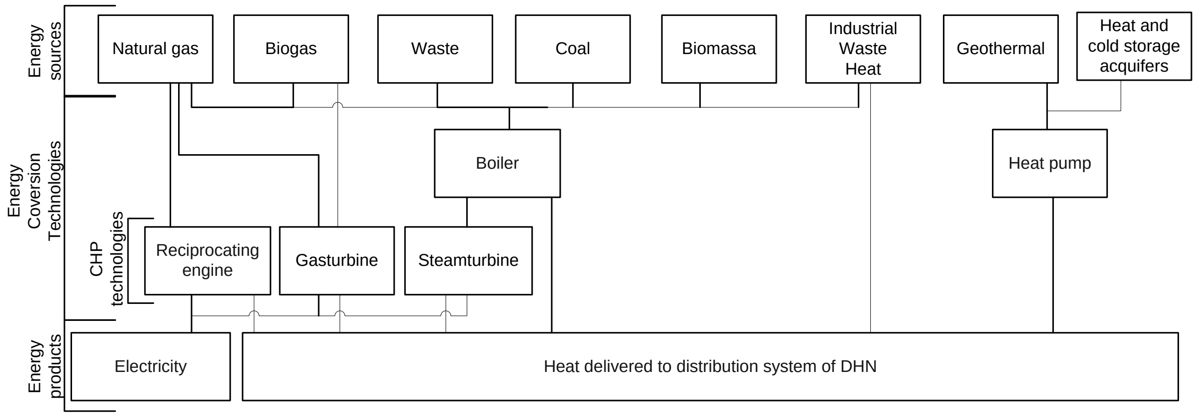

Figure 6: Overview of the energy supply to the distribution system of DHNs

A description of each energy conversion technology shown in Figure 6 is provided in Appendix A. In addition, Figure 7 shows the energy technologies adopted by city wide DHNs.

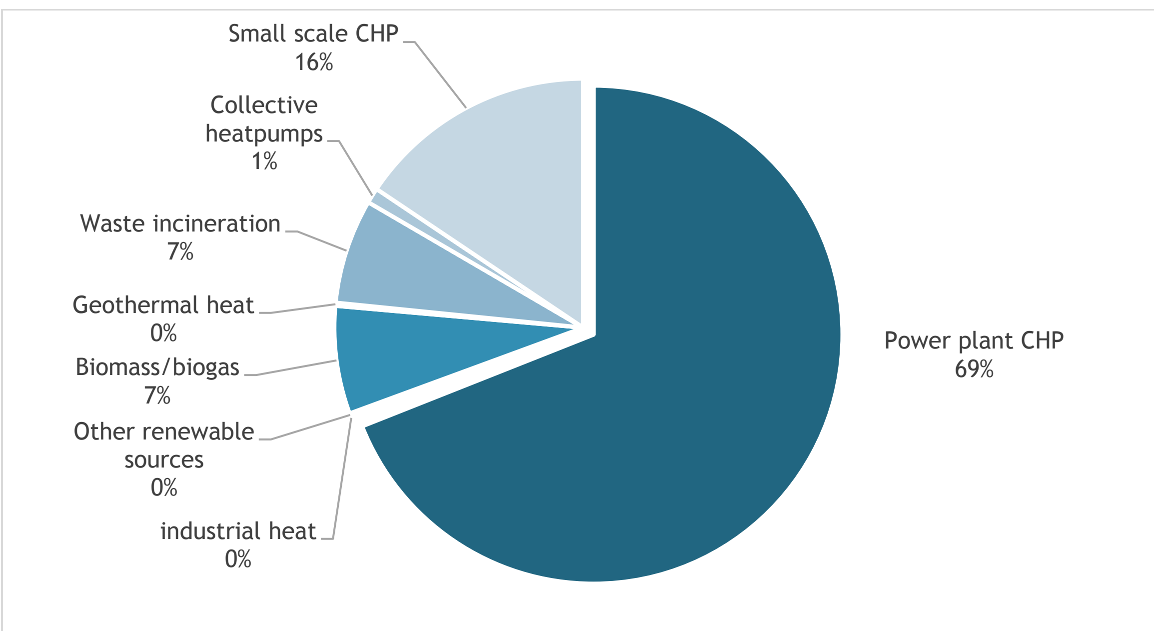

Figure 7: Energy sources for city DHNs (Niessink & Rösler, 2015)

Power plant CHPs have the largest market share in the Netherlands for city wide DHNs. Most of the power plant DHNs were established within "the first wave" of DHNs back in the '70s and early '80s (e.g. Amsterdam, Almere, Purmerend, Enshede). During this "second wave" of DHNs in this century the attention has been more on waste incineration plants and biomass boilers (e.g. new DHNs in Nijmegen, Lelystad, Ede), but also small scale CHPs on neighbourhood level. Furthermore, more waste incineration plants and biomass boilers are starting to replace old CHP plants (e.g Rotterdam, Enschede, Purmerend).

4.4 Value network

An example of the value chain of a DHN is shown in Figure 8. These stakeholders are typically present in every DHN, although the configuration might differ from Figure 8. Each following subsection will discuss these stakeholder roles of DHNs.

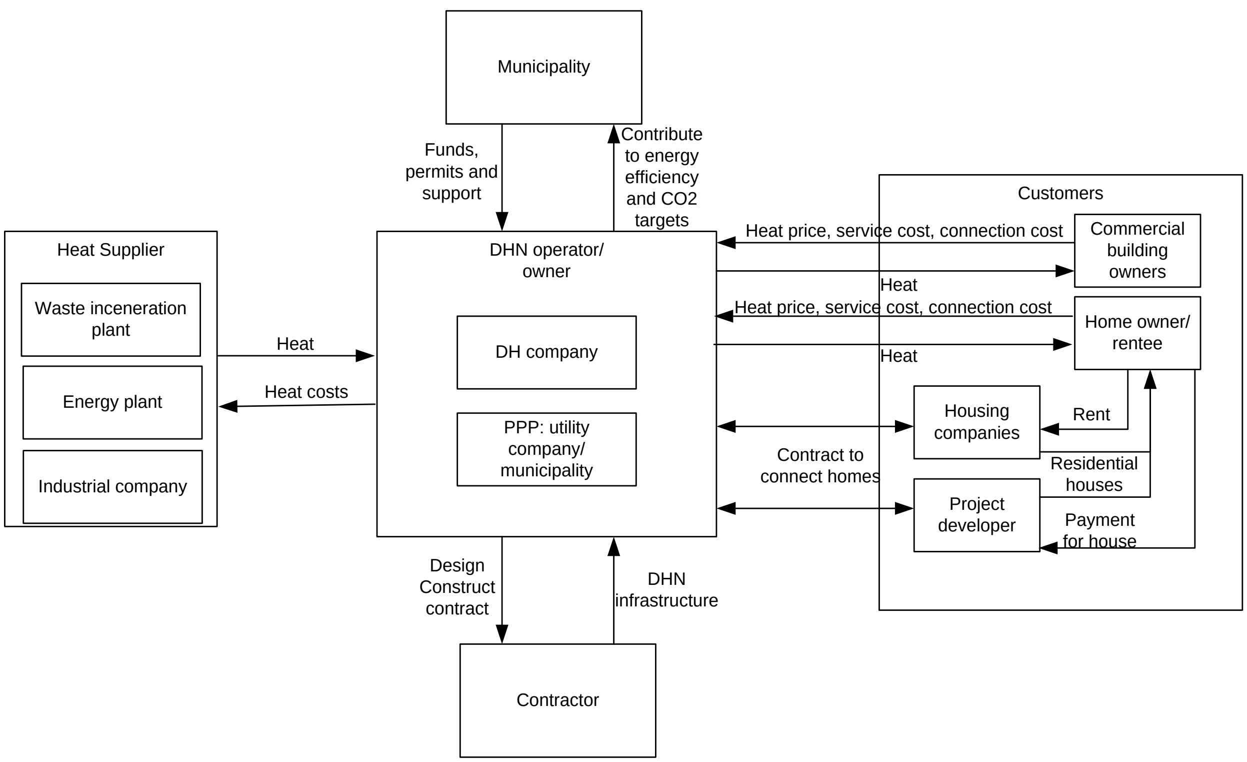

Figure 8: Typical stakeholder roles and interdependencies of a DHN

4.4.1 Heat suppliers

The most common heat suppliers for DHNs in the Netherlands are owners of energy plants (i.e. CHP installation or large scale boilers), waste incinerations or industrial companies (CE Delft, 2009).

For energy plants, producing and selling heat and/or electricity is their core business. Therefore, their main interest to connect to a district heating network is based on a financial analysis. This does not mean that other considerations do not play a role in the decision to connect to a DHN, however, for energy companies, economic feasibility is a fundamental prerequisite (Bardouille & Koubsky, 2000). The economic feasibility for energy plants largely depends on reaching at least a minimum market volume (Enzensberger, Wietschel, & Rentz, 2002). In other words, the heat demand that the energy plant can serve must be high enough to justify the investment in the infrastructure.

4.4.2 Municipality

In the 70s and 80s, DHN were operated by energy plants who had a surplus of heat after electricity production. Nowadays, municipalities have gained a more central role with the development of sustainable DHNs (Tachet, 2009). The main interest of these municipalities is to accomplish energy efficiency and CO_2 reductions with renewable and efficient energy technologies, such as a DHN. Additionally, more and more municipalities are willing to bridge the financial gap, since the profitability of DHNs are low in the Netherlands due to the high infrastructure cost and highly competitive gas network (Bre, 2013; Ligtvoet, 2012).

4.4.3 DHN operator and owner

The DHN operator is responsible for a reliable delivery of heat to the customer. In many DHNs in the Netherlands, the owner of the energy plant (i.e. the heat supplier) is also the operator and owner of the network (Niessink & Rösler, 2015). Furthermore, the operator of a DHN has a natural monopoly for the delivery of heat in the region they operate. Consequently, the interest of the operator is much aligned with that of the heat supplier, which is to have an attractive system to exploit and a large customer base to ensure the overall profitability of the DHN.

Despite this predominantly financial focus, the DHN operator (and heat supplier) are often willing to make concessions towards the other parties of the DHN and lower their required rate of return in order to strengthen relationships, promote goodwill, be involved, learn from others, and show a green face (Ligtvoet, 2012).

Table 3 shows an overview of the DHNs operators for small scale customers. The energy companies, Eneco, Nuon and Ennatuurlijk have the largest market share of DHNs. There are also many homeowner associations that control their own block heating installations. Furthermore, housing cooperations also have a large market share through block heating and neighborhood level DHNs.

Table 3: DHN operators of the Netherlands for small scale customer (Haffner et al., 2016)

DHN operators	# DHNs	# of connections	% of total
City DHN operators			
Eneco	85	113.436	15%
Nuon	34	107.662	14%
Ennatuurlijk	49	62.653	8%
SV Purmerend	1	24.850	3%
HVC	5	5.467	1%
Other operators	131	15.172	2%
Subtotal	305	329.240	43%
Other DHN operators			
Home owner associations (VvE)	5.575	212.000	28%
Housing coorperation	3.555	183.672	24%
Other distributors	720	32.634	4%
Unknown	166	5	1%
Subtotal	10.016	433.329	57%
Total	10.321	762.569	100%

4.4.4 Customers of DHNs

The customers of DHNs are commercial building owners, housing companies, project developers, renters/home owners. For residential buildings, the DHN operator signs contracts with the housing companies or project developers to deliver heat to the dwellings, not the actual resident. These residents are restricted to the DHN for their heating purposes. This means that acquisition of customers happens through the housing companies and/or project developers, not the actual consumer. This is because DHNs can only operate cost efficiently when there is enough heat demand to recover the cost for the DHN infrastructure. Laying down costly infrastructure for one house at the time is not a cost-effective option for DHNs. This means that to acquire residential homes for the network, DHCs must convince housing companies and/or project developers to connect their (new to build) properties with the DHN.

4.5 Value finance

The value finance consists of the pricing method, total cost of ownership and revenue structure. Each of these elements are discussed in the section below.

4.5.1 Pricing method

The pricing method for DHNs depends whether the consumer is a large-scale consumer (heat capacity connection >100 kW) or small-scale consumer (heat capacity connection < 100 kw). The prices for small-scale consumer of DHNs in the Netherlands are regulated through the Dutch Heat

Act with the so called “no more than otherwise” principle (in Dutch: niet meer dan anders principe). This principle was created to set maximum prices that DHN operators can charge their customers in order to protect the customers from the monopolistic position of the DHN operator (Consuwijzer, 2015). The maximum heat price is based on all costs that users would have incurred if they had had a natural-gas connection and consumed the same amount of heat (ACM, 2013). The Netherlands Authority for Consumers and Markets (ACM) is responsible for setting the maximum prices each year. The maximum price consists of three parts and for 2015 the ACM has set the following prices (ACM, 2013):

1. The maximum price for supplying heat. This tariff is composed of a fixed amount of EUR 254 with a variable tariff of EUR 24.03 per gigajoule. This maximum tariff is set for the entire year and cannot be changed during the year.
2. The tariff for metering. This tariff has been set at EUR 24.54 for 2015.
3. The connection tariff. For 2015, this tariff has been set at EUR 911.78 for all new connections up to 25 meters from an existing heat network. For connections further than 25 meters, an additional tariff of EUR 31.31 per meter is added.

Besides these price components, the total price also contains a fourth component, which is not included in the maximum tariffs set by ACM: rent for a heat delivery set. The ACM prescribes the DHN operators that this price should be “reasonable” based on the cost incurred. Since the DHNs are a natural monopoly, all DHNs operators choose the maximum price as their price point for all three components listed above (Savelkouls, 2016).

In case of large scale customers (heat capacity connection >100 kw) there are no restrictions for district heating prices. The reasoning behind this is that large scale consumers have sufficient bargaining power to negotiate a fair deal on their own due to their high heat demand (which makes them a strategically favourable customer for DHN operators to acquire) and more possibilities to find other heating alternatives.

4.5.2 Total cost of ownership and revenue structure

To illustrate the total cost of ownership and revenue structure, Table 4 shows an actual business case for a DHN in the Netherlands.[3]

[3] Due to reasons of confidentiality, the exact details about the project are not enclosed.

Table 4: Business case of an existing DHN project in the Netherlands

	Initial investment		€ 18.189.034,00	
	Re-investments		€ 10.310.529,00	
	Exploitation			
	Energy purchases	€ 24.619.652,00		
	Maintenance, monitoring, billing, staff etc.	€ 26.667.183,00		
	Total exploitation		€ 51.286.835,00	
	Interest payment		€ 555.144,00	
	Loan payments		€ 2.960.769,00	
	Taxes		€ 3.753.860,00	
Total Cash Outflow				€ 87.056.171,00
	One time connection cost		€ 3.735.573,00	
	Heat sales		€ 70.755.193,00	
	Annual service charges		€ 19.263.971,00	
Total Cash inflow				€ 93.754.737,00
Net cash flow (inc. inflation of 2,5%, yearly gas price increase of 3,75%)				€ 6.698.566,00
NPV (1.5%)				€ 2.328.105,00
IRR				2,6%
Payback period				24,9 years

This overview shows that the total investments are almost 35% of all the cost and the return on the project is at 2,6%, which is very low for commercial standards. Furthermore, the payback period is 24,9 years, while there are many uncertainties regarding future revenues due to uncertain future gas prices and heating demand. Although with all business cases of infrastructure projects there is some degree of risk involved (especially in the construction phase), the gas price and heating demand are of particular importance for business cases of new DHN.

Future gas price

As discussed earlier, the maximum sale price of district heating in the Netherlands is determined by the gas price. Business cases of DHNs have relatively long time horizons. For example, the time horizon of the business cases in Table 3 is 30 years. To calculate the total revenues of a DHN project, assumptions on future gas price developments have to be made for the entire time horizon of the business case. However, future development on the gas price are highly uncertain and depends on many factors such as the oil price, energy policies, geopolitical relationships, new gas field discoveries and technological development to name a few. This means that a decrease in the gas price has a direct negative effect on the business case of a DHN and vice versa. For example, when the gas price only increases by 3% instead of the assumed 3,75%, the NPV drops down to -€802.00,00.

Heat demand

The other factor that determines the profitability is the estimated heat demand during the life span of the business case. In essence, the heat demand that the DHN serves must be large enough to cover the investment and exploitation cost. New DHN incorporate a certain rate of new building development in their business case (in Dutch this is referred to as the "volloopscenario"). This depends on uncertain factors such as the economic climate and willingness of commercial building owners to sign a contract with the DHN operator. For district heating projects, capital is typically invested prior to the connection of customer buildings; thus, the greatest risk in system deployment is load uncertainty (UNED, 2015).

4.6 Conclusion

The purpose of this chapter was to answer the following question: *What business model configurations do district heating companies currently use to develop district heating networks in the Netherlands?* Through a desk study on the DH market in the Netherlands an overview was provided of the important facts and figures of the business model components of DHNs (see Figure 9).

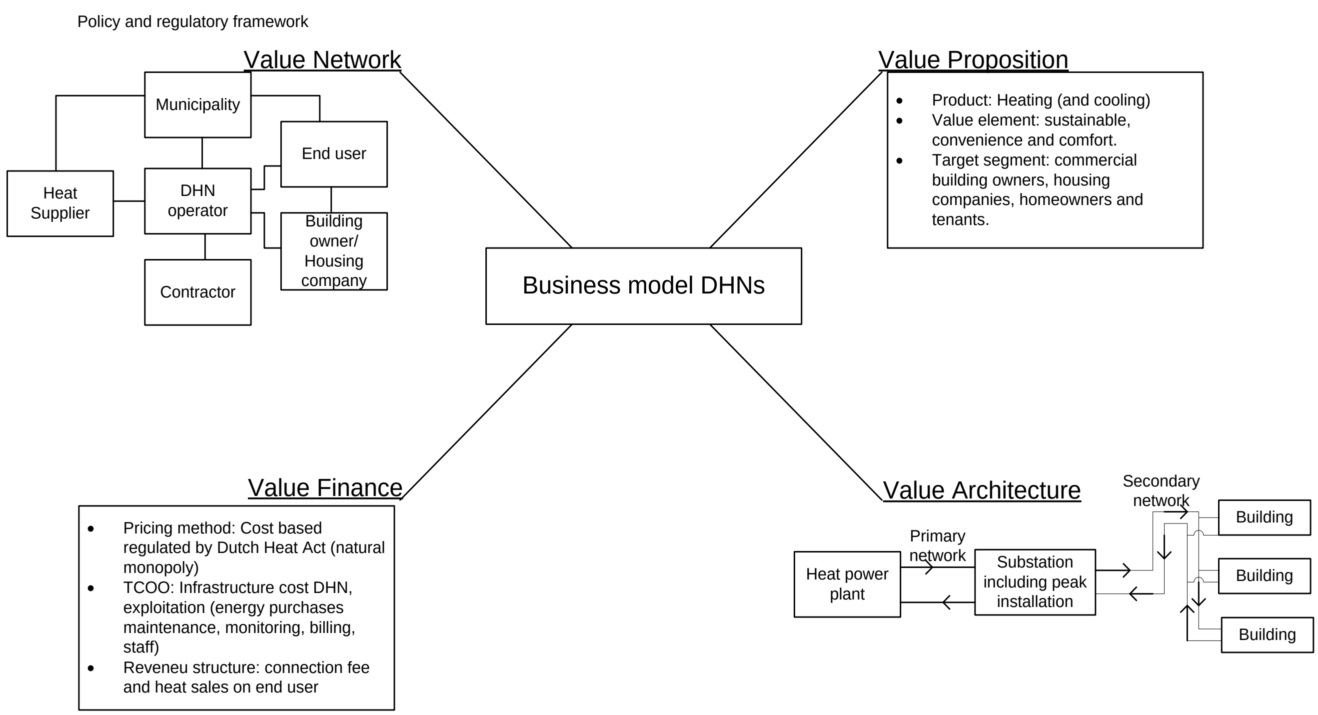

Figure 9: Basic components of a business model framework for a general DHNs in the Netherlands

First, the value proposition of DHNs showed that there was not much variety in the value element offerings. DHNs focus on sustainable, comfort and convenience as their value element. The reason for the lack of variety between DHNs is because DHNs do not have to compete with each other, they have a monopoly in the region serve. The value elements are set against individual heating technologies such as gas-fired boilers.

For the architecture, we saw that the power plant CHP technology, which were mostly built in the '70s and '80s, dominates the market in the Netherlands of city wide DHNs. More recently, the focus has been more on waste incineration and biomass technology. Going into the future the largest market for DHNs lies in the existing residential areas, but these areas are also the most technically challenging and expensive to connect.

For the value network, we saw that the key players in the DHN are the heat supplier, DHN operator, the customers and the municipality. Since the Netherlands have signed the Kyoto protocol, Municipality have gained a more central role in the DHN network in order to cut down CO_2 emissions, sometimes even taking over the role of DHN operators. As for the customer, dwellings are the most targeted customers with a total of 14 PJ, followed by commercial building owners (5 PJ).

The financial component of DHN business model seems the most limiting factor for DHN development. The prices for small-scale consumer of DHNs in the Netherlands are regulated through the Dutch Heat Act, which stipulates that the heat prices for customers cannot be higher compared to heating with a gas fired boiler. Furthermore, the business cases of DHN are overall characterized with high initial infrastructure investments and marginal rate of returns. Also, determining future revenues in the business case of DHNs is difficult due to uncertain gas prices and future heat demand.

5. Potential barriers for DHN development

The purpose of this chapter is to provide an overview of the barriers of DHN development that are discussed in the (grey) literature. The findings from the literature can be examined in contrast to the findings in the interviews within the case studies in the following chapter to identify any gaps or discrepancies with the literature. Furthermore, the findings from this chapter can serve as preparation for the interviews in the case studies to be able to ask in depth question when these barriers are mentioned in the interviews.

This list of challenges was comprised by searching articles on scholar.google.nl with the search words: district heating/warmtenetten/stadsverwarming/district heating barriers. Articles found through these searches were scanned for any mentioning of any barriers/problems/obstacles. When any barriers were found, additional searches were done on these barriers (for instance: district heating heat losses). During the search process, there were few scientific publications found on barriers for DHN development in the Netherlands. Since contextual factors play an important role in DHNs development, additionally publication in trade journals were searched through the database of Stichting Warmtenetwerk and additional information on the barriers were searched through google. The challenges that were found are organized along the business model components: value proposition (Section 5.1), value architecture (Section 5.2), value network (Section 5.3) and value finance (Section 5.4). Lastly, a conclusion is presented in Section 5.5.

5.1 Value proposition

Discrepancy between value offering and customer needs

For the value proposition, there seems to be a barrier due to a discrepancy between value offerings and customer needs. This discrepancy is twofold. First, it seems that there is a discrepancy between the value proposition of DHNs and the customer needs. DHN propositions primarily focuses on sustainability, comfort, and convenience (see Section 4.1), while energy costs are often the prime driver for decisions on heating alternatives. Studies of Roos & Manussen (2011), Bouw (2014) and Dóci & Vasileiadou, (2015), who all conducted surveys amongst tenants and homeowners confirm that costs aspects were considered more important than environmental, climate related or societal arguments. Tenants were prepared to contribute to energy savings, but this mostly concerns efficiency measures that also lead to cost savings (Bouw, 2014). Furthermore, there are multiple ongoing disputes between DHN operators and customer groups throughout various cities in the Netherlands (see e.g. Almere, The Hague, Tilburg, Leiden, Helmond). All these disputes illustrate a strong dissatisfaction about the offerings of DHNs. Despite the Heat Act, that is supposed to protect customers of DHNs from high prices, many customers of DHNs in the Netherlands still believe that they are paying more than they would in the situation with a gas connection. The was also found by studies of e.g. Huygen, Lavrijssen, Vos, & Wit (2011) and Janssen (2015).

The second discrepancy involves the decision to connect to a DHN. In the case of dwellings, the end user does not make the decision to connect to a DHN, but the connection to the DHN is "part of the deal" when the user buys or rents the dwelling. The developer or housing company, often in collaboration with the municipality, makes the decision to connect to the DHN. In some DH projects, even the developer or housing company has no choice in the matter, because the municipality obligates them to connect to the DHN through building regulations of their municipal (Israëls, 2013). This shows that the true driving force behind the demand for DHN are the municipalities. Keep in mind that interest for DHNs in the 21st century in the Netherlands was primarily initiated by (local) government institutions to reduce CO2 emissions (see also Section 4.1). This makes the value proposition towards the actual user less important, since they do not make the decision to connect. For a DHN operator, it is much more important to have a local government institution that is willing to invest in a DHN, since they are the ones that actually create the demand (Patil, Ajah, & Herder, 2006; Tachet, 2009). This means that a partnership between the DHN operator, the municipality and the developer/housing companies is key for DHN development and the relationship with the end user comes second.

5.2 Value architecture

There are many scientific publications on the technology of DHNs, the main concerns within these publications are the following: heat losses, DHN design, and connecting existing buildings stock.

Heat losses

A major issue of DHNs are the heat losses throughout the network that have to be compensated by additional heat generation (see e.g. Dalla Rosa, Li, & Svendsen, 2011; Rezaie & Rosen, 2012). Every GJ of heat lost in the network cannot be sold and has therefore a negative effect on the balance sheet. Heat losses depend on the driving temperature difference between medium and surrounding ground and surface area. An annual heat loss of 5% in district heating distribution is considered a good result, but in outdated and/or poorly maintained DHNs the heat losses can easily reach tens of percent's (Rämä & Sipilä, 2010). Minimization of the losses can most easily be achieved by reducing the network temperatures or improving insulation (Bargel et al., 2010).

Optimal "future proof" DHN design

For every engineer working on a DHN the goal is to design and operate an optimal network. To save cost, the DHN operator can design the pipe dimensions and select materials according the current demand of the DHN. Ideally, the DHN wants to have the ability to expand the DHN into other areas to generate more revenue, however, when and if opportunities to expand arise is often uncertain. Furthermore, the design has to anticipate lower energy requirements of new buildings and potentially retrofitted existing buildings (see e.g. Åberg & Henning, 2011; Dalla Rosa, Boulter, Church, & Svendsen, 2012). Lower heat demand of new dwellings require different technologies and lower design temperatures than traditional DHNs.

Balancing these different considerations makes it difficult to design an optimal network for the entire life extent of a DHN (Åberg, Widén, & Henning, 2012; Robineau, Fazlollahi, Fournier, Berthalon, & Verdier, 2014; Vesterlund & Toffolo, 2017). On the one hand, more money could be generated when future heat demand is anticipated and pipe dimension of the primary network and substation installation are designed accordingly. On the other hand, money can be saved when expected future developments fail to appear.

Connecting existing building stock

Another challenge concerning the value architecture is connecting existing building stock onto a DHN. The mutation (renewal) of the residential building stock is only a small share of the entire building stock (Niessink & Rösler, 2015). Heat demand in the existing housing stock is about 30 to 40 percent higher than in new housing and due to the energy efficiency policies of the EU, the heat demand of new buildings are getting even more lower in the future (Bouw, 2014). Therefore, there is large potential for heat networks in the existing built environment. As heat demand is larger in the existing housing stock, revenues are also higher. However, connecting existing building stock is more complex and often more expensive than new buildings. Construction of heat infrastructure in the existing city is associated with high installation costs due to obstacles and larger resource intensity of the installation (Bouw, 2014).

5.3 Value network

Fragmented value chain

The development of a sustainable DHN depends on the cooperation of many stakeholders. This may fit badly in a market context where every little link of the value chain is organised separately with an interface of costs and revenues to other links (Henning & Mardsjö, 2010). A fragmented value chain increases interface costs and total risk. Between the links of a fragmented supply value chain, many complicated agreements are required, which all include risks (see Figure 10). It means a larger total financing risk, which raises interest rates and shortens amortisation periods for loans. (Henning & Mardsjö, 2010).

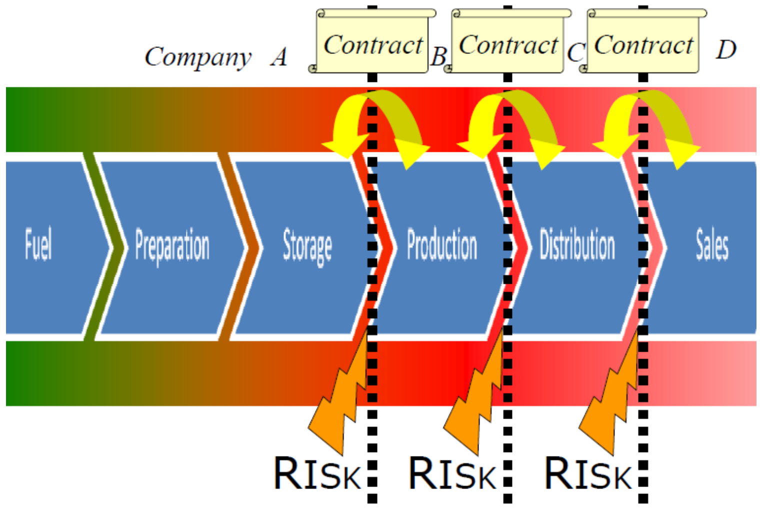

Figure 10: Fragmentation of the value chain (Henning & Mardsjö, 2010)

Monopolistic position of DHN operator is undesirable

A problem often mentioned in the literature is the monopolistic position of the DHN operators (see e.g. Akerboom, Linden, & Bommel, 2014; Spijker, 2015). Since the owner of the network is also responsible for heat delivery there is no room for competition. Especially in the Dutch heat market were customers are used to switching heating providers in the gas market, the monopolistic position of DHNs is perceived as a step back. In order to protect the customers of DHNs from the monopolistic position of DHN operators, the government established the Dutch Heat Act (see Section 4.5.1 for more about the Dutch heat act). However, whether the Dutch Heat Act is effective in doing so is questionable (see Section 5.1).

5.4 Revenue structure

Financing seems the largest barrier to district heating development. The Netherlands has the most extensively spread gas network second to none and the lowest prices for gas boilers in Europe, which makes it a challenging environment for the out roll of renewables in the heating sector (Delta Energy & Environment, 2014). Furthermore, district heating is an infrastructure industry with major reinvestments and long payback times (Rydén et al., 2013).

Unattractive business case

Sustainable DHNs are characterized by high capital cost, low return on investment, long payback times and many uncertainties about future demand and district heating prices: an overall unattractive business case. A typical cash flow curve for DHN projects is shown in Figure 9. Due to the large upfront investment, the cash flow for a typical DHN project is negative for a long time. Payback periods between 20 to 30 years are very common for city wide DHNs in the Netherlands. Figure 11 also shows that revenues are low in the beginning but increase as more buildings are connected to the DHN and the gas price increases. Nowadays, a gas price increase around 2 to 3 percent is factored in the business case (see e.g. EY TAS, 2016; Gemeente Den Haag, 2014), before 2012 business cases even incorporated a gas price increase of 4 of 5 percent. Furthermore, heat demand from new real estate development projects are also incorporated in the business case. Both the gas price and real estate development projects are uncertain factors. For instance, gas prices stagnated between 2012 and 2014 and the recent economic crisis in the Netherlands halted many real estate projects. Such developments have an immediate effect on the financial returns of a DHN, making it a risky investment for private companies.

Studies of Nma, (2010) and Oxera (2009) show that to cover the risks involved in DHN projects a reasonable return for private energy companies should be between 6-8%. Current DHN projects do not achieve such returns, at least not without the help of government grants and subsidies. Most schemes that have progressed during the last 10 years have benefited from some form of grant support (Haffner et al., 2016).

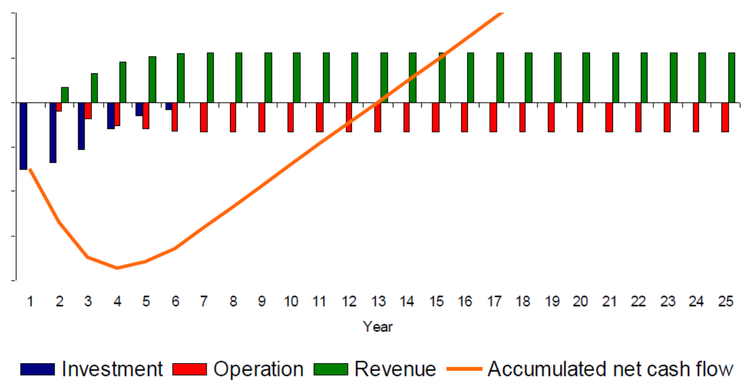

Figure 11: Example of a typical cash flow curve for a new DHN (Henning & Mardsjö, 2010)

Other benefits of DHNs are not valued in business case

From a purely business perspective, the interest in the development of DHNs in the Netherlands would not exist. The strength of DHNs lies in their potential to reduce CO2 emissions and decrease primary energy use significantly compared to individual gas fired boilers. However, these benefits of DHNs are not valued financially in the business case. This means that public involvement may be necessary for the deployment, modernisation and long-term development of district heating systems (Bernotat & Lübke, n.d.; Henning & Mardsjö, 2010).

Reduced heating demand through energy efficiency measures on building level reduces the revenue stream of DHNs.

Another challenge for DHNs is the future heat demand and the intended decrease of it through European and National policy measures. In 2002, The EU called the Energy Performance of Buildings Directive in to force. The principal objective of the Directive is to promote the improvement of the energy performance of buildings within the EU through cost-effective measures (i.e. minimum energy performance requirements and establishment of a calculation methodology for the energy performance of buildings including an energy performance certificate). In the Netherlands, this directive has resulted in strict building regulations on the energy performance of new buildings. This means that the energy demand of buildings is becoming lesser over the years, which has a negative effect on the potential and the economic feasibility of DHNs in the future.

5.5 Conclusion

The purpose of this chapter was to develop a comprehensive overview of the (potential) barriers of DHN development that are discussed in the literature. An overview of the barriers found in the desk study are shown in Table 5. Whether a DHN in the Netherlands experience these barriers and to what extent is difficult to determine from the literature. Furthermore, DHN in the Netherlands might experience barriers that are not covered in the literature. The interviews in the next chapter can shine a light on that.

Table 5: Barriers of DHN in the Netherlands

Value proposition	
	Discrepancy between value offering and customer needs.
Value network	
	Fragmented value chain: many stakeholders involved, many complicated agreements are required.
	Monopolistic position of DHN operator is undesirable.
Value architecture	
	Heat losses in network.
	Optimal network design: cost efficiency vs. flexible network
	Connecting existing residential areas to a DHNs is difficult and expensive.
Value finance	
	Sustainable DHNs are characterized by high capital cost, low return on investment, long payback times and many uncertainties about future demand and district heating prices: an overall unattractive business case.
	Other benefits of DHN outside the business case also may not be priced such as reductions in primary energy consumption, lower greenhouse gas emissions and improved air quality.
	Reduced heating demand through energy efficiency measures on building level reduces the revenue stream of DHNs.

6. Within case study analysis

This chapter and the next will focus on the following question:

> What are the barriers that district heating networks currently face with their business models and what solutions do they provide?

To answer this question case studies were performed on four DHNs. The within case analysis will focus on the barriers and solutions typical for the case. In the cross case analysis we will compare all factors that were mentioned by the interviewees.

The chapter will continue in Section 6.1 with the selection of the case studies. Then, in Sections 6.2, 6.3. 6.4 and 6.5 are each dedicated to the within case study analysis of one case study. The analysis for each case study consists of the following components:

- Brief history of DHN development
- Business model configuration
- Barriers found within the DHN development
- Solutions provided to overcome the barriers

6.1 Case study selection

In order to provide a structural representation that matches the purpose of the study, the following three criteria were used to select the most information rich cases:

- The DHN needs to be developed in the past 15 years or have undergo major redevelopments in the last 15 years, because we are interested on how to develop DHN in current times and DHNs developed in the past might not be relevant for new DHN development .
- The DHNs are being developed from a clear ambition to develop a cleaner heating alternative for the public. DHNs that still run on gas or coals with a CHP installation from the 1980s or gas-fired boilers are excluded from the selection.
- As explained in Section 1.3. This study will focus on DHN that operate on a city wide level aiming to deliver heat to as many buildings as possible. This excludes block heating or DHNs limited to exclusively industrial (single user) restricted DHNs (steam trading).

A selection of 13 DHNs were found that satisfy these criteria, which are shown in Table 6. Eventually, the four DHNs that were contacted and willing to participate are highlighted in Table 7.

Table 6: DHNs that satisfy the selection criteria

City	Heat Supplier	DHN Operator	Heat production	Primary energy	WEQ (x 1000)[4]
Rotterdam	AVR Rozenburg	Primary net: Warmtebedrijf Rotterdam (private-public partnership (PPP) Municipality, Woonbron, E.ON) Secondary net: NUON and ENECO	Waste Incineration	Waste	50
Amsterdam north and west	AEB Amsterdam	Westpoort Warmte (PPP: nuon and AEB)	Waste Incineration	Waste	17,6
Purmerend	Stadsverwarming Purmerend (Municipality)	Stadsverwarming Purmerend (Municipality)	Biowaste Boiler	Bio waste	25
Arnhem/Duiven/Westervoort	AVR Duiven	NUON	Waste Incineration	Waste	22,8
Enschede	Twence	Ennatuurlijk	Waste Incineration	Waste	20
Nijmegen	ARN Weurt	Primary net: Indigo B.V (PPP Municipality and Alliander), Secondary net: NUON	Waste Incineration	Waste	3,7
Hengelo	Akzonobel	Primary net: PPP Alliander and Municipality, Secondary net: PPP Ennatuurlijk and Municipality	Industrial waste heat	Industrial waste heat	1,7
Lelystad	Nuon	Nuon	Biomass Boiler	Biowaste	6
Ede	Bio-energy de Vallei	Primary network: Warmtebedrijf Ede, Secondary network: Nuon	Biowaste Boiler	Biomass	5
Delft	Eneco	PPP: Eneco, Municipality and housing companies	CHP	Gas/biowaste	1,5
Dordrecht	HVC	HVC	Waste incineration	Waste	1
Sittard Geleen	Biomassa Energiecentrale Sittard	PPP: Ennatuurlijk and municipality	Biomass boiler and Industrial waste heat	Biomass and Industrial waste heat	0,5
Roosendaal	Suez	Municipality	Waste incineration	Waste	0,4

Table 7: The DHNs selected for the case study

	Hengelo	Nijmegen	Purmerend	Enschede
Customers (weq)	1.700	3.700	25.000	20.000
Technology	Industrial waste heat	Waste incineration	Biomass boiler	Waste incineration
t supplier	Akzonobel	ARN	Stadsverwarming Purmerend B.V.	Twence
Primary energy source	Industrial waste heat	Waste	Biomass	Waste
DHN operator	Primary net: PPP Alliander and Municipality, Secondary net: PPP Ennatuurlijk and Municipality	Primary net: Indigo B.V (PPP Municipality and Alliander), Secondary net: NUON	Stadsverwarming Purmerend B.V.	Ennatuurlijk

[4] WEQ stands for “woning equivalent”. This is a way to sum up the heat demand of dwellings and commercial builldings. One “woning equivalent” is equal to 100 m^2 of commercial building space and also equal to 27 GJ, which is the average heat demand of dwellings per year in the Netherlands (C. Leguijt, Bennink, & Wielders, 2011).

6.2 Hengelo

6.2.1 Brief History of the DHN in Hengelo

Hengelo is a small city in the Netherlands with a population of 81.070 and located near the border with Germany in the province of Overijssel. Around 2002, the Municipality of Hengelo started to adopt action plans and policies to reduce CO2 emission and increase the share of renewable energy in Hengelo. The following years several feasibility studies were conducted to find viable options to help achieve their goals. One of the options was a city wide DHN, for which a trail project was developed near the center of Hengelo in 2005. The municipality received positive feedback from the trial project and decided to develop a DHN throughout the city of Hengelo. However, at that time no private parties (e.g. energy utility companies, district heating companies, project developers etc.) were willing to take up such a project. For the municipality the environmental benefits outweighed the risks and low financial prospects, therefore, they decided to initiate the development of a DHN in Hengelo on their own.

In 2007, the municipality of Hengelo (The Netherlands) started Warmtenet Hengelo (WNH), a district heating company aiming to deliver heat to homes and businesses in Hengelo through a waste heat DHN. The strategy of WNH has been to primarily focus on large-scale business clients and new (housing) development projects (Warmtenet Hengelo, 2012). With this strategy, the DHN has been slowly but steadily growing to 528 dwellings and 18 businesses (see Figure 12).

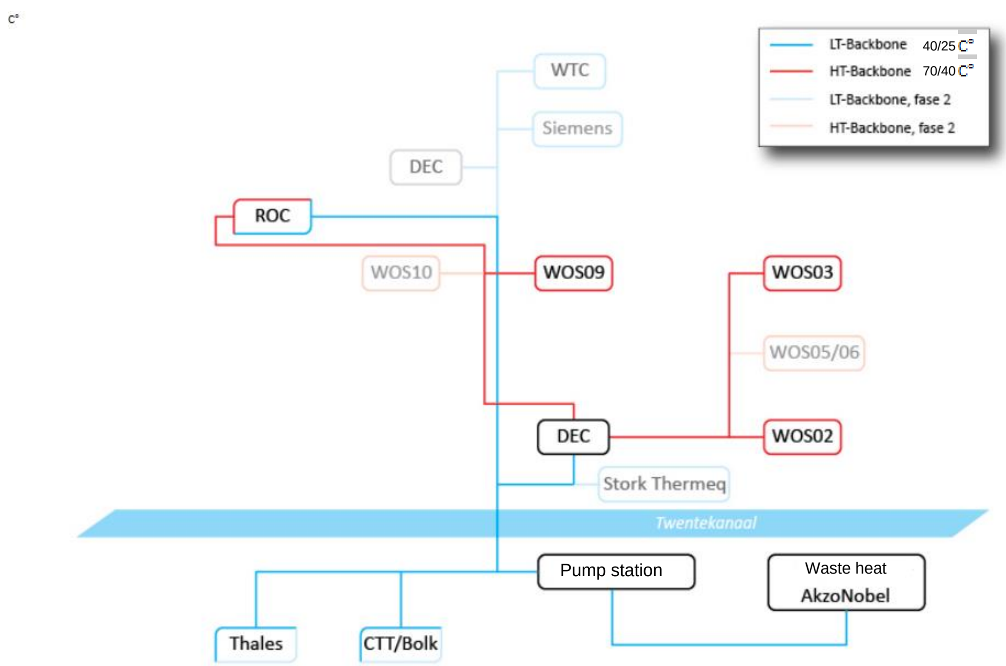

Figure 12: Intended DHN configuration of WNH in 2015 (WOS are back up stations connecting residential area's to the primary network. DEC is a decentralized energy plant).

At the meantime, WNH has been searching for a suited partner to supply the heat for the DHN. Initial plans were to use the waste heat from Twence, a waste incineration plant. However, they choose to use their waste heat for other purposes. Another option was waste heat from AkzoNobel, as they are currently discarding cooling water of 40 ˚C in a canal. After a long negotiation period, WNH eventually came to an agreement at the end of 2014 with AkzoNobel to use their cooling water free of charge.

From the beginning, it has always been the intention of the Municipality to set up WNH as a separate company (instead of a division within the Municipality) (Municipality of Hengelo, 2016). After some delays, WNH managed to enter into a private public partnership with Ennatuurlijk B.V. and Alliander Gebiedsontwikkeling in 2016. In 2017, Ennatuurlijk and Alliander took over the operations, and the organization of WNH was dissolved. The municipality is a minority shareholder of the DHN.

6.2.2 Business model configuration of Warmtenet Hengelo

Table 8: Value proposition DHN Hengelo

Product	Heat
Target Audience	Large scale business consumers, new residential building development
Value element	Sustainable, convenience, comfort

Table 9: Architecture DHN Hengelo

Strategy	Invest in decentralized projects throughout the city when opportunity arises. Connect decentralized project to primary network when enough demand is created.
Heat supply	Industrial waste heat Akzonobel, 40 ˚C
Primary network	40-25 ˚C
Secondary network	40-25 ˚C and 70-40 ˚C
Substations	Heat pumps and back-up boilers

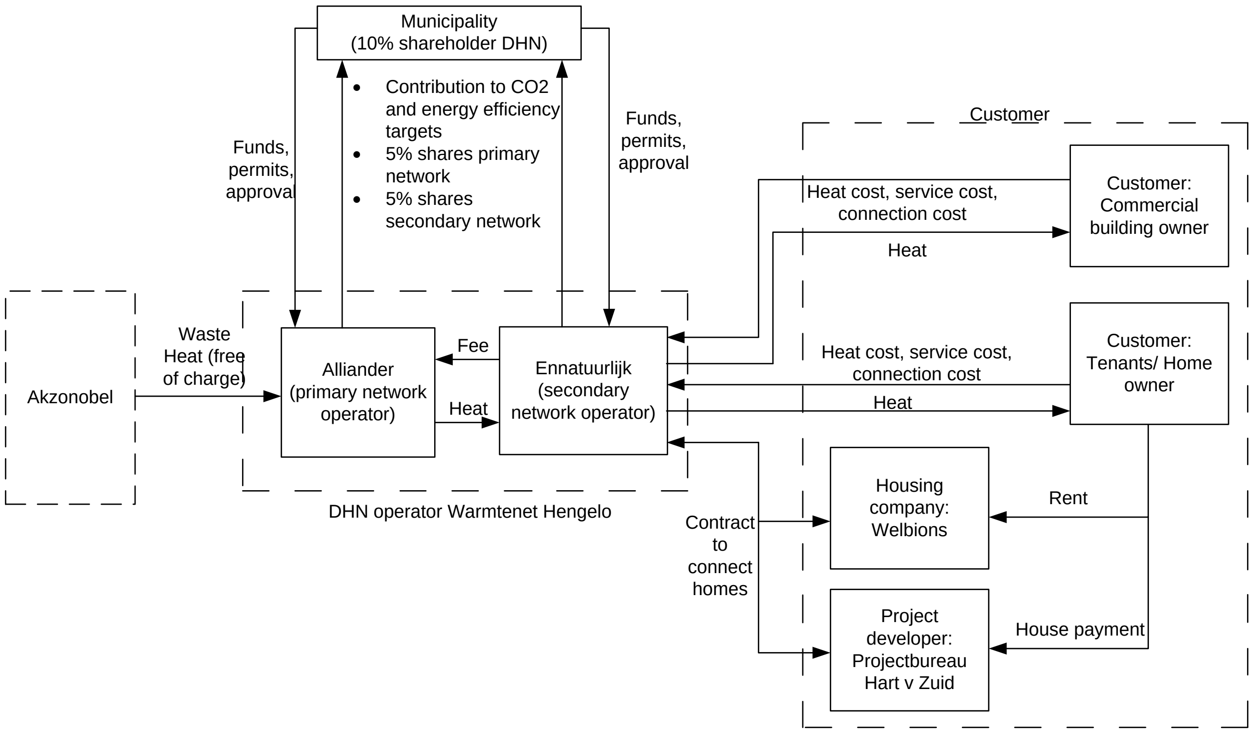

Figure 13: Value network

Table 10: Finance DHN Hengelo[5]

Investments	(mil. €)	Revenues	Risks	Risk carrier
Subsidy Province	5,8	Ennatuurlijk	Construction risks primary network (e.g. extra work, soil sanitation)	65% Municipality, 35% Alliander/Ennatuurlijk
Subsidy Government	3	Alliander	Exploitation risk	
Municipality Hengelo	8,5	Municipality of Hengelo (10%)	Future heat demand	Alliander/Ennatuurlijk
EU grant	0,6		Gasprice	Alliander/Ennatuurlijk
Ennatuurlijk	5,5		Supply security Akzonobel	Alliander/Ennatuurlijk
Alliander	1,04			
Total investment	24,44			

[5] Source: (Municipality of Hengelo, 2016)

6.2.3 Business model analysis of Warmtenet Hengelo

Barriers

- ***Running a DHC within the organization of a municipality has shown to be unpractical for WNH.***

With multiple parties in the municipality council, political interest and commitment towards WNH was diverse and subject to sudden changes due to elections. This created uncertainty and instability for WNH because the municipality had to approve every investment into WNH. For example, in 2014, a new municipality council was elected in Hengelo which immediately put WNH on hold (with regards of the decision of the old council) until they provided an updated business plan and more certainty about the contracts and financing (Warmtenet Hengelo, 2015). Negotiations with potential clients and suppliers also had to be put on hold, which makes WNH come across as an unreliable and instable partner. The remarks of a council member of the Municipality of Hengelo, in our interview illustrates some of the resistance that WNH had to deal with:

> "Developing a city wide DHN should not be the task of a municipality. You should leave that up to the energy market. The role of the municipality should be to facilitate, for instance through a onetime subsidy. If it would up to me, we would stop any further activities of WNH, before it gets completely out of hand and we put the Municipality of Hengelo at serious financial risk."

Since the beginning of WNH in 2008, the intention of the municipality was always to establish WNH as a separate company. However, this process was delayed on multiple occasions in the past. The repeated delays to separate WNH as a company put both the municipality and WNH in an awkward position. On the one hand, since the municipality was waiting for WNH to become a separate company it was never fully imbedded into the organization of the municipality (Kennispunt Twente, 2015). On the other hand, WNH did not have the freedom to set up their management procedures as they were still part of the municipality. This has put a lot of tension on WNH as the where trying to operate as a business while at the same following the procedures of a municipal organization (Kennispunt Twente, 2015).

- ***Economic crisis hampered the progress of WNH severely.***

After WNH was established in 2007, the Netherlands underwent one of the most severe economic crises in decades. This resulted in large budget cuts of the government, a declining building industry in which many housing projects were postponed and a cautious investment climate. These developments limited the opportunities of WNH to acquire clients and negotiations with clients, supplier and partners were troublesome. Particularly the stagnating gas prices meant that WNH had difficulty to present competitive proposals towards potential commercial clients.

- ***Innovative character of low temperature DHN caused some startup problems.***

The municipality of Hengelo took initiative by establishing WNH, since there were not enough financial incentives for private parties to develop a DHN in Hengelo. The ambition of WNH was to develop a low temperate DHN from the waste heat of Akzonobel. At that time, there were no other low temperature DHNs on a city-wide level, therefore this was an innovative project. With every innovative project, the start can be difficult to manage and WNH experienced also experienced some of those start-up problems.

For instance, there were some process related issues with acquiring the waste heat from Akznobel. Although eventually the objective was achieved, the process leading up to the contractual agreement was a turbulent and lengthy process. The good intentions of both parties were there from the start, however, working out the due diligence and coming to an actual contract took much longer than anticipated. The negotiations started in 2009 and WNH and Akzonobel came to an agreement in March of 2015. In this case, AkzoNobel did not want to commit until the heat demand was secured. While, industrial clients did not want to commit to the DHN, until the waste heat was secured. This makes it difficult to set up a realistic timeline for the DHN in the early stages, because it is difficult to predict when parties can come to an agreement.

- ***Outsourcing operations was not as efficient and effective as expected***

Since this was an innovative project, often engineering and consultancy firms were hired to work out design, technical and legal aspects. Furthermore, much of the operational activities (e.g monitoring the heat use, invoicing the clients and maintenance) were outsourced to third parties in order to be able to focus on growing the network. However, WNH found that outsourcing these operations did not unburden them as much as they expected. There was a lack of linkage between the outsourcing companies and the system of the municipality in which WNH was working. While outsourcing is a logical strategy in order to be able to focus on the core activities of the company, WNH found that a certain level of (technical) know how is needed within WNH to operate the outsourced activities efficiently (Warmtenet Hengelo, 2015). Furthermore, it is better to have expertise within the organisation to be able to make strategic choices, be able to ask the right questions and have control about the quality. Therefore, this has been a learning process for both the municipality and WNH. After a few years of struggling to contract enough clients and a suitable heat supplier (also partially due to the crisis), WNH and the Municipality found it would be too risky and costly to continue operations internally (Municipality of Hengelo, 2016). Therefore, they started negotiations in 2015 with private companies Ennatuurlijk B.V. and Alliander. From 2017 Ennatuurlijk and Alliander took over the operations, and the Municipality of Hengelo remained as a minority stakeholder.

Success factors of Warmtenet Hengelo

- ***Importance of process management: willingness and ambitions of WNH to keep bringing parties together***

As with most DHNs in the Netherlands, the cooperation of many stakeholders was needed to come to an agreement for the DHN in Hengelo. Many negotiations are contingent upon each other and have to be dealt with in parallel. In the case of WNH, some industrial clients did not want to commit to the DHN until the waste heat was secured. While the heat supplier (i.e. AkzoNobel) did not want to commit until the heat demand was secured. With many different interests to manage, the process of coming to an agreement can become very lengthy. The interim CEO of Warmtnet Hengelo elaborated as follows:

> *"It is much easier to do things individually, than coming up with a solution that works for everybody. If you want a more sustainable city, you need to come up with a collective solution. You have to create support and the stakeholders involved have to actually want to participate. Forcing stakeholders in an agreement will create more trouble in the long run. Every DHN project needs an initiating stakeholder that is able and willing to carry the project for a long time."*

Some of the stakeholders admitted they had giving up on the idea of a DHN in Hengelo. If it was not for the perseverance of WNH to keep bringing parties together and keep looking for opportunities to meet the needs of all the stakeholders, the development of a DHN in Hengelo probably would have never happened.

- ***Seeking grants, funds and subsidies, from province, national and municipality to reduce the risk, and attract private partners and customers***

As can be seen by the investments in Table 10, most of the investment into the DHN comes from public money, while the revenues end up with the private parties (Ennatuurlijk and Alliander are 90% shareholder of the DHN). Private parties as Ennatuurlijk are part of publicly traded companies, which means that their investment requires a profitable return. Moreover, the commercial clients expect a competitive proposition from the DHN for them to connect to the DHN. In order to develop a DHN in Hengelo public money was necessary to present competitive propositions for commercial building owners and to provide the private parties with an acceptable return on their investment.

- ***Seeking PPP with Ennatuurlijk and Alliander***

The ultimate goal of the Municipality is to reduce CO_2 as efficiently as possible. The DHN is just a means to this end. After struggling a few years on their own, it made sense to leave the operations to a party with the knowledge and experience in managing and developing a DHN. The Municipality as a partner can make sure that goals on CO2 reduction and renewable energy are met for Hengelo and unburden themselves of future risks. The private parties can unload some of the risks involved of the high initial investment and build a reasonable return on their business case and look for opportunities to grow the DHN further (Municipality of Hengelo, 2016).

- ***Develop decentralized projects throughout the city when opportunity arises***

Based on an energy scan, WNH divided Hengelo in substation areas. Then, whenever the opportunity arises, WNH develops decentralized projects by connecting customers to (temporary) substations in these areas. The main idea behind this approach was to keep the momentum of the project by creating a large customer base as fast as possible and start developing a primary network whenever a sufficient demand was created to justify the large investment in the primary network.

It is a useful strategy for a DHN when there are no large-scale building projects to create a large demand on the short term. Until the primary network is ready, temporary gas fired boilers within the (temporary) substations are used to provide heat for the customers.

6.3 Nijmegen

6.3.1 Brief History of the DHN in Nijmegen

In 1998, the municipality of Nijmegen formalized plans for an expansion of Nijmegen with a new area consisting of 12.000 dwellings called the Waalsprong. The plan was to develop the area in different phases, which started in 1999 and would be finalized in 2015. Around the same time, the municipality was exploring possibilities to cut back the CO_2 emission of Nijmegen and the Waalsprong was viewed as an ideal opportunity to showcase their ambitions. For the first two neighbourhoods heat pumps and a small-scale CHP were utilized to provide for the heating demand (Trommelen, 2000). After these projects, the Waalsprong project came to a standstill for two years because the Council of State disapproved certain aspects of the environmental impact assessment of the project (Municipality of Nijmegen, 2002). The development of Waalsprong continued in 2005. From this time, also the idea for a large scale DHN started to bounce back and forth between the stakeholders of Waalsprong. Eventually, the plans became more concrete in 2009 when the first business cases were formed for a DHN (Roos et al., 2009). These business cases were based on a DHN using waste heat from a waste incineration plant located to the south of Waalsprong (see Figure 14).

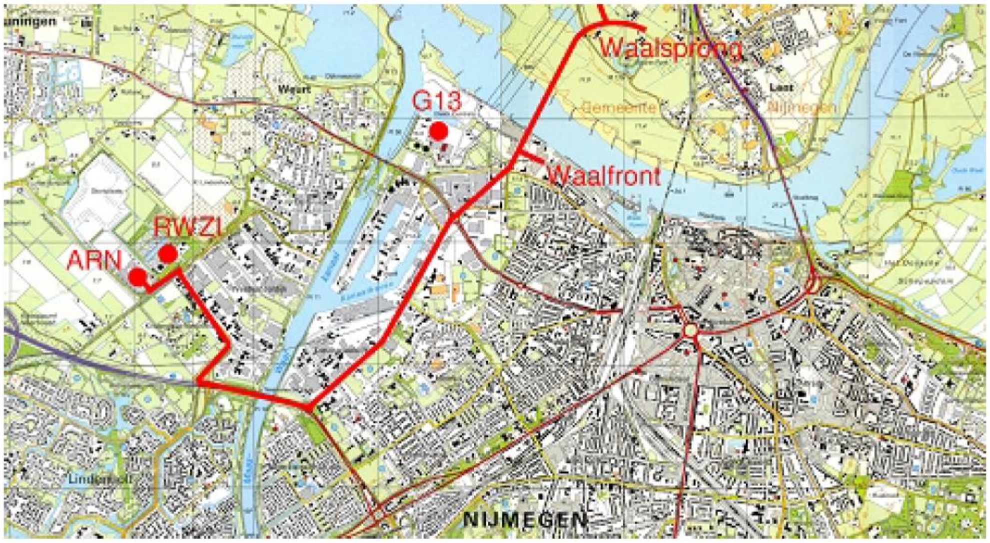

Figure 14: DHN route of Nijmegen

The actual agreement on the financing between ARN (the waste incineration plant), Nuon (DHN operator), Municipality of Nijmegen, Alliander and Province Gelderland was signed in 2012, after which the construction could start. The construction of the 6,1 km long pipeline from ARN to the Waalsprong was finished in 2015. Currently there are 3750 dwellings in Waalsprong and Waalfront connected to the DHN and an additional 9250 new to build dwellings will also be connected to the DHN.

6.3.2 Business Model DHN Nijmegen

Table 11: Value proposition DHN Nijmegen

Product	Heat
Target Audience	Primarily new residential building development
Value element	Sustainable, convenience, comfort

Value network DHN Nijmegen

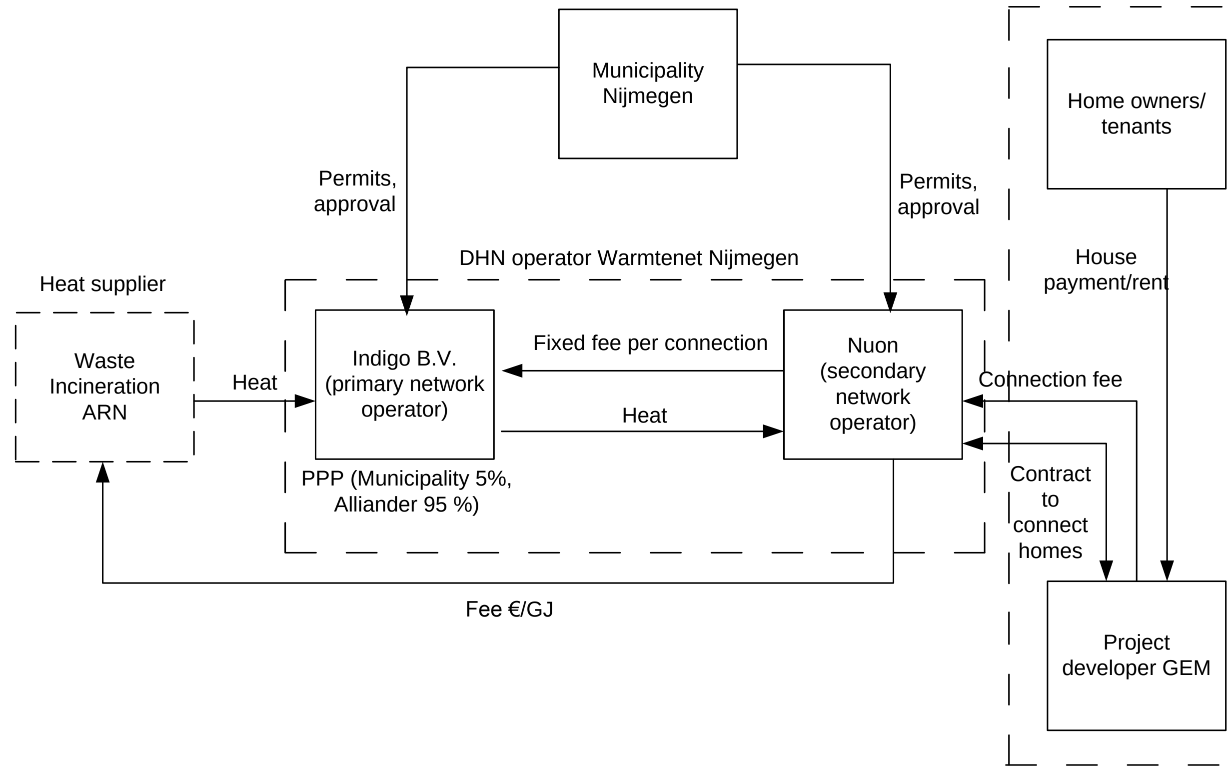

Figure 15: Value network DHN Nijmegen

Table 12: Value Architecture DHN Nijmegen

Strategy	Develop a DHN for a large scale residential building project of 12.000 dwellings
Heat supply	Waste Incineration ARN
Primary network	70-40 ˚C
Secondary network	70-40 ˚C
Substations	CHP installation and back-up boilers

Table 13: Finance DHN Nijmegen

Investments	**(mil. €)**	**Revenues**	**Risks**	**Risk carrier**
Nuon	82	Nuon	Construction risks primary network(e.g. extra work, soil sanitation, steel price.)	Alliander/Municipality
Subsidy Province	5	Alliander	Exploitation risks	
Municipality Hengelo	3,8	Municipality (5%)	Future heat demand	Nuon
Subsidy Government	2,5		Gasprice	Nuon
Alliander	10		Supply security ARN	Nuon/Alliander
	103,3			

6.3.3 Business model analysis of DHN Nijmegen

Barriers

- ***Temporisation in housing development***

The development of the DHN in Nijmegen was completely depended on the development of new housing in Waalsprong and Waalfront. This means that the required amount of connections for the business case of the DHN is based on an amount of housing development within a certain period (in Dutch also referred to as 'volloopscenario'). If the development of new housing slows down it directly affects the return on investment in the business case.

When the municipality bought the ground in 1997, the plan was to build 12.000 dwellings by 2015 (van der Meer & Jenne, 2015). However, the project had their first setback in 2002 when the environmental impact assessment was disapproved and the project came to a standstill for 2 years. After this, the economic crisis hit the Netherlands in 2008 and the project developers involved in the Waalsprong were not willing to invest anymore (Municipality of Nijmegen, 2013). Currently, the Municipality have adjusted their plans to complete the development of 12.000 new dwellings in 2028. In the meantime, the business case for the DHN had to be adjusted several times, since the revenue on the already finished houses (and future revenues) was less than expected.

- ***Negotiations with stakeholders were long and difficult***

The Municipality committed to a DHN for the Waalsprong and Waalfront without having an agreement in place with a heat supplier or DHN operator. The first 3000 dwellings were connected to a temporary CHP installation, until a supplier was found (Roorda & Hunnik, 2007). The problem with the temporary installation was that the margins were very slim and the project was running at a lost. In addition, these houses did not have a gas connection, which means that there was no backing out of the project (at least not a reasonable cost). As long as the primary network with the waste incineration as heat supplier was not in place, the project would remain losing money indefinitely. In 2007, the negotiations between the Municipality, the project developers and Nuon (the DHN operator of the temporary CHP installations) came to a complete standstill when Nuon demanded higher connection costs, than the one agreed upon in 1997 (Nijhuis, 2006). The issue needed to be settled in court after which the plans for a DHN were put on hold indefinitely (Trouw, 2006). Eventually the parties involved came to an agreement in 2012 with additional funding from the Province and National Government. The project leader at the municipality, Harm Eetgering, commented the following on the negotiation process:

> "With DHNs you always have to deal with the chicken and egg story. Project developers do not want to commit until there is a DHN in place, while suppliers and DHN operators do not want to commit until there is certainty about customers. In our

case we got out if this impasse through subsidies from the Province, National government, and Municipality."

- ***Low temperature hybrid network was rejected by private partners***

Since backing out of a DHN would be very costly for the Municipality, it was forced to find a solutions for the heating needs in Waalsprong (De Gelderlander, 2007). In 2009, the Municipality along with various consultancy companies developed a business case for a low temperature hybrid DHN. This DHN would use "pure" waste heat of 45 ˚C for heating in combination with a heat pump installation at every dwelling to provide warm tap water and use the cooled down water at the heat pump for comfort cooling in the summer (Roos et al., 2009). Although the idea was innovative and would be able to reduce fossil consumption and CO_2 emissions even more than "regular" DHNs, the idea fell through because the private parties were less enthusiastic about this alternative. The private parties found that due to its innovative character the hybrid network was more risky and more expensive to exploit. Meanwhile, two years had gone by without any progress in the DHN.

Success factors DHN Nijmegen

- ***PPP between Municipality and Alliander***

The Municipality had the will and ambition to develop a DHN but lacked the technical knowhow, for instance in the procurement and tendering of a DHN pipeline and the exploitation of a DHN. Through the PPP, the Municipality could share most of the risks in execution and exploitation with a more qualified party, in this case Alliander. The financial risks of the Municipality was limited to the share capital of €300.000 in return of 5% of the shares in Indigo B.V. (i.e. PPP) On the other hand, due to the subsidies, Alliander could buy in at relative low-cost and form a solid business case for their part. In return, the municipality arranged to have equal say in strategic matters of public interest, particularly those in terms of sustainability policy and fair treatment of the customers (Municipality of Nijmegen, 2012).

- ***Importance of process management: strong will and leadership of Municipality***

The development of this DHN had a particular long lead up. Talks about a DHN started in the late nineties and the first developments of the DHN begun in 2001. The stakeholders were finally able to complete the construction of the primary network pipeline in 2015. Still there is a long way to go until all the 12.000 dwellings will be connected and the project may even extend to other parts of the city and the neighbouring city Arnhem. There were a few times that the project came to a complete standstill and there were concerns that the project would completely fall through. In this case, it was due to the credit of the Municipality, who initiated the projects and kept bringing parties together until they found a solution that works for everyone.

> "A DHN project can be a long winded affair and you need someone who as the drive and ambition to keep carrying the project forward. I don't see any another party except the municipality who can take up that role. Municipality have a public interest to reduce CO2 emission. They are well- connected with Province and national government to bring additional financing to the project as well as with the local community."

On the other site, you can argue that the Municipality committed too early to a large-scale project while there were so many uncertainties. However, if they did not commit, they opportunity would relinquish completely, since the Waalsprong would have chosen a different heating alternative. Eventually the strong will and leadership of the Municipality to keep pushing and creating opportunities was a decisive factor in the success of the DHN in Nijmegen.

- ***Public subsidy was necessary to make the project feasible***

This project would not be possible without public money. Especially with residential buildings, there is maximum price (due to the Dutch heat act) that the DHN operator can charge, which often means that the revenue cannot cover the high upfront investment (In Dutch this is referred to as the "onrendabele top"). To ensure return on investment for the private parties and cover some of the risk involved in construction and exploitation of DHNs subsidies were necessary.

6.4 Purmerend

6.4.1 Brief History DHN Purmerend

The DHN in Purmerend was established in 1980, like many of the other large DHNs in the Netherlands from that time (e.g. Almere, Enschede, Leiden, Helmond, Amernet), it was established as a response to the 2e oil crisis (Fruyt van Hertog, 1982). During that time, DHNs were presented as a viable options to conserve fossil fuels. Purmerend was one of these cities, because the Dutch government had designated Purmerend as an area for a large development project to reduce the housing shortage in the neighbouring city of Amsterdam (Municipality of Purmerend, 2006). In 1980 the population of Purmerend was 37.000 (Waterlands Archief, 2013), since then the population has grown to 79.000, from which 60.000 are connected to the DHN (Stollmeyer, 2011).

Until 2007 the DHN was fully owned by the municipality as a separate division within the organisation of the municipality, but it never was able to turn a profit during that time (Koerts, 2014). In 2007, the Municipality decided that it needed to change things drastically to turn the misfortunes of the DHN around. With the electricity and heat market already liberalised in the Netherlands a few years prior to 2007, the Municipality found that heat delivery should not be a part of the core activities of a public institution. Beside this, they believed that a separate company could run the DHN more effectively.

The Municipality set up a separate DHC in 2007 called “Stadsverwarming Purmerend BV” (from here on out “SVP”) that would take over all the DHN related activities from the Municipality (Koerts, 2014). A team of 8 persons started to develop solutions and business plans that would make the DHN profitable again. They found that most of the pipes and the primary and back up heating installations were up for replacement. The team considered a complete exit scenario from the DHN, but this would be even more costly. Instead, SVP decided to completely renovate the DHN with new pipes, and turn the DHN in a sustainable heating alternative with a large biomass fired boiler as the primary installation. The Municipality (as the sole shareholder) approved the plans in 2012, after which the procurement and construction of the DHN could start. The project was completed in the beginning of 2015 and the biomass DHN currently delivers heat to around 25.000 households in Purmerend (75% of the population).

6.4.2 Business Model DHN Purmerend

Table 14: Value proposition DHN Purmerend

Product	Heat
Target Audience	Existing residential building development and small scale businesses
Value element	Sustainable, convenience, comfort

Value network in Purmerend

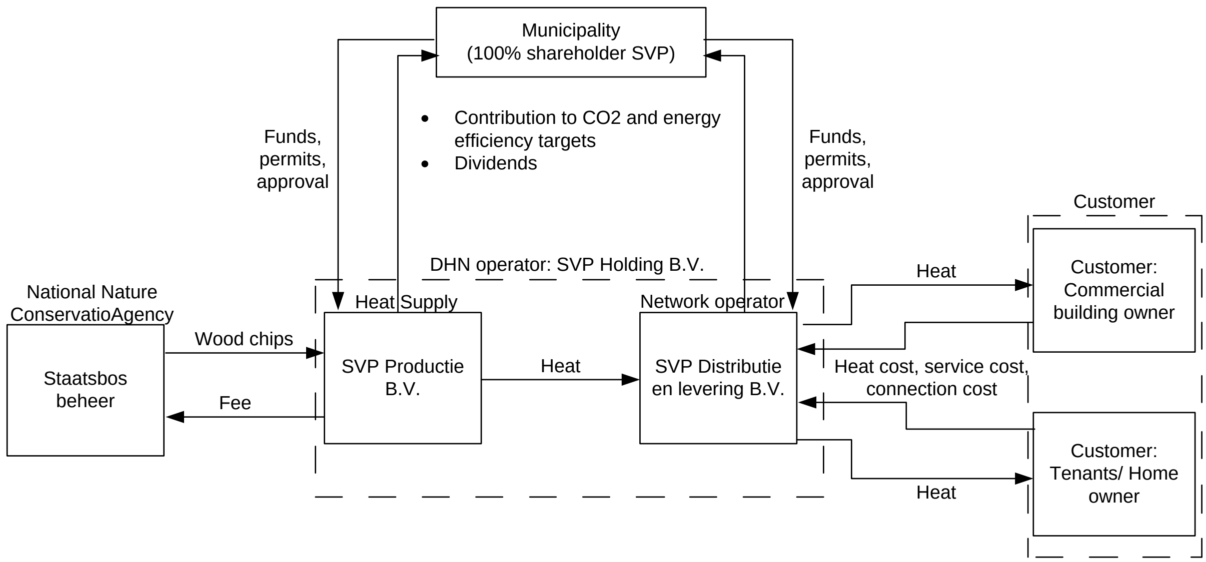

Figure 16: Value network DHN Purmerend

Table 15: Architecture DHN Purmerend

Strategy	Redevelop an existing DHN with a new energy supplier
Heat supply	Biomass boiler
Primary network	90-70˚C
Secondary network	90-70 ˚C
Substations	CHP installation and back-up boilers

Table 16: Finance DHN Purmerend

Investments (mil. €)		**Revenues**	**Risks**	**Risk carrier**
Municipality loan	45	Municipality	Gasprice	Municipality
Bank loans	46.7		Wood chip price	Municipality
EU grant	1,8			
Government subsidie SDE+				
	103,3			

6.4.3 Business model analysis DHN Purmerend

Barriers

- ***Staggering heat losses and defects in heat distribution***

One of the reasons that SVP was not able to turn a profit in the past, is that the heat losses from the distribution network were at 35% (van Lier, 2015), which basically means money thrown down the drain. The heat losses were caused by poor maintenance, many leakages and disruptions in heat supply. In 2012, SVP implemented a plan to reduce the heat losses gradually from 35% to 22.% in 2016 (Municipality of Purmerend, 2014). The plan aimed to eliminate unnecessary distribution loops, improve just in time heat production, and replace piping, substations and heat delivery sets (SVP, 2013). 22% is still considered high for modern DHN standards, however, SVP is somewhat limited to reduce losses even more because many dwellings in Purmerend operate on old radiators, which means that SVP has to operate at high supply temperatures (up to 90 ˚C).

- ***Outsourcing operations did not work well***

Before 2007, the Municipality operated the DHN within their own organisation. In reality, the Municipality chose to keep limited internal staff on the project and outsource most of the operations to outside companies. For example, until 2004, Nuon had a contract to operate the DHNs for the Municipality including back office (such as billing, customer service etc.). However, due to the continuing losses, the Municipality wanted to sell the DHN to a private party and thought that an outside party would be more interested if the operations were not "deeply rooted in the organizations of a third party" (Sweegers, 2004). Therefore, the Municipality decided to end the contract with Nuon. However, even without Nuon, there were no buyers interested in the DHN. In the meantime, the Municipality decided again to outsource the operations to an outside company. This time Any-G took over the back office and Hak was responsible for maintenance work (Sweegers, 2005). To make it easier for a private party to buy the DHN, The Municipality decided to separate the DHN from their organization and set up a separate company, SVP. In turn SVP made the strategic decision to insource their activities and take the reins. SVP would establish its own customer care organization and handle all operational and financial processes itself with a new, integrated IT system (Mecoms, 2009). CEO of SVP, Gijs de Man, recalls:

> "If you outsource, you have to be on top of everything. Otherwise the piping will be faulty, the customer service will not be good enough, and the problems starts pilling up. On paper, it looks as a good solutions, but the outsourcing companies has also 20 other clients who he has to deal with. If you do not have expertise internally to tell them exactly what to do, it will not work."

Success factors DHN Purmerend

- ***Developing a separate company***

A key aspect to the success was to set up a separate company for the DHN instead of operating from within the Municipality in Purmerend. The Municipality found that energy distribution should not be activity of a governmental institutions and a separate company could operate the DHN more effective (Koerts, 2014). A newly assigned team set up SVP to continue the activities of the DHN in Purmerend with the Municipality as the sole shareholder. At a later stage, SVP was turned into a holding company containing two subsidiary companies: a production and a distribution company (SVP Productie B.V. and SVP Distributie & Levering B.V.). SVP and the municipality chose this structure to make it easier for other private parties to participate or buy a part of the company, and this structure was fiscally more beneficial (Daan, 2014). In their business plan of 2009, SVP developed a strategy to redevelop the DHN of SVP and in the following years SVP has been able to successfully carry out the strategy (Daan, 2010). The strategy consisted of three main parts :

  - Optimize company operations

Since 2009, SVP insourced their front and back office activities and currently has 45 employees working on customer service, administration, billing and engineering.

  - Redesign the distribution network to make it more efficient

SVP developed Slimnet, a model to redesign the distribution network and replace 4000 connections, which cuts down heat losses by 33% and unplanned repairs by 84% (SVP, 2015).

  - Switch to a sustainable heat source

SVP developed a biomass boiler to be the primary heat source for 25.000 customers.

- ***Demand already exists, less risks involved in the business case***

One of the major advantages of SVP was that they did not have to worry about heat demand, since 25.000 connections were already in place in Purmerend from the old DHN. This makes the business case of SVP much less risky than DHNs cases were the initiators have to negotiate with customers to secure their demand. Instead, SVP could focus on finding a sustainable supplier and making the network operate more efficient. Furthermore, SVP was less depended on subsidies to develop a solid business case. A consortium of banks, primarily consisted of Triodos Bank and BNG Bank were willing to loan SVP their investment, with the requirement that the Municipality could guarantee the loan.

- ***Biomass boiler as the primary heat source: more sustainable and better margins***

Before 2014, a fossil-fuelled CHP-installation of Nuon was the primary heat source for the DHN in Purmerend. This installation was up for replacement and SVP decided to end the contract with Nuon. Instead, SVP took this opportunity to take over the supply chain to choose a “greener” heat source as well as improving their operational margins. After first exploring the option of geothermal energy, which the soil conditions in Purmerend did not permit, SVP constructed their own large scale biomass boiler for their primary heat source. Currently, this installation is producing 80% of the heat and the back-up take care of the other 20%.

6.5 Enschede

6.5.1 Brief history of DHN Enschede

Similarly as the DHN in Purmerend, the first DHN in Enschede was established in 1984 as a response to the 2e oil crisis. For a long time, Essent (a Dutch energy company) operated and owned the DHN. However, in 2013 Essent sold all its DHN operations to PGGM (pension fund) and Dalkia (energy service company). These two companies continued the DHN operations in the Netherlands under a separate company called “Ennatuurlijk BV”. Currently Ennatuurlijk is the only DHC that operates throughout the Netherlands and solely focuses on DHNs. They have 66.000 connections throughout Netherlands mostly concentrated in Noord-Brabant (primarly the Amer centrale). Since 1984, Essent has developed two other smaller DHNs in Enschede, which Ennatuurlijk also owns now (see Table 17).

Table 17: Different DHNs in Enschede

	Dwellings	Other buildings	Technology
South/West Enschede	4187	154	Waste Incineration
Roombeek	1226	15	CHP-unit
Tattersall	540	0	CHP-unit
Total	5453	169	

The largest of the three DHNs was initially also using a CHP unit, but in 2011, Essent partnered with Twence to use waste heat from their waste incineration plant located in the Neighbouring city of Hengelo. Among the buildings connected, there are some large-scale buildings such as a football stadium and an university campus, making the total heat distribution equivalent to 20.000 dwellings (see Figure 17).

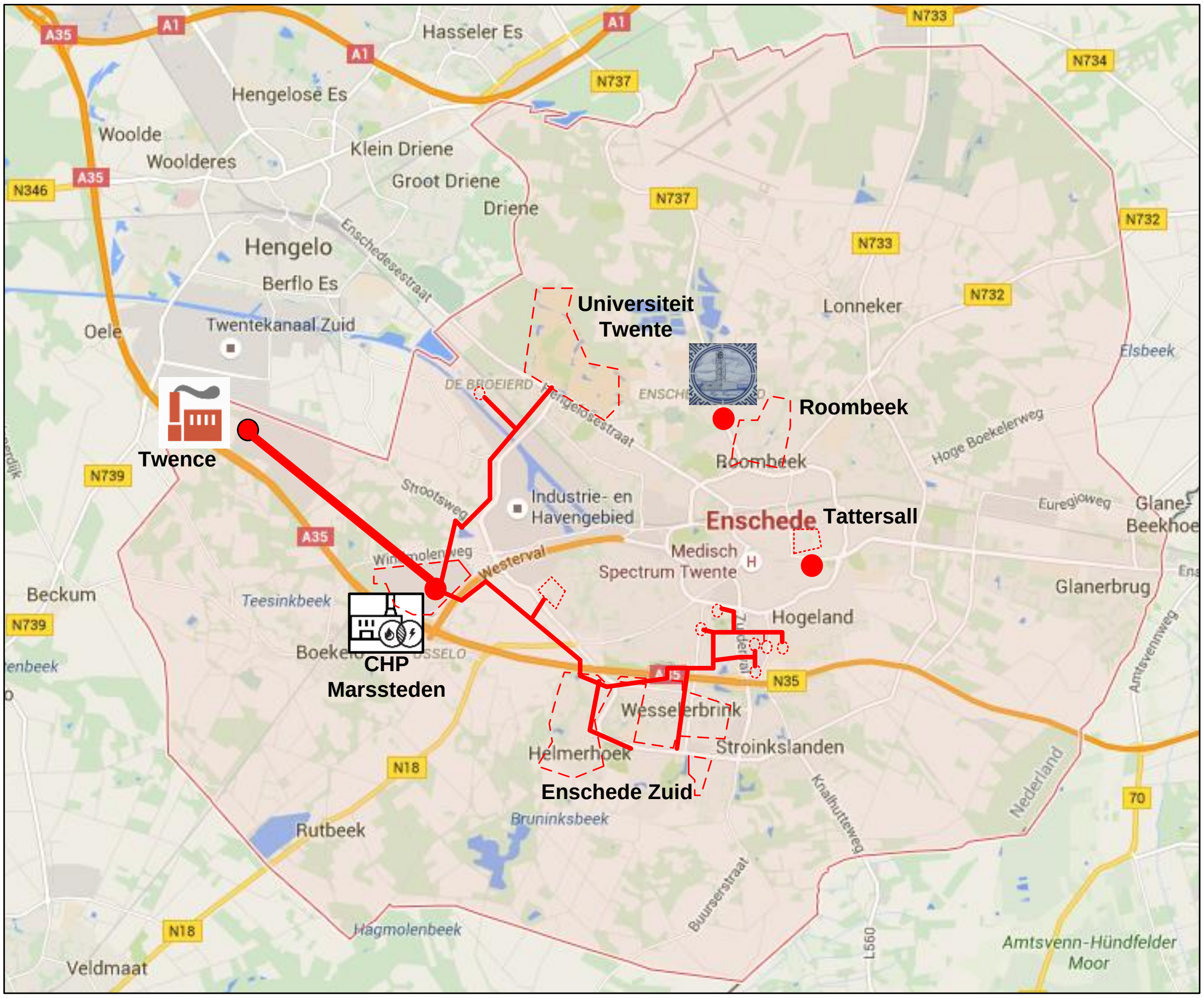

Figure 17: DHN of Enschede

6.5.2 Business model DHN Enschede

Table 18: Value proposition of the DHN in Enschede

Product	Heat
Target Audience	Residential building and commercial building development
Value element	Sustainable, convenience, comfort

Value network of DHN in Enschede

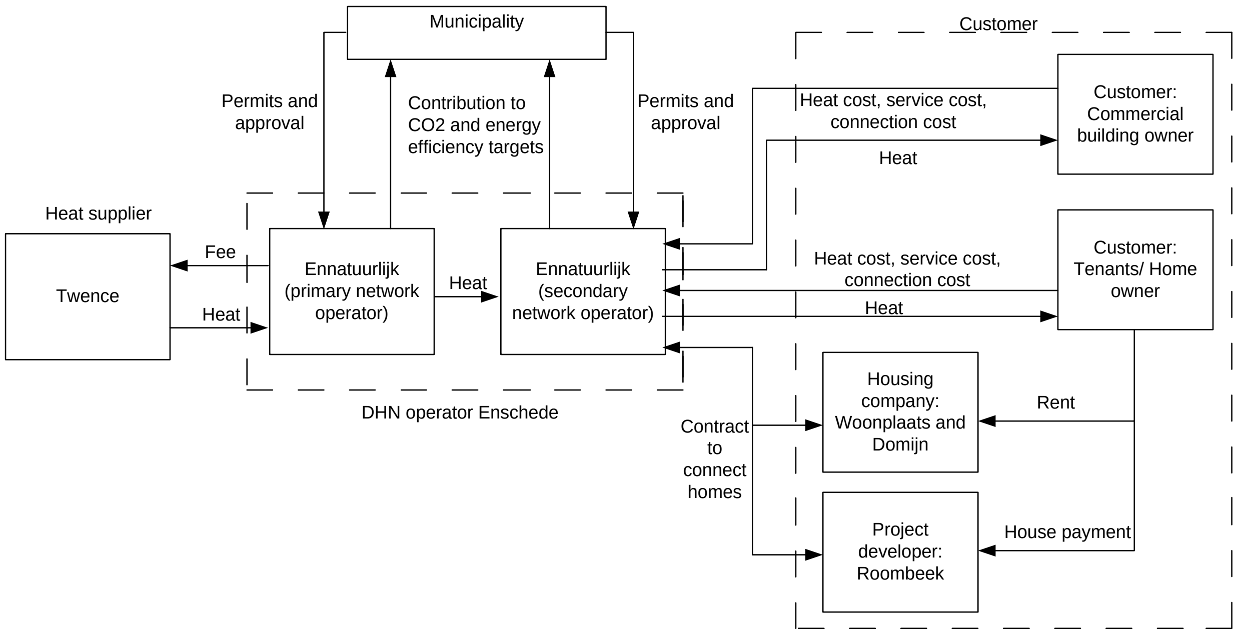

Figure 18: Value network of DHN in Enschede

Table 19: Architecture of the DHN in Enschede

Strategy	Connect an existing DHN with a new energy supplier
Heat supply	Waste incineration
Primary network	110-90˚C
Secondary network	90-70 ˚C
Substations	CHP installation and back-up boilers

Table 20: Finance of DHN in Enschede

Investments[6]	**(mil. €)**	**Revenues**	[redacted]	**Risks**	**Risk carrier**
Twence	-	Ennatuurlijk		Construction risks primary network(e.g. extra work, soil sanitation, steel pricec.)	Twence
Government subsidie	-	Twence		Exploitation risk	
				Gas price	Ennatuurlijk
	20				

[6] Twence has not disclosed how much subsidy they received and how much they invested themselves. The investment was for the pipeline from Twence to the CHP unit in Marssteden.

6.5.3 Business model analysis of DHN Enschede

Barriers

- ***Complaints about prices and service***

One of the aspect that Ennatuurlijk/Essent had to deal with is complaining customers about prices of DHNs. In the last decade, there have been several lawsuits of customers and interest groups against Essent/Ennatuurlijk claiming that they are paying too much (Nautilus, 2015). The most alarming case for Ennatuurlijk is from Tilburg, where an interest group subpoenaed Ennatuurlijk with a claim of €76 mil on behalf of the customers of the neighbourhood Reeshof (Reeshofwarmte, 2016). The verdict of this case is still pending at the moment of writing this thesis. Also Enschede had its issues with complaining customers, particularly in Roombeek and Tattersal. For Roombeek, the municipality, Essent and the neighbourhood association of Roombeek decided to issue an investigation into the matter. Based on a sample of 14 dwellings, the investigation concluded that the prices were in line with the Dutch Heat Act and some, due to the large size of the houses, had some issues with the inside installation (Borghuis, 2011). However, customers heavily criticized the study and questioned the impartiality of the study since it was conducted by Essent (Tubantia, 2011) .

In another lawsuit in Enschede, a customer in a rental house refused to be connected to the DHN of Ennatuurlijk and pay the yearly fixed costs for his connection. Although the Dutch law requires a tenant to accept a DHN, the judge ruled in the favour of the customer based on European legislation (Valk, 2013). This case might seem a minor issue, but the ruling of the judge might create precedence for other customers of DHNs, which provides an extra risk factor for the business cases of DHN.

- ***Struggling to make a sufficient return in the past***

In the media, Essent explained that they sold their DH operations because of insufficient returns (Straver, 2012). They also stated that DHNs did not fit the profile of Essent anymore, which would put its focus on innovation and sustainability in the electricity market (Straver, 2013). A study of The Dutch Competition Authority (Dutch: Nederlandse Mededingingsautoriteit, Nma) showed that the return of Essent on their DH activities was merely 0,3% in 2008 (Nma, 2010). The DHNs in Enschede, as their second biggest DHN (after Amernet in Noord Brabant), played a major part in the insufficient returns.

Despite these insufficient returns, Essent managed to sell their DHNs to PGGM (80% of the shares) and Dalkia (20% of the shares). Although, the involved parties have not disclosed any details about the deal, it seems likely that PGGM and Dalkia have depreciated the book value of the assets of Essent in order to develop a business case for their required return. PGGM, as a pension fund, are seeking stable long term returns (PGGM, 2014), which usually fits the profile of business cases DHNs. According to Nma, an sufficient return for DHN operators should be 6,3% in order to be able to cover returns for equity shareholders and debt capital (Nma, 2010). Mathijs Groeneveld, senior sales manager East region at Ennatuurlijk commented the following on this subject:

> "We (Ennatuurlijk) have learned a lot since our time as Essent. Our business cases now require a minimum return of 7/8%. There are many uncertainties and over time we have become much more careful in our assumptions in the business cases about gas prices and heat demand. Furthermore, we need firm contracts from stakeholders until we proceed with investments."

Success factors DHN Enschede

- ***Switching to Twence as main heat supplier: a win-win situation***

In 1997, Twence established a waste incineration in Hengelo to produce electricity. Although there were also plans to produce heat, it was not until 2008, when Twence expanded their operations with a third incinerator that gave them enough capacity to also produce heat. After negotiations with the DHNs in Hengelo as well as in Enschede, Twence decided to partner with Enschede. The business case with Enschede was less risky and more lucrative, since Enschede had already established a large heat demand with their DHN. Therefore, Twence invested €20 mil in a 5 km long pipeline from Twence to the CHP installation of Essent (now Ennatuurlijk) in Enschede. Wim de Jong, at Twence, elaborated as follows:

> "In essence, you have to have enough heating units to cover the cost, so that the cost/heating unit becomes lower than the generated revenue. We (Twence) did the investment ourselves, but in return, we could instantly serve a high demand. Furthermore, we made an arrangement with Ennatuurlijk that they will take a certain heat volume each year, which also covers a large part of the investment risk."

For Essent, the decision was also beneficial. Until 2011, the gas fired CHP installation was supplying the DHN of Enschede with heat, however, the margins between gas purchasing, and heat and electricity sales were low. Twence provided the opportunity to improve their margins significantly with heat from the waste incineration. Furthermore, along with the CHP, Twence increases the heat capacity of the DHN from 120 MW to 200 MW, providing the DHN with enough opportunities to expand.

- ***Subsidies to cover the upfront investment in the pipeline***

Although Twence did not disclose the exact amount of subsidies, they stated that the "the business case for the 5km pipeline would not be possible without subsidies". Twence has used the following subsidy programs to finance the €20 mil investment:

- “Energy investment deduction” (in Dutch: Energie-Investeringsaftrek) from the department of Economic Affairs
- “Unique opportunities deal” (in Dutch: Unieke kansen regeling) from the department of Economic Affairs
- “Sustainable energy production and energy savings subsidy” from the province of Overijssel.

7. Cross case analysis

This chapter will continue the case study analysis from the previous chapter by comparing the data from the cases with each other and complete the answer on the second research question:

What are the barriers that district heating networks currently face and what solutions do district heating companies provide?

The interviewees from the case studies were asked about the barriers and potential solutions within their own case, but also about barriers on DHN development in general. The data from the case studies were arranged along the business model components. Each section in this chapter discusses a business model component (Value proposition in 7.1, Architecture in 7.2, Network in 7.3, and Finance in 7.4). Each section shows a table with the barriers and solutions provided to these barriers that the interviewees discussed during the interviews. These common factors are discussed in more depth to determine how to generalise for all DHN.

7.1 Value Proposition

As discussed in Section 3.2, the value proposition consists of the product, the target market, and value elements. The value propositions of each case study are shown in Table 21 and the barriers are shown in Table 22. Both are discussed in the subsections below.

Table 21: Value propositions of case studies

	Hengelo	Nijmegen	Purmerend	Enschede
Product	Heat	Heat	Heat	Heat
Target audience customer acquisition	New residential building development and existing utility buildings	Primarily new residential building development	New residential buildings and small business customers	New residential building and (existing and new) utility buildings
Value element	Sustainable, convenience, comfort	Sustainable, convenience, comfort	Sustainable, convenience, comfort	Sustainable, convenience, comfort

Table 22: Barriers and solutions provided within the value proposition

Value proposition	Barriers	Provided solution
	Negative public image of DHNs.	Be transparent towards customers.
	Persuading customer: discrepancy between offering and customer needs.	Think along the needs of the customer.
	Acquiring existing residential buildings.	Work with a heat plan.

Product

One thing that immediately stands out is that there is little diversity in the product delivered to the customer, which is in all four cases heat. Nowadays it is also possible to deliver cooling through a DHN through absorption cooling methods, but the market for absorption cooling is very limited in the Netherlands. It is not common for Dutch dwellings to have air-conditioning due to the mild climate. Offices often do have air-conditioning, so there is a market potential there, but companies that can deliver this technology are scarce in the Netherlands and there are very few reported cases so far.

Target market

- *Barrier: Negative public image of DHNs*

According to many DHN operators there is still a negative public image of DHNs. Some argue that this is a heritage of the previous wave of DHNs from the 70's and 80's which were often badly maintained, and had high heat losses and faulty measuring devices. There is also the perception that DHNs are more expensive than individual gas heating, despite the *no more than otherwise principle* of the Dutch Heat act. Furthermore, interviewees argue that when it comes to energy services, customers are used to having a choice and perceive the monopolistic position of DHN as a step back.

- *Solution: be transparent towards the customer*

DHN operators argue that being transparent helps to get rid of the negative public image. The argument is that customers are more perceptible towards DHNs when they know what the cost and benefits of DHNs are, and they understand that the DHC is not taken advantage of them through their monopolistic position. It also helps when public institutions are involved in the DHN project, so there is someone in the project that does not have financial motives and can take away some of the financial risks.

Value element

Similar to the product, there is no differentiation in the value element of the offerings, all cases communicate sustainability, convenience and comfort as the value element for their product. It makes sense that DHNs do not differentiate from each other, since DHNs do not compete with each other for customers (i.e. they have a monopoly for a certain region). The main competitor for DHNs are individual heating alternatives, predominantly gas fired boilers. That is the benchmark DHNs use to present their value element.

- *Barrier: persuading customer, discrepancy between offering and customer needs*

We already saw in Section 5.1 that surveys among individual customers show that price is the most important criterium for most customers to choose a certain heating alternative. Interviews with DHN operator, industrial and commercial building owners confirm this sentiment. Although companies these days like to show a green face, this does not change that the price of DHNs needs to be competitive compared to other heating alternatives. Then customers are willing to consider all the other benefits that DHNs have compared to gas fired boilers. Furthermore, some building owners find it a hassle to go along with a DHN project, since it takes more time and is more complicated than a simple gas connection.

- *Solution: think along the needs of the customer*

Sometimes large-scale customers (e.g. offices, industrial buildings etc.) have an ambition of their own to become more sustainable, but they lack the resources or time to follow through on their ambition. There are different kinds of subsidies and incentives programme for renewable energy and energy efficiency initiatives for companies. In some cases, the DHN operator can present a better business case for the company if it combines a DHN with other renewable energy technologies and benefit from different incentive programmes. Furthermore, the DHN operator has the expertise to set up the project and unburden the company of the work. A good example is Eaton B.V in Hengelo were WNH developed a biomass boiler in combination with solar panels above a parking garage. WNH operates the biomass boiler, which also has capacity to serve other companies in the area.

- *Barrier: acquiring existing residential buildings*

In all cases, the customer acquisition efforts are focused on new residential building development and (new and existing) commercial building development. There is little customer acquisition within the existing residential buildings. As discussed in Section 4.2, a large market potential lies within the existing residential market. However, convincing a large group of individual residential building owners in a concentrated area to switch to district heating is almost impossible. It is possible trough housing companies who own a large stock of dwellings in a certain area. In that case, the negotiations are reduced to one party, the housing company, but still the price must be right for the housing companies, and the dwellings have to be located at a reasonable distant from the existing DHN to justify the investment in the infrastructure. This limits the opportunities for DHNs to a great extent.

- *Solution: work with a heat plan*

A heat plan (in Dutch: warmteplan) is a municipality council decision to designate certain areas in the city for a DHN. New development projects are required to connect to a DHN in this area or they have to come up with their own alternative that is equally or more environmental friendly than the DHN. With a heat plan you can take away some of the risk of load uncertainty of the DHN. Therefore, it is important for the DHN operator to foster a good relationship with the municipality in order to draw out a heat plan.

7.2 Value Architecture

The value architecture consists of the technological architecture and the organizational aspects behind the DHN. Table 23 shows the barriers and solutions derived from the interviews that cover the value architecture of DHNs.

Table 23: Barriers and solutions provided for the value architecture

Architecture	Barriers	Solutions
Organisational	Lack of knowledge and expertise.	Private public partnership (PPP) constructs as organisational mode to acquire knowledge and expertise.
	A DHC within the organisation of the municipality is unpractical.	
	Outsourcing operations is subpar solutions to lack of knowledge and expertise.	Unbundling of network activities and heat delivery into separate legal entities to become more attractive for private party partnership.
Technological	Reduced heat demand and energy efficient houses.	Develop small decentralized projects.
		Do not cut cost on quality.

Organisational

- *Barrier: lack of knowledge and expertise*

A barrier that interviewees across all four cases noted as important for DHN development was (a lack of) knowledge and expertise. Developing a DHN requires specialized knowledge such as technical knowhow about designing, tendering and operating DHNs, but also managerial activities such as customer acquisition, and back and front office management that local authorities attempting to develop a DHN often do not possess. Moreover, the margins in the business case are very low as it is, so there is barely any room to make mistakes along the way. DHN operators over the four cases admit that they often had to learn the hard way and that an experienced player on top is key to the success of a DHN.

- *Barrier: outsourcing DHC is a subpar solution to a lack of knowledge and expertise*

The DHNs in Purmerend, Hengelo and Nijmegen initiated all from the municipality. In the beginning, knowledge and expertise into DHNs was limited within these municipalities, which they decided to resolve by outsourcing many activities to private parties. The experiences can be summed up as unsatisfactory. The main argument is that even if you outsource many activities, you need expertise within the organisation to be able to ask the right questions and have control about the quality. Furthermore, to develop a DHN, input from various disciplines has to come together. The organisation that develops a DHN needs to have a good sense of the big picture and be able to integrate input from various disciplines. That part cannot be outsourced, you need to have that expertise within your organisation.

- *Barrier: a DHC within organisation of municipality can be unpractical*

In both Purmerend and Hengelo, the DHC operated for a long time (respectively 26 and 10 years) within the municipalities' organisation. The intentions of both municipalities, was to set up a separate company for their DHN activities, but through various reasons including the two barriers discussed in the subsections above, this took more time than expected. In the meantime, these DHN operators found that operating within the municipality limits some of their business activities, such as attracting equity partners. Furthermore, different political agendas within the municipality can cause uncertainty or influence strategical decisions that might not be in the interest of the DHN.

This is not to say that public parties should not be involved in the development of DHN, on the contrary. It is very common that public parties own infrastructure in the Netherlands. For instance, all the gas and electricity network operators require by law to have a public party as majority shareholder, but all these network operators are organised in separate companies.

- *Solution: public-private partnership*

DHN operators from all four cases explained that going in to the future, PPPs are going to a desirable organisational mode. The main argument of interviewees is that both local authorities as well as private energy and network companies possess vital assets for DHN development that the other party does not have.

One the one hand, you need private companies that have experience and expertise in the energy business to operate a DHN efficiently. Municipalities have no interest nor expertise to run an energy company, there main interest lies in reducing CO2 emissions. There is also the option to set up a public company and attract all the resources from outside (similar to SVP in Purmerend), but in general this is more expensive and time consuming. Private companies already have a front and back office in place and they can benefit from economies of scale.

On the other hand, infrastructure is a common public interest and DHN operators need the support of public authorities to develop a DHN. Clients, suppliers and investors are more willing to participate when a public party also invests in the network and has an equity share. Long-term public involvement shows trust and commitment towards the stakeholders, which can cover some of the uncertainties and risks that stakeholders of DHNs have. Furthermore, public authorities can use their equity share to protect the public interest and their goals towards CO_2 reduction. The public party can be the minority shareholder but have an equal say in the matters that are important to the public party through priority shares (e.g. sustainability, fair treatment for customers etc.).

- *Solution: split heat transport and heat delivery into spate legal entities*

Purmerend, Nijmegen and Hengelo choose to unbundle heat transport (network operator) and heat delivery (energy company) into two separate legal entities. The main argument for this type of unbundling is that it allows more independent management of activities and it can attract outsider investments more easily. Energy companies are more specialized in energy delivery and the surrounding activities such as customer service, billing, while network companies are more specialized in operating the network. These companies prefer to invest in the activities they control best, which is why DHCs separate the network activities and heat delivery into two legal entities. Furthermore, independent network companies and energy delivery services can respond better to regulatory incentives (e.g. tax benefits, subsidies).

In Purmerend the unbundling is only legal, ownership remains all in the hands of one shareholder (the municipality). In Nijmegen, also the ownership is unbundled between network operator (Alliander and the Municipality) and heat delivery (Nuon). Unbundling is common in the Dutch energy sector. For electricity and gas networks unbundling is required by law. With the development of new DHNs this type of unbundling has also become more common due to arguments presented above.

Technological

Information on the technological configuration are shown in Table 24. As to be expected, the heat supply is moving in the direction of cleaner technologies. Enschede and Purmerend went from old CHP units towards more CO_2 friendly technologies. Moreover, Hengelo and Purmerend have a primary heat supply with zero CO_2 emissions. For completely new DHNs, such as Hengelo and Nijmegen, low temperature DHNs were implemented which are more energy efficient and reduce more CO_2 than high temperature DHNs. Enschede and Purmerend are restricted to high temperature DHNS due to older building stock with radiator installation that are not suitable for low temperature district heating. As back-up and for peak heat demand, gas-fired technologies remain dominant because of their high reliability and low cost.

Table 24: Technological properties of the DHNs

	Hengelo	**Nijmegen**	**Purmerend**	**Enschede**
Strategy	Invest in decentralized projects throughout the city when opportunity arises.	Develop a DHN for a large scale residential building project of 12.000 dwellings	Redevelop an existing DHN with a new energy supplier	Connect an existing DHN with a new energy supplier
Heat supply	Industrial waste heat	Waste Incineration	Biomass boiler	Waste incineration
Primary network	40-25 ˚C	70-40 ˚C	90-70˚C	110-90˚C
Secondary network	40-25 ˚C and 70-40 ˚C	70-40 ˚C	90-70 ˚C	90-70 ˚C
Substations	Heat pumps and back-up boilers	CHP installation and back-up boilers	CHP installation and back-up boilers	CHP installation and back-up boilers

- *Barrier: reduced heat demand and energy efficient houses*

DHN operators noted the reduction in the heating demand of houses through better insulation is a potential threat for the revenue stream of DHNs as new development projects are in general more easily to connect. However, they also see it as an opportunity for more low temperature DHNs.

Furthermore, 90% of the current building stock will still be available in 2050 so they feel there is enough room to grow in the existing building stock.

- *Solution: decentralized projects*

For new DHNs, it is difficult to develop a DHN when there are no large-scale development projects going on in the city. A useful strategy that was adapted by Hengelo and suggested by some of the interviewees is to develop decentralized projects throughout the city whenever the opportunity arises to connect customers. These opportunities can for instance arise when energy contracts of commercial or industrial building owners are up, project developers initiate new building projects or if the DHC can convince housing cooperatives to connect to the DHN. The DHC connects these customers to (temporary) substations until the demand of the decentralized projects are large enough to invest in the primary network and the DHC has found a suitable supplier.

The benefit of this strategy is that you do not have to make a large investment into the primary network without having enough heat demand in place. The downside is that the margins on the energy purchasing, which usually consists of gas or biomass, for the decentralized projects are often low (sometimes even under the break-even point). This means that the DHC can come into financial problems if it cannot find a central energy source within a few years.

- *Solution: do not cut cost on quality*

Two DHN operators stated that lowering the initial investment by choosing inferior materials or products may be more costly in the long run. The infrastructure has to create revenue for 30 years. If the performance of the infrastructure or metering devices is lacking, this can result in many interruptions, repairs, and high heat losses, which will eventually be more costly in the long run. Furthermore, DHNs prefer to anticipate future heat demands and design the DHN to meet future requirements.

7.3 Value network

The value network is a description of the position of an organization in the value system and its relationships with different stakeholders. The barriers and solutions for the network component are shown Table 25 and will be discussed in the subsection below.

Table 25: Barriers and provided solutions for the network component

Network	Barriers	Solutions provided
	"Chicken and egg conundrum".	Strong willed initiator is needed to mediate the process and push the project forwards.
	Commercial building owners do not want a long-term contract.	Process management: ability to create trust, willingness and support from stakeholders.

- *Barrier: "Chicken and egg conundrum"*

A problem encountered by Hengelo and Nijmegen is often referred to as the "chicken and egg conundrum". A DHN requires the cooperation of many stakeholders with a variety of (conflicting) interest. Creating the right conditions for stakeholders may take a long time. A common problem is that you get caught in a conundrum: no-one wants to sign up to connect if you do not have a heat supplier or an infrastructure to supply the heat, and you cannot afford to put the infrastructure or convince heat suppliers to join unless you can demonstrate you have customers. Often the DHN operator or the municipality has to give extensive guarantees for both parties in order to cover the financial risks. Purmerend and Enschede did not have to deal with this problem, since they already had heat demand in place from the old DHN.

- *Solution: strong willed initiator to mediate the process and push the project forwards*

In three of the four cases, the municipality played a central role in the early stages of the DHN as initiator and financer. Initial stages of a DHN project can be very lengthy, there might be many times that the project seems to fall through. During this time, a party is needed to push the project forward and keep looking for opportunities to break impasses along the way. Many interviewees suggest that this is where the municipality can play a central role in the DHN development of DHN. There are various reasons that the municipality is the most suited for this role:

- The municipality often has a strong ambition to develop a DHN, but also the time and patience to see the project through.
- The municipality can function as an impartial mediator in the negotiation between the private parties.
- Companies are more at ease when the municipality is involved in the DHN project so that their needs will be met and they will not get the short end of the stick in the negotiations.
- Municipality is well connected with the local stakeholders, but also has connections with the Province and National government.

It might be necessary for the municipality to bring in an outside project manager with experience on DHNs to lead the process on behalf of the municipality, since municipalities often do not have someone internally with the experience to do so.

- *Barrier: industrial and commercial building owners do not want a long-term contract*

Interviewees from DHN operators as well as large-scale customers admit that industrial and commercial building owners prefer short-term contract (2/3 years) for their energy services. The reason is that they can test the market every few years and negotiate a better deal. DHNs on the other hand require long term contracts with large scale customers (10+ years) in order to have some certainty in their business case and be able to provide a competitive offer to the customer.

It is always a challenge to convince large-scale customers to give up their flexibility in return for sustainability and convenience.

- *Solution: process management, ability to create trust, willingness and support from stakeholders*

During the interviews, many respondents suggested certain qualities that refer the process and how to manage the process in order to get trust, willingness and support from stakeholder. The initiator of a new DHN plays a crucial role as the process manager in the initial development stages of a DHN. Creating the right conditions for stakeholders to commit may take a long time. It is the role of the district heating company to keep the dialogue alive, bring parties together and create goodwill and trust among the parties by:

- knowing the interest of all parties involved;
- managing expectations from the stakeholders involved;
- not steering on strict objectives and time tables early on, because the interdependencies of the stakeholders makes it difficult to predict when all parties can come to an agreement.
- educating the public on the benefits of a DHN and keep the media and public informed during the process.

It is difficult to explain what the exact actions or decisions are "best" for the process in every case, because this may vary widely among the cases. It seems that instinctive qualities of the project manager (or team) in charge plays an important role in the process. That is why many interviewees emphasize on expertise and experience for DHN development.

7.4 Value finance

The last component is the *finance structure*. This dimension depicts information related to costing, pricing methods, and revenue structure. See Table 26 for the barriers and provided solutions of the finance component.

Table 26: Barriers and provided solutions of finance component

	Barriers	Provided solutions
Finance	Marginal business case	Governmental subsidies to bridge the financial gap in business cases of DHNs.
		Advantages of heat needs to be priced.
	Economic crisis.	

- *Barrier: marginal business case*

This barrier was already discussed in the literature (see Section 4.4) and also confirmed widely by the interviewees. To summarize the issues from the cases: DHNs require a large upfront investment, have low margins on energy purchasing, have long payback times, and involve high risks on future demand and gas prices.

- *Solution: subsidies to fund DHN development*

All case studies used some sort of subsidy or grant to cover the investment into the DHN and present a feasible business case for the stakeholders. In addition, the interviewees confirm that subsidies are absolutely crucial and most (if not all) DHNs would not exist without public investments. Looking into the past, infrastructure has always been a public good and funded by the government. This was also the case with electricity and gas networks, from which the majority is still owned by government institutions. The future of DHNs very much depends on how the Dutch government wants to deal with their energy policy. The Dutch energy plans bring DHNs forward as one of the pillars to cut down CO_2 emissions (SER, 2013). Considering the dependence of DHN on subsidies already, much of the faith of DHNs seems to rely on whether the government decides to implement measures to execute their sustainable energy plans.

- *Solution: advantages of DHN need to be priced*

According heat suppliers and DHN operators a problem of the current DHNs is that advantages such as CO_2 reduction and renewable energy productions are not valued in the business cases of DHNs. A key factor for the future of DHNs could be to put instruments in place through which the advantages of DHNs can be priced.

Some interviewees suggest that energy taxes can be an appropriate instrument to price the advantages of DHNs. Currently energy consumers are charged taxes on electricity and heat, however, the government does not distinguish the source of the energy (e.g. gas, coal, renewables etc.). Furthermore, based on the energy content, taxes for electricity are much higher than gas. In 2016, the Dutch Senate approved a new tax plan that determines energy taxes based on the energy content and CO_2 performance of energy sources. This means that taxes for gas will be raised and taxes on electricity will decrease, which is beneficial for DHNs. The maximum price DHNs can charge is based on the price of gas ('no more than otherwise' principle in the Dutch heat act). This means that the increase of taxes on gas means that DHNs can charge more, thus improving their business cases.

Another suggestion is to "socialise" the cost of DHNs, which means that all Dutch citizens pay for the infrastructure of DHNs through taxes. One argument is that gas and electricity networks are also socialised, which puts DHNs at an unfair disadvantage. Another argument is that CO_2 reductions is a national public concern of the Dutch people, which means that the government should finance energy alternatives that can cut down CO_2 emissions such as DHNs.

- *Barrier: economic crisis*

A common problem for new development DHNs has been the economic crisis of the few past years. Many business cases were not feasible anymore because of government budget cuts, temporisation of the housing stock and stagnating gas prices.

7.5 Conclusion

The purpose of Chapter 6 and 7 was to answer the following question: What are the barriers that district heating networks currently face and what solutions do district heating companies provide? The barriers to DHN development and potential solutions to these barriers from the interviews are shown in Table 27.

Table 27: Overview of barriers and provided solution within the DHN business models

	Barriers	Provided solutions
Value proposition	Negative public image of DHNs.	Be transparent towards customers.
	Persuading customer: discrepancy between offering and customer needs.	Think along the needs of the customer.
	Acquiring existing residential buildings.	Work with a heat plan.
Value Architecture Organisational	Lack of knowledge and expertise	Private public partnership (PPP) constructs as organisational mode to acquire knowledge and expertise.
	Outsourcing is a subpar solution to lack of knowledge and expertise	
	DHC within organisation of municipality is unpractical	Unbundling of network activities and heat delivery into separate legal entities to become more attractive for private party partnership.
Technological	Reduced heat demand and energy efficient houses	Develop small decentralized projects to create demand and minimize risk
		Do not cut cost on quality
Network	“Chicken and egg conundrum”	Strong willed initiator to mediate the process and push the project forwards
	Commercial building owners do not want a long- term contract	Process management: ability to create trust, willingness and support from stakeholders
Finance	Marginal business case: high initial investment	Governmental subsidies bridges the financial gap in business cases of DHNs
		Advantages of heat needs to be priced
	Economic crisis	

The value propositions towards end customers in the residential sector showed little variations between the case studies. The focus is more on the relationship between municipality, developer, and large-scale building owners, because these are the stakeholders that make the decision to develop a DHN. The key is to create goodwill and trust among these parties, since financial benefits are often not present. The analysis of the value proposition also showed that there is still a negative public image among customers about DHNs that was mostly created by mismanagement of the older DHNs. Educating customers about the modern, energy efficient and cleaner DHNs can take away some of these negative perceptions.

The case studies showed remarkable barriers in organizational and stakeholder management. Interviewees reported that there was a lack of knowledge and expertise in DHN development. The reason for this is that municipalities had to initiate the development of DHNs in the beginning with little experience, because private companies did not see any financial benefit in DHNs. Although lack of technical knowledge could be somewhat outsourced to consultancy firms, the lack of experience with the process management cannot be outsourced easily. PPPs with private energy and network companies were used to overcome the lack of knowledge and experience. At the same time the private companies could build a reasonable return in their business case due to the financial backing of the municipalities. Overall, the financial component seems the key limiting factor for DHN development, which makes public involvement necessary for DHN development.

8. Recommendations for business model syntheses for DHN development

This chapter will focus on the following question:

How can district heating companies configure their business model to develop sustainable district heating networks in the Netherlands?

The previous two chapters showed barriers for DHN development in the Netherlands and solutions to these barriers provided by four case studies. The purpose of this chapter is to use the findings from the literature and the case studies to provide recommendation to develop successful business models for DHNs. The unified business model by Al-Debei and Avison's [2010] is taken as a starting point to point out the key areas of attention within the business model components when constructing the business model for DHNs.

A side note to consider is when to develop the business model. The department of economic affairs published a blueprint for the development of DHNs, which consists of five stages (RVO, 2014):

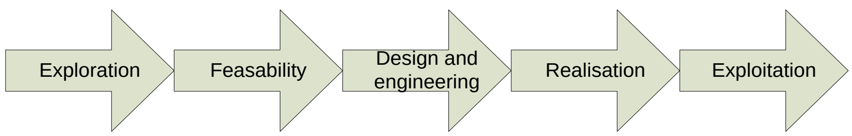

Figure 19: stages of DHN development

During these developments stages, the stakeholders of the DHNs have to make decision on the business model components. In general, a complete business model has to emerge before the realisation stage (i.e. the construction of the primary network), because at this point the DHN owners have to put up the large investment in the infrastructure and the point of no return will pass. Therefore, the business model syntheses primarily happens in the first three stages and the focus will be on these stages (exploration, feasibility, and design and engineering stages). Particularly, in the initial stages it can be a good exercise to develop a business model in order to test the business logic and discover any discrepancies early on.

8.1 Value proposition

As we saw earlier, the intended value element is the same for almost all DHNs (i.e. sustainable, comfortable and convenient heating) towards home owners and tenants. To develop a DHN, the focus in the first place should be on creating value for housing companies, developer and large-scale building owners (office and industrial buildings). The focus of the DHC should be on creating good will and trust, since financial gains are often scarce at best. Furthermore, working on a heat plan with the municipality for the city can help to take away some of the initial load uncertainty of the DHN and help provide more financial offering towards existing building owners.

Another key point to consider is that although tenants and home owners do not actually make a decision to connect to a DHN, it is important for the DHC to have a sense of how the community perceives a new DHN in order to create support and prevent any backlash from the community. Otherwise the backlash can be picked up by the local media, which in turn can influence the decision-making process of a municipality council or building owners. Therefore, it is important to educate the public on the benefits of a DHN and keep the media and public informed during the process.

8.2 Value architecture

Technology

DHC do not perceive technology as a barrier, rather as an opportunity that needs to be explored. The first step Is to find out if there is any (potential) demand in the city for a DHN and are there any energy suppliers (e.g. waste incineration, geothermal sources, energy plant etc.) nearby to feed the DHN or can one be created against reasonable cost (e.g. CHP, biomass boiler). With new DHNs it is key to design a flexible network that takes future possibilities to grow the network into account and can anticipate technological developments. These developments include low temperature DHNs to go along with lower heat demand of future buildings.

Organizational

Although the Municipality has a key interest (i.e. CO_2 reduction) and important assets for the development of DHNs. it is important to have a separate organization set up outside the municipality to develop a DHN. For new DHNs, this is preferably done through a PPP in which the private companies can bring experience and expertise in the energy business to operate a DHN efficiently. The municipality is needed to ensure the sustainability of the DHN. Furthermore, the municipality is well connected with the local stakeholders, and also has connections with the Province and National government. Furthermore, unbundling of the network operations and energy delivery activities into two legal entities can attract outsider investment more easily because private companies prefer to invest in the operations they can control best.

8.3 Value network

Creating support from the stakeholders is a key element of the business model of DHNs. The aim is to find out which parties are really interested and move the process along with these parties. However, it is difficult to steer on strict objectives and time tables early on, because of the many complexities and interdependencies of the stakeholders that make it difficult to predict when all parties can come to an agreement. Furthermore, the stakeholders should want to participate in the project and not be forced into agreements somehow (e.g. through building regulations), because this may backfire in the long run. Most stakeholders are willing to participate in a DHN project even if there is no financial benefit. However, they do not want their core business to be negatively influenced by the DHN or to be bothered by the hassle of a large-scale infrastructure project. Therefore, it is key to manage the process with these stakeholders to create trust and willingness to participate. Preferably the municipality takes this role. The municipality can function as an impartial mediator in the negotiation between the private parties. Long-term public involvement shows trust and commitment towards the stakeholders, which can cover some of the uncertainties and risks that stakeholders of DHNs have.

8.4 Value finance

Developing feasible business cases is particularly difficult for DHCs. With the competitive Dutch gas network and institutional boundaries of the Dutch heat act there is not much room to increase revenue. Therefore, it is crucial to get funding and subsidies from public parties such as municipality, province, national government and even the EU.

A useful strategy for when you do not have the funds for a large investment into the primary network is to develop decentralized small-scale projects throughout the city. When there are sufficient decentralized projects you can then connect them together with the primary network in one large DHNs.

8.5 Conclusion

This chapter focused on the following question: How can district heating companies configure their business model to overcome the barriers to district heating network development? The key takeaways for the business model configuration are summarized below:

- In the initial stages of the development of new DHNs establishing a relationship with key stakeholder is more important than value propositions towards end customers.
- During these stages, the municipality plays a key role as the financer, initiator and mediator to create trust and willingness from the stakeholders.
- Set up a separate company for the DHN with public and private involvement, preferably in a PPP:
    - to acquire knowledge and experience from private parties to run a DHN;
    - to have long term commitment from public party to create trust.
- Unbundle network related activities and energy delivery activities in separate legal entities to attract private investment more easily.
- Develop decentralized projects throughout the city and connect these projects together in a large DHNs when this becomes feasible.

- Take advantage of the Province and National government subsidies for CO_2 reduction.
- For the network, it is important to have a flexible design to take future heat demand and technological developments into account.

9. Discussion

9.1 Interpretation of findings

This research started out by discerning the problem of DHNs seeming unable to seize their potential in the Netherlands. Considering the climate, high population and heat density, and public support for DHNs, there is indeed a large potential for DHNs in the Netherlands (see also e.g. Hoogervorst, 2017; Cor Leguijt & Schepers, 2014). Besides obvious financial barriers that come with large infrastructural projects, this study uncovered that there are key organizational and process related issues in the business model of DHNs that impede DHNs to seize their potential. These issues include a lack of knowledge and experience with the inherently complex process of developing a DHN in the Netherlands and a lack of support due to conflicting interests of the stakeholders. Furthermore, the highly competitive gas network in the Netherlands puts even more pressure on the process by creating a large financial constraint on DHN projects, which provides little margins for mistakes or misfortunes. To overcome these barriers, the case studies showed solutions with the organization and network component of the DHN business models. These solutions include PPPs between municipality, and network operators and energy companies. Network operators and energy companies bring the experience and expertise, while the municipality can cover the financial gap in the business case. Furthermore, stakeholders of the DHNs stressed the importance of having a strong-willed initiator to mediate the process and an experienced process manager with the ability to create trust willingness and support from stakeholders.

These findings are interesting in relation with the current scientific literature on DHNs. The literature review on the barriers for DHNs in Chapter 5 showed that scientific literature on DHNs predominantly focuses on technological aspects. These include mostly issues as heat losses, optimal network design, and energy and exergy efficiency of the network. Dutch DHN trade journals brought more insight in some of the barriers for DHNs in the Netherlands, however, the focus here was also on technological applications of DHNs or institutional aspects (e.g. Dutch heat act, monopolistic position and other regulatory schemes).

In contrast, the emphasizes within the interviews was more on organizational and process related aspects of DHN development, such as the difficulties to keep parties interested due long negotiations and bringing knowledge and experience within the organizations. DHCs did not perceive technology as a barrier, but rather an aspect that needed to be figured during the process. A plausible explanation to why researchers focus less on these organizational and process related aspects can be because they are specific for the Dutch context and the scientific research, which comes from a variety of different countries, does not perceive these problems. For instance, much of the scientific literatures comes from Scandinavian countries were DHNs are much more embedded in the energy system and the organizational problems are less of a factor. Another explanation which might also contribute to these process related factors coming to light is choosing for interviews as the research method. The interviewees can rant freely about the problems they experience, which can provide a deeper understanding of DHN development in the Netherlands.

Although this was a qualitative study, we do believe the findings on the barriers and solutions provided to these barriers by the case studies are transferrable to other new DHNs in the Netherlands. The characteristics of DHNs business models overall show many similarities as those in the case studies. First of all, there is not one new city wide DHNs (as shown in Table 6) that has not been helped by public funding or subsidies. Secondly, the DHN landscape in the Netherlands shows a clear trend toward cleaner sources. New city wide DHNs are focused on sustainability with heat sources from biomass, waste incinerations and industrial waste heat (see Table 6). Also, some of the largest DHNs in the Netherlands are replacing old CHP installation with heat from waste incinerations and biomass such as in Rotterdam, Amsterdam north and west, Arnhem, Purmerend and Enschede.

Thirdly, there is a clear trend towards a central role of municipalities as initiator and the preferred public private modes of collaboration. Out of the 13 DHNs that satisfied the criteria of new city wide DHN developments 9 are PPPs, 3 are privately operated and 1 is publicly owned (see Section 6.1). As discussed in Section 7.2, most municipalities goal is to cut down carbon emission, they do not have the ambition to start an utility company. However, due to the low returns, private parties did not want to take risk on their one, which forced municipalities to start the development of DHNs if they wanted to realize their CO2 emissions. These trends indicate that the barriers perceived with DHNs in this study are common practice for new Dutch DHNs and the business model recommendation provided in this study can be helpful for new city wide DHN development.

This thesis used the business model framework to study the problems of DHNs in the Netherlands. Business model research is a relatively new field and research on the business models of DHNs was limited. One of the functions of the business model concept is a tool to analyze and compare businesses with each other on how they create, deliver, and capture value (see Section 2.2). In this sense, the business model framework provided a useful approach to identify, categorize and analyze the barriers of DHNs. Furthermore, Zott et. al. (2011) explained that business models emphasize a system-level, holistic approach toward explaining how firms “do business” and business models center on the logic of how value is created for *all* stakeholders, not just how it is captured by the focal firm. Such a comprehensive view fits well with the context of DHNs with a local set of stakeholders with different interest dependent upon each other to create value.

Another function of business models is to understand how businesses can innovate through their business models with new ways to create, deliver and capture value. In the field of sustainable development, business models are an useful instrument to explore innovative ways to capture economic value while delivering social and environmental benefits, which coincide with the objectives of new DHNs in the Netherlands. However, we found the application of that aspect of business model limited for DHNs in the Netherlands. DHNs are somewhat restricted by the Dutch heat act and financial barriers limit the opportunities to innovate on the business model even more. Furthermore, DHNs are long term infrastructural projects that cannot quickly change strategy or pivot into new opportunities.

9.2 Limitations of research

Since this was a qualitative study, one important limitation of this research was that the significance of the barriers and the solutions provided to these barriers where not explored in depth. Measures were taken through data triangulation by interviewing different stakeholders of DHNs (e.g. DHN operators, heat suppliers and customers) and verify information with different sources (news articles, municipal record and interview) to ensure that a set of barriers was found that is significant. However, how much these barriers impact the development of DHNs was not investigated through statistical means.

Another limitation of this study was that the institutional environment was treated has a constant in this study. However, the institutional environment is subject to change, which means that new governmental policies and regulations can take away (or cause) some of the barriers for DHN development. Moreover, the government has probably the largest influence on the future of the DHNs through the Dutch heat act, but also through their energy policy in general (e.g. subsidies, grants, CO_2 regulations). Overall, the Dutch government support the development of DHNs as part of their CO_2 reduction strategy, however in practice the national support is limited to subsidies for cleaner energy. Actions to develop DHNs are left at the will of municipalities with the help of provinces.

The third limitation is that the focus of this study has been on city wide DHNs. As we discussed in Section 4.2, the definition of DHNs can include block heating, heat exchange between industrial companies or small scale DHNs. We choose to study DHNs with a city wide with the aim of reducing carbon emissions, because these are the most challenging DHNs to develop and have a large potential to cut down CO_2 on a wide scale. However, there are also opportunities to reduce carbon emission in small scale DHNs on community level. There are some experiments and studies throughout the Netherlands of creating self-sufficient energy communities with DHNs with only few houses or a small neighbourhood. The findings of this study might be limited for those DHNs, since they are working in a different (smaller) playing field, which can mean that the organizational and network related issues might be less of a factor. These communities are rather focused on innovate technologies to become completely renewable and self-sufficient, for which perhaps technology might be a much larger barrier than in city wide DHNs.

10. Conclusion

10.1 Conclusion

This research studied barriers of DHN development in the Netherlands and the solutions that DHNs provided to overcome these barriers through their business models with the purpose of answering the following question:

> *How can district heating companies configure their business model to overcome the barriers of district heating network development?*

The main conclusion is that there are three key ingredients for a successful business model of DHNs: *willpower, knowledge* and *capital*. First, there has to be a party that has the willpower to initiate, develop and operate a long term infrastructural project with low financial returns. Out of all the stakeholders of DHNs, municipalities possess the most interest and willpower to develop city wide DHNs, because DHNs have the potential to achieve the ambition that many municipalities have to cut down CO_2 emissions. Furthermore, the municipality is often well connected with local stakeholders and can function as an impartial mediator to break impasses between stakeholders. Therefore, municipalities play a central role in the DHN development.

Although municipalities have the willpower to develop a DHN, they often lack *knowledge* and experience to develop and operate a DHN. Energy companies and network operators do possess the necessary knowledge and experience to develop a DHN, however, the low financial returns are often not worth to take the risk of a long-term project for them. Many DHNs found a PPP construction an ideal organisation mode to combine the vital assets of both parties. In this way, the municipality can benefit from the expertise of the private companies, while the private party can operate the DHN at a reasonable return due to financial backing of the municipality. To become more attractive for investment of private companies, municipalities can unbundle heat transport (network operator) and heat delivery (energy company) into two separate legal entities. Private companies prefer to invest in the activities they control best, which is why it is sensible to separate heat transport (i.e. operating the primary network) and heat delivery (i.e. energy company related activities: energy delivery, customer service and billing) into two legal entities.

The last and most challenging ingredient is *capital*, because developing feasible business cases for DHNs is particularly difficult. DHNs require a large upfront investment, have low margins on energy purchasing, have long payback times, and involve high risks on future demand and gas prices. A useful strategy to avoid making a large upfront investment into the primary network without having enough heat demand in place is to develop decentralized projects throughout the city whenever the opportunity arises to connect customers. The DHC can invest in a primary network when the demand of the decentralized projects is large enough. Beside this, public investment remains crucial for DHN development and most (if not all) DHNs would not exist without it.

10.2 Practical relevance

The research has practical relevance by providing recommendations on business models of DHNs, which can contribute to a more sustainable future for the heating sector. Scientists have reached widespread consensus on climate problems, however, the road towards a future of renewable energy sources remains highly uncertain. This study provided practitioners with a set of guiding principles to enhance their chances to develop new, successful business cases for sustainable DHNs. In turn, these sustainable DHNs can contribute towards the wider climate goals of the EU. Beside this, insight in the business models of DHNs helps practitioners understand what various stakeholders of DHNs value and how to create business models to facilitate the cooperation of these stakeholders.

Although some of the recommendation in this study seem apparent from the outside, in practice the conflicting interest of the stakeholders can cloud the judgement of the decision makers. For instance, this study showed that having a PPP in the early stages can be beneficial for municipalities, however, this reasoning is not often clear cut to them from the outset. Although many DHNs have end up in a PPP, they often not start out as one. Municipalities prefer private companies to develop a DHN on their own, however, the private companies often refuse to develop a completely new DHN unless the majority of the investment comes from public funds. Municipality councils are not eager to hand a large sum of money to private companies. Therefore, municipalities in the past have often decided to develop the DHN on their own, because they have to make the investment themselves anyway, municipalities reckon that might as well get a return from the DHN by developing a business case on their own. This study showed that going to the startup stages on their own, may even be costlier and time consuming for the municipality than going with a PPP in the first place. Then, after a couple of years the municipalities often make the decision to transition into a PPP after all. In retrospect, the municipality might save time and money by investing in the infrastructure and partnering with a private energy company from the beginning. This thesis has distilled these retrospective views from interviews with DHN operators and their stakeholders into recommendations that can benefit municipalities who are trying to develop new DHNs. The DHN development within the case studies were confronted with many adversities and other municipalities can benefit from the experiences of these DHNs to prevent some of their mistakes and apply their lessons learnt.

Lastly, unless there is going to come a major disruptive innovation in the heating sector, the switch from a fossil fuel system to a renewable and clean heating sector needs major public investment with limited financial returns. Humanity has not the luxury to wait for a disruptive technology anymore, because the threat of climate change is urgent and disastrous. Currently, DHNs are the most promising technology in the heating sector to cut down CO_2 emissions. Therefore, it is up to the (local) government institutions to face the barriers head on and make the transition happen before it is too late.

10.3 Theoretical relevance

This research contributes to the scientific domain of district heating and business models by providing insight on the business models of DHNs. In the field of business-related literature, there is still a clear trend towards analyzing the relevance of the business model concept. In particular, researchers want to test the business model concept in practice. Identifying and classifying business models of DHNs is therefore fruitful to the general discussion on business model theory. Beside this, barriers of DHNs are mainly studied from a policy perspective or a purely technical and design perspective. Business models provided a fresh perspective to comprehensively study the barriers of DHNs and determine how DHCs can develop DHNs despite these barriers. Lastly, since the goal of many scholars is to contribute to a sustainable future, this study attempts to provide a stepping stone in that direction.

10.4 Future research

Considering the qualitative nature of the study, the findings on the barriers of DHN development and the recommendations for the business model of DHN can be treated as propositions. Scholars can empirically test these propositions to determine the impact of these findings. Then, scholars can focus future studies on the most significant results that can improve the business model of DHNs.

This study showed that the municipality often plays a central role in the development of DHNs. To help municipalities be more effective in their efforts, future research could focus on what kind of skills and actions municipalities need to adopt to mediate effectively between stakeholders. Furthermore, studies can focus on what type of policies can improve the willingness of stakeholders to be part of a DHN.

Another outcome of this study was that PPPs can be used to overcome some of the barriers of DHNs. Future studies can elaborate on what criteria have to be met to make these collaboration work for DHNs. It might also be interesting to explore additional methods to overcome the lack of expertise within the municipality (instead of PPPs) so that public funds are spend more effectively or focus on other types of collaboration that might be more effective for DHN development.

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Appendices

Appendix A: District heating network technologies

A complete overview of the energy supply side, including the energy sources, conversion technologies, and the energy products delivered to the distribution system of the DHN are shown in Figure 20.

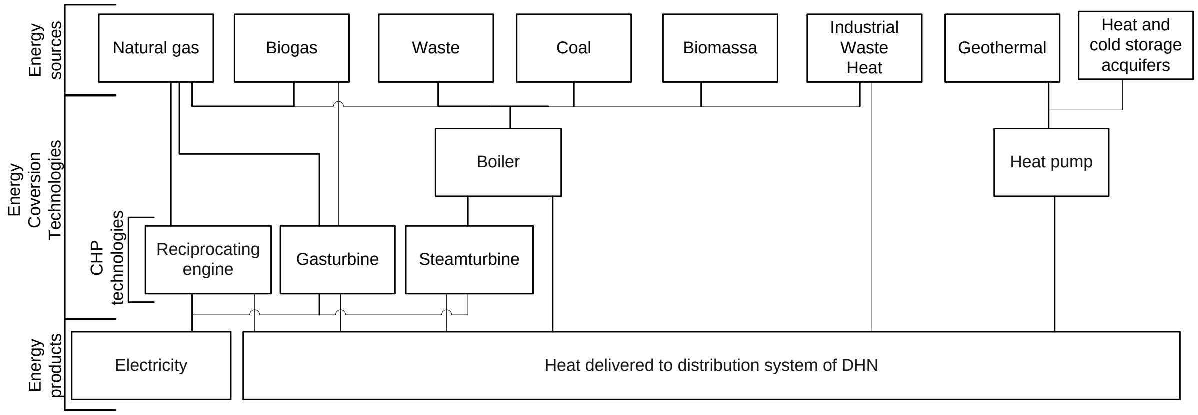

Figure 20: Overview of the energy supply to the distribution system of DHNs

A.1 Energy conversion technologies of DHNs

There are four main ways to converse energy in heat for the DHN: Combined heat and power (CHP) technologies, boilers, industrial waste heat and heat pumps. Each of the conversion technologies will be described in the sections below.

A.1.1 Combined heat and power (CHP)

Combined heat and power (CHP), also known as cogeneration, is the simultaneous production of electricity and heat from a single fuel source, such as: natural gas, biomass, biogas, coal, waste heat, or oil (EPA, 2015). For comparison, an conventional electricity conversion system has an energy performance between 30% and 50% because the generated heat is not used, while a cogeneration systems can have an energy efficiency of +80% (van beek).

CHP systems can be characterized either as topping-cycle or bottoming-cycle generation. Topping-cycle systems produce electricity first, then recover the excess thermal energy for heating or cooling applications. By contrast, bottoming-cycle systems, also known as “waste heat to power,” are a process whereby waste heat from an existing process is used to produce electricity. To determine what thermodynamic cycle is better suited for topping or bottoming application, they can be ranked according to their operating temperature range (Korobitsyn, 1998), as shown in Figure 21. High-temperature cycles are good candidates for topping cycles, and medium- and low-temperature cycles for bottoming (Korobitsyn, 1998). However, some cycles, such as the Stirling and Rankine cycle, can be used for both topping and bottoming cycles.

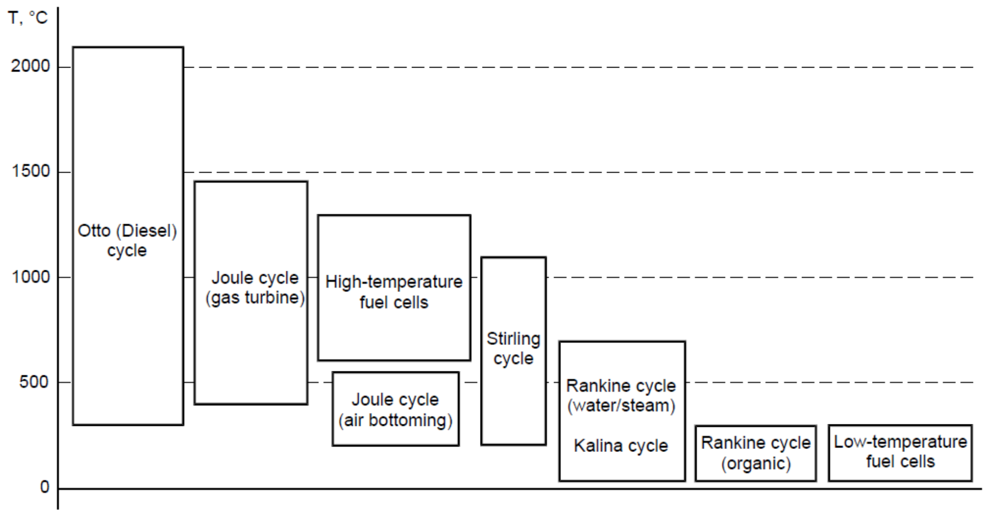

Figure 21: Temperature range of thermodynamic cycles used for CHP technologies

All the thermodynamic cycles shown in Figure 21, except for fuel cells, are a class of technologies known as heat engines. Heat engines combust the fuel to produce heat, and a portion of that heat is utilized to produce electricity while the remaining heat is exhausted from the process. The three most common technologies used in CHP are gas turbines, steam turbines and reciprocating engine. These technologies will be explained briefly in the sections below.

A.1.1.1 Gas turbines and reciprocating engine

Gas turbine or reciprocating engine[7] CHP systems generate electricity by burning fuel and then use a heat recovery unit to capture heat from the combustion system's exhaust stream (EPA, 2015) (see Figure 22). This heat is converted into useful thermal energy, usually in the form of steam or hot water.

[7] Reciprocating engine is mentioned here becomes it has the same lay out. However, how the energy is converted differs from gas turbines and this will be discussed in section 3.1.1.3.

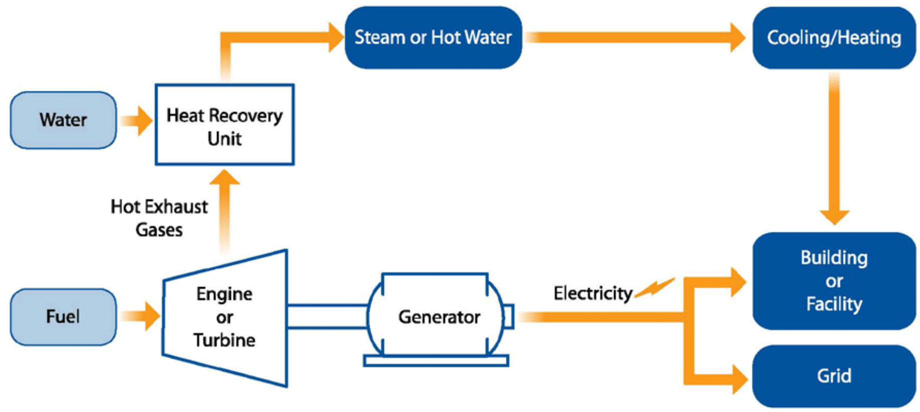

Figure 22: overview of gas turbine and reciprocating engine CHP systems adapted from EPA (2014)

Gas turbine systems operate on the Joule dynamic cycle, a constant pressure open cycle heat engine (Darrow, Tidball, Wang, & Hampson, 2014). The Joule cycle consists of a compressor, a combustion chamber, and an expansion turbine. The compressor heats and compresses the inlet air which is then further heated by the addition of fuel in the combustion chamber. The heated air naturally wants to increase in pressure and expand. The hot air and combustion gas mixture drives the expansion turbine producing enough energy to provide shaft-power to the generator or mechanical process and to drive the compressor as well.

A.1.1.2 Steam turbines

Steam turbines normally generate electricity as a byproduct of heat (steam) generation, unlike gas turbine and reciprocating engine CHP systems, where heat is a byproduct of power generation. Steam turbine-based CHP systems are typically used in industrial processes, where solid fuels (biomass or coal) or waste products are readily available to fuel the boiler unit (EPA, 2015). The energy is transferred from the boiler to the turbine through high pressure steam that powers the turbine and generator. The separate boiler enables steam turbines to operate using a large variety of fuels, from clean natural gas to solid waste, including all types of coal, wood, wood waste, and agricultural byproducts.

The thermodynamic cycle for the steam turbine is as the Rankine cycle. This cycle is the basis for conventional power generating stations and consists of a heat source (boiler) that converts water to high pressure steam (Spellman, 2013). In the steam cycle, water is first pumped to elevated pressure, which is medium to high pressure, depending on the size of the unit and the temperature to which the steam is eventually heated. It is then heated to the boiling temperature corresponding to the pressure, boiled (heated from liquid to vapor), and then most frequently superheated (heated to a temperature above that of boiling). The pressurized steam is expanded to lower pressure in a turbine, then exhausted either to a condenser at vacuum conditions, or into an intermediate temperature steam distribution system that delivers the steam to the industrial or commercial application (EPA, 2015).

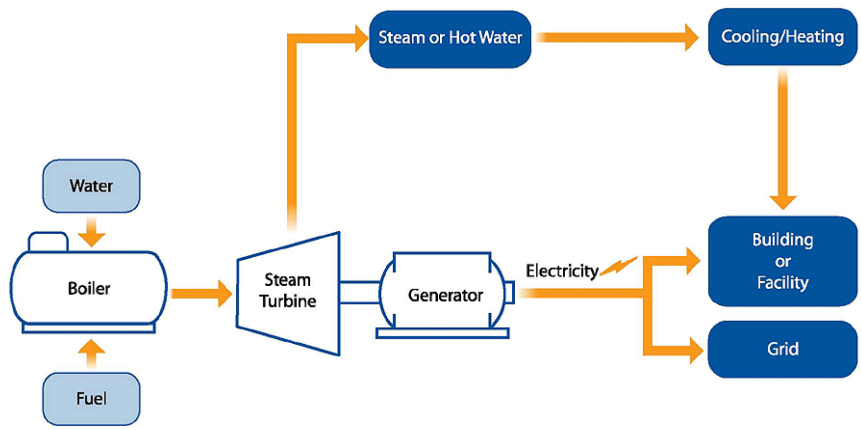

Figure 23: Overview of steam turbine chp adapted from EPA (2014)

A very common application for DHN is the steam turbines located in waste incineration plant. Unlike a fossil-fuel-fired power plant, a Waste to Energy (WtE) plant is usually located close to its energy source, which is often a populated urban or industrialized area (Ryu & Shin, 2012). Due to this reason, WtE plants can operate in a CHP mode, that is, the residual heat in the steam after power generation is exported to a DHN or to nearby heat demanding industries as process heat (Ryu & Shin, 2012).

To increase the efficiency even more combined cycle units are used in energy plants. In a combined cycle unit, a gas turbine generator generates electricity and waste heat is used to make steam to generate additional electricity via a steam turbine. Combined cycle power plant as in name suggests, it combines existing gas and steam technologies into one unit, yielding significant improvements in thermal efficiency over conventional steam plant (Ramireddy, 2012).

A.1.2 Conventional boiler

A boiler is "a closed vessel in which water or other liquid is heated, steam or vapor is generated, steam is superheated, or any combination thereof, under pressure or vacuum, for use external to itself, by the direct application of energy from the combustion of fuels, from electricity or nuclear energy" (Ezwan, 2012). Conventional heating systems consist of gas powered boilers that use natural gas for generation of heat for domestic hot water and space heating. Natural gas enters the boiler from a pipe in the street. The boiler contain a combustion chamber in which hot gases are created by burning the gas (see Figure 24). This is surrounded by a heat exchanger, which transfers heat from the gases into the water inside, heating it up. In condensing boilers, a second heat exchanger removes even more of the heat from the flue gases. It pre-warms water coming back into the boiler from a heating system, so you burn less gas to heat the water up. Although the boiler in dwellings burn natural gas, many more fuel option exist, such as coal or biomass.

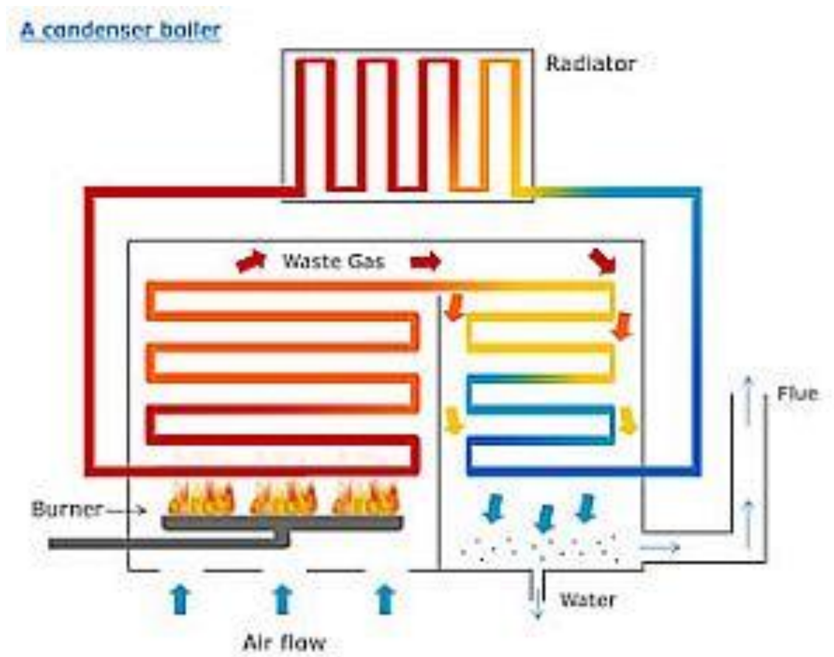

Figure 24: Overview of a condenser boiler adapted from Barwise (2015)

For DHNs gas boilers are used as a back up option for peak demand in the winters. Beside this, large scale biomass boilers are also used to provide heating for an entire DHN (see e.g. Stadsverwarming Purmerend B.V., 2014).

A.1.3 Heat pump

There are many different kinds of heat pumps, but they all operate on the same basic principle - **heat transfer (Salem, 2009). Heat moves from the higher temperature object to the lower one. Based on this principle,** heat pumps use a refrigerant to move heat during the winter inside the building and release heat during the summer to the outside. So heat pumps do not generate heat themselves, it just moves the heat from one place to another.

The principles of the heat pump are illustrated by a air-to-air heat pump in Figure 25. Every heat pump consists of four basic components: evaporator, compressor, condenser and expansion valve.

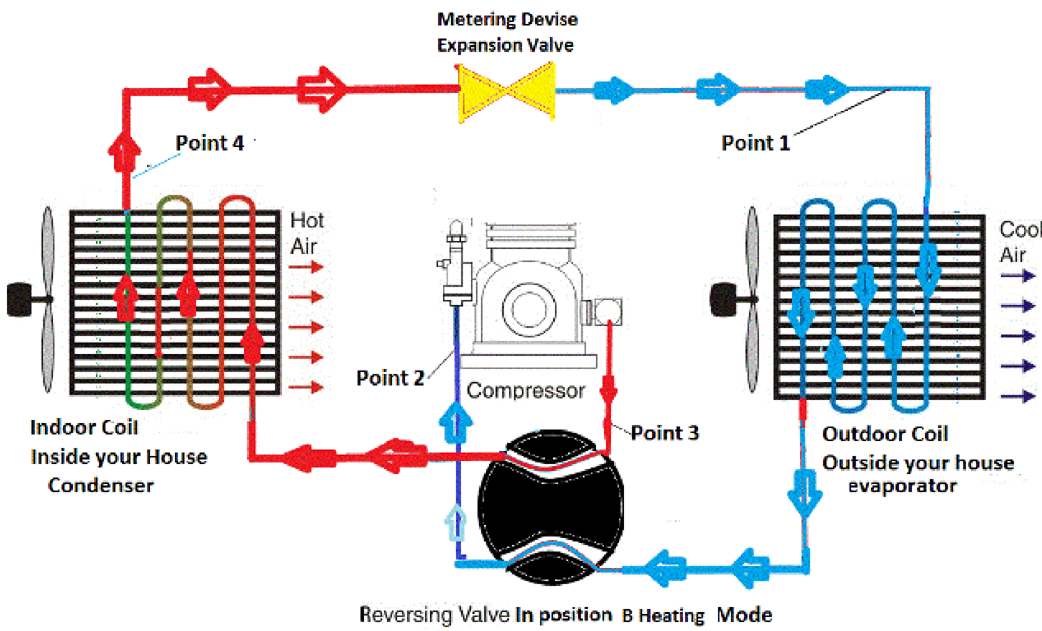

Figure 25: Overview of an air-to-air heat pump adapted from Salem (2009)

At the beginning of the cycle (point 1) the refrigerant is in a liquid form. This liquid refrigerant has to have a lower temperature than the outside air so that it can absorb heat. It enters the evaporator coil located outside the house. The outside air moves over the coil and the air starts to transfer its heat to the refrigerant. Then, the refrigerant enters the compressor which mechanically pressurizes it (point 2). That process will increase its temperature so the refrigerant will leave the compressor as hot gas (point 3). The refrigerant next moves to the condenser coil located inside the house. Because the temperature inside is lower than the temperature of the hot gas, the heat is transferred from the refrigerant in the coil to the house. The refrigerant leaves the indoor condenser coil as warm liquid (point 4). After this, the warm liquid refrigerant is made cold by the metering device, which drops the pressure on the warm liquid and thus drops its temperature.[8] Dropping the temperature enables the refrigerant to absorb more heat. So the refrigerant leaves the metering device as a cold liquid, ready to repeat the cycle again. This process can also be reversed by turning the reversing valve into cooling mode. This way the heat pump extracts heat from the inside and releases this heat to the outside. In the cooling mode, a heat pump operates exactly as a central air conditioner.

One of the limitation of air to air heat pumps is that the refrigerant going to the outdoor coil has to be colder than the outside air for it to absorb any heat. In general when the temperature outdoor fell below 4°C the air source heat pump , does not work very well (Salem, 2009). Therefore, air to air are mainly applied in moderate climates or mild climates (as an air conditioner).

A.1.3.1 Geothermal heat pump

In colder climates (such as in North and Western Europe) geothermal heat pumps (GHPs) can be used. GHPs take advantage of the fact that ground temperatures remain relatively constant throughout the year one meter below ground or deeper. GHPs collect and transfer heat from the earth through a series of fluid-filled, buried pipes running to a building, where the heat is then concentrated for inside use. A GHP operates much like the common air-source heat pump by transferring heat using the cycle of evaporation, compression, condensation and expansion (Omer, 2008). The relatively stable temperature source for heat transfer contributes to the ground source heat pump's more stable operating capacity and increased efficiencies (Salem, 2009). Typically, an individual geothermal heat pump will deliver three or four times as much thermal energy (heat) as is used in electrical energy to drive the system (Omer, 2008).

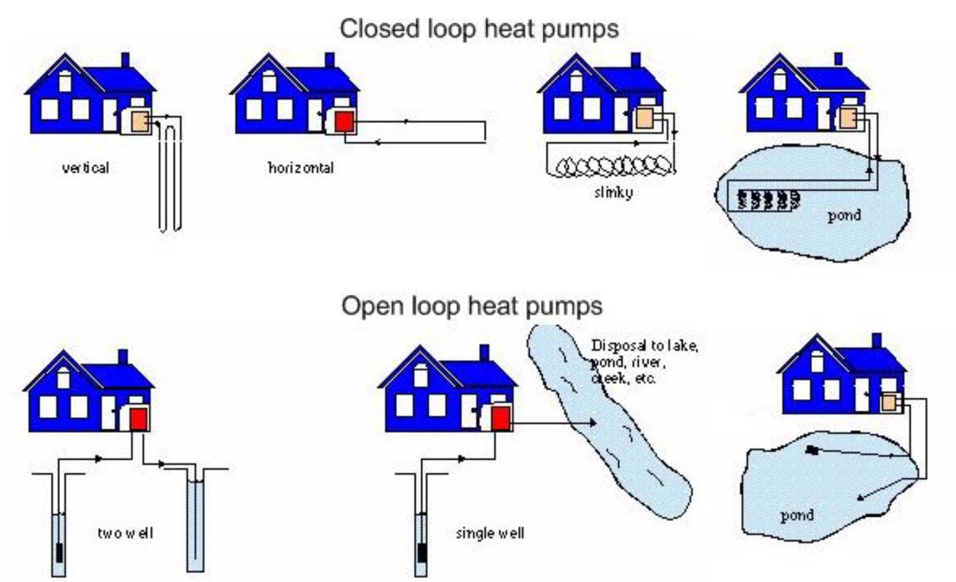

Figure 26: Examples of open and closed heat pumps configurations

The system can be configured as either a closed or open loop, and the loop itself can be either horizontal or vertical (see Figure 26). Closed-loop systems circulate a fluid mixture within the buried pipes, while open-loop systems circulate well or surface water. Open loops are less common because it requires a lake or well nearby, maintenance costs are usually higher than for closed loop systems and environmental issues have to be considered. On the other hand open loop systems are more efficient than closed loop, especially at large depths (> 300 meter).

However, how much energy can be yielded with a heat pump largely depends on the geological conditions of the ground layers, such as the type of sediment and the permeability. For the Netherlands the temperature below the earth surface is around 10 °C and the temperature increase with a rate of approximately 31 °C/km (Heekeren., 2015). For individual homes and buildings depths of 1.5 meter until 300 meters, a closed loop heat pump is sufficient. For large offices or a group of dwellings heat and cold storage aquifers, either with an open or closed loop system up to 300 meters can be used. For depths below 500 meters, the temperatures are high enough to be directly used (without the use of a heat pump) to heat a neighborhood. However, there are few places where the ground characteristics favorable for heat pumps at such a depth.

A.1.4 Industrial waste heat

Much of the energy required for industrial processes is ultimately emitted again to the environment in the form of heat. This waste heat can be used in a DHN by connecting industry with urban or commercial areas. The use of low temperature heat and waste heat can represent a major contribution to the improvement in the efficiency of the utilization of energy resources.

The efficient application of residual heat means that a balance between demand and supply has to be found. The heat demand for space heating and tap water is unevenly divided in time, whereas waste heat from industry is usually available in a relatively constant flow. A small part of this lack of synchronicity can be solved by storing heat in heat buffers, but even then the available heat can usually only be deployed for 30 to 45 %, whereas peaks in heat demand also require an auxiliary boiler to cater for 10 to 15 % of the heat demand (Daniëls, Wetzels, & Wemmers, 2012).

Another important aspects are the exploitation risks for operators in combination with an large initial investments. The operator depends on the industrial partner for the waste heat during the project lifetime. Innovation or operational changes in the industrial processes can result that the waste heat is no longer available for the DHN.

A.2 Network components

The distribution system consists of distribution pipes, substations and a delivery set. Each will be discussed in this section.

A.2.1 Distribution pipes

The primary and secondary network operate on different temperatures and pressures, which means that different pipe dimensions are used for both networks. Most commonly, the primary and secondary pipe network are completely separated through a heat exchanger within the substation. The distribution pipes of the primary network are, as a rule, made of steel (Danfoss, n.d.; Skagestad & Mildenstein, 1999). For smaller dimensions pipes made of heat resistant plastic are also used. Furthermore, the pipes are insulated to keep heat losses in the network as small as possible. Many pipe systems also include (within the foam insulation) a detection system that constantly monitors for the presence of moisture. The monitoring system provides an early warning to the DH operator so that he is able to carry out preventative corrections.

The pipe dimensions are determined by the distance of the network, the heat demand and the operating temperatures within the network. The sizes of pipework range, typically, from DN 25 mm up to DN 1000 mm, and normally come in straight lengths of 6m, 12m and 16m, which are welded in situ (Skagestad & Mildenstein, 1999). When designing pipe systems an economic water rate has to be maintained. Too low a rate will give large-size pipes, deposits in the pipes, larger heat losses and temperature drops, but of course also a lower flow resistance and thereby lower operating costs for the pump (Danfoss, n.d.). The relationship between load density and piping costs influences which areas within a community can be profitably served (Meeker, Astrand, & Einsweiler, 1985). Furthermore, to operate efficiently, the return temperature of the DHN should be as low as possible. A low DH return water temperature enables the efficient use of low-grade energy sources. This is because low temperature return water is able to absorb more thermal energy from these sources. For this reason, the temperature level of consumer installations should be as low as possible.

Traditional methods of DH pipe dimensioning involve use of a size-searching algorithm in which the lowest pipe diameter possible is defined in accordance with the maximum velocity and/or with the maximum pressure gradient, so as to avoid the installation of an over-dimensioned and unnecessarily costly DHN (Tol & Svendsen, 2012).

A.2.2 Substation

A district heating networks consist of different stations to distribute heat to the delivery points. The stations can be used to divide the heat to various delivery points and to recover the pressure that is lost in the network and in station components, like heat exchangers and pumps (Van Beekum, 2009). Furthermore, the substation are equipped with back up installation that can be used for peak demand or in case of malfunction within the primary network. The substation also contains control equipment such as pressure gauges, thermometers and shut-off valves to enable proper monitoring, optimizing and maintenance of the DHN.

A.2.3 Delivery set

Building systems may be connected directly or indirectly to the DH distribution system. With a direct connection, the DH heating water is distributed within the building to directly provide heat to terminal equipment such as radiators, unit heaters. An indirect connection uses a heat exchanger in the building to transfer the energy from the DH heating distribution system (primary system) to the building distribution system (secondary system). Dutch DHNs are almost exclusively indirect systems with a heat exchanger. Compared to the direct system, the indirect system has the benefit that no hot water storage tank is required. This reduces cost, space requirements and standing heat losses from the how water tank (Skagestad & Mildenstein, 1999).

Appendix B: List of interviewees

In the Table below a list is shown of the stakeholders which participated in the interviews. Due to confidentiality reasons the name of the interviewees are not mentioned.

Hengelo	
Supplier	Akzonobel
Operator	WNH
Operator	WNH
Developer	Projectbureau Hart van Zuid
Housing company	Welbions
Client	Stork
Municipality	Municipality council
Purmerend	
Operator	SVP
Supplier	SVP
Municipality	Municipality council
Nijmegen	
Operator	Municipal
Supplier	AVR
Municipality	Municipality council
Enschede	
Supplier	Twence
Supplier	Twence
Operator	Ennatuurlijk
Client	Utwente

Appendix C Interview guide

Toelichting op onderzoek

Vanuit de Universiteit Twente is een onderzoek naar duurzame warmtenetten opgezet. Centraal in dit onderzoek staat de bedrijfsmodellen rondom duurzame warmtenetprojecten in Nederland. Warmtenetten worden steeds vaker aangedragen als een duurzame en toekomstbestendige oplossing voor de warmtebehoeftes van huishoudens en bedrijven. Echter blijkt in de praktijk de ontwikkeling en uitvoering van duurzame warmtenetprojecten een complex karwei. Derhalve is het doel van dit onderzoek om de problematiek en succesfactoren bij het ontwikkelen van warmtenetten in kaart te brengen en aan de hand hiervan aanbevelingen te doen om tot rendabele bedrijfsmodellen voor duurzame warmtenetten te komen.

De centrale vraag in het onderzoek luidt als volgt:

- Wat voor bedrijfsmodellen kunnen worden gebruikt om duurzame en rendabele warmtenetprojecten op te zetten?

Een essentieel onderdeel van het onderzoek is om de ervaringen, opvattingen en expertise van de stakeholders van warmtenetten in Nederland in beeld te brengen. Hiervoor is een serie interviews gepland met de stakeholders van warmtenetten. Het doel van deze interviews is om de succesfactoren, valkuilen en barrières van warmtenetten te ontrafelen en deze inzichten te gebruiken om aanbevelingen te doen voor het zetten van warmtenetten.

Vragenlijst

Een complete lijst met interviewvragen is hieronder weergegeven. De vragen voor de interviews zijn onderverdeeld in de vier componenten van een bedrijfsmodel: aanbiedingsvoorstel, technologische-organisatorische infrastructuur, netwerk en verdienmodel. Voorgaand aan het interview zal de interviewer een korte toelichting geven over bedrijfsmodel en de bijbehorende componenten. Het interview zal ongeveer één uur in beslag nemen.

Algemeen

- Wat zijn volgens u de belangrijkste barrières bij het opzetten van een warmtenet in het algemeen? En in uw warmtenet?
- Wat is volgens u de belangrijkste factoren om een duurzaam warmtenet tot een succes te maken in het algemeen? En in uw warmtenet?

Aanbiedingsvoorstel (aanbod aan klant, voordelen aan klant, klantsegmenten)

- Wat is volgens u voor een warmteleverancier de belangrijkste voorwaarden om bij een warmtenet aan te sluiten? Hoe heeft u het onderhandelingsproces met commerciële partijen ervaren?

- Wat waarderen volgens u klanten in het aanbod het meest (b.v. duurzaamheid, lage prijs etc.)? Is er een verschil tussen klantsegmenten?
- Wat waarderen leveranciers van warmte in het aanbod om te participeren het meest?
- Welke voordelen bieden volgens u warmtenetten t.o.v. andere opties?
- Hoe vindt de acquisitie plaats van nieuwe klanten voor het warmtenet?

Technologie-organisatorische infrastructuur (kerncompetenties, technologische configuratie)

- Als je hebt besloten om een warmenet te beginnen - Op basis van welke afwegingen wordt de infrastructuur (energiebronnen, temperatuur, ontwerp) van een warmtenet bepaald? (op basis
- van energiebronnen, warmteleveranciers, potentiele klanten of iets anders?) Met welke aspecten moet er vooral worden opgelet?
- Welke competenties zijn volgens u essentieel voor een warmtenetbedrijf (b.v. technisch inzicht, sales, relaties kopellen/managen etc.)

Netwerk (actoren, relaties, samenwerkingsverband, netwerkstructuur)
- Welke partij(en) kan/kunnen kan het beste volgens u duurzame warmtenetprojecten initiëren? (privaat, gemeentes, provincie, pps, anders?)? Hoe?
- Hoe kan je actoren het beste aan je netwerk verbinden? Wat voor samenwerkingsverbanden u kunnen dit het beste faciliteren?
- Welke partijen zijn eigenaar in uw warmtenet? Wie zijn verantwoordelijk voor exploitatie, distributie en onderhoud? Wat was de voornaamste redenen om het warmtenet zo op te zetten?

Verdienmodel (prijsbepaling, kostenstructuur, eigenaarschap, subsidies)
- Hoe wordt een business case van warmtenetten opgezet?
- Wat vindt u van de prijzen die worden gehanteerd in uw warmtenet? Wordt er genoeg inzicht verschaft in de prijsopbouw? Kunnen de prijzen lager? Hoe?
- Welke kostenposten zijn doorslaggevend voor de winstgevendheid van een warmtenetproject? Waar kunnen warmtenetten het verschil maken?
- Welke factoren bepalen de rentabiliteit van warmtenetten?
- Welke eisen worden er gesteld aan het rendement van de investering?

- Wat voor rol spelen subsidies bij het opzetten van uw warmtenetprojecten? Zou u warmtenetproject tot stand zijn gekomen zonder hulp van subsidie? Worden deze subsidies volgens u effectief benut?
- Waar liggen de kansen van warmtenetbedrijven om hun concurrentiepositie te versterken t.o.v. van gasnetwerk?

Appendix D: Overview of large DHNs in the Netherlands

City	DHN	Heat Supplier	DHN Operator	Heat production	Primary energy	WEQ (x 1000)
Amsterdam	Amsterdam south and east	Nuon	Nuon	Combined cycle CHP	Gas	34,4
	Amsterdam north and west	AEB Amsterdam	Westpoort Warmte (PPP: nuon and AEB)	Waste Incineration	Waste	17,6
Rotterdam	Rotterdam	AVR Rozenburg	Primary net: Warmtebedrijf Rotterdam (PPP Municipality, Woonbron, E.ON) Secondary net: NUON and ENECO	Waste Incineration	Waste	50
Almere	Almere	Nuon	Nuon	Combined cycle CHP	Gas	42,9
Utrecht	Utrecht	ENECO	ENECO	Combined cycle CHP	Gas	41,7
Breda, Tilburg,Oosterhout, Geertruiden, Oosterhout, Made	Amernet	RWE/Essent	Ennatuurlijk	Combined cycle CHP	Coal and biowaste	33,4
Purmerend	Purmerend	Stadsverwarming Purmerend (Municipality)	Stadsverwarming Purmerend (Municipality)	Biowaste Boiler	Bio waste	25
Arnhem/Duiven/Westervoort	Arnhem/Duiven/Westervoort	AVR Duiven	NUON	Waste Incineration	Waste	22,8
Enschede	Enschede	Twence	Ennatuurlijk	Waste Incineration	Waste	20
Den Haag	Den Haag	E.ON	ENECO	gas turbine CHP	Gas	16,3
Nijmegen		ARN Weurt	Primary net: Indigo B.V (PPP Municipality and Alliander), Secondary net: NUON	Waste Incineration	Waste	3,7
Helmond	Helmond	Ennatuurlijk	Ennatuurlijk	CHP	Gas	7
Leiden	Leiden	E.ON	Nuon	CHP	Gas	6,3