



Designing a market that facilitates access to multiple independent producers in district heating networks in the Netherlands

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Graduation thesis - Delft University of Technology



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Jua Lisa van Woerden  
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## Summary

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District heating is a public utility, similar to other large scale networked systems such as electricity, gas, telecom and even railway networks, with a large network and characteristics of natural monopolies. Due to this, competition has been absent in district heating markets in the Netherlands. For example the situation in The Hague and surroundings, where part of the city centre is connected to a district heating system. Within this system, consumers are designated to Eneco, who is the only distributor. Eneco in its own turn, buys heat from E.ON Benelux, producer of heat in The Hague. In short, the district heating network has one producer, one supplier and multiple consumers.

For producers, like E.ON, this essentially means that they must produce the entire quantity demanded for security of supply reasons. The problem with this is, however, that sometimes producers would like to produce less or nothing. This situation, where one producer is forced to supply is called a 'must-run' situation. If, however, not one energy company but more parties could supply this on the network, such as certain industrial facilities that also produce heat, not only the must-run situation can be avoided, but also more waste heat in total could be reused. Having more producers feed-in on one network would benefit the environment and could save costs for current and future producers.

There are some knowledge gaps when it comes to introducing multiple producers on the supply side of the district heating network:

- There is a lack of insight into how to deal with the complexity of the market in a changing environment
- There is a lack of awareness what possible market models and configurations are available in theory
- There is a lack of understanding of how this can fit in the Dutch context of district heating

This leads to the following main research question:

**What combination of design choices would be suitable for facilitating access to multiple independent producers of heat on district heating networks in the Netherlands?**

The approach taken to answer this research question is threefold, namely exploration, analysis and application. The exploration phase covers a theoretical exploration and a systems analysis of the current district heating market in The Hague and the desires of the stakeholders for a future market. Analysis covers a conceptual model of the district heating market that can be used to model the current, as well as any new market situation. The conceptual model is validated by an application to the current situation in The Hague. Furthermore, alternatives for a future district heating market are generated, and a discussion on how these can be simulated in the future concludes the research.

Due to the many similarities, the electricity market may be the most comparable market for district heating. The utilities are similar in their value chains from production-consumer, both make use of a large network, have natural monopoly characteristics, security of supply is extremely important, also both are a basic need/utility and have to deal with hourly and seasonal changes in demand. Other markets that share the same similarities are the gas and water market, which like electricity could be used to draw lessons from. There are also some differences between district heating and these other utility markets. Such as the fact that storage of heat is possible, there are higher barriers to entry, transport costs and heat losses occur even when there is no demand, the balancing mechanism is less important for district heating and also the networks are more local. With taking into account the

differences that are typical for the district heating market, comparisons can be made between a market for district heating and the electricity market.

When looking at the current district heating system, there are three perspectives that can be distinguished: the technical, economic and institutional perspective. The technical perspective entails the physical artefacts and the operationalisation of the technology, or everything to do with the actual heat flow. The economic perspective includes the cost flow, of how this is build up and how prices are determined. Lastly, the institutional perspective contains values, norms, laws, rules, arrangements and contracts, and how rights of ownership are divided.

There are different design choices when designing for competition in a utility market. The degree of market opening, the capacity mechanism and the supply temperature are for district heating the main design choices. Together with the three perspectives the design choices are combined in the conceptual model made for district heating. In this conceptual model the technical, economic and institutional layers are shown separately. However, they are much more intertwined. Therefore interfaces are included in the conceptual model. The interfaces include variables that either influence two layers or are influenced by two layers. Also, the three design choices are demarcated within each separate layer, to indicate which elements are subject to change when designing a new market.

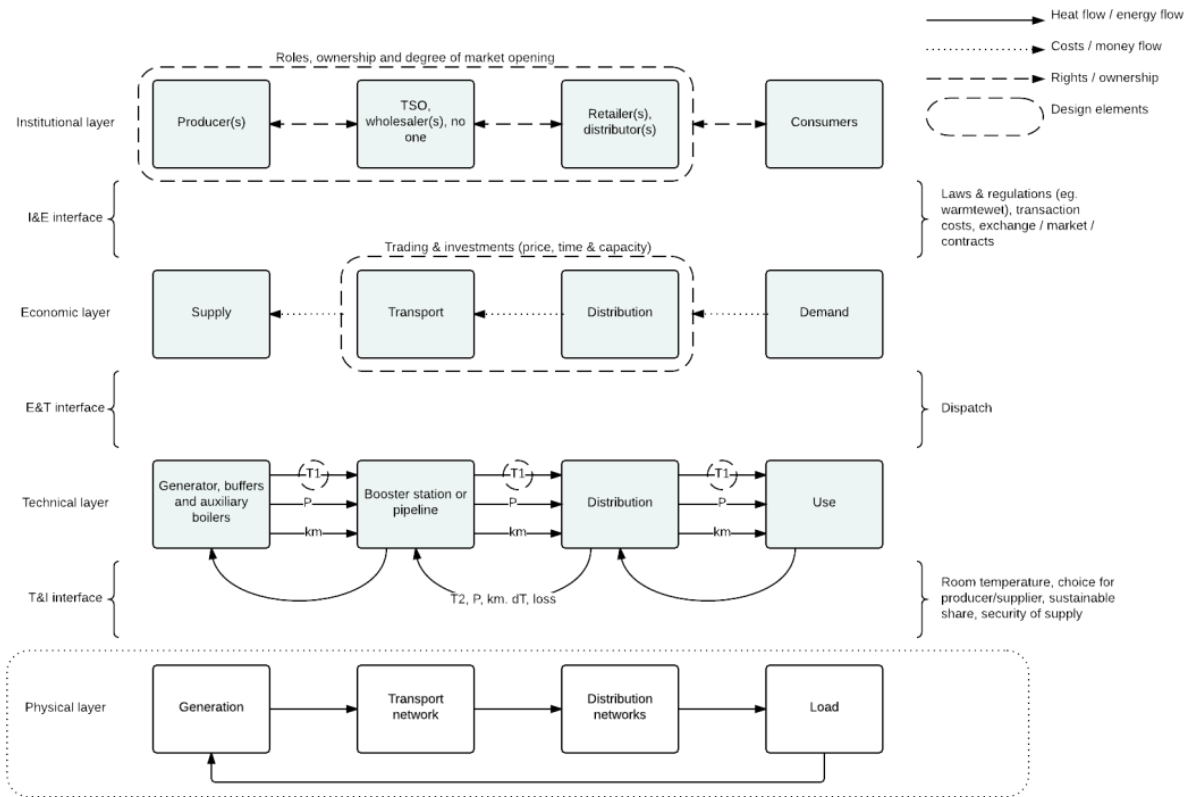


Figure: The conceptual model of the district heating system (for an enlarged view, see page 39)

The conceptual model creates awareness of all concepts involved, gives insight in all three layers and with that bringing added value. It also provides the means to represent the different flows, since together with heat cost and ownership are important. Applying the model has also shown that one layer cannot change without the



others, and looking at just one perspective is not sufficient. Also, when applied to a specific situation, this can form a complete picture and a basis for simulation.

The three design choices are filled in to form three different alternatives for a future district heating market. The degree of market opening for alternative 1, 2 and 3 are retail competition with open access, single-buyer model with pooling and wheeling respectively. The capacity mechanisms chosen for each alternative are capacity payments, a capacity market and a strategic reserve and the supply temperature for alternative 1 is changed to a low temperature network, alternative 2 a high temperature network and in alternative 3 both can exist next to each other.

The most promising alternative for the situation in The Hague seems a combination of the first two alternatives, taking the degree of market opening from alternative 2 and the other two design choices from alternative 1, the capacity payment mechanism and the low temperature network. The single-buyer model allows for multiple producers, but does not require as many as in alternative 1 to work. Since in The Hague and surroundings there are not many potential producers, this is a plus. At the same time the low temperature network allows for more potential producers, so that the heat that is available in the area can be used. And lastly, the capacity payment mechanism is easy to implement and adjust to the situation. In order to say something about the combined effects of these measures, the alternative must be simulated. This is essential to predict any sort of combined behaviour of the market with certain circumstances and the behaviour of its parts (stakeholders). It is advised to make an agent-based model to capture the desired insights on the behaviour of the market.

The agent-based model should have the design choices as inputs, and the objective values that resulted from interviews taken as outputs. The market design alternatives can then function as several experiments that can be conducted with the model to see which combination of design choices generates the best desired behaviours. This is summarised in the figure below.

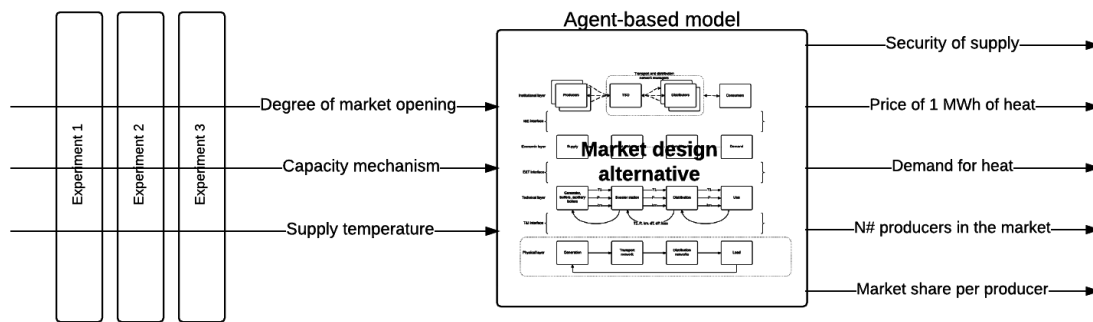


Figure: Inputs, outputs and experiments of the agent-based model

It is recommended that this agent-based model is built in the future. For E.ON this could mean they could strategically position themselves within the new market situation of district heating. For society and science, this could give insights into the energy transition and how district heating can contribute to this.



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# Part I: Problem definition

# 1. Introduction

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*This chapter introduces the subject of this research: district heating in the Netherlands. The introduction will start with the context of the current situation of district heating networks. The problem that is central in this research is introduced and research questions are presented. At the end of the chapter, the structure of the research and this report are explained. But firstly, what is district heating?*

## 1.1. Problem description

One of the basic needs of a human being is heat. Heating in households is very common, and nowadays many people take it for granted. Heating in households can be referred to as space heating. Many households have an individual gas powered boiler in the Netherlands, but space heating can be organised in different ways. For example by a collective district heating system. A collective district heating system is a network of pipes, which uses centrally produced heat to heat up households through radiators or floor heating for example.

Up until now, municipalities in the Netherlands have ensured that district heating networks have been established and expanded. After privatisation of energy companies in the Netherlands in 1995, the district heating system has been advanced through financial investments, defining concession zones and building control regulations, amongst other methods. Through these ways municipalities have been expanding connections to district heating (Hawkey & Webb, 2014). Currently, per local district heating network, one energy company supplies heat on the net.

An example of a district heating network is that in The Hague and surroundings. A portion of the city centre is connected to the district heating network. The energy company that supplies heat on the district heating network in The Hague and surroundings, is E.ON Benelux N.V.. E.ON Benelux is the division of E.ON that operates in the Netherlands and in Belgium. E.ON, the mother company, is a German company, which has divisions throughout several countries in Europe. In The Hague, 40.000 households and buildings are currently connected to the district heating network, and the municipality is looking to increase this to 100.000 connections. E.ON Benelux now supplies the heat, but when increasing the amount of connections, room is created for more potential producers.

Having more producers on one network could have several benefits. For example, more waste heat from industrial facilities could be reused, posing environmental benefits. Also, for E.ON in this case, it would mean that they are not forced to supply heat all the time, but can make more strategic decisions when it comes to efficient use of their combined heat and power plant (CHP). Having more producers supply on one network would also mean that less additional heat from buffers our auxiliary boilers needs to be produced to meet consumer demand. Which in total would benefit the environment and could save costs for current and future producers.

District heating networks throughout the world, including in the Netherlands, have characteristics of natural monopolies (Li, Sun, Zhang, & Wallin, 2015; Söderholm & Wårell, 2011; Wårell & Sundqvist, 2009), similar to other large scale networks such as electricity, gas, telecom and even railway networks. Up until now, competition within the district heating sector has occurred amongst networks, as opposed to within one single network (Wissner, 2014). Currently, like the aforementioned networks have had in the past, the district heating network has one producer, one supplier and multiple customers. The customers cannot choose their supplier, as this is operated by a monopoly. Suppliers are bound by the 'Warmtewet', which provides a price ceiling in order to protect the customers



(“Warmtewet,” 2013). However, the demand for having more suppliers and producers on one network is increasing, as competition in these areas could have benefits for the market and its consumers (Söderholm & Wårell, 2011).

A direct motivation for looking into introducing more producers within one district heating network is the recent letter by the minister of Economic Affairs. His suggestion concerning district heating is to make current district heating networks ‘open networks’. In his letter, an ‘open network’ is defined as the possibility that customers can choose their supplier and that more producers can supply heat on the network (Kamp, 2015). For this research the focus is on introducing multiple independent producers on one network of district heating.

Opening the market for more than one producer poses technical as well as economic and institutional issues. Groenewegen (2005) has discussed these three aspects in his ‘designing markets in infrastructures’. The technology domain encompasses “how to engineer the physical environment” (Groenewegen, 2005, p. 2), the economic domain is said to include the production of goods and services and the different economic levels that occur with that. The institutional domain contains values, norms, laws and other arrangements that are linked to coordinating transactions. Groenewegen also states that this is “the domain of designing markets” (Groenewegen, 2005, p. 3), which is relevant for this thesis. When analysing the district heating network, focus should be on all three perspectives. The three domains and how they relate are shown in figure 1.



Figure 1: A multi-disciplinary, multi-level and multi-actor system (Groenewegen, 2005)

Introducing multiple producers on one district heating network is high on the agenda, according to the heat vision by the Ministry of Economic Affairs. Since many changes are to occur on the production side of district heating in the Netherlands, E.ON Benelux is set to be the problem owner. They clearly need to anticipate to changes in the sector. They can also be seen as the problem owner since the goal is to introduce more producers in the district heating market and specifically in their segment, which is their area of expertise. Further knowledge gaps, problem statements and research questions will therefore be derived from their point of view.

## 1.2. Problem statement

From the previous section it can be noticed that there are some knowledge gaps when it comes to introducing multiple producers on the supply side of the district heating network:

- There is a lack of insight into how to deal with the complexity of the market in a changing environment
- There is a lack of awareness what possible market models and configurations are available in theory
- There is a lack of understanding of how this can fit in the Dutch context of district heating

These elements combined lead to one large knowledge gap: a lack of insight into which market design would be suitable for district heating when introducing more producers on one district heating network in the Netherlands, so that it remains profitable for the district heating activities of parties that play a role in the value chain.

Considering that the problem owner is the current producer, E.ON Benelux, the following problem statement can be defined:

**It is unknown which design choices for a market can facilitate access to multiple independent producers of heat on district heating networks in the Netherlands, and which combination of design choices suit the district heating system the most.**

The project is delineated to the Netherlands only. This geographical boundary is chosen because the context of district heating, such as laws, regulation, the energy market and other aspects, can differ widely amongst countries. The problem statement focuses on the supply side of district heating only, since this is where the introduction of more producers takes place. Producers are specifically those that produce the heat. Any market design made for this project will include the whole value chain, even though the focus is on facilitating access to producers on the network.

## 1.3. Research questions

From the problem statement, the main research question is formulated as follows:

**What combination of design choices would be suitable for facilitating access to multiple independent producers of heat on district heating networks in the Netherlands?**

In order to structure the research better, the main research question is divided into several parts. The following sub-questions are formulated:

1. What are the design choices for a new district heating market model in theory and what are the possibilities for filling in these design choices in practice?
  - 1.1. What are, in theory, comparable markets, market design choices and market models for other utilities that could be applied to district heating?
  - 1.2. What does the current district heating market look like in practice terms of the technical structure, the economic principles and the institutional context?
  - 1.3. What are the possibilities for the design choices considering the stakeholder setting?
2. What would a conceptual model look like for district heating market?
  - 2.1. What technical, economic and institutional elements should be included in the model?

- 2.2. What are the relations between the technical, economic and institutional elements of the market for district heating?
3. What advice can be given, to achieve the technical, economic and institutional design choices that allow multiple independent producers on the district heating network in The Hague?
  - 3.1. What are the alternative market designs for district heating?
  - 3.2. What are the strengths and weaknesses of the alternative market designs?
  - 3.3. How can the conceptual model and alternatives serve as a basis for future simulation of the market?

## 1.4. Design approach

For this research, the objective is:

**To research which design choices there are for a district heating market, how these design choices can be filled in, and eventually what market design suits the district heating system the best when facilitating access to multiple independent producers.**

This objective requires to find design choices, and eventually fill these in for a complete market design. To get to a market design, a design study is proposed. There are different types of design approaches that address the design process. Cross (2005), discusses descriptive models, prescriptive models and an integrative model in his book 'Engineering design methods'. The most basic descriptive model by Cross shows four steps: Exploration, generation, evaluation and communication. Apart from the last step, this model is similar to one described in Sage & Armstrong's 'Introduction to systems engineering' (2000), who state that there are three fundamental steps for systems engineering activity, namely: Formulation, analysis and interpretation, which recur throughout the engineering design process.

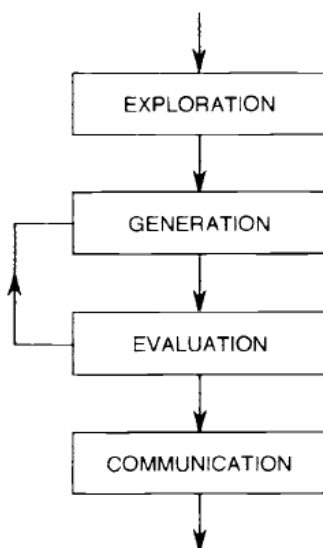


Figure 2: A simple four-stage model of the design process (Cross, 2005, p. 30)

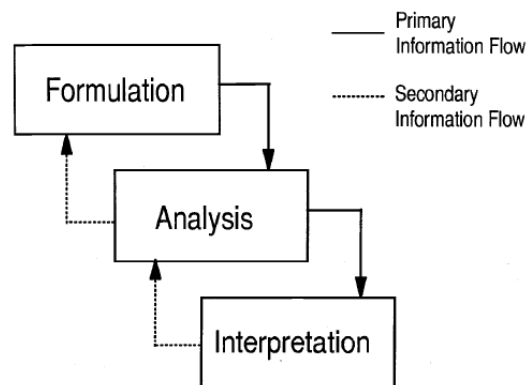


Figure 3: A conceptual illustration of the primary systems engineering steps (Sage & Armstrong, 2000, p. 51)

The two design approaches do not differ a great deal, however, a combination of the two approaches provides a complete design process. Therefore design approach chosen for this research project is exploration, analysis and application. Application includes both evaluation and interpretation, in the form of evaluation of alternatives and interpretation for future simulation. These phases are further explained in the next section, which specifically explains which methods will be used in the suggested phases and elaborates on the content of the phases.

### 1.5. Research methods

To answer the research question, a design study is proposed. In order to design a market model, first the options existing theory proposes are explored, and to match this with practice both the current as the desired situation for district heating in case of E.ON and The Hague is mapped. The design area is then formed, within which a conceptual model is designed of the district heating market. This model is validated and applied to the current situation, and alternatives for future market configurations are suggested.

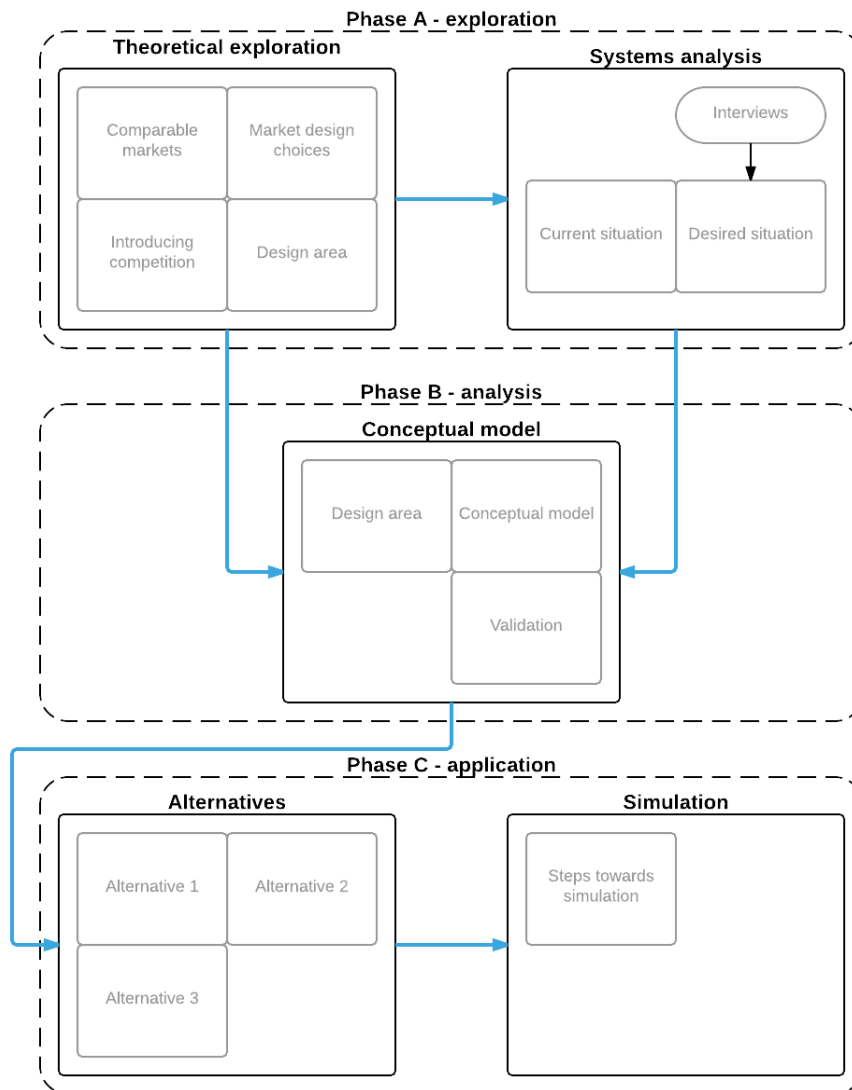


Figure 4: Research overview

### 1.5.1.Phase A - exploration

The first phase of the research approach uses a theoretical exploration and expert input through interviews as methods to answer the first sub-question covering the exploration phase of this research. The theoretical exploration covers the most relevant literature for this project. The theoretical base of this research will be obtained through articles, books and other relevant literature. These are found through several search engines, such as Scopus, Science Direct, Web of Knowledge and Google Scholar. Using many search terms, that cover 'district heating', 'market models', 'competition in network industries', 'design of access in utility markets' and several others. Expert interviews are conducted to perform a systems analysis. There are different ways to conduct interviews. The expert interviews for this project are classified as semi-structured in-depth interviews (DiCicco-Bloom & Crabtree, 2006). This type of interviews are interviews that are only conducted once, with one individual at a time. Also, the interviews are organised in advance, using a set of pre-determined open-ended questions, while also having room for dialogue (DiCicco-Bloom & Crabtree, 2006). Both the theoretical exploration and the expert interviews should give insight into the current district heating system. This should cover the current technical structure, economic model and institutional framework in place, as well as any desires for a future district heating market and system. Deliverables in this phase are a complete theoretical exploration of the possibilities and a systems analysis, encompassing the system in its totality, including the boundaries of the system for this project. How to perform a systems analysis is described in 'Policy analysis of multi-actor systems' (Enserink et al., 2010), which will be used to guide this process.

### 1.5.2.Phase B - analysis

Phase B consists of several parts. Firstly, phase A forms the basis for delineating a design area and also for developing a conceptual model. Ideas from 'Conceptual model in a qualitative research project' (Doorewaard, 2009) are used to shape this. A conceptual model is made to form a basis for defining alternative market designs. The conceptual model will be made based on the experiences gained in phase A, from both theory and practice. This is the analysis phase of the project. The model will be validated by an expert panel, formed by experts in the field to test whether the theory matches practice by applying the conceptual model to the current situation in The Hague. Deliverables of this phase are a conceptual framework that contains all relevant elements of the district heating system, and a validation of this conceptual model.

### 1.5.3.Phase C – application

This phase consists of the application of one or more market designs developed in phase B to the situation of E.ON and the municipality of The Hague. This phase is important, since it will provide the analysis necessary to give advice to E.ON and The Hague on what they could do to in order to get closer to introducing multiple producers on the district heating network. It will be very difficult to evaluate and compare the alternatives with each other. Therefore an important part of this phase is to lay a foundation on how the alternatives can be simulated, in order to validate the choice for a certain alternative. Deliverables of this phase are several alternatives, an evaluation of the alternatives and proposed steps of how the alternatives can be simulated.



Part II: Phase A - exploration



## 2. Theoretical exploration

*The goal of the theoretical exploration is to look from a theoretical perspective at the possibilities and opportunities for facilitating access to multiple independent producers on one district heating network. The results of this theoretical exploration then serve as a foundation for the analysis phase of this project. Firstly, the district heating systems in place in the Netherlands are discussed in general. Subsequently, the district heating market is compared with other utility markets that already provide access to multiple producers. Lastly, theoretical concepts that are associated with introducing competition in these other utility markets are explored and applied to district heating.*

### 2.1. The current district heating system

District heating is a collective heating system that distributes heat to houses, buildings and other locations (Collins Dictionary, n.d.). In such a system, heat is centrally produced and supplied to houses and buildings through a network. District heating networks are often local, connecting households and buildings of one neighbourhood or area to a district heating network. There are many municipalities in the Netherlands that have a district heating network. Below the existing networks in Zuid-Holland are shown.

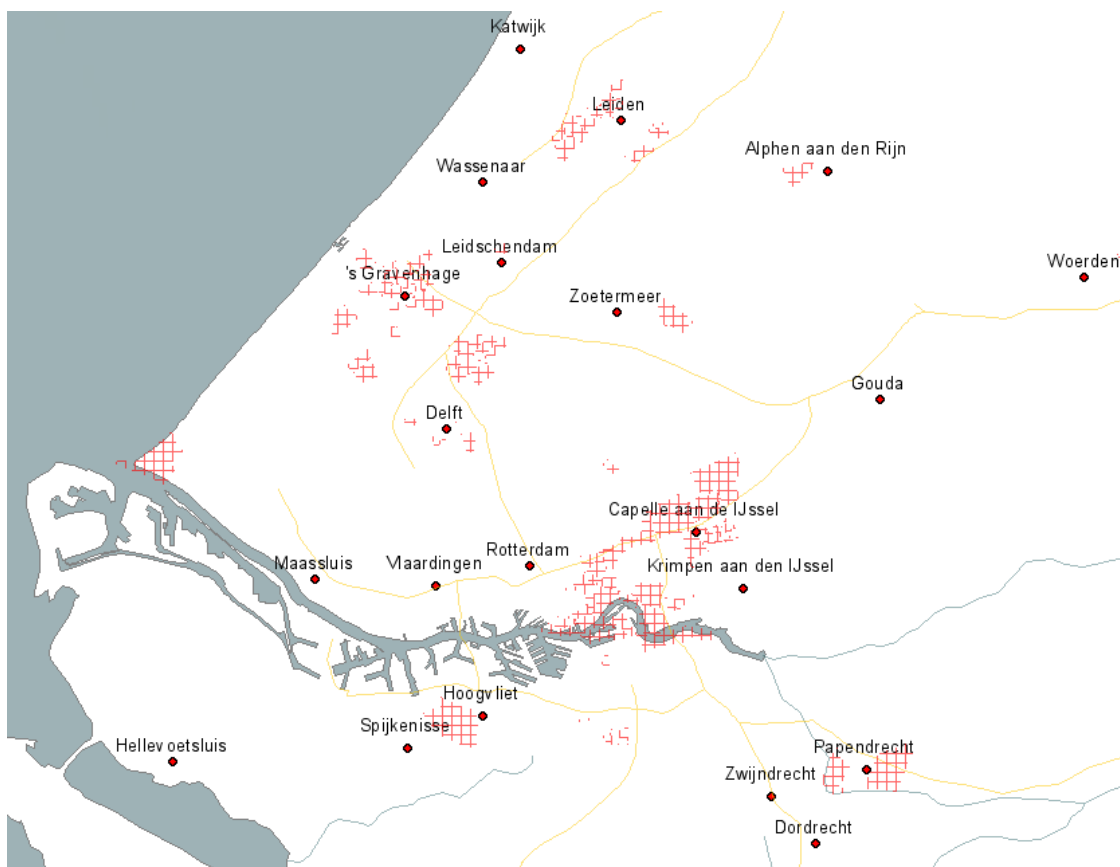


Figure 5: Map of district heating networks in Zuid-Holland (Agentschap NL, from [warmteatlas.nl](http://warmteatlas.nl), retrieved at 17-09-2015)

District heating networks require a large, cumbersome infrastructure, with very high sunk costs (Wårell & Sundqvist, 2009). The sunk costs of this network are so high, it does not make sense to have more than one network parallel to the other. Therefore, district heating networks have



characteristics of natural monopolies (Li et al., 2015; Söderholm & Wårell, 2011; Wårell & Sundqvist, 2009). Furthermore, the network required for district heating is so costly, it creates a barrier to entry for producers to enter the district heating market. And, since it would be a waste to have several parallel networks of this type compete with each other, access to this one infrastructure is necessary if producers want to compete (Klein, 1996). Due to the fact that district heating is a natural monopoly, one producer is connected to the network and the network is owned by one distributor who supplies heat to consumers.

From the *Warmtevisie* (Kamp, 2015), it can be derived that opening the district heating network for more producers is a focus point for the government, and therefore it is important to look at how and to what extent the market for heat production for district heating can be liberalised. The vision is that instead of tendering the production to one party for a longer period of time, it should be possible for more parties to emit their waste heat, or sustainably produced heat, on the network. Heat is being promoted by the national government in relation to the 20-20-20 targets, set by the EU. The goal is to decrease emissions by 20% by the year 2020. One of the effective options to work towards this target, is by making space heating more sustainable. The goal that has been set by the government in light of these targets and in relation to space heating is that 14% of space heating used in Zuid-Holland should be from sustainable sources by 2020. Many stakeholders in the energy sector are striving for this already. Introducing more producers on one network could give the potential the sector needs to reach the 14% that is needed. This is equal to connecting 350.000 households and 1000 acres of horticulture in Zuid-Holland to a district heating network. This is quite a lot, considering currently only 7% of households in the Netherlands are connected to a district heating network.

Many industries with similar network characteristics, such as natural gas and electricity markets, have been subject to change in the Netherlands the past years. To create room for competition, these industries were liberalised (Klein, 1996). Either the whole market or specific divisions of the market were subjected to liberalisation. When liberalising the market for electricity and gas, this had a great impact on district heating. District heating has its origins in supplying waste heat from energy plants. When the energy markets liberalised, some things changed. Amongst them privatisation of energy companies and its plants. The companies have now adopted a far more commercial position, and profitability is now of the essence. The same energy companies producing electricity are also producing heat, causing the liberalisation to have effect on district heating as well. The producers and distributors of heat, were now keen to make profits from heat as well as electricity, and have the opportunity to ask monopolistic prices for heat.

Another aspect changed, namely the gas price. Before the liberalisation of the gas market there was one gas price, that was fixed for a whole year. After the liberalisation this changed to a gas price that could vary over time (Schepers & van Valkengoed, 2009). This had a big effect upon district heating because the districting heating price was always largely based on the gas price. After the liberalisation there was no fixed gas price, but a varying gas price to base the district heating price on, taking away the foundation it once had. This, together with the now private and looking for profit energy companies brought forward the creation of the 'warmtewet', the heat law. This law has been in effect as from 01-01-2014 ("Warmtewet," 2013) and determines the maximum prices (small) consumers should pay.

The Authority Consumer and Market (ACM) wield the following calculation for the price ceiling for heat:

$$P_{maxw} = 281,78 + 22,64 * W_w \text{ [€}, incl. BTW]$$

Where  $W_w$  = the yearly consumption of the consumer in Gigajoule, multiplied by the price per Gigajoule 22,64 and in addition of 281,78, which represents the maximum connection fee of a whole year. The calculation is based on a principle called the 'niet meer dan anders', or not more than otherwise (NMDA) principle. This principle has been included in the heat law to ensure consumers of district heating would not pay more than their neighbours who have space heating through a gas connection, or all-electric. This is because district heating consumers cannot choose a district heating supplier, or switch to another form of space heating. In theory, this is a good idea. However, the heat law does not say anything about a price ceiling for the rent of a heat exchanger. A heat exchanger is necessary in every home, which consumers are forced to rent. In practice, the rent of such an apparatus is quite high, making district heating more expensive than gas, despite the NMDA principle. This is another reason why facilitating access to multiple independent producers is a good idea for the district heating market.

## 2.2.Comparable markets

In many ways electricity, gas, water and district heating are similar, but to what extent can these markets be compared? In this paragraph firstly a comparison between the characteristics of electricity as a product and a service and district heating as a product and a service is made. Their value chains for example are very similar. From production to transmission/transport to distribution to consumer, the essential steps are comparable. Both make use of a large network and share natural monopoly characteristics. Since both heat and electricity are a basic need, their security of supply is highly valued and they both have to deal with seasonal and even hourly changes in demand. However, district heating is different in some ways as well. Where storage of electricity is practically impossible, storage of heat is more easily achieved, currently buffers and auxiliary boilers do so. Another difference is that for district heating the barriers to entry are even higher than for electricity. The transport network is much more expensive and transport costs and heat losses occur even if there is no demand because the water flows constantly through the system, whether it is heated up and used or not. In case of shortages, there is a difference as well. Where in case of electricity blackouts occur, for heat it causes more of a queue or traffic jam situation. It will simply take longer to reach the desired temperature, making a balancing mechanism less important than for electricity. Also district heating networks in the Netherlands are very local, where the electricity grid is connected nationally. These similarities and differences are summarised in table 2.

Due to the many similarities, the electricity market may be the most comparable market for district heating. Other markets that share the same similarities are the gas and water market. They are also basic needs, where security of supply is very important, make use of large networks and share natural monopoly characteristics and also have seasonal and hourly demand changes. Networks like telecom and rail also make use of large networks where a monopoly makes a lot of sense, however, the security of supply is strictly not as essential as for the before mentioned utilities, which is why the electricity, gas and water markets are a better fit for district heating. Since there is a lot of literature available on electricity markets, the liberalisation of electricity markets worldwide and the lessons learned, many of the discussions in this chapter will concern the electricity market. However, the differences as identified in table 2 should not be neglected. The differences between heat and electricity make heat a simpler flow to manage, but with higher transport costs a higher barriers to

entry. This means that from a market design perspective, heating is easier to design, but practically, it is more difficult to attract new producers. Even though comparisons between the markets are drawn, attention should be paid what the effects of the heat characteristics are.

Table 1: Similarities between electricity and heat as a product and service

Similarities	Differences
Value chain from production-consumer	Storage is possible
Make use of a large network	Higher barriers to entry
Natural monopoly characteristics	Transport costs and heat losses when there is no demand
Security of supply important	Balancing mechanism less important
Both a basic need/utility	More local networks
Hourly/seasonal changes in demand	

As stated before, the gas and electricity markets have been reformed over the past years. All companies in these markets started out as public utility companies, with monopolies forming naturally on each part of the value chain. Since customers have no choice in supply, either between district heating suppliers or other forms of space heating, high prices can be charged in these monopolies. Monopolies are not challenged to become more efficient or deliver a better service, again because they cannot lose customers to competitors. The only way to change this, is by interference in the market by for example the government. It is exactly this interference that has happened to electricity and gas markets all over the world, and which can be learned from to apply to district heating. Now that it is established which markets are comparable to district heating and on which points, it is important to look at what design choices were considered when liberalising the electricity market, and what lessons can be learned from introducing competitions in utility markets.

When looking at introducing competition it is important to establish whether introducing a form of competition is “for the market”, “over existing networks”, or “among multiple networks” (Klein, 1996). In the case of district heating, currently the competition is for the market. For the market means that firms compete to be able to provide heat on the network, this is done through concessions. Whoever owns the concession, has ‘won’ the competition for the market for the next coming years. However, if multiple independent producers provide heat on one network, this method is not sufficient. In that case, the competition would be over existing networks, by multiple producers gaining access to the monopoly segment of the network (transport). There are many ways in which competition over existing networks can be organised. This requires a market design, on the technical, economic and institutional domains.

### 2.3. Market design choices

Much of the literature on designing markets for utility networks is applicable to electricity. As established previously, there are similarities and differences between electricity and district heating as a utility. The design choices for designing an electricity market as noted by Correljé and de Vries (2008) will be discussed and for each, options for the district heating market will be given. It is also possible that a design choice is not suited for district heating at all, or in the light of this project, which will also be indicated. A summary of the design choices for district heating can be found in table 3 in section 2.3.11.

There are 13 design choices when it comes to a market design for the electricity market (Correljé & de Vries, 2008). Of these 13 design choices, 10 will be discussed for district heating. Three out of the 13 choices are regarded as irrelevant for this case of district heating, because of its local nature. District heating networks in the Netherlands are generally local without any connection to other areas or other district heating networks. This is why any design choice regarding congestion management and arrangement with neighbouring networks is discarded from this research. The remaining design choices are: The degree of market opening, an integrated versus decentralised market, public versus private ownership, competition policy and horizontal unbundling, network unbundling, network regulation of network tariffs and access conditions, balancing mechanism, wholesale and end-user price regulation, capacity mechanism and the position of the regulator. Below the options for each design choice are discussed, and will also be summarised in a table at the end of this section.

### 2.3.1. Degree of market opening

Degree of market opening means to what extent and in which sections competition is introduced in the market (Correljé & de Vries, 2008). When introducing competition it is important to know which type of competition is meant. As stated before, currently the system operates with 'competition for the market'. According Klein (1996), there is only one option for having competition in that case: bidding for monopoly franchises. However, introducing competition in district heating in terms of multiple producers means that instead of having 'competition for the market', 'competition over existing networks' is required. In the case of 'competition over existing networks' literature speaks about two sides to the degree of market opening design choice. One discussing the organisation of access, and the other concerning the market structure. The options for organising access in electricity markets in literature are: open access, pooling, and timetabling (Klein, 1996) and a scale from access regulation to vertical separation (OECD, 2001). Different market structures for electricity markets can also be found in literature: Wheeling, single-buyer model, wholesale competition and retail competition (Correljé & de Vries, 2008), portfolio manager model and the 'customer choice' or 'retail wheeling' model (Joskow, 1997), as well as two market structures for district heating: the network access and again the single-buyer model (Korhonen, 2014). First the different types of organising access are discussed.

#### *Organising access to the network*

Open access is an option where open access is granted to the bottleneck facility (Klein, 1996). In the case of district heating the bottleneck facility is the transport and distribution network. This is regarded as the bottleneck facility because it does not make sense to build a parallel network of pipelines on the same route. All producers must therefore have access to this one facility, which is why it is the bottleneck in this system. For district heating, this can work if the suppliers do not have an interest in producing. Without an interest in production, it will always pay for the suppliers to allow additional access, if their capacity allows it, since this means more revenue for them. In combination with a competitive spot market for peak load and longer-term hedging contracts for base load, this could work for district heating. Regulation of access prices for producers could still be necessary, since the transport and distribution part of the system could still be a monopoly segment.

Similar to open access, is vertical separation. Vertical separation 'reduces the incentive of the owner of the non-competitive component to restrict competition in the competitive component' (OECD, 2001, p. 20). Meaning that if separate stakeholders operate on different components of the chain, the transport operator will not have an incentive to grant favours or pose barriers for competitors in the production component that would obstruct competition. They could even undertake pro-competitive

actions, such as creating more capacity to compete for, or upgrade metering and billing capabilities for example. This is very similar to the open access suggestion by Klein (1996), only the OECD report approaches it from a different angle, where separation leads to open access. Klein's approach is that open access can be achieved by separating the interests of the bottleneck facility owner from production. Which essentially boils down to the same thing. Open access and vertical separation can be seen as an extreme. In these options, access itself is not paired with any terms and conditions. All other suggestions do have terms and conditions applied in terms of who gets access and who does not.

One of the suggestions which organises access and comes with terms and conditions is pooling (Klein, 1996). In this configuration, a central dispatch system optimises system flows, while also balancing supply and demand. There is open access, in the sense that winning bidders will always be dispatched until demand is met. The way that winning bidders are determined is not discussed by Klein. In the electricity market this is organised by a merit order based on marginal costs of production. For district heating, however, it is not sure that marginal cost is the right approach to configure a merit order. There are different options to consider as pricing mechanisms for district heating. Difs and Trygg (2009); Li et al. (2015); Zhang, Ge, & Xu (2013), suggest different possible pricing mechanisms. These are marginal cost, cost-plus method, the incremental cost approach and the shadow price method. These different pricing mechanisms are based on different ways of allocating the cost of production. This can provide for an elaborate discussion, which will not be included in this thesis because the focus is first on establishing a market design and how access can be organised. In the case of pooling as an access method, limits should be placed on horizontal and vertical integration, as firms with stakes in more than one aspect of the value chain could give themselves an advantage in trading, creating unfair and imperfect competition. Pooling allows production and distribution to be open, whereas the transport system would still remain a monopoly and require regulation.

Instead of limiting access according to prices, it is also possible to limit access by selling time slots or capacity. Timetabling is a form of competition where slots of time or space on the network are auctioned, and optimal routing is calculated (Klein, 1996). Routes can be decided on a decentralised basis and on a centralised basis. Timetabling is an approach that is more easily applied to systems such as district heating where it does not matter whether a customer receives the exact heat produced by the supplier it has a contract with, since the product is identical enough with that of other suppliers. Whereas with railway or airlines it does matter, because a certain person needs to be transported from A to B and it does matter whether it is you or your neighbour for example. Timetabling for systems with homogeneous products becomes a 'simple network optimisation problem' (Klein, 1996). For district heating shortages of heat should be minimised, therefore a centralised timetabling system would be preferable instead of a decentralised based routing system. Especially in the case of a heat roundabout being formed in Zuid-Holland, a centralised routing calculation seems optimal at first glance.

The options for organising access are essentially, either granting complete access or limiting access to the bottleneck facility. When limiting the access, this can either be done based on prices, time or capacity. Apart from organising access, also market structures for introducing competition fall under degree of market opening. The market structures indicate in which parts of the value chain competition is introduced. Again, literature on electricity market is used. There are several ways in which electricity markets throughout the world are structured, namely: wheeling, single-buyer,

wholesale competition, and retail competition. Wheeling is the simplest in terms of organisation, making one party responsible for production, transport as well as distribution, where trade between these integrated utilities can take place (Correljé & de Vries, 2008).

#### *Market structures for introducing competition*

The single-buyer model does allow more producers to be in one market, who sell to one power purchasing company, who then sells it to one distribution company, or itself is responsible for distribution. Often, part of the production is also owned by the power purchasing authority, giving a disadvantage to independent power producers (Correljé & de Vries, 2008). This configuration seems like it can be an option for district heating in the Netherlands. The single-buyer option is implemented in district heating systems in for example Sweden, Finland, Estonia, Latvia and Lithuania (Korhonen, 2014).

Another configuration is called wholesale competition or portfolio manager model, where more producers sell to more transportation companies, often through long-term contracts (Correljé & de Vries, 2008; Joskow, 1997). Transport and distribution (or retail) are integrated, making this quite a simple organisation. This could be a possibility for district heating, except that it would not make sense to have more than one transportation company. However, the one company could, through long-term contracts with producers, establish the supply needed to meet the demand. In this way the producers would compete for capacity in the longer term, covering some risks as well. And when demand increases, new contracts with more producers could be made.

The fourth and last suggestion is retail competition, which is the configuration under which the Dutch electricity market operates (Correljé & de Vries, 2008). Retail competition in electricity markets has many names in literature. This is also called the customer choice or retail wheeling model (Joskow, 1997) and the network access model (Korhonen, 2014). This would be a very interesting market structure to look at for district heating, applying the reforms and structures of the Dutch electricity market to the Dutch district heating systems. Many national energy policies have only been applied to electricity and gas, whereas it could or should be applicable to district heating as well. However, this market structure for district heating brings the highest transaction costs out of all options, and it should be carefully looked at whether this is worth the reform. This would entail large changes and alterations and is most difficult to accomplish.

To conclude, there are four different market structures available in literature for the design of electricity markets; wheeling, single-buyer model, wholesale competition or portfolio manager model, and the retail competition (or customer choice, retail wheeling model or the network access model). These could be applicable to district heating as well in theory.

#### *2.3.2. Integrated versus decentralised market*

An example of an integrated market is one with a mandatory pool. Compared with a decentralised market, an integrated market has lower transaction costs (Correljé & de Vries, 2008). But having a mandatory pool gives both economic and physical control to one single party. Whether an integrated or a decentralised market is designed for district heating, is somewhat dependent on the choice for degree of market opening. Certain market designs, wheeling and single-buyer configurations for example, would imply more integrated markets, where wholesale competition and retail competition have a tendency to have a more decentralised structure.

### 2.3.3. Public versus private ownership

This design choice is a very interesting one. Ownership of different sections of the value chain can differ amongst each other between public and private. Many considerations can be made, however, due to path dependence some are more likely than others. Producers of district heating are likely to remain private parties. E.ON is a private energy producer and other potential producers in the area are for example the horticulture and industrial facilities in the Port of Rotterdam. Or perhaps new geothermal wells or other newly created sources. It is most likely that these are all privately owned. However, the transport and distribution network could be publicly owned in theory, as is also the case for some other utility networks. Currently this is privately owned, which could form a barrier if this should become a public utility. The benefits of the transport and distribution network being publicly owned is that regulation of a private party that owns the infrastructure is not necessary.

### 2.3.4. Competition policy and horizontal unbundling

As described earlier, district heating can be classified as a natural monopoly. Monopolies generally have the chance to ask monopoly prices. However, even markets with more competitors can abuse their market power. Competition policy and horizontal unbundling addresses how market power abuse can be monitored. In practice, market power abuse mainly occurs when one of the parties in the market is significantly larger than the others and can influence prices in their favour. One option is to instate a regulator. This regulator could impose rules and agreements and furthermore check whether producers or other stakeholders in the systems live up to these rules, without abusing the market power they may have. Another option, in the case of perfect competition, is to let the market solve this by itself. In a perfect competition situation, there are enough competitors in the market. Not one of these has enough market power to abuse it, and together the competitors eventually reach a stable situation.

### 2.3.5. Network unbundling

Network unbundling addresses the extent to which the network operator or manager is willing to give access to all producers and the extent to which the network operator or manager provides equal conditions for all users of the network. Both Klein (1996) and the OECD (2001) state that unbundling of the bottleneck facility (Klein) or non-competitive component (OECD) is necessary, so that they do not have interest in restricting access to this facility or component, in the case of district heating the transport and distribution network. In the case of district heating, unbundling seems necessary, in order to provide equal conditions for all users. Unbundling can occur in three different ways (Jorritsma-Lebbink, 2000). These different ways of separation are:

- Accounting (by correct cost allocation)
- Organisational (place into different business units)
- Judicial (split into different companies)

In case of electricity and gas, it has been chosen to unbundle in a judicial manner, splitting every part of the chain up into different companies. Also, the owner of the transport network and the owner of the distribution net are not the same parties as those that supply on it. For water this is different, one company is in charge of everything, from production to use and is also owner of the network. For district heating all three options of unbundling can be applied, accounting, organisational as well as judicial. Currently the network is also owned by the party that operates on it, and it could be preferable to unbundle this.

### 2.3.6. Network regulation of network tariffs and access conditions

The equal conditions mentioned in the previous paragraph concerning network unbundling, are for example equal network tariffs and equal access conditions. Even when the network is unbundled, it may still be necessary to regulate the network tariffs and access conditions. Again, this can be done by a regulator or by the market itself. The options are (Jorritsma-Lebbink, 2000):

- Negotiated third party access
- Regulated third party access
  - o Price cap regulation
  - o Rate of return regulation

Negotiated third party access is where market parties themselves determine the network tariffs. This does come with the obligation to wield the same calculation for all users. In the case where market parties cannot agree on a tariff, the regulator can determine the solution. Regulated third party access requires a regulator or the government to set tariffs for the use of the network. There are two ways to do this, either by a price cap or rate of return regulation (Jorritsma-Lebbink, 2000). The price cap is a relatively simple method where a certain maximum tariff is set for a few years for access to the bottleneck facility. The rate of return method can be applied quickly in situations where market power is being abused. The maximum rate of return of the monopolist is determined in this method, limiting the profit the company can make. For district heating, the effectiveness of negotiated third party access is questionable. E.ON as current producer is willing to make room for other producers, but is Eneco, the owner of the distribution network, just as willing to facilitate access to more producers? Facilitating this access is likely require expanding their current network, which is very costly. In the case of regulated access, Eneco might have no choice but to comply.

### 2.3.7. Balancing mechanism (in decentralised markets)

Balancing demand and supply is important when it comes to utility markets. Utilities are by definition essential to modern day life, which is why shortages are preferably avoided. A shortage in district heating is slightly different than for electricity for example. Electricity shortages are blackouts, where all of a sudden no electricity is available at all in a certain area. Shortages in district heating create more of a congestion situation, where it takes longer for a room or tap water to heat up to a certain temperature. However, not only supply and demand should be balanced in district heating, also the pressure needs to be balanced. There are at least two ways in which balancing both can be done. Either the network operator is responsible for balancing pressure and temperature and also pays for the difference or shortage when this occurs. Or per producer a separate agreement on which pressure and which temperature to produce is finalised, and each producer separately pays if there is a difference from this agreement.

### 2.3.8. End-user price regulation

If it is necessary, end-user price regulation can be established. Either the market facilitates this by itself, or a regulator can regulate end-user prices. This can be done in different ways. Currently, a maximum price for the connection and the use per Gigajoule is set every year in the heat law. Apart from setting a maximum price, restricting the revenues of stakeholder can also be done. These are basically the same two options as for regulated access.



### 2.3.9. Capacity mechanism

In the electricity sector, many capacity mechanisms have been designed. A capacity mechanism is a policy instrument to influence investments in capacity and with that security of supply. A capacity mechanism can be necessary when price restrictions have been imposed, in order to recover part of the lost revenue and avoid under-investment in generation capacity by production companies (Correljé & de Vries, 2008).

There are two types of capacity mechanisms, either by providing incentives to invest in new capacity or by regulating the volume installed (Battle & Pérez-Arriaga, 2008). Within the two categories, there are different mechanisms. Capacity payments and a strategic reserve are from price-based mechanisms. Capacity-based mechanisms include three different types of capacity markets. These three different markets can be characterised as a: capacity obligation, capacity auction and reliability options (Meulman & Méray, 2012). These five types of capacity mechanisms are described below.

Capacity payments basically means that producers are paid to have a certain amount of generation capacity installed. These payments can either be fixed or dynamic. Fixed capacity payments are straightforward, a fixed amount for having a certain generation capacity installed. Dynamic payments can vary taking into account the already installed capacity and the target capacity. The closer to the target, the lower the payments (Meulman & Méray, 2012).

The other price-based mechanism is having a strategic reserve. In the electricity market in the Netherlands, the price for electricity is determined by demand and supply at a certain time. Supply is ranked according to the merit order, which is determined by the marginal costs of each generation facility. The marginal costs basically come down to the cost of the fuel used to produce electricity. A strategic reserve then comes in, at the end of the merit order, being the most expensive production plant which is only used when demand cannot be met by all other installed generation capacity. A central buyer in the system is in charge of this strategic reserve.

Another option is to have a capacity-based mechanism in the form of a capacity market. The first type of market described is that with a capacity obligation. In this type of capacity market producers have to contract a certain capacity with retailers. A retailer has to contract as much as their customers cumulative peak load. Producers contract this amount with them, and thus receive payments for having capacity installed. The second type of market includes a capacity auction. In this type of market, contracts for having a certain capacity installed are sold through an auction. In both types of capacity markets, there is a penalty for non-availability of the capacity. The third option is to have a market with reliability options. This involves a slightly more intricate process. Reliability options are sold either through contracts, like the capacity obligation market, or through an auction, like the capacity auction market. Either way, reliability options have to be bought and when a pre-set so-called 'strike price' is reached on the market, the reliability-option owner is obliged to provide electricity for this strike price. The strike price functions as a revenue cap for the reliability option provider (Meulman & Méray, 2012).

These five capacity mechanisms seem also applicable to district heating. However, since storage of heat is possible, this will influence the effects of capacity mechanisms on the market. Storage can facilitate a part of the total installed capacity, which will be very interesting to look at when designing a market for district heating, in chapter 8. For the time being, the effects of the capacity mechanisms on a district heating market are unknown, therefore all five will remain as an option to fill in the design choice for district heating.

### 2.3.10. Position of regulator

When designing for a regulator in the market, regulation can take place in two ways. Either beforehand, or afterwards or ex ante and ex post respectively. Ex ante regulation has the difficulty that it occurs in advance and tries to prevent market failures, any unforeseen circumstances that happen later on, are difficult to correct. Ex post regulation would solve for this problem, but regulation after any failure in the market has occurred can only mitigate harm from the market failure and does not avoid the failure from happening. Both can be used in the district heating market, for this design choice identifying the market failures that can occur and the chance that they will occur is important to make a decision for ex ante or ex post regulation.

### 2.3.11. Summary of design choices

To summarise the different options that are proposed in literature for each design choice, a table is created.

Table 2: Design choices and the options for each summarised

	Design choices	Options in theory
1	Degree of market opening (organising access)	Open access Access regulation: Pooling Access regulation: Timetabling Vertical separation
	Degree of market opening (market structure)	Wheeling Single-buyer model Wholesale competition / portfolio manager model Retail competition / customer choice model or retail wheeling / network access model
2	Integrated versus decentralised market	Integrated or decentralised
3	Public versus private ownership	Public
		Private
		Public private partnership
4	Competition policy and horizontal unbundling	Regulator
		Market (with perfect competition)
5	Network unbundling	Accounting
		Organisational
		Judicial
6	Network regulation of network tariffs and access conditions	Negotiated third party access
		Regulated third party access: price cap regulation
		Regulated third party access: Rate of return regulation
7	Balancing mechanism (in decentralised markets)	Network operator responsible
		Individual companies responsible
8	Wholesale and end-used price regulation	Maximum price for consumers by law
		Restrict revenue for stakeholders

9	Capacity mechanism	Capacity payments
		Strategic reserve
		Capacity market: capacity obligation
		Capacity market: capacity auction
		Capacity market: reliability options
10	Position of regulator	Ex ante
		Ex post

In order to determine which options for each design choice are possible for district heating, and especially district heating in The Hague, a systems analysis should be carried out. The systems analysis in chapter 3 points out what in practice is actually possible and what design choices are relevant at this time from the options given in theory.

#### 2.4. Concluding remarks theoretical exploration

The theoretical exploration poses a foundation for the research further on in this project. The most important remarks are:

- The current district heating system is a natural monopoly. This needs to be changed to allow multiple independent producers on district heating networks.
- The district heating system is comparable to the electricity, gas and water utility systems as a product and service, but has its differences as well. These need to be taken into account when designing a market for district heating
- There are 10 design choices for a market for district heating with each several options theoretically

The questions that arise from the theoretical exploration are:

- Do the stakeholders, apart from E.ON and the Ministry of Economic Affairs who do want to change, in the current district heating system also want to change from monopolies to a competitive market?
- There are 10 design choices theoretically, which are the most important choices in practice?

These are the questions that the next chapter will answer, amongst analysing the current district heating systems in The Netherlands.

### 3. Systems analysis of district heating

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*This chapter will provide an analysis concerning district heating networks in general. First the system will be analysed as a whole, where after an analysis of the three domains follows. This will allow for a district heating network in The Hague is analysed through interviews with experts in the field. Together the analyses will narrow down which design choices from theory are possible in practice and which are relevant at this point in time.*

From the theoretical exploration, it has become clear that there are many design choices when it comes to designing a market and introducing competition in a utility network. It is good to know what all the options are, however, theory does not always match with what happens in practice. Since this research also focuses on the situation of E.ON Benelux in the area of The Hague, it is important to know which theoretical options for the design choices are plausible in practice. In order to do so, part of a systems analysis is executed. Both Sage & Armstrong (2000) and Enserink et al. (2010) are used to conduct the analysis.

Sage & Armstrong describe that exploration can be made up of two scenario's, a descriptive and a normative scenario. Also referred to as the current situation and the desired situation respectively. This is very relevant for this research. To come to a realistic market design, both the theory outcomes as well as the practical outcomes out of this systems analysis are essential. First of all, mapping the current situation is of the essence to understand what technical, economic and institutional arrangements are in place and any limits that this may pose on a future market. Secondly, it is also important to know of each stakeholder what their desired situation does or does not look like.

To get insight into the desired situations of each stakeholder, interviews are conducted. Interviews are conducted conform the rules of semi-structured in-depth interviews described by DiCicco-Bloom & Crabtree (2006), in order to ensure a valid procedure. The answers of each interview are used to come to a means-ends diagram for each stakeholder. The means-ends diagram is created by asking 'why' and 'how' questions with regard to each stakeholders' fundamental objective (Enserink et al., 2010). This should give enough insight into what options for design choices from theory are desirable or undesirable in practice. With that demarcating the options for a future market for facilitating access to multiple independent producers in district heating networks.

#### 3.1. Descriptive scenario – the current situation

To begin with, the current situation of the district heating system in The Hague is described. By means of the three domains, namely the technical, economic and institutional, the district heating system is described. Before describing these elements in detail, the physical layer that provides the foundation for further analysis of the district heating system is established and the market context is identified.

### 3.1.1. Physical layer

The physical layer of district heating starts at production and eventually leads to consumer or use. Between production and use, heat is transported and distributed. This can be summarised in the following diagram:

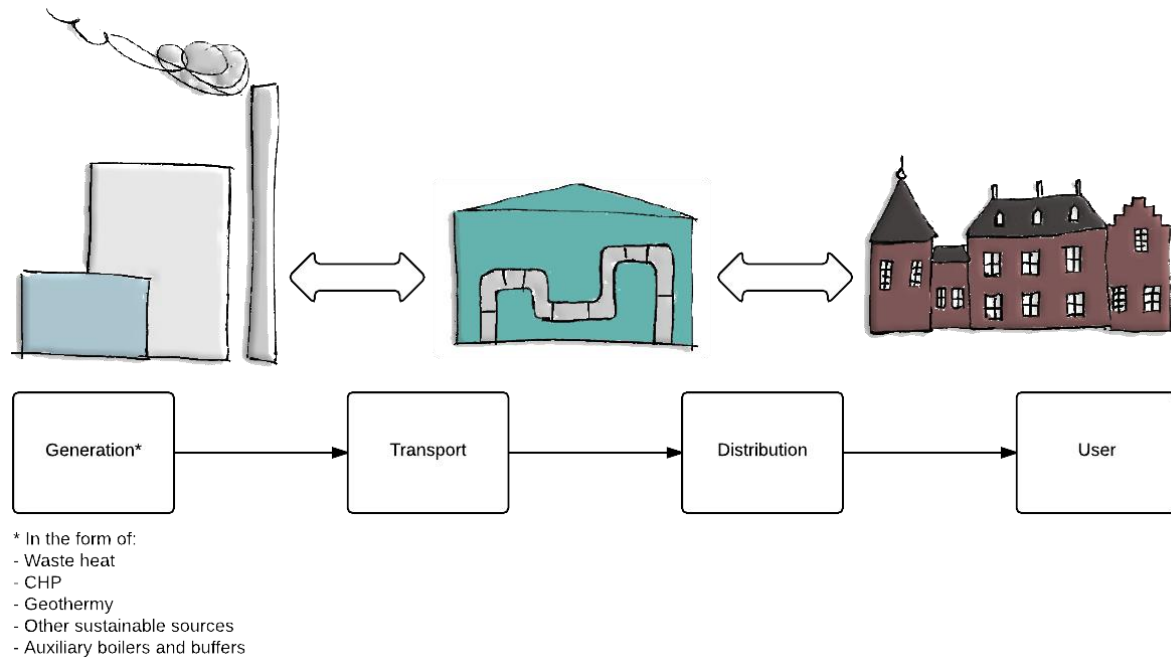


Figure 6: Physical layer of the district heating network in The Hague and area

Each segment in the physical layer is owned and operated by a stakeholder. E.ON Benelux is the current producer and Eneco the distributor. Currently, in The Hague there is no need for transport network or operator. Since the distance between the generator and consumers is small, the heat goes straight from production to distribution. The producer and distributor have interests within a specific part of the chain, namely production and distribution. Both of them 'own' or at least exploit that part of the value chain. There are also stakeholders that transcend the physical layer and are more involved with the system as a whole. The Ministry of Economic Affairs, Province Zuid-Holland, Programmabureau Warmte-Koude Zuid-Holland and the Municipality of The Hague are these transcending stakeholders for the situation of district heating in The Hague.

The end-users are not in the scope of this project, since the focus is on introducing more producers in the market for district heating. They are included in the physical layer and in any analysis that requires knowledge of the whole chain, however, no special attention is paid to their share in the district heating system. The positions of E.ON and Eneco are further clarified in the market context section, where after an analysis of the technical, economic and institutional aspects of the current situation follows.

### 3.1.2. Market context

Private companies are in charge of parts of the value chain. E.ON is the current monopolist producer of district heating in the case of The Hague. E.ON trades its heat with Eneco, who is the current

monopolist distributor of heat in this area. They have a contract together, which lasts from 2008-2023, in which a certain price per MW (thermal) is agreed upon as is the temperature at which is supplied. This temperature is variable with the outside temperature, as higher district heating temperatures are required when it is freezing outside and lower temperatures are sufficient when it is warmer.

Since E.ON is the sole producer of heat for district heating for The Hague, whatever is demanded is also what E.ON must supply to Eneco. This seems to be natural. However, since E.ON produces heat using a Combined Heat and Power plant (CHP), heat is not the only product of that plant. Therefore, it is not always to their advantage to produce the heat that is necessary to fulfil heat demand. With the CHP, a certain trade-off situation is created. It is fuelled by natural gas, which is then either transformed into power or heat. Whenever the electricity prices are high, it is much more to E.ONs advantage to produce more power and less heat, since the heat prices are fixed for longer term. As one can imagine, power prices are high when demand is high, which is during winter and peak hours mostly. As it turns out, these are also the moments at which the most heat is required, creating a serious strategic disadvantage for such plants. E.ON must supply the heat, and can therefore not use its CHP to earn profits on selling electricity for high prices on the spot market. This is referred to as a must-run situation.

It can be concluded that E.ON has been put in a difficult position, because on top of the must-run situation they are dependent on Eneco for purchasing their heat. Eneco has a monopoly on distribution and they decide whom to buy heat from. This dependent position brings insecurities and risks for E.ON. At the same time, there is a large barrier to entry for both producers and distributors on the district heating market. The costs of the necessary equipment are so high, making it almost impossible for any potential producers to come up with a positive business case.

### 3.1.3. Technical domain

The technical structure of district heating is very complex. A brief overview of temperature requirements, capacity of the pipeline and the complexities these bring are given. Firstly, the supply temperature of heat at households should always be 90°C, in order to reach a room temperature of 21°C with the standard radiators in the Netherlands. Taking the 90°C as a given, the temperature at which heat leaves the plant varies between 120°C and 95°C, dependent on the outside temperature. The return temperature is then dependent on how much a household uses, but is generally measured to be 68-70°C. This gives us a temperature difference, also known as  $\Delta T$ . This difference is important, because it co-determines the capacity of the pipeline. The larger  $\Delta T$ , the more capacity the pipeline can hold.

The pressure in the network is controlled with the use of booster stations. As the name suggests it boosts the pressure of the water flow, since there is a certain pressure drop over the distance travelled. Then there is also the flow, with which the heat travels through the pipeline. The flow is the volume per time unit. This is dependent on the diameter of the pipeline. Together with the pressure, pressure drop and  $\Delta T$  the capacity of the pipeline can be determined. The pressure, pressure drop and diameter of the pipeline are stable, however the  $\Delta T$  changes daily, seasonally and so forth with demand and outside temperature for example. Therefore, the capacity of the pipelines varies over time.

The fact that the capacity varies over time and is dependent on  $\Delta T$ , brings technical complexity. From the producers and distributors point of view on efficiency, it is desirable to have a large  $\Delta T$  so that smaller pipelines can be installed that can still hold the capacity that is necessary to meet demand.

This would lower the barrier to entry significantly. At the same time, it is more efficient from a societal and consumer point of view, to have a lower  $\Delta T$ . This would mean households use less heat, because their homes are well isolated, or make use of floor heating for example. This lowers their costs of heat use, and since a smaller amount of heat is used, this is more efficient for them as well. Because there are multiple points of view on the  $\Delta T$ , this is an important factor to take into account when designing a new market for district heating.

Since the temperature plays such an important role in what technically is possible for district heating, this should become an additional design choice. The options for this choice are: either a high temperature network as it is now (90-120°C) or making a switch to a low temperature network with supply temperatures between 40-70°C.

#### 3.1.4. Economic domain

There are several economic principles that are used in practice in district heating systems in the Netherlands. The two design choices from theory that are economically relevant are the end-user price regulation and the capacity mechanism. The current situation only has an end-user price regulation in place, and does not have a capacity mechanism installed. In this paragraph, only the organisation of the end-user price regulation is discussed.

Since consumers cannot choose within district heating who supplies them, or even choose another form of space heating. Consumers are completely surrendered to the one supplier of district heating in their area. To reduce the negative effects of this monopoly position for the consumer, a maximum price is set that suppliers can ask. This price calculation is divided into a connection fee and a variable cost that is dependent on the Gigajoules (GJ) of heat used per consumer, the exact calculation is demonstrated in the theory exploration chapter.

E.ON and Eneco as producer and distributor have agreed upon a price per GJ. The basis in this calculation finds itself in the heat law as well. In this law, it is established that a producer can receive a reasonable return on the heat delivered. The costs made by Eneco are therefore based on the costs made by E.ON for production in addition with a reasonable margin for E.ON. Dispatch is calculated using the established price agreement. Because prices are constrained by the NMDA principle in the heat law, it is less likely that producers will invest in generation capacity. In order to stimulate investments in generation capacity, a capacity mechanism could be installed. Therefore this is another design choice worth looking into. The capacity mechanism is therefore included in further analyses in this project.

#### 3.1.5. Institutional context

In order to define the institutional context, Williamson's (1998) layer model is used. This model maps four different layers of institutions, varying from those that are completely embedded in society to temporary agreements that are made, as shown in the theoretical exploration in chapter 2. In the figure below, this framework is applied to the case of district heating in the The Hague area.

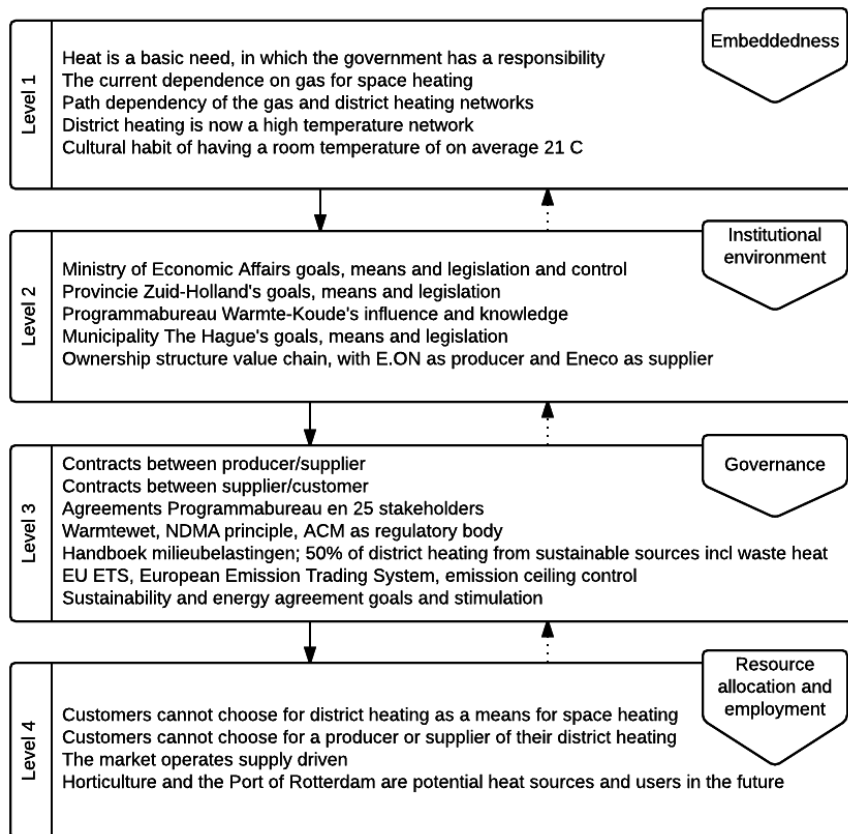


Figure 7: Institutional layers of the current district heating system, framework by Williamson (1998)

### Level 1

To elaborate upon the figure, a few institutions will be explained. The first layer includes norms, values, cultural habits and other completely embedded institutions. Heat is seen as a basic need for human beings, and therefore the government is responsible for the availability for citizens. This means they have to ensure even households with the lowest income can afford this service. In the past, much of space heating in houses has been provided by gas. Generally, each house has a gas connection, which though an individual boiler heats up water for radiators and tap water. Simultaneously, many houses therefore have a gas stove as well. Since the Groningen gas field was discovered, this has become the norm in the Netherlands. The effects of these norms on district heating have been that all houses are built based on 90°C water running through radiators. This is to meet the cultural norm of an average 21°C room temperature. To illustrate that this is actual culturally determined an example of another district heating is given. For example in Sweden, radiators are larger by default creating a larger surface area, which only requires 72°C water in order to reach the similar 21°C average room temperature.

### Level 2

Then on to the second layer. This level includes the institutional environment, or the formal rules of the game so to say. Which pays special attention to property, in the polity, judiciary and bureaucratic sense. Formally speaking, the value chain is divided as illustrated at the beginning of this section, where the Ministry of Economic Affairs, Programmabureau Warmte-Koude Zuid-Holland, Provincie Zuid-Holland and the Municipality of The Hague have chain-wide interests and control. Others, like



E.ON, Eneco, own a specific part of the chain, production and transportation, and distribution respectively. To clarify the relationships between each stakeholder, a simple diagram is made.

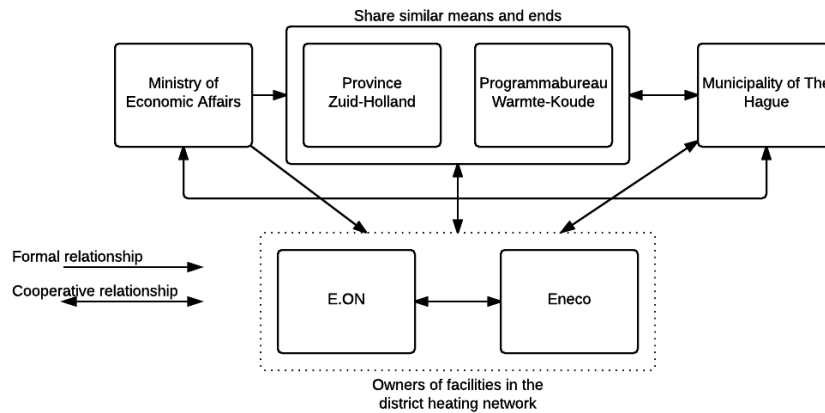


Figure 8: Stakeholder relationships

### Level 3

The second layer has direct effects on the third layer, which includes governance, or so-called play of the game, with especially contracts and aligning governance structures with transactions. In this layer, the contracts within the chain are important, physical and verbal agreements included. Not only the contracts, but also the laws and regulations that apply to district heating are in this layer. Some of them are applicable specifically to the economics of the system, they have been explained in the previous paragraph. Sustainability goals are applicable for district heating as well, this influences which sources should be used in the near future. The European Emission Trading System (EU ETS) is also included in this diagram, because the Port of Rotterdam is one of the potential producers of district heating. They reach their maximum allowance of the allowed emissions, and up until now reusing waste heat for district heating does not count as a saving on the emissions. If it would, they would be far more likely to want to connect to the district heating system for example.

### Level 4

The fourth and last layer includes the institutions on resource allocation and employment. For this system, this means the fact that consumers cannot choose their supplier, or for district heating as a form of space heating at all. The market thus far has been focussed on 'there is heat supply' and not 'there is heat demand', which has made it supply driven. Lastly, horticulture and the Port of Rotterdam are seen as potential producers, so knowingly or not any plans made are already focussed on these parties.

## 3.2. Consequences for design choices

Reflecting back on the design choices found in literature, this part of the systems analysis has shed light on the importance of some of the design choices in practice. The degree of market opening and with that the introduction of competition is clearly of utmost importance, as it focuses on the core of this research. The institutional exploration has shown what institutionally is in place now, creating the context of what needs to change when adapting the degree of opening. Apart from that, a capacity mechanism is identified important to stimulate investments, in case of price regulation in the economic analysis of this chapter. And in addition, from the technical analysis, the supply temperature of the heat, and with that  $\Delta T$ , is very significant to the design of any future market. The three design choices that will be leading in any market design to be made are summarised in table 4.

Table 3: Final design choices for district heating

	Design choices	Options in theory
1	Degree of market opening (access related)	Open access
		Access regulation: Pooling
		Access regulation: Timetabling
		Vertical separation
	Degree of market opening (market structure)	Wheeling
		Single-buyer model
		Wholesale competition / portfolio manager model
		Retail competition / customer choice model or retail wheeling / network access model
2	Capacity mechanism	Capacity payments
		Strategic reserve
		Capacity market: capacity obligation
		Capacity market: capacity auction
		Capacity market: reliability options
3	Supply temperature	Low temperature network (40-70°C)
		High temperature network (90-120°C)

Before giving meaning to the design choices, an analysis of the desired situation is done. This shows what the stakeholders deem as important and with that what objectives are set for the new system. From then on, it is necessary to develop a conceptual model. This conceptual model should capture the different layers of the district heating system in general. With such a general model, the design choices can be given different meanings so that alternatives for a future market can be generated.

### 3.3. Normative scenario – desired situation

*The desired situation is composed by doing several expert interviews discovering the means and ends of the identified stakeholders. For each stakeholder, a short description of their means and ends will follow, finalised by a concluding paragraph on the direction the sector would like to move in. First the relationships between the stakeholders is briefly clarified, when it comes to district heating in The Hague and surroundings and the goal of the interviews will be explained.*

For each of the mentioned stakeholders in figure 8, their means and ends are identified through an expert interview. In these interviews stakeholders have expressed their interests, objectives and with that a problem perception towards the district heating market. These are important in order to formulate potential market alternatives, or at least the direction the individuals would like to move in. The value of these market alternatives is much higher when these are realistic within the means and ends of the stakeholders.

The approach take with these interviews is as follows. In advance of these interviews, a means-ends analysis based on desk research for each stakeholder is carried out. Then through an interview, these analyses are verified. This is done by asking ‘why’ and ‘how’ questions, as suggested in Policy analysis of Multi-actor Systems (Enserink et al., 2010). The means-ends diagrams can be found in

appendix B, a short description of the most important means and ends per stakeholder can be found here in this chapter.

### 3.3.1.E.ON

E.ON's highest goal is to be the number 1 in management of district heating. This includes providing dispatch services as well as generation capacity. E.ON has more plants that could supply heat than are currently connected to the network. Another is to contribute towards a 'warmterotonde', with access for E.ON as a producer, through providing manpower and investments as well as increasing room for other producers. The 'warmterotonde', or heat roundabout, is an idea where in the province of Zuid-Holland all district heating networks are interconnected, instead of being separate networks. Thirdly, in order to become the number 1 in management of district heating, E.ON could optimise dispatch and heat trading of their current production facilities. Optimising dispatch for E.ON includes providing a certain amount of heat and a certain amount of electricity with the CHP, depending on when prices for heat or electricity are higher than the other. Thus increasing their production flexibility and avoid the so-called must-run situation for heat. A fourth mean to achieve being the number 1 in district heating is to increase participation in new district heating projects, for example the Cluster West project. This project looks at the possibility to use waste heat from the Port of Rotterdam through the greenhouse area 'Westland', all the way to The Hague.

### 3.3.2.Ministry of Economic Affairs

The Ministry of Economic Affairs of the Netherlands is the highest institution that can exert control over the district heating network. After carefully considering the 'heat vision' which was recently published, it is clear that they want to improve the sustainability of the district heating system, as well as making district heating competitive with gas and electricity, while maintaining security of supply and affordable heat. The ministry can improve the sustainability by increasing the amount of producers, increase the availability of sustainable resources, increase awareness of heat consumption of consumers, increase isolation of houses and buildings, improve radiators, floor heating etc. as well as adapt the temperature of the district heating system. Hereby, they also deem it necessary to look at potential other market models to regulate the market in a different way, and allow competition in the production segment of the market.

### 3.3.3.Province of Zuid-Holland and Programmabureau Warmte-Koude Zuid-Holland

The highest goal the Province Zuid-Holland has in regard to district heating is 'to provide 14% of space heating from sustainable resources by 2020', the same holds for Programmabureau Warmte-Koude. Overall their means and ends are similar, considering the Programmabureau was an initiative of the Province Zuid-Holland and the chairperson of the steering committee is also from the Province Zuid-Holland. This is why they will be discussed together here in the results. The main difference is that the Province Zuid-Holland has a sub-goal besides realising the warmterotonde, namely setting up a so called heat fund, from an EU fund for low-carbon initiatives. There are several means to realise the warmterotonde for both the Province Zuid-Holland as the Programmabureau Warmte-Koude. Important for them is that district heating expands in the near future and they believe no one stakeholder can do this alone and a united collaboration is needed to exploit the potential district heating has. They value the consumer greatly, and find it very important that the price of district heating remains affordable.

### 3.3.4. Municipality of The Hague

The municipality of The Hague is trying to achieve an energy transition away from gas and become energy neutral in 2050. They are setting up a separate company, the so-called 'Haags Warmtebedrijf', which should embody this goal. Their vision is to ensure energy supply by transitioning away from natural gas and towards sustainable, renewable energy sources. This also goes for space heating, which is why they have created a 'heat map'. This heat map divides areas into where district heating has large potential, compared with for example 0-energy neighbourhoods or individual heating solutions. District heating can play a large role in this transition, but access for more producers is prerequisite for this as far as the municipality is concerned.

### 3.3.5. Eneco

Eneco is the current distributor or supplier of district heating in the The Hague and Rotterdam areas. They have as a goal to provide everyone with energy from 100% sustainable, renewable sources and have the image of 'the sustainable energy supplier'. In this context, their goals are to supply heat only from renewable sources. It is interesting, because they do not see waste heat as a renewable source, and therefore they are looking for alternatives for this in the future. In order for Eneco to grow within district heating, their vision is that the transport of district heating has a future as a public utility, separate from distribution of heat. And that they remain a monopoly on the distribution network that is already theirs now. They are strictly against competing for distribution.

## 3.4. Consequences for market design

Results of the many means-ends analyses are different goals, and different functions per stakeholder. These separate analyses can be found in appendix B. Looking at the means and ends of all stakeholders, one thing stands out. All stakeholders want multiple producers to feed to the network of district heating. This is an important finding, since this is also what the problem owner, E.ON, wants. This means that all stakeholders agree on this point and there will be little resistance or discussion on this front. There will most likely be discussion about how to do this and what such a market should look like.

Objective variables have resulted from the interviews that sketch the desired situation for each stakeholder. Out of all the means and ends of all stakeholders, a table with functions of the new market has been created. The table can be found in appendix B. This total list of means and ends can be seen as functions the new system should have. It is not realistic that all functions are fulfilled, therefore a short list is made of what the most objective variables are of a new district heating market. Implicit information obtained through conversation with stakeholders was also used for this.

These are the objective variables for a new market for the district heating system:

- The security of supply [ratio]
- The price of 1 MWh of heat [€/MWh]
- The demand for heat [capacity, volume]
- The number of producers in the market [1...10]
- The market share per producer [%]

This list will be used to compare the alternatives on. By filling in the design choices per alternative, and through knowledge and modelling, the effects on these variables should be given. On this basis a comparison can be made and a best alternative for a market design is chosen.

## 4. Conclusion phase A

Much of the available literature on market structures of utilities does not address district heating. The literature research shows that district heating has similar characteristics to other utilities, such as electricity, gas and water, which is why this literature can be used to design a market model for district heating based on these utility markets. However, there are also some differences, which should be taken into account when designing a model. The similarities and differences are summarised in the table below.

Table 2: Similarities electricity and heat as a product and service

Similarities	Differences
Value chain from production-consumer	Storage is possible
Make use of a large network	Higher barriers to entry
Natural monopoly characteristics	Transport costs and heat losses when there is no demand
Security of supply important	Balancing mechanism less important
Both a basic need/utility	More local networks
Hourly/seasonal changes in demand	

Introducing competition in district heating by facilitating access to multiple producers to the monopoly segment of the network (transport), is introducing competition over existing networks. There are several design choices when designing for competition. The market design choices from theory that can be applicable to district heating are

Table 4: Final design choices for district heating

Design choices	Options in theory
1 Degree of market opening (access related)	Open access
	Access regulation: Pooling
Degree of market opening (market structure)	Access regulation: Timetabling
	Vertical separation
	Wheeling
	Single-buyer model
	Wholesale competition / portfolio manager model
2 Capacity mechanism	Retail competition / customer choice model or retail wheeling / network access model
	Capacity payments
	Strategic reserve
	Capacity market: capacity obligation
	Capacity market: capacity auction
3 Supply temperature	Capacity market: reliability options
	Low temperature network (40-70°C)
	High temperature network (90-120°C)

Apart from the design choices, there are several critical success factors that are critical for any district heating market design to work. These are essentially having more potential producers that can produce heat, and expansion of the current network by having an increase in demand and acceptance, and an investments and risk bearer. However, this project focusses on the design of the market and will not go further into detail on the critical success factors. It does acknowledge that these factors are essential and need to be carefully considered before implementing any sort of market reform.

Complex systems, such as the district heating system, where multiple actors are involved, from both public and private nature, are best described from three different perspectives. In such systems the technological component does not determine the working of the system, but the behaviour of actors that take certain decisions have a great part. The three layers, technical, institutional and economic will be leading in any market design that will be made for this project, they are all essential to design a complete market.

The current situation poses a must-run situation for E.ON, where they have no choice but to supply the required demand even if strategically it would be better to do otherwise. The technical characteristics of heat are a certain supply temperature, a pressure and a flow. Heat goes from production, through pipelines via transport, a booster station to distribution and eventually is used by the consumer. Economically, a certain price is determined which consumers pay for their demand, which then flows back to distribution which Eneco accounts for. They then have a contract with E.ON with amongst other things a price agreement. Looking at the institutional analysis, many different institutions on different levels can be identified. Considering roles and ownership and the degree of market opening, currently, E.ON is in charge of production and Eneco of distribution, where they are the monopolists in the market for district heating in The Hague.

When interviewing the stakeholders in the district heating system in the case of The Hague, it became apparent that they have different means and ends, and also different goals. All stakeholders want multiple producers to feed to the network of district heating, which is a positive finding, however there will most likely be discussion about how to do this and what such a market should look like. These are the criteria or objective variables for a new market for the district heating system:

- The security of supply [ratio]
- The price of 1 MWh of heat [€/MWh]
- The demand for heat [capacity, volume]
- The number of producers in the market [1...10]
- The market share per producer [%]

These criteria will be used later on to compare the market design alternatives.

# Part III: Phase B - analysis



## 5. The conceptual model design

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*Now that it is made clear what the current situation looks like, and what is desired of the future situation, a design area can be scoped. In this chapter, the variables that are 'design variables' are identified. This is done by reasoning logically and looking back at the theoretical exploration, keeping in mind what elements make up a market design. This design area will show start demarcating where the design phase of this project will put its focus. Based on this, the conceptual model can be developed. The elements of the model will be explained in this chapter.*

### 5.1. Design area

As identified in the theoretical exploration, there are 13 market design choices for electricity markets and of those 13, 10 are said to be relevant for district heating. From the systems analysis, these 10 have been narrowed down to 3 important design choices for district heating. Namely the degree of market opening, capacity mechanism and supply temperature. This is what will be redesigned in any market design alternatives. However, before market design alternatives can be created, it is important to make a conceptual framework that encompasses the market in its entirety. This will allow to see where the design choices are in comparison to the whole market design and give an overview of the district heating market as a whole. This is important because in a later stage, the other design choices will become important and a conceptual model can provide a foundation for that.

What should be included in the model are the three design choices as mentioned, and how they fit into the technical, economic and institutional aspects from the systems analysis. As can be seen in the systems analysis, the degree of market opening can be seen as an institutional element. The capacity mechanism is more of an economic aspect, regarding investments and the supply temperature belongs to the technical side of the district heating system. Other elements that the conceptual model should include is the value chain presented in the systems analysis. This can provide the foundation to show where the three design choices are located and how they are related. For the conceptual model, it is therefore important to create a technical, economic and institutional layer that can encompass the steps that happen on those levels compared with the physical level. First, the design area of the elements to be included in these layers is shown in figure 9.



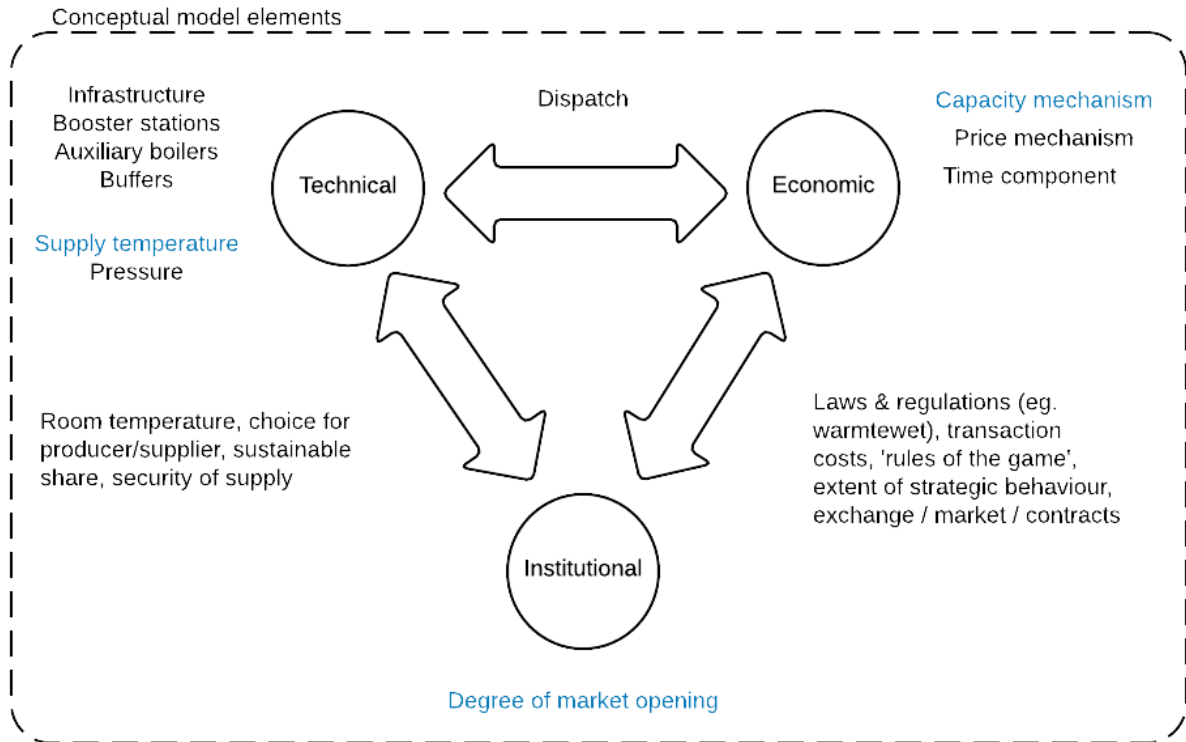


Figure 9: Design area of conceptual model elements

The market design will still focus on the three design choices identified. However, the conceptual model should also include the elements that are demarcated in the market design box above.

## 5.2. The conceptual model

The idea behind this conceptual model is to map the system as a whole including the relations between different variables in the system. The conceptual model consists of three layers: a technical layer, an institutional layer and an economic layer. Each layer describes a different aspect of the market design, occurring at the same physical stage of the market. The physical stage guiding the other layers consists of the four main activities, namely: production, transport network, distribution networks and load, representing the different activities in the value chain through which heat passes from production to consumer. The technical, institutional and economic layers each have their influence on each other and share an interface where the layers interact.

The layers include the following:

- The institutional layer indicates who or what type of organisation is active within each stage, or the roles they have with respect to the physical stage in which the heat is located. This can be different with respect to each market design, depending on the degree of market opening, which is indicated by the dashed box around the elements.
- Then the economic layer indicates how the heat is traded from each stage to the next. This could also vary, depending on the institutional design of the structure, and the technical interpretation of the system. In this layer the capacity mechanism is important as a design choice, which is again indicated by a dashed box around the elements.

- The technical layer shows what technically needs to happen to get the heat from the place where it is generated to where it is being used. This structure is not likely to vary, but the implementation may differ in temperatures, losses, kilometers etc. As indicated, the supply temperature is what is focussed on, this is demarcated by a dashed box.

As is already becoming clear, the layers are very dependent on each other and cannot be seen separately. Therefore interfaces are included in the diagram. The interfaces show aspects that will need to be balanced between the layers, being influenced by or influencing multiple layers. As an example, room temperature is demonstrated. This is a cultural habit, and will be different per country or region, or even differ within cities where communities with different cultural backgrounds live together in neighbourhoods. In the Netherlands, a room temperature of 21°C is maintained. From the technical side, this means that the supply temperature must be high enough to heat households to this temperature, either through radiators or floor heating or otherwise. As is illustrated a quite simple aspect such as room temperature can have a big impact within different layers of the system.

### 5.3. Technical layer

First off, the technical layer. This layer encompasses the actual heat or energy flow and its characteristics. The temperature, the pressure, the pipeline, the network, and the return flow of water. This is comparable with the paragraph 'technical domain' in the systems analysis chapter and design area. Not much is likely to change within this structure for district heating when more producers are added to one network of district heating. There will still be a generator, booster stations, distribution and the use of heat and between the elements, the heat will flow with a certain temperature, pressure and over a certain distance. The distances may change, and the amount of generators, booster stations might change, but this does not alter the fundamental technical structure. There is one aspect in the technical layer that does have an impact when changed, this is the supply temperature, a design choice as mentioned in chapter 3. Therefore this aspect is demarcated with a dotted line.

The current supply temperature is 90°C the moment it enters households. This is necessary to heat up rooms to 21°C, our cultural standard, with the size of the radiators that houses generally have. Several aspects can be changed with respect to supply temperature. For example, floor heating has a much larger surface area which reduces the necessary supply temperature to as low as 40°C to reach the same comfortable room temperature. There are several reasons a lower temperature could benefit the district heating market. First of all, more producers would qualify to supply heat on the network because not all sources can reach 90°C. This implies that more waste heat can be reused and more sustainable sources can be connected to the network if the temperature is lowered. Overall larger number of potential producers can be identified if that is the case. Additionally, pipelines that are newly constructed can be made of cheaper materials, because of the lower temperature. This would reduce the barrier to entry for distributors as well.

However, there are also downsides to switching to a lower temperature. Firstly, this has the consequence that households need to change their radiators to floor heating for example, which involves a cost shift to consumers. Secondly, with a lower supply temperature, it is more difficult to obtain a large  $\Delta T$ . The smaller the temperature difference between the supply and return temperature, the smaller the capacity of heat on the same pipeline. Even though with a lower supply temperature, the pipelines can be made from cheaper materials, the diameter of the pipeline might need to increase to accommodate the same capacity. There are different benefits and doubts about this design choice, which is mainly why it is an interesting element.

## 5.4. Economic layer

The economic layer is already more subject to change than the technical layer. Trading and investments can be done in many ways. Through an exchange, a market, or contracts are just some of the options possible for this layer. This conceptual model shows that in the transport and distribution network sections of the value chain, the economic counterparts are not set in stone. These are to be filled in, when designing alternatives for the market. These elements in the economic layer are related to the institutional layer and the structure that is designed there. It must be kept in mind that these cannot be seen completely separate. Within this layer, there is one design choice that is very important, namely the capacity mechanism. A capacity mechanism is a policy instrument to give incentive to investments. Especially in potential new market situations, a big question is 'who is responsible for investments in which parts of the value chain' and how can be made sure that investments are made?

In the Netherlands, the electricity market is a so-called 'energy-only' market, with no capacity mechanism in place. This works under rules and regulations that give enough incentive to invest (Meulman & Méray, 2012). However, in some other countries in Europe, capacity mechanisms are installed in electricity markets. Capacity mechanisms are becoming increasingly important with the required flexibility dealing with wind and solar energy for example. For district heating, which has some different characteristics compared with the electricity market, it could be necessary to install a capacity mechanism as a way to ensure investments are made by the right parties. The consideration is here, will investments occur on its own, or do the parties involved need an incentive? The difference between heat and other utilities here is that heat is often a by-product, either of an industry or of a CHP plant for example. This would imply logically, that some form of incentive is needed to ensure security of supply of heat, since investments in a by-product are not evident. On the other hand, another difference is that storage of heat is possible, whereas for electricity and gas this is not available yet or very expensive. This would mean that some form of spare capacity can be stored to use when needed, and investments in a new plant will logically occur when the price of storage exceeds the price of a new plant. For the district heating market, different capacity mechanisms can be considered, as identified in the theoretical exploration. These will be further discussed in the alternatives chapter.

## 5.5. Institutional layer

The institutional layer is perhaps the most intricate of all, since these elements are mostly variables you cannot calculate or give a value to, for example elements like roles, responsibilities, and ownership. Looking back at the institutional analysis in the system analysis, there are four layers that can be identified. All these institutions do not necessarily operate on the institutional layer itself, but also either in the economic & institutional interface or the technical & institutional interfaces, since institutions can be nested anywhere. That is why in the institutional layer itself, it is chosen to visualise the parties that operate on those steps in the physical layers. Other institutions from the four layered model should be seen as institutions that can occur or influence the system from other positions in the conceptual model, such as the interfaces. What is the most important in this layer, is to show the degree of market opening. This is also why it is chosen to show the stakeholders in the institutional layer rather than all institutions per se. The focus is then on where competition is introduced and how ownership occurs in the district heating system.

For the design of electricity markets, four distinctions in market structure are made: wheeling, single-buyer model, wholesale competition, retail competition (Correljé & de Vries, 2008), as also mentioned

in the theoretical exploration of this report. These could potentially be applied to district heating, since conceptually, they are based on the same value chain from production through transport and distribution networks and eventually to the consumer. For this research, we will assume that the degree of market opening distinctions can also be made for district heating. Keeping in mind that, currently, there is no real transport going on yet, only distribution. This could most definitely change, considering when more producers are added to the network, transport is likely to be required. As is also the case with the heat roundabout plans by the Province Zuid-Holland. For the degree of market opening the four options will be considered in the alternatives later on, and the transport step should be included for now.

Apart from the market structure, access organisation is also part of the degree of market opening. Different options from literature are applicable here, open access, pooling, timetabling and vertical separation. These different ways of granting access will be applied in designing the alternatives and be slightly dependent on the market structure chosen. The access organisation element is also included in the conceptual model within the marked design choice area in the institutional layer. It is less clear from the diagram itself than the market structure is indicated, however, it is important to include in the alternatives.

## 5.6. Interfaces

Variables that either influence elements from two layers, or themselves are influenced by elements in two different layers, are placed in the interfaces. Three different interfaces can be identified. The I&E, E&T, T&I interfaces include many variables. Many of these variables are actually institutions, but since these are important for more than the institutions layer, they intervene on the interfaces. The variables on the I&E interface are the laws & regulations, transaction costs, and the institution through which trading takes place, for example contracts, an exchange or a market. The E&T interface includes only one variable, which is the dispatch. How the dispatch is calculated depends on the economic and technical configuration, which is why it is on that interface. On the third and last interface, the T&I interface, room temperature, whether there is a choice for producer or supplier for consumers, the sustainable share and the security of supply are situated. This is all summarised in figure 10.

## 5.6.1. The conceptual model for district heating in the Netherlands

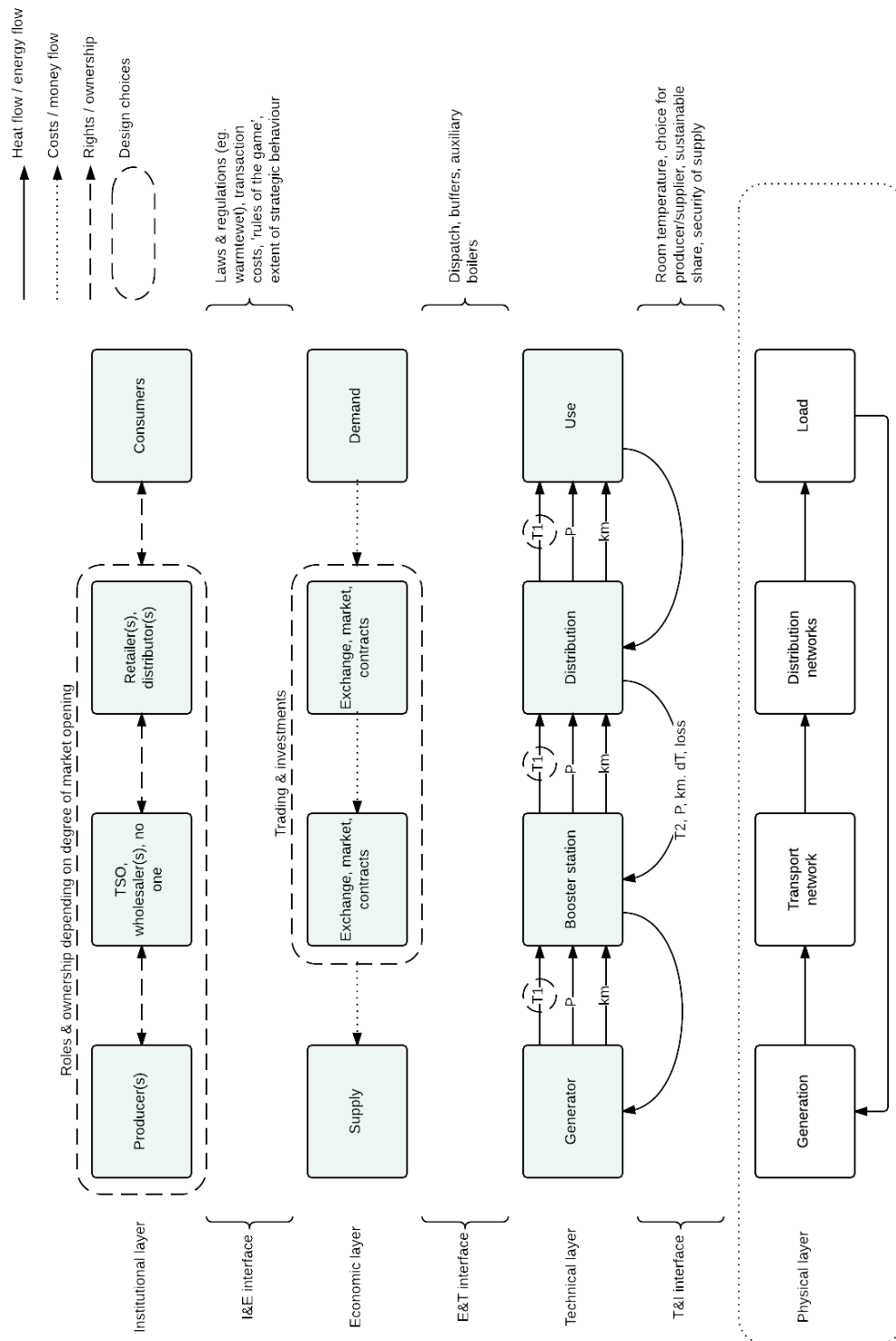


Figure 10: The conceptual model of the district heating system

**Reading guide:** The physical layer forms the foundation on which the rest is based, showing the stages of the value chain from left to right. The institutional, economic and technical layers show what occurs on that level per stage in the physical layer. There are also variables indicated per interface, concepts of what could occur in those spaces.

After having designed the general conceptual framework of the district heating market elements, some important discoveries were made. The conceptual model has several advantages, to begin with it clearly creates awareness of all the concepts involved in the district heating system. Additionally to the heat flow from production to consumer, it is clear that economic and institutional domains accompany the technical domain. Many different configurations within the three layers are possible. Another advantage is that it gives insight in all the three layers, and not just one. The added value of this is, that when looking for change within any or more of the elements in the district heating system, it can be placed in context. Knowing where in the conceptual model a certain element interacts, is very useful if change is necessary. Especially since, one layer cannot advance without the other. For example, even if technology advances and economically investments are organised, if the institutional domain does not support the change, it is very unlikely to happen. Another advantage is, is that the conceptual model is generalised and can be applied to different district heating networks in the Netherlands. It is not meant to be applied to anywhere outside the Netherlands, since rules and regulation can be very specific. However, perhaps it can be in further research. Nevertheless, when the conceptual model is applied to a specific situation, it form a complete picture of the district heating system. This can serve as a basis for simulation, when this is of interest.

It is also important to note some disadvantages or limitations of the conceptual model. During the process of designing, it turned out that it was very difficult to capture all the dynamics of the district heating system in one diagram. More than once, it was found that it was desirable to design a model that could advance over time. For example, when looking at the demand for district heating, it was a difficult choice how to put this in the model. Should demand be expressed in volume, in capacity? And it varies hourly as well as seasonally, how should this be captured. Eventually, it was decided that the conceptual model had to be quite high level, in order to deal with these difficulties. Furthermore, even though a demarcation in terms of the design area was necessary, it does limit the elements included in the conceptual model. However, the design area is based on the theoretical exploration and the systems analysis of the district heating system in The Hague, therefore it is not sudden that the design area is demarcated where it is. To conclude, the different advantages and disadvantages are briefly summarised below.

Table 4: Advantages and disadvantages of the conceptual model

Advantages:
Creates awareness of all concepts involved;
Gives insight in all three layers, which brings added value;
Provides the means to represent the different flows, for it is not only heat going from A to B and back;
One layer cannot advance/change without the others, which means looking at one perspective is not sufficient;
Can be applied to different situations in the Netherlands for different district heating networks;
When applied to a specific situation, this can form a complete picture and a basis for simulation.
Disadvantages:
Difficult to capture all relations and dynamics in a diagram that does not show change over time;
The design area demarcates the research, but limits the depth in which the model has been built.

These findings should not pose barriers for the conceptual model to be used. However, a validation step is needed in order to see whether the model is right. Experts in the field can be used to check whether this model is correct in depicting the district heating system. Subsequently, the capability of applying the model to the situation in The Hague can be studied. The validation step should provide enough analysis to develop alternatives and look for a suitable market design for The Hague and surroundings.

## 6. Validation

The validation chapter will concern itself with checking the conceptual model and looking at whether it compares well with current data and knowledge of the situation. This is done by the researcher herself, and also by an expert panel to avoid bias. The conclusions of the workshop held with the expert panel will be presented here and the value of the conceptual model will be discussed. This will form the basis for generating alternatives in the next section.

From the systems analysis, many insights into the current situation were explored. By doing this exploration and by having developed the conceptual model, it should be possible to combine the two and fill in the generic model with the current situation details. As the researcher of the project, this is done using personal insights. It looks like this:

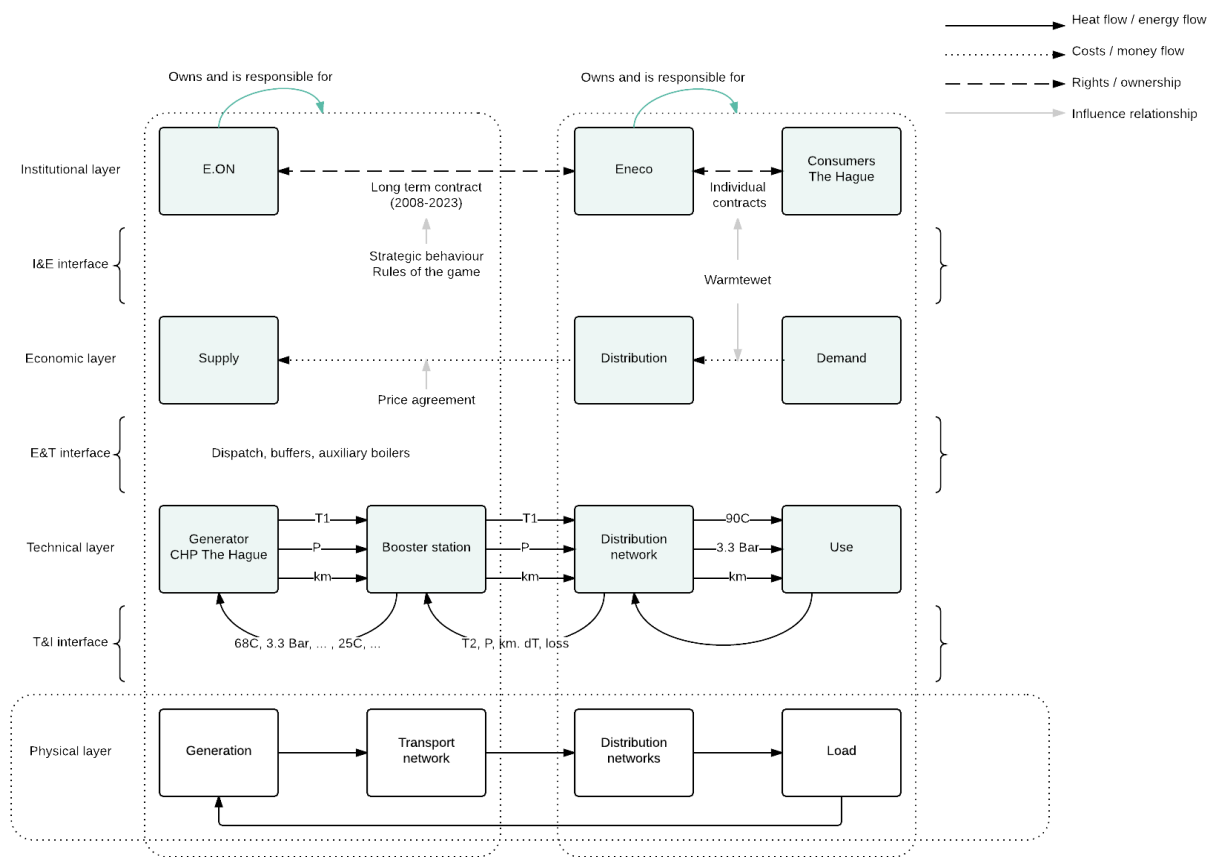


Figure 11: Application of conceptual model to current situation by researcher

By doing this application, the following insights are reached:

- De design elements are the only blocks that have been changed, therefore these will be leading when designing alternatives
- The blocks that were there, were enough to fill in the current situation, therefore this conceptual model can be used to model district heating networks



- Extra frames were needed to indicate ownership was on more than one stage of the chain, this could be necessary also in other situations and should perhaps be included in the generic model.

Nevertheless, since I am the one that made the model and to do the application, it is unsure what these insights are worth. Further validation is needed, to answer the question 'are we building the right product'. To do this, an expert panel is asked to do the same procedure, to apply the generic model to the current situation. The experts are all professionals in the field, very well aware of current practices. They are less familiar with the technical, economic and institutional divisions, which is why a separate meeting per person is scheduled to clarify this.

### 6.1. Expert panel findings

During the workshop in which the expert panel validates the model, the following question is key: **Is the model capable of representing the current situation, conceptually?** In preparation of the workshop, the conceptual model was explained to the experts involved. This allowed them to be prepared for thinking in the three layers. Considering the expert panel consisted of professionals in the field, they are not used to looking at the system from three perspectives. In order to have a fruitful workshop, it was essential to explain systems thinking beforehand.

During the workshop, the most challenging aspect was getting across the meaning and essence of the institutional layer. Some experts grasped quickly what this meant, while others stumbled slightly with this layer. After a brief discussion of the general conceptual model, empty conceptual models were handed out, which can be seen appendix C. These empty models consisted of a 4x5 matrix, in order to not have the experts be confined to a 3x4 model. The physical layer is assumed not to change, therefore this remained the same in the otherwise empty model. The experts were then asked to fill out their own ideas first, after which a group discussion was started to reach consensus.

After having asking the experts to fill it out for the current situation, some differences were noted compared with the scheme above. Regarding their expert opinions and their feedback, the application to the current situation should be like this:

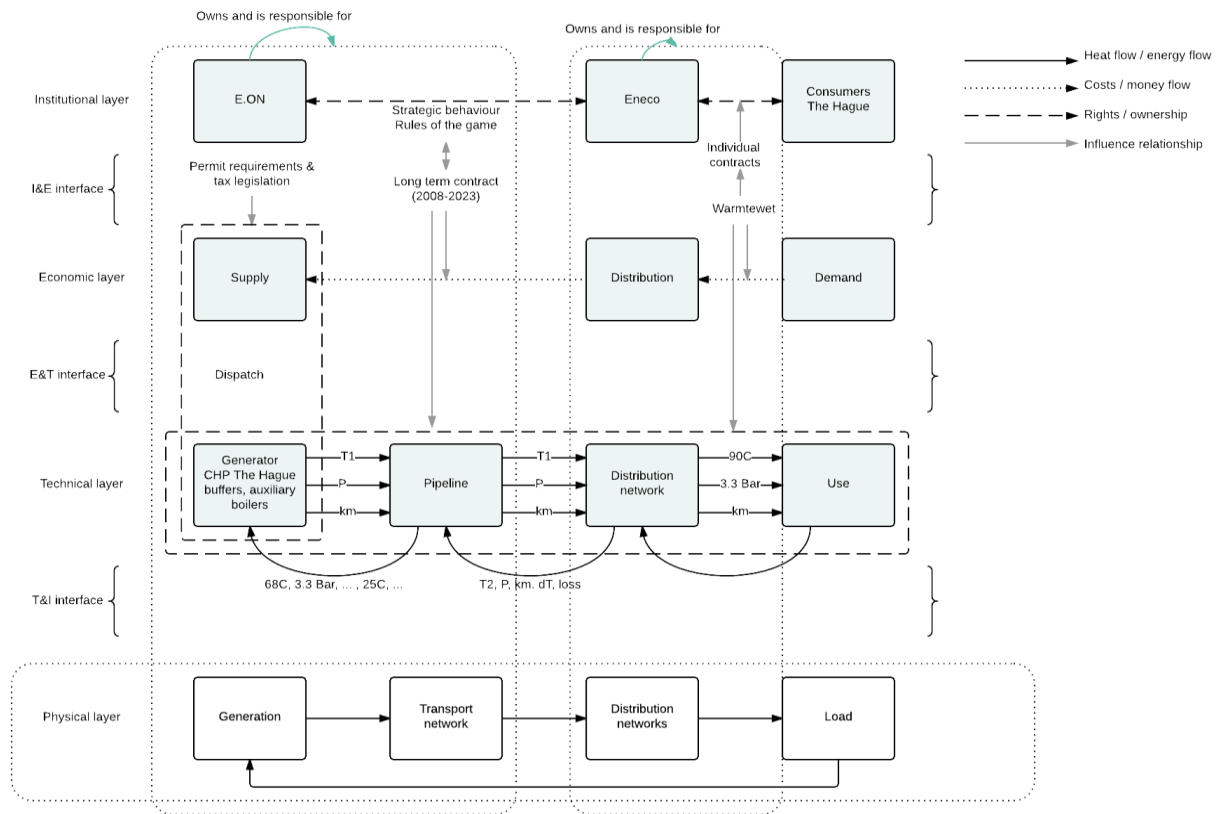


Figure 12: Application conceptual model to current situation expert panel

The main changes with respect to the previous diagram are:

- Eneco is not responsible for customers and that part of the value chain, therefore the marking ends abruptly before the consumer box.
- Contracts as an institution are moved to the I&E interface, since this has a large influence and cohesion with the economic layer as well. It is therefore no longer defined as the relationship between the stakeholders.
- The Warmtewet does not only have influence on individual contracts and the costs and prices for a certain demand, but also on the technical layer, since the law also poses requirements for the quality of the heat.
- The same goes for the long term contract, it does not only contain price agreements, but also technical requirements and arrangements.
- Permit requirements and tax legislation are added, since this is what E.ON has to comply with in terms of production.

Some limitations were also discovered either explicitly mentioned or implicitly brought forward during the exercise.

- The boxes in the institutional layer only contain stakeholders, the actual institutions are either represented by arrows or take place in the interfaces;
- The model and the current situation are focussed on households as customers and do not include large consumers;
- There are many details that are not included in the model, it does not cover a lot of detail but it focusses on concepts and high level aspects only;
- The step from going from concepts to using it to represent the current system is quite wide, this could pose difficulties for the usability of the conceptual model.

These limitations should be taken into account when using the general conceptual model for future purposes. The purpose for this study is to use it to develop alternatives. The different implementations of the design choices are combined into alternative market designs in the next phase. They will then be evaluated and used to form a basis for simulation in the last phase of this study, phase C the application.

## 7. Conclusion phase B

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In phase B the design area is demarcated to certain design variables in the three perspectives, technical, economic and institutional. The design choices within the model are the degree of market opening, the capacity mechanism and the supply temperature. Other than the design variables, various other variables are identified that should appear in the conceptual model. These originate from the systems analysis.

The conceptual model was then developed, based on the design area demarcations. The conceptual model has several advantages, namely:

- Creates awareness of all concepts involved;
- Gives insight in all three layers, which brings added value;
- Provides the means to represent the different flows, for it is not only heat going from A to B and back;
- One layer cannot advance/change without the others, which means looking at one perspective is not sufficient;
- When applied to a specific situation, this can form a complete picture and a basis for simulation.

It is also important to note some disadvantages or limitations of the conceptual model. During the process of designing, the following findings were noted:

- Difficult to capture all relations and dynamics in a diagram that does not show change over time;
- The design area demarcates the research, but limits the depth in which the model has been built.

The model was then applied by the researcher to the current situation in The Hague to see if this was possible and how this would work. By doing this application, the following insights are reached:

- The design elements are the only blocks that have been changed, therefore these will be leading when designing alternatives
- The blocks that were there, were enough to fill in the current situation, therefore this conceptual model can be used to model district heating networks
- Extra frames were needed to indicate ownership was on more than one stage of the chain, this could be necessary also in other situations and should perhaps be included in the generic model.

Following the researchers application, a panel of experts in the field was asked to do the same in order to validate the conceptual model. They were given an empty model, with an extra row and an extra column in order to not limit them to the model made in this project. They then applied the current situation, and the main changes with respect to the previous application are:

- Eneco is not responsible for customers and that part of the value chain, therefore the marking ends abruptly before the consumer box;
- Contracts, as an institution, is moved to the I&E interface. It is no longer defined as the relationship between the stakeholders;

- The 'Warmtewet' does not only have influence on individual contracts and the costs and prices for a certain demand, but also on the technical layer, since the law also poses requirements for the quality of the heat;
- The same goes for the long term contract, it does not only contain price agreements, but also technical requirements and arrangements;
- Permit requirements and tax legislation are added, since this is what E.ON has to comply with in terms of production.

Some limitations were also discovered either explicitly mentioned or implicitly brought forward during the exercise.

- The boxes in the institutional layer only contain stakeholders, the actual institutions are either represented by arrows or take place in the interfaces;
- The model and the current situation are focussed on households as customers and do not include large consumers;
- There are many details that are not included in the model, it does not cover a lot of detail but it focusses on concepts and high level aspects only;
- The step from going from concepts to using it to represent the current system is quite wide, this could pose difficulties for the usability of the conceptual model.

These limitations should be taken into account when using the general conceptual model for future purposes. This concludes the conceptual model and validation chapters.



## Part IV: Phase C - application



## 8. Market design alternatives

*This chapter will describe the design choices made per alternative, covering the degree of market opening, capacity mechanism and the supply temperature. Furthermore the design choices will be entered in the conceptual model, in order to visualise and present the complete alternatives. Finally, the step from alternatives to simulation will be presented.*

### 8.1. Design choices

As has been leading throughout this report, the focus is on three design choices. When designing alternatives for the district heating market allowing multiple independent producers, these three design choices will be filled in. The design choices and the options available for each design choice have resulted from the theoretical exploration and the systems analysis. The conceptual model from chapter 5 will help construct the alternatives into whole designs of markets.

The alternatives can be summarised in the following table. This shows which choice is made for the market designs in three alternatives.

Table 5: Alternative market designs for district heating

Design choices	Alternative 1	Alternative 2	Alternative 3
1 Degree of market opening (access related)	Open access	Pooling	-
Degree of market opening (market structure)	Retail competition / customer choice model or retail wheeling model / network access model	Single-buyer model / portfolio manager model	Wheeling
2 Capacity mechanism	Capacity payments	Capacity obligations	Strategic reserve
3 Supply temperature	Low temperature network (40-70°C)	High temperature network (90-120°C)	Both can exist next to each other

#### 8.1.1. Degree of market opening

The degree of market opening has been designed for three alternatives. As discussed in the theory chapter, there are four 'degrees' of opening when it comes to the electricity market in terms of market structure, and several other options regarding the organisation of access. For alternative 1 open access together with the retail competition / customer choice model or retail wheeling model / network access model is chosen. The second alternative will combine pooling as an access method with the single-buyer or also called the portfolio manager model. The third alternative will have wheeling as a market structure, with none of the access options, since wheeling inclines vertical integration, without access for others. Advantages and disadvantages of each will be discussed.

##### *Alternative 1*

In this alternative production and retail are open for all who wish to enter. There is a DSO that owns the distribution network, which is a public utility, and there are several producers and retailers that supply heat on these networks. The DSO buys heat from producers, in a certain merit order, creating competition amongst producers since the cheapest ones will be bought first and receive the largest



profit margin. The DSO is also in charge of efficient allocation of the heat. Retailers will then buy heat from the heat exchange, at the market price of that moment. They compete for contracts with consumers, whom can choose their retailer. The access for producers is organised through open access, granting full access to all that wish to enter the market.

The advantages of such a design are:

- Potential long-term benefits for society;
- Lower prices for consumers (Joskow, 2008);
- Higher efficiency/allocation;
- Choice for retailer.

Disadvantages:

- High transaction costs (Correljé & de Vries, 2008);
- Needs a lot of regulation;
- Needs many producers due to the high barriers to entry, or this degree of market opening will not work.

#### *Alternative 2*

In this alternative production is open, distribution access is limited, due to the single-buyer structure. Multiple producers can supply to the purchasing company, who then distributes the heat to consumers. The single-buyer ensures demand is met, either by producing its own heat or by buying it from independent heat producers. In this case, the party that is the single-buyer is still subject to the must-run situation in case it has not contracted all capacity to other producers. Pooling is applied as a form of access in order to ensure that the independent heat producers have a fair chance of competing. This way, the winning bidders will be dispatched, which gives an incentive to offer heat at the lowest prices. However, it could still be that in this case the single-buyer gives himself unfair advantage and will always be the cheapest and will therefore always be dispatched. This should be taken into account.

Advantages:

- Simple model with low transaction costs (Joskow, 1997);
- The single-buyer can plan generation, while there is competition for investment in generation by independent heat producers;
- The single-buyer can absorb the investment risk of the network (Correljé & de Vries, 2008).

Disadvantages:

- There is a risk of corruption and inefficient planning by the single-buyer;
- If single-buyer does not have financial credibility, he becomes an obstacle to investment (Correljé & de Vries, 2008).

#### *Alternative 3*

In this alternative the market is relatively closed. This will be a strict alternative for district heating. Some companies are given the exclusive right and duty to supply in their specific distribution area. They then also own the infrastructure and are responsible for investments. Each company is then responsible for production, transport and distribution and competition occurs for the different

distribution areas. These companies can trade with each other if the networks are linked to each other. This could be considered as wheeling for the degree of opening design choice. In order to guarantee fair prices for consumers and the heat companies, representatives of either the municipality or province are in the board of the heat companies. The shareholders decide the prices to be paid based on the costs and taxes.

Advantages:

- Very low transaction costs;
- Established companies can guarantee security of supply;
- Implementation of (sustainability) policies is easy.

Disadvantages:

- Limited incentive for efficiency (Jorritsma-Lebbink, 2000);
- No need for innovations (Jorritsma-Lebbink, 2000).

### 8.1.2. Capacity mechanism

There are different capacity mechanisms that can be applied to district heating. Capacity mechanisms are either incentive based or regulation based. As discussed there are five options for introducing a capacity mechanism, namely: capacity payments, a strategic reserve and capacity obligations, capacity auction and reliability options (Meulman & Méray, 2012). Three options are selected and discussed for each alternative.

#### *Alternative 1*

The way capacity and investments are realised in this alternative is through capacity payments. This is a price-based mechanism, providing incentive to invest in new capacity. Fixed payments are paid to producers for having a certain amount of capacity installed or available, in essence to improve security of supply. Dynamic payments are similar but vary according to the capacity that is available as a reserve. Either method of capacity payments should ensure some reserve capacity, either in generation facilities or in storage.

Advantages:

- Easy to implement as a mechanism;
- Provides investment incentive.

Disadvantages:

- Effect of the payments is uncertain, determining the size of the payment is complex (De Vries, 2007; Meulman & Méray, 2012);
- Regulation can be needed in order to ensure payments are invested in capacity;
- Incentive-based mechanisms are considered less effective and efficient than regulation based (Meulman & Méray, 2012).

#### *Alternative 2*

The capacity mechanism in place is a capacity market in the form of capacity obligations. Next to the market for heat, a capacity market is introduced. This means that producers are required to buy capacity obligations, which includes the peak consumption and a fixed margin on top of it. This

margin is determined by the regulator. Amongst producers capacity credits can be traded strategically.

Advantages:

- In electricity markets such a mechanism is proven to be effective;
- Stabilises prices (De Vries, 2007);
- Robust way to ensure the determined capacity margin (De Vries, 2007);
- Gives incentive to involve demand.

Disadvantages:

- Capacity market can be instable;
- Difficult to implement (De Vries, 2007).

### *Alternative 3*

The capacity mechanism in this alternative is a strategic reserve. The strategic reserve is reserve capacity that is government owned and controlled for example. This could be older units, storage facilities or separate units that produce heat when necessary. The dispatch of this extra capacity should be higher than that companies charge, so that they have some sort of penalty to pay for not living up to the capacity required, so that it is not misused.

Advantages:

- Easy to implement;
- Old units can be reused, thus prevents them from closing (De Vries, 2007).

Disadvantages:

- Incentive for price manipulation still there (Meulman & Méray, 2012);
- Risk of inefficient dispatch (Meulman & Méray, 2012);
- Determining the amount of reserve capacity and at what price is complex (De Vries, 2007).

### 8.1.3. Supply temperature

The recently published 'Warmtevisie' indicates there is potential for changing the supply temperature of the district heating network. These options will be discussed below per alternative.

#### *Alternative 1: Low temperature network*

The supply temperature for this alternative is changed to low. It is believed that creating the most successful conditions with this alternative can only be done with a low temperature network. This is because many producers are needed on the network to make it work, and having only two or three on a high temperature network would lead to either an oligopoly or even monopoly, since one large party could potentially outcompete the others. On a low temperature network the chances of plenty of producers on the network is much larger.

Advantages:

- More potential producers
- Higher chance of an open market succeeding

- Lower costs of transport network

Disadvantages:

- High costs for consumers due to switching to larger radiators or floor heating

*Alternative 2: High temperature network*

The temperature in this alternative is kept high. This means fewer potential producers, but no cost shift to consumers. Potential producers would then only be industries using high temperature heat, like aluminium or paper factories, as well as energy plants and waste incinerators for example. Having few players could lead faster to a stable market and market price.

Advantages:

- No cost shift to consumers, radiators can stay the same
- Current equipment for providing high temperatures can stay the same for E.ON

Disadvantages

- High barriers to entry remain
- Few potential producers, which causes the that the must-run situation is not avoided easily

*Alternative 3: Both high and low temperature networks can exist next to each other*

In this alternative, the different companies could choose which temperature to adopt. This could differ per area if needed. However, if users than over time come to fall under a different area, with a different temperature, they could be forced to change their radiators or adopt floor heating, involving large costs. With this being a negative effect, having different temperature networks throughout the country, could lead to much more use of sustainable heat sources and more use of waste heat, since per area can be determined what is most available to them. Also, if consumers get some say in it, the acceptance can be increased.

Advantages:

- Locally available heat can be used
- Likely to be more accepted than current district heating market

Disadvantages:

- Switching between low/high temperature supplier difficult
- Choosing supplier not likely

## 8.2. Concluding remarks alternative market designs

The different design choices chosen for the alternatives all have many advantages and disadvantages. It is therefore very difficult to say which alternative is better than the other. The different alternatives are shown in appendix C in the form of the conceptual model developed in this thesis. The following section makes an attempt at evaluating the alternatives and choosing the best contents for each design choice for district heating.

### 8.3. Evaluation of alternatives

The design choices have been filled in for each alternative. Even though that this has been leading in the design phase of this research, in order to say something about the combined effect of the choices, three complete alternatives will be sketched. More details will be filled in and described in this chapter in order to bridge the gap towards simulation.

From the expert interviews in the systems analysis chapter, a list of objective variables was decided upon. These variables are:

- The security of supply [ratio]
- The price of 1 MWh of heat [€/MWh]
- The demand for heat [capacity, volume]
- The number of producers in the market [1...10]
- The market share per producer [%]

Unfortunately, it is impossible to give a judgement on the above objective criteria at this time. Giving a judgement would not be more than guesswork. Since that is not valid enough for this research it is decided to merely give a judgement per implementation of design choice in comparison with each other. When judging the design choices per alternative separately, a score of -, 0 or + can be given per alternative.

Table 6: Judgement of design choices per alternative

	Alternative 1	Alternative 2	Alternative 3
<b>Degree of market opening</b>	0	+	-
<b>Capacity mechanism</b>	+	0	0
<b>Supply temperature</b>	+	-	0

When looking at the degree of market opening, it is important to remember the critical factors in the theory exploration. One of them is that there should be multiple producers. Since for alternative 1 the number of producers needed to make the market work is relatively high, this alternative is given a 0. It remains to be seen whether there are many producers in the area that want to become producers, otherwise, this alternative has many benefits. Alternative 2 does receive a +, since this is a more realistic scenario. Many other district heating markets in Europe operate under the single-buyer structure, such as Sweden, Finland, Estonia, Latvia and Lithuania (Korhonen, 2014). The water alternative gets a negative sign, since this does not actually facilitate multiple independent producers on one district heating network, but facilitates different district heating networks to exist next to each other with one producer on each.

The next design choice is the capacity mechanism. The capacity payment in alternative 1 receives a plus, since it is easy to implement and directly gives an incentive. The capacity market receives a 0, due to the difficulty of implementation versus the effectiveness of the mechanism, which is relatively unsure. Thirdly, the strategic reserve also receives a 0, because even though it is also easy to implement, there is still an incentive to manipulate prices with this mechanism. Also it remains questionable who would manage the strategic reserve in practice, since Eneco is owner of the distribution network at the moment and this could pose difficulties for this mechanism.

The last design choice, the supply temperature is also scored. The low temperature network is assumed to be the best option, since this lowers the barrier to entry for producers, which in the light of this thesis is very important. This is also why the high temperature design choice receives a minus, this does not lower the barrier for potential producers. The last alternative allows both types of supply temperature to exist next to each other, which is why this is awarded with a 0.

The most promising alternative for the situation in The Hague seems a combination of the first two alternatives, taking the degree of market opening from alternative 2 and the other two design choices from alternative 1, the capacity payment mechanism and the low temperature network. The degree of market opening allows for multiple producers, but not as many as in alternative 1. Since in The Hague and surroundings there are not many potential producers, this is a plus. At the same time the low temperature network allows for more potential producers, so that the heat that is available in the area can be used. And lastly, the capacity payment mechanism is easy to implement and adjust to the situation. In order to say something about the combined effects of these measures, the alternative must be simulated. This is essential to predict any sort of combined behaviour of the market with certain circumstances and the behaviour of its parts (stakeholders). It is advised to make an agent-based model to capture the desired insights on the behaviour of the market.

## 9. From alternatives to simulation

*Simulating the district heating market alternative(s) can be done in many ways. It is important to note that the model made in this research is a conceptual model. Any model is in essence a representation of a real world system. If this model is to serve as a basis for a more intricate simulation of the district heating system, it is important to know how to do this. This will be done by referring to modelling and simulation theory concerning ‘agent-based’ modelling. First it is established that this is the modelling paradigm that matches the complexity the district heating system requires. Then a preliminary simulation setup is suggested including a design of experiments.*

### 9.1. Modelling and simulation of systems

Agent-based modelling of socio-technical systems (van Dam, Nikolic, & Lukszo, 2013) will be used to guide this chapter of how to go from the alternatives sketched to a simulation model. Firstly, it should be established that the district heating system meets the requirements to be modelled in an agent-based manner. The book describes three conditions for modelling complex systems using agent-based concepts (van Dam et al., 2013). How the district heating system meets these conditions is described in table 7.

- “The problem has a distributed character; each actor is to some extent autonomous.
- The subsystems (agents) operate in a highly dynamic environment.
- Subsystem interaction is characterised by flexibility: it can result from a reactive or pro-active attitude, from a propensity to co-operate or to compete, or it can be the result of social interaction (including, for example, trust or empathy)” (van Dam et al., 2013, p. 5).

Table 7: How district heating meets the conditions for agent-based modelling

Agent-based modelling conditions	District heating system
<b>The problem has a distributed character; each actor is to some extent autonomous.</b>	The distributed character is present in the district heating system. Each actor, producers as well as distributors have their own plans, actions, behaviours and independent from others to a certain extent.
<b>The subsystems (agents) operate in a highly dynamic environment.</b>	The environment of district heating is highly dynamic. Especially now, with so many stakeholders that want to make a change. The ministry of economic affairs with their proposed heat vision, the Programmabureau with the steps towards a heat roundabout. Also E.ON itself is undergoing organisational changes. With energy policy high on the agenda, a dynamic environment is a given.
<b>Subsystem interaction is characterised by flexibility: it can result from a reactive or pro-active attitude, from a propensity to co-operate or to compete, or it can be the result of social interaction (including, for example, trust or empathy).</b>	Interactions between the different actors, whether producers or distributors, is very much a result of their different attitudes and social interaction. Currently this is already the case between E.ON and Eneco, who have a certain trust relationship amongst

each other for example. In a new market situation, interactions only increase and will be even more flexible since there is more choice of producers and distributors.

From this table we can conclude that the district heating system does meet the conditions and can therefore be modelled using agent-based concepts. Some further steps in the process are proposed in this chapter. The steps in the same book will be used. Step 1 and 2 of a total of 10 steps will be completed, namely the problem description specific to the model and also a system demarcation including a design of experiments.

## 9.2. The simulation problem description

In order to look further into how to simulate the district heating market alternative, a problem description is necessary. The problem description consists of several parts, a lack of insight, an observed emergent pattern, a desired emergent pattern and an initial hypothesis. To complete the problem context, a problem owner is identified, the other actors that are involved are mentioned and the role of the modeller is briefly pointed out. Together this will complete step 1 of the agent-based modelling process (van Dam et al., 2013).

The research statement of this thesis as identified in chapter 1 is:

**The design choices for a market that can facilitate access to multiple independent producers of heat on district heating networks in the Netherlands and which combination of design choices suit district heating the most, are unknown.**

In this thesis the design choices are identified, they are visualised in a conceptual model, and structured according to several alternatives. Even though the alternatives have been compared on the design choice level, the effect of the combination of design choices has not been determined yet. The lack of insight the agent-based model should address is therefore:

**Which combination of design choices suit the district heating system the most?**

Where the design choices are the degree of market opening, a capacity mechanism and the supply temperature of the system as discussed in this thesis.

The observed emergent pattern of interest follows from the current situation as described in chapter 3, the systems analysis. The observed emergent pattern of interest is the monopolistic division of activities, a closed market with one producer, one distributor where laws are needed to prevent monopolistic prices. There is also not a lot of incentive to invest and path dependency has determined a high temperature network. The desired emergent pattern if interest follows from the desired situation and the interviews held with certain stakeholders also in chapter 3. This is an open and demand driven market, with multiple producers and a choice for consumers.

The initial hypothesis for the difference between the observed pattern and the desired pattern is that a degree of market opening as described in alternative 2 in chapter 8, a capacity payment mechanism and a low supply temperature network should lead to the open market as desired. However, we are not entirely sure that this configuration of design choices is the one leading to the desired emergent pattern.



The further research in terms of an agent-based model continues to address E.ON Benelux as the problem owner. However, an agent-based model of the district heating system could also be interesting for other involved stakeholders. The simulation model provides insights into the behaviour of these stakeholders and the market as a whole. The stakeholders in the model that are the most important are producers and distributors. Their behaviours are of interest in case of the new market.

Additionally, the conceptual model made in this thesis can be used to structure the modelling process. The conceptual model is filled in for the final alternative in appendix C. The advantages of having the conceptual model of the alternative is that it is easily visualised and forms a good starting point to depart from. It offers a way to structure the agent-based model in future steps.

### 9.3. System identification and decomposition

In step 2 the system to be modelled is described and demarcated. This thesis has made many steps regarding this aspect already. The conceptual model in chapter 5 provides a clear demarcation of the concepts in the system. Furthermore the final alternative, of which a diagram is provided in appendix C, provides the exact system to be modelled in a future study. This will be discussed in the system demarcation. The inputs, outputs and design of experiments will conclude this section.

#### 9.3.1. System demarcation

The system is defined as the technical, economic and institutional aspects that are relevant to the problem. As the focus has already been on the three design choices, the degree of market opening, a capacity mechanism and the supply temperature, these are also the focus for this model. The goal is to find out the type of behaviour these aspects generate in the market for district heating. This behaviour that emerges is what we are interested in, the behaviour of the agents in an open market.

The interviews done in phase A of this research have shown that the stakeholders in the situation of E.ON and The Hague have certain ideas about the new system. There are several factors of interest in the system, that the agent-based model could provide insight into. These are:

- The security of supply [ratio]
- The price of 1 MWh of heat [€/MWh]
- The demand for heat [capacity, volume]
- The number of producers in the market [1...10]
- The market share per producer [%]

#### 9.3.2. Design of experiments

With the model, certain experimental setups can be simulated in order to measure the difference of each setup on the outputs of the model. In such an experimental setup, different degrees of market opening, capacity mechanisms and supply temperature can be used as inputs. The combined effect of these alternatives can then be measured on the output variables, in order to suggest the best alternative market design for district heating. The optimum values or range of optimum values must be determined of each output variable, in order to see which experimental setup has the best results.

The first experimental setup that is proposed to test, is that of the best alternative resulted from this study. Which means, a certain degree of market opening, together with a capacity mechanism and a supply temperature will be tested. Secondly, other configurations of the design choices can be experimented with, to see when the observed security of supply, price, demand, n# producers, and

market share per producer reach their optimum values. And thus which is the best market design for the district heating system.

All of the above can be summarised in the following figure.

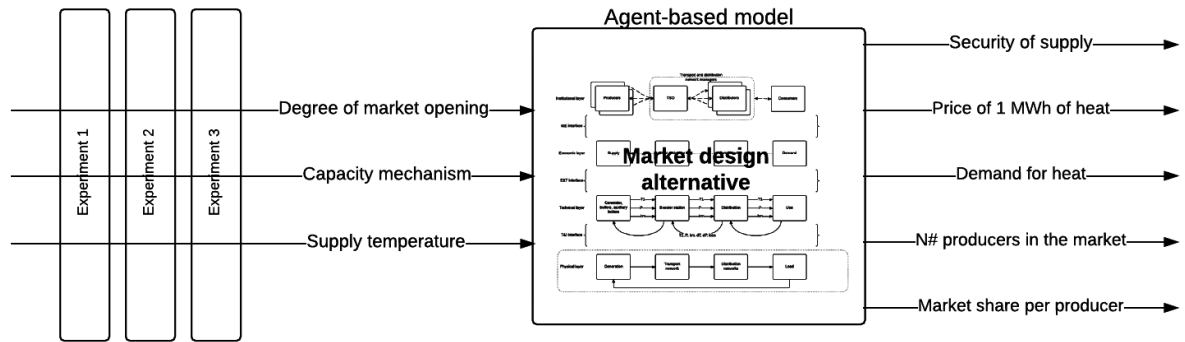


Figure 13: Inputs, outputs and experiments of the agent-based model

## 10. Conclusion phase C

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In alternative 1, production and retail are open for all who wish to enter. There is a DSO that owns the distribution network, which is a public utility, and there are several producers and retailers that supply heat on these networks. This is combined with a capacity payment mechanism, paying producers to have a certain capacity installed, which can be easily implemented. For this alternative a low temperature network is chosen that lowers the barrier to entry for potential producers. However, this does imply that consumers have to change to different radiators or floor heating, in order to still reach 21 degrees Celsius with a lower supply temperature.

In the second alternative production is open for heat producers, distribution access is limited, due to the single-buyer structure that is implemented. Multiple producers can supply to the purchasing company, who then distributes the heat to consumers. The single-buyer ensures demand is met, either by producing its own heat or by buying it from independent heat producers. The capacity mechanism in place is a capacity market in the form of capacity obligations. Next to the market for heat, a capacity market is introduced. This means that producers are required to buy capacity obligations, which includes the peak consumption and a fixed margin on top of it. Also, in this alternative, a high temperature network is maintained, which avoids the cost-shift to consumers.

In alternative 3, the market is relatively closed. This will be a strict alternative for district heating. Some companies are given the exclusive right and duty to supply in their specific distribution area. They then also own the infrastructure and are responsible for necessary investments. The capacity mechanism in this alternative is a strategic reserve. The strategic reserve is reserve capacity that is, for example, owned and controlled by the government. This is easy to implement and gives old units the opportunity to be reused. In this alternative the supply temperature can vary per local network, so that local sources can be used optimally.

Based on the advantages and disadvantages of each design choice option per alternative, the most promising alternative is a combination of alternatives 1 and 2. To answer the research question: The degree of market opening in alternative 2, the single-buyer model, together with the capacity mechanism and supply temperature of alternative 1, namely capacity payments and a low temperature network, seems the most promising for a new district heating market. However, this judgement cannot be validated further without further research. Therefore, it is suggested that a simulation model of the situation is made, which enables further testing of the alternatives.

In order to facilitate further research, the first transformation steps from alternatives to simulation are also made in this phase. In this case, agent-based simulation is the best simulation method for the district heating system. Agent-based modelling as a method that creates insight into behaviour of the system as a whole, as well as its individual parts. These insights are necessary in order to evaluate the alternatives in case of introducing a new market structure for district heating in The Hague. The model can contribute to the decision making process by simulating different configurations of design choices and their resulting outcome. This outcome is measured in form of the security of supply, the price per MWh of heat, the demand for heat, the number of producers in the market, and the market share per producer. Theory goes a long way, especially in this stage of developing an new market for district heating, but a simulation model can take the results from this research to the next level.





Part V: Discussion, Conclusion & Recommendations

## 11. Discussion

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*This chapter will provide a discussion of the results and an evaluation of the value of this research. First district heating itself will be put into context. Then designing a market model and the principles it is based on will be discussed, as well as the methods and theory used in this research project.*

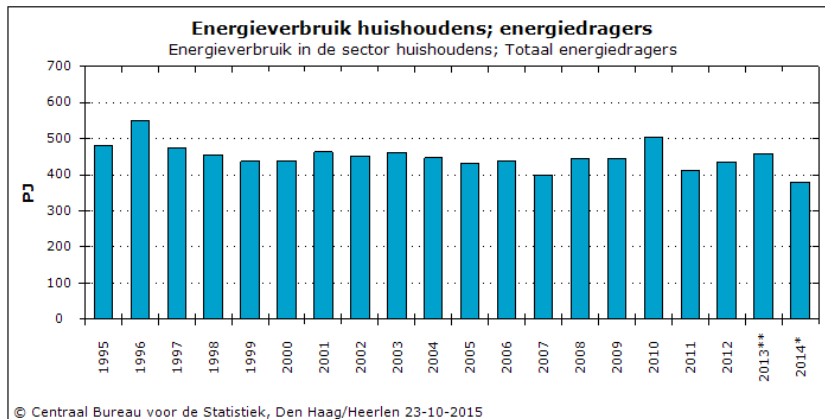
### 11.1. The potential of district heating

During this research the focus has been on district heating as a form of space heating. Of course there are alternatives to sources of space heating, such as gas and electricity. Most households in the Netherlands have a gas connection, since the gas field in Groningen was discovered, gas has become the main fuel for space heating. District heating can be seen as a direct competitor for gas, as well as 'all electric' solutions. The energy consumption of households is gradually decreasing as can be seen in figure 14. Of that share of total energy use, the share of gas is decreasing, the share of electricity is increasing and the share of heat is also increasing (figure 15 and 16). Even though the potential for district heating is mostly limited to existing constructions, there is a definite place in the energy mix. One of the drivers is that the Netherlands wants to become less dependent on gas. The first reason to decrease gas dependency is that the Groningen gas field is depleting. The second reason is that using as much gas from the Groningen gas field as we do is causing earthquakes in the region. The bottom-line is that sometime in the future the Netherlands will need to import more gas than it will export. Imports are likely to come from Russia through Ukraine, which is currently not a stable region. It is not desirable for the Netherlands to be dependent on Russia considering the political climate at present.

The municipality of The Hague certainly sees a future in district heating. Together with Programmabureau Warmte-Koude Zuid-Holland and the Province of Zuid-Holland, a map of the province is made (M. van der Steenhoven, personal communication, May 26, 2015; R. Geurts, personal communication, June 2, 2015; T. Zwietering, personal communication, June 4, 2015). This map shows which form of space heating suits which area most based on cost-efficiency. For example, for new buildings and constructions, it makes less sense to have a connection to the district heating network. New buildings and houses are often highly isolated and do not require a lot of heat at all, which would make all electric a better suited solution, for example. However, in inner city centres, where there is not a lot of space and the houses are a lot less efficient considering heat use, district heating is the most cost-efficient option for space heating. The potential for district heating is therefore mostly limited to existing constructions. To conclude, this means that even though the share of district heating as a form of space heating is increasing, there is a limit to its growth due to the limited potential areas of use.

Despite the limits to growth, if space heating is to become sustainable, district heating is necessary in the energy mix. Apart from 'green gas' or all electric solutions using wind or sun generated energy, district heating is one of the only collective systems with a large sustainable potential. The district heating network is very costly, and requires investments if growth of the network is to be realised. Such investments go hand in hand with risks. For example, in the case that Eneco remains in charge of the distribution network, they are faced with several risks. Either, they attract producers and allow open access to everyone, and have the risk of having excess supply, driving down prices according to a traditional demand and supply curve. Or, in case they do invest in a larger network and therefore create more demand, they risk the chance of not earning back their investments over time, since the

payback time is long. Probably, none of the stakeholders in the field are willing to carry the risks of such large investments. Many of the companies are risk averse and do not want long-term contracts, making it very difficult to absorb the risks of investments in such a large network. The government will have to propose a plan for investments and offsetting the risks somehow. In what way, is yet to be determined.



\*\* provisional figures  
 \* second provisional figures

Figure 14: Total energy use of households in the Netherlands

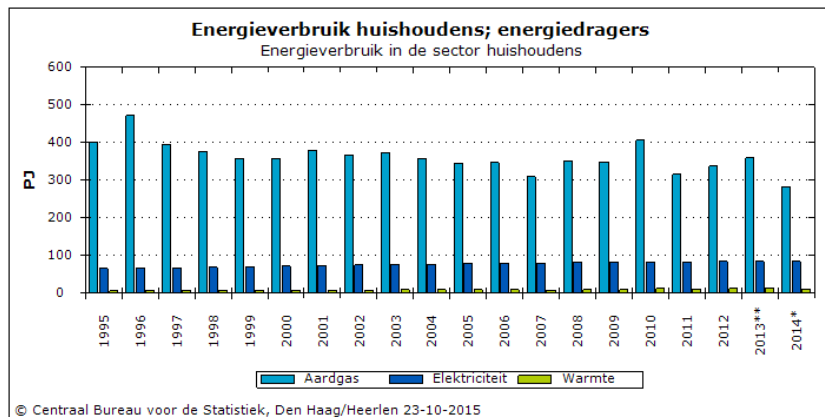


Figure 15: Gas, electricity and heat use of households in the Netherlands

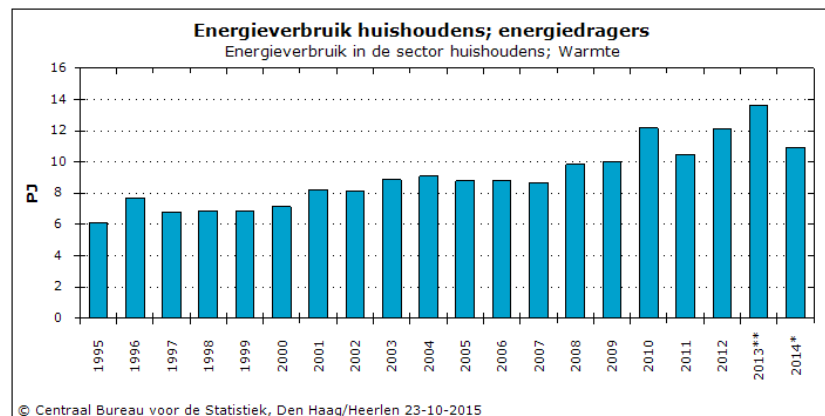


Figure 16: Heat use of households in the Netherlands

Another issue that influences the prospective district heating system, is that of potential producers and sources in the area. Which heat generators qualify to become producers depends highly on the temperature of the network. Few sources can provide high-grade (or high temperature) heat, making the potential for competitors small. However, with lower supply temperatures, more sources qualify. It is therefore preferable when looking at introducing competition on district heating networks to have a low temperature network. However, currently a high-grade network is in place, under the ownership of Eneco. When the electricity market was liberalised, the network was already owned by the state, making it much more easy to control this element of the value chain. For district heating this is more complicated, can Eneco keep determining the temperature or can the government oblige them to change to a low temperature network. This is another risk for the future of district heating.

Independent of the choice for the temperature of the network, several sources are available in the area local to the network. Geothermal plants are said to be a potential source (Kamp, 2015) in case of a low temperature network. However, drilling deep wells in the ground in a densely populated area is not likely to be popular amongst citizens. Especially in the current climate, where gas drilling in a less densely populated area, such as Groningen, has caused many damages. Geothermal wells go a lot deeper into the ground, shrinking its chances of being a potential heat source. Additionally, the extent to which this source is sustainable is questionable. A geothermal well uses heat from up to four kilometres into the ground and uses it to heat water. It also pumps cooled down water back into the ground a few kilometres further away. This cooler groundwater share keeps increasing, eventually reaching the spot where the geothermal well pumps up heat. The temperature will be much lower here now, questioning whether geothermal heat is in fact a renewable source.

Another potential source is the Port of Rotterdam. The Port of Rotterdam houses many industries that have heat emissions. Many industries, such as paper and aluminium factories for example, even emit high-graded heat. This can be captured and used for district heating. The Port of Rotterdam responsible for the entire area, therefore if companies are to contribute to capturing heat, the Port should organise a network in the area that they own. However, as mentioned before in this thesis, the district heating network is very costly. The Port of Rotterdam is only interested in this, if they have some sort of gain from becoming a producer. An example of what such a gain could look like, is that the heat captured is deducted from their emissions. The Port of Rotterdam has reached its emission ceiling, and if the captured heat is deduced, they create room to attract more companies within the same emission ceiling. This could provide the incentive they need to build a district heating network in the Port. Having more room to grow, would improve the competitiveness over the Port and contribute to the Dutch economy as a whole. This shows that attracting the Port of Rotterdam to become a district heating producer could have many benefits for other sectors as well.

Additionally, apart from attracting potential producers, there are other conditions that must be satisfied to achieve open access, or pooling for example in the district heating network. First of all, the barriers to entry for the producers must be as low as possible. They should not be required to additional tasks such as managing part of the distribution network, or supplying to consumers to avoid additional costs associated with these tasks. The lower the barrier to entry, the better for facilitating access to multiple independent producers. Another issue is that the district heating networks are very local. The smaller the network, the smaller the chance potential producers are available in the area. Since transport of district heating is not common, and costs a lot of money even when it is not in use, this is to be avoided. This poses a difficult dilemma, of wanting more producers, which may not be situated close by, and fending off a transport network. This will remain an issue in any case, therefore



it is recommended to map any potential heat sources in the area before liberalising the district heating network. The heat vision of last April (Kamp, 2015), contains such a map.

Another point of discussion is that when liberalising the electricity and gas markets, the networks were already owned by public parties and thus easily subjected to regulation, or independent network operators for example. For district heating this is different. Most of the networks are in hands of a private party, which is also the case for The Hague where Eneco is the owner of the distribution network. Opening the network for access can thus pose more difficulties, apart from the investment risks mentioned earlier in this discussion. Eneco could not want to participate and exert their power by limiting access for example. Or they could still ask monopolistic prices from consumers, even with competition on the production side of the market. This is a very difficult problem, that could obstruct the implementation of a new district heating market. It is recommended that this issue is laid out to the Ministry of Economic Affairs and to let them know that if they want consumer price to fall, something must be done to take away this market power from Eneco. Either by regulating how they grant access, or by transferring ownership of the network to a public authority for example.

The last remark is that of the heat law or 'Warmtewet'. This law has only been introduced on 01-01-2014 ("Warmtewet," 2013) and is already being revised now, in 2015 (Kamp, 2015). This testifies to varying policy. Varying policy has also had its influences on liberalising the electricity market. The fact that policy has varied over time, has negatively impacted and interfered with the market regardless of the content of the policy. It is therefore emphasized that the market for district heating must be carefully designed and thought out, before a new heat law is imposed to limit varying policies for district heating in the future.

To conclude, there is potential for district heating as a competitor of gas and electricity for space heating. Even with limits to growth, district heating is needed in the energy mix for the Netherlands to become more sustainable and come closer to the 20-20-20 goals. In order to live up to this potential in The Hague and surroundings, heat producers in the area should be attracted. Where geothermal heat as a source has its pitfalls, the Port of Rotterdam provides more solid sources of heat. If measures are taken to make it more attractive for the Port of Rotterdam, they could be a potential producer for district heating. Other conditions that need to be met, are lower barriers of entry by limiting responsibilities for producers to production and not have them take part in any other part of the chain. The distribution network will not easily become a publicly owned utility, but either that needs to happen or the way Eneco grants access to multiple producers is to be regulated. Apart from this, it is necessary to come up with one policy for the future of district heating, seeing as changes in policies can obstruct the sector.

## 11.2. Methods used in this research

The main elements used in this research that are interesting to deliberate are the comparison with the electricity market and the design choices in the theoretical exploration, and the conceptual model made. These aspects will be thoroughly discussed in the next sub-sections of this chapter.

### 11.2.1. The electricity market as an example for district heating

From theory, many examples and ideas for market models have been adapted from the electricity market to the case of district heating in this research. Because not a lot of research has been done regarding market models for district heating specifically. This has caused many of the principles and literature findings to be based on the electricity market. The two utilities do have many similarities,

however, this remains an assumption. It is unsure to what extent this assumption is accurate and how large the impact is of the differences between the two utilities.

One of the main elements characterising both the electricity and district heating markets is their value chain. From production to transmission/transport to distribution to consumer, the essential steps are comparable. Both utilities make use of a large network and share natural monopoly characteristics. Since both heat and electricity are a basic need, their security of supply is highly valued and they both have to deal with seasonal and even hourly changes in demand. However, district heating is different in some ways as well. Where storage of electricity is practically impossible, storage of heat is more easily achieved, currently buffers and auxiliary boilers do so. The transport network is much more expensive and transport costs and heat losses occur even if there is no demand because the water flows constantly through the system, whether it is heated up and used or not. In case of shortages, there is a difference as well. Where in case of electricity blackouts occur, for heat it causes more of a queue or traffic jam situation. It will simply take longer to reach the desired temperature, making a balancing mechanism less important than for electricity. Also district heating networks in The Netherlands are very local, where the electricity grid is connected nationally.

To conclude, the electricity market is a good comparison for the district heating market considering the similarities and the differences between the two utilities. The differences between heat and electricity make heat a simpler flow to manage, but with higher transport costs the barriers to entry higher. This means that from a market design perspective, heating is easier to design, but practically, it is more difficult to attract new producers. Even though the comparison is not a bad idea, questions can be raised about the working of the electricity market in the Netherlands since the liberalisation. The next paragraphs will discuss this point.

The electricity market is an energy only market, which means no capacity mechanism is installed. Thus far, many investments made have been towards either coal fired power plants, or wind and sun energy in the Netherlands. Investments towards wind and sun energy can be seen as positive for the sustainable 20-20-20 goals the EU has evoked. However, investments in these sources have been heavily subsidised, withdrawing them completely from any market signals (Hiroux & Saguan, 2010). Market signals in theory should indicate the necessity of investments in generation capacity. Since subsidies are granted per MWh renewable energy, these plants are running whenever possible, not taking into account the demand for energy at that instance. Since the merit order for electricity production is based on marginal costs, renewables always come first with a marginal cost of zero. This causes relatively low electricity prices, making it harder and harder to make profits for other than renewable plants, encouraging coal plants with the lowest fossil fuel cost as opposed to gas, which is more expensive but emits less CO<sub>2</sub>.

These market circumstances essentially create two markets, one where as much energy is produced as possible without any regard for capacity and another that does receive market signals for investing in generation capacity and with lower profits stimulating coal fired power plants. A solution to these investment issues is to introduce a capacity mechanism in the electricity market. A capacity mechanism is an instrument to influence investments. Since this has been a large problem in the liberalised electricity market, in this thesis a capacity mechanism for district heating is directly taken into account. The options for different capacity mechanism are considered, such as capacity payments, a strategic reserve and different forms of capacity markets. Since the barriers to entry for the district heating market are even higher than with electricity, providing incentives for investing in generation capacity of heat seems even more crucial.

What has not been taken into account in this thesis is the pricing mechanism for district heating. The previously described failures in the electricity market are partly caused due to the marginal cost based merit order. Marginal costs of renewables are zero, driving down prices for electricity, and as well as causing investment problems in the market, also causing coal to gain market share. For district heating it is therefore important to consider what pricing mechanism would suit the market the best and stimulate sustainable sources. There are different options to consider for district heating: marginal cost, cost-plus method, the incremental cost approach and the shadow price method (Difs & Trygg, 2009; Li et al., 2015; Zhang et al., 2013). These different pricing mechanisms are based on different ways of allocating the cost of production. The marginal cost and the incremental cost approach are the same. The marginal costs of heat differ per source. For waste heat from industry, the marginal costs of heat will be nearly 0, since it is a by-product. In case of a CHP, the marginal costs are the costs of the fuel to produce it. However, since the CHP cogenerates electricity and heat, and the ratio in which this is generated influences the performance of the plant, the marginal costs are difficult to determine. For a geothermal well, the marginal costs are also likely to be 0 or nearly 0, causing all sources to create a relatively 'cheap' market price. This is not desirable, since it does not stimulate investments or renewable heat sources. Other approaches such as the cost-plus method or shadow price method might prove to be more suitable. More research is needed.

It is also important to reflect on the consequences of choosing a *design* study. In essence there are three ways to approach the problem of introducing competition, namely analysing (filleting the situation until you know how it works), designing (devising a socio-technical system through for example a systems analysis) and reasoning (give observation of existing model of which you know it should work and draw conclusions). The consequences of choosing designing as an approach, is that even though the basis is in literature and practice, it is still the designers' interpretation. In order to mitigate this potential flaw, validating the design is necessary. However, validation of such a design is difficult due to lack of standard validation approaches. In this thesis, validation has been executed by means of a sound theoretical foundation, a systems analysis guided by experts in the field and eventually a validation workshop for further validation of the conceptual model. Due to the extensive involvement of both theory and practice, the effect of the potential biased perspective of the designer is reduced to a minimum.

This thesis has approached the problem of introducing multiple independent producers on district heating networks from a broad perspective, namely the technical, economic and institutional perspectives. This broad approach has caused an unavoidable lack of depth in the results, as compared to a more focussed approach on for example one perspective. Nevertheless, there are strong arguments for choosing the broader approach. E.ON has plenty of experience with analysing and designing projects from a technical and economic perspective. A lack of incorporating the institutional perspective has sometimes caused unnecessary disruption during project development. The value of this thesis is that it incorporates all three perspectives, thus including the institutional aspects. By incorporating all three perspectives in the design, it ensures that the situation is presented as a whole without overlooking potential institutional barriers. One of the main insights has been that even if technology allows it, and it is cost-efficient, it can institutionally still be unfavourable. One layer cannot advance or change without the others, which means looking at one perspective is in this case simply not sufficient.

Another point of discussion is the selection of design choices. From literature, 13 design choices are indicated for electricity markets. Of those 13, 10 were assumed to be applicable for district heating. Of

those 10, 2 were chosen to be relevant in this stage of designing a market for district heating and a new design choice for district heating was added. One could argue that leaving out 8 of the in theory defined design choices impacts the validity of the design outcome. However, as was demonstrated in the systems analysis chapter, the degree of market opening, capacity mechanism and supply temperature essential parameters of a successful district heating market design at this time. The other design choices should be taken into account at a later stage, when the effects of the chosen design choices are known.

### 11.2.2. The conceptual model and the link to simulation

In this project, a conceptual model has been developed. Towards the end, it is strongly advised to make a simulation model of the district heating system using the conceptual model as a basis. A clear point of discussion is why the simulation model was not built for this thesis as well. A conceptual model does not capture the dynamics of the district heating market the same way a simulation model would, since does not advance over time. However, before a simulation model can be built, insights in the relations between the different elements in the technical, economic and institutional layers are needed. The conceptual model provides these insights. It was necessary to first have this conceptual model because it creates awareness of all concepts involved. It was needed to provide the means to represent all the different flows, for it is not only heat going from A to B and back, but the transferring of ownership and costs as well, which the conceptual model does very well. With this knowledge a simulation model can be built that is a better representation of the district heating system than without this knowledge.

An interesting point of discussion is what the conceptual model means for practical implementation. As the validation workshop with experts has indicated, is that the step from going from concepts to using it to represent the current system is quite wide. It also showed that thinking about institutional concepts was quite difficult, because they occur on many levels (which is shown by Williamsons four layer model in this thesis (Williamson, 1998)). To bridge this gap, the representation of the current district heating system can be useful. By looking at how the current district heating system is represented using the conceptual model, in practice any other district heating system in the Netherlands should be able to be characterised using the conceptual model in this thesis, as well as any new alternative for a district heating market. A drawback of this is that the conceptual model on its own is not enough to get started in practice. However, this thesis has provided many applications of the conceptual model, that with some reading, it is ready to be used in practice. The foremost application of this conceptual model has been to build an agent-based simulation model and to bridge this gap, a detailed simulation proposal is provided in this thesis to overcome the initial drawbacks of the usability of the conceptual model.

The relation between the model and its use in agent-based modelling of complex adaptive systems is that the conceptual model can be used to guide the development of the simulation model. From the conceptual model it is known that there are three flows: heat, costs and ownership. This is also what should flow through the agent-based model, from producer to consumer. It is also known from the conceptual model that there is a market structure, for example the single-buyer structure, and that this is what the market should look like. That is why not only the suggested alternatives, but the conceptual model is of the essence. It could be that the suggestions made for market design alternatives are not adequate, and that different design of experiments are needed. The conceptual model gives the framework to think of different options, within the district heating system.

Another point of discussion concerning the conceptual model is that it is applied to the situation in The Hague, while this thesis is aiming to provide a solution for facilitating access to multiple independent producers in district heating networks in the Netherlands. During the research project the general conceptual model has been validated by applying the model to the situation in The Hague, using experts in the field. However, is the conceptual model also applicable to the situation in Utrecht for example? In order to look at the practical implementation of the conceptual model on district heating networks in other regions of the Netherlands, it is advised to perform a similar session to the expert workshop in this thesis. By presenting them the conceptual model and brainstorming together about what it would look like in their situation should provide a schematic representation of the district heating network. To take it one step further, if this is done in many cities, the conceptual model can be validated further and the model can then even be adjusted if in all of the Netherlands a certain configuration is in place. If, for example, in none of the district heating networks a transport network is present, perhaps it can even be deleted from the basic diagram. For this project it was chosen to validate the model using a specific case, but it could be validated using generalisability in the future.

With the conceptual model, it has been difficult to determine the effects of a certain degree of market opening, capacity mechanisms and the supply temperature on the five objective variables (security of supply, the price of 1 MWh of heat, the demand for heat, the number of producers in the market and the market share per producer). This has been difficult, because the conceptual model captures the different flows in the system, and not the relations per se. Relations between elements are generally quantifiable, meaning a number or equation can be given. However, that was not the goal of this conceptual model. The goal of the conceptual model was to capture the district heating system and all the elements on different layers. The simulation model will have to look at the relations and quantify these. For example, the simulation model should not only determine the effect of the single-buyer market structure on the costs for the consumer, but the combined effect of the single-buyer design, the capacity payments and the lower supply temperature. And not only the effect on the consumer price, but also on the other four objective variables (figure 17). Since this is becoming very complex, a simulation model is needed to define and quantify the relationships.

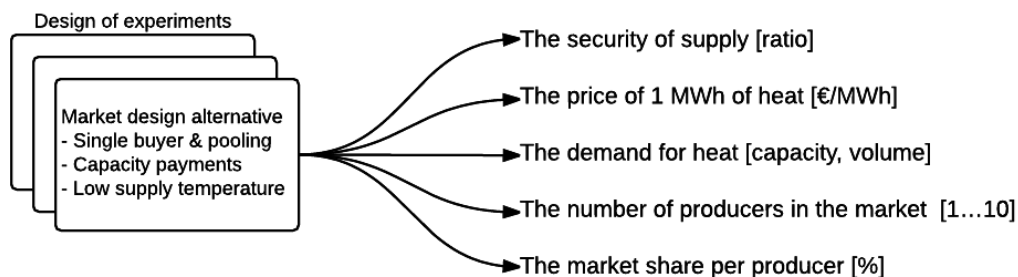


Figure 17: Purpose of the simulation model

However, we do know some of the effects of a single-buyer market design in electricity markets. The single-buyer market structure is easy for attracting multiple producers, such as industrial plants as waste heat producers. The single-buyer structure enables them to be just producer and not have distribution costs or additional costs associated with sales to consumers (Söderholm & Wårell, 2011). This makes this a simple structure with low transaction costs, attracting competitors on the producer side of the market. Even though more competition should reduce the price of heat theoretically, the single-buyer, if not regulated properly, can still ask monopolistic prices from consumers in theory.

These are the effects we can derive from theory. The benefit of the simulation model would be to see even more effects than theory can analyse.

Besides, it is very difficult to theoretically determine what will happen in the long run. Even Klein, Joskow and other leading regulation, access and utility market authors can be questioned. Liberalisation of energy markets was first started in the 80's and 90's. Theories that funded the liberalisations have investment cycles of about 40 years, so in reality we do not know the exact effects of these theories. Now, the world is at a point that is close to reaching the 40 years and it remains to be seen what the workings are of the implemented market designs. As stated in this discussion, in the electricity market investments are already falling short, so it is not all that promising. Therefore it is wise to learn more lessons from the liberalisation of electricity and gas markets the coming years, and prevent certain outcomes for the district heating market.

To conclude, the conceptual model that has been made in this study embodies the first steps towards a new district heating market. It visualises the complexity of the market, including technical, economic and institutional aspects. The conceptual model provides a basis for simulation, which would give more insights into the behaviours of stakeholders in the market than theory can provide. Theory goes a long way, especially in this stage of developing an new market for district heating, but a simulation model can take the results from this research to the next level. The conceptual model can be used in practice, firstly by applying it to current situations of local district heating networks. Secondly, by designing new desired district heating markets in the same framework, and thirdly by using it as a basis for simulation.

## 12. Conclusion

The district heating system in the Netherlands still operates as a monopolistic facility. In order to facilitate access to multiple independent producers on one network, research has to be done. The main research question is as follows:

**What combination of design choices would be suitable for facilitating access to multiple independent producers of heat on district heating networks in the Netherlands?**

In this chapter an answer will be given to this question, by means of providing the results from each phase in this research. Throughout this report several conclusion chapters have already been added. This final conclusion chapter takes those conclusions and presents them taking into account the previous discussion chapter. The main conclusions from the discussion are firstly, that there is potential for district heating in the energy mix. It can compete with gas and electricity as forms of space heating, especially in existing build in densely populated areas. In order to live up to this potential, the district heating system needs to grow and attract new producers. One of the areas with the most potential for district heating producers, is the Port of Rotterdam. Changing legislation to allow the heat captured from industries to discount on their total emissions, should give the Port incentive to become a producer of district heating.

Besides that, the comparisons made throughout this research with the electricity market has brought forward many insights. However, the comparison between heat and electricity can be critiqued as well. The differences between heat and electricity show that heat is an easier flow to manage, since storage of heat is easier and shortages cause less of a problem. Nevertheless, the barriers to entry for heat are a lot higher, making it more difficult to attract more producers. The liberalisation of the electricity market of the past decades, has led to several lessons for the district heating market. Apart from the designs made in this thesis, it is important to focus on the pricing mechanism. In the electricity market, having a marginal cost based pricing mechanism has caused many issues in the working of the market, especially with the growing share of renewables. Since the potential of district heating is largely due to its more sustainable nature, it would be advisable to look at a pricing mechanism that is different from the marginal cost mechanism in the electricity market.

Three design choices are important at this stage in time for developing a district heating market that facilitates access to multiple independent producers on district heating networks in The Netherlands. For each design choice several options are identified as presented in table 4.

Table 4: Final design choices for district heating

	Design choices	Options in theory
1	Degree of market opening (access related)	Open access
		Access regulation: Pooling
		Access regulation: Timetabling
		Vertical separation
	Degree of market opening (market structure)	Wheeling
		Single-buyer model
		Wholesale competition / portfolio manager model

		Retail competition / customer choice model or retail wheeling / network access model
2	Capacity mechanism	Capacity payments
		Strategic reserve
		Capacity market: capacity obligation
		Capacity market: capacity auction
		Capacity market: reliability options
3	Supply temperature	Low temperature network (40-70°C)
		High temperature network (90-120°C)

Next to the design choices, another aspect is very important for designing a market for district heating. Complex systems, such as the district heating system, where multiple actors are involved from both public and private nature, are best described from three different perspectives. In such systems the technological component determines the working of the system to a lesser extent, but the behaviour of actors that take certain decisions have a greater influence on the system. The three layers, technical, institutional and economic are leading in any market design that will be made for this project, they are all essential to design a complete market.

The technical characteristics of heat are a certain supply temperature, a pressure and a flow. Heat goes from production, through pipelines via transport, a booster station to distribution and is eventually used by the consumer. Economically, a certain price is determined which consumers pay for their demand, which then flows back to distribution which Eneco accounts for. They then have a contract with E.ON with amongst other things, a price agreement. Looking at the institutional analysis, many different institutions on different levels can be identified. Considering roles and ownership and the degree of market opening, E.ON is in charge of production and Eneco of distribution in the current situation. This means they are the monopolists in the market for district heating in The Hague. This situation poses a must-run situation for E.ON, where they have no choice but to supply the required demand even if strategically it would be better to do otherwise.

When interviewing the stakeholders in the district heating system in the case of The Hague, it became apparent that they have different means and ends, and also different goals. All stakeholders want multiple producers to feed to the network of district heating, which is a positive finding. However there will most likely be discussion about how to do this and what such a market should look like. These are the criteria or objective variables for a new market for the district heating system: The security of supply [ratio], the price of 1 MWh of heat [€/MWh], the demand for heat [capacity, volume], the number of producers in the market [1...10], the market share per producer [%]. A new market design should be tested using these criteria.

The conceptual model that is made for the district heating system shows the three design choices and the three different perspectives, namely the technical, economic and institutional layers of the district heating system. Since this is a design study, it is important to note that the model is an interpretation of the designer of the district heating system. In order to mitigate this potential flaw, validating the design is an important step. Experts in the field have contributed to this. Due to the extensive involvement of both theory and practice, the effect of the potential biased perspective of the designer is reduced to a minimum. The conceptual model has several advantages, it namely:



- Creates awareness of all concepts involved;
- Gives insight in all three layers, which adds value;
- Provides the means to represent the different flows, for it is not only heat going from A to B and back;
- One layer cannot advance/change without the others, which means looking at one perspective is not sufficient;
- When applied to a specific situation, this can form a complete picture and a basis for simulation.

It is also important to note some disadvantages or limitations of the conceptual model. During the process of designing, the following findings were noted:

- Difficult to capture all relations and dynamics in a diagram which does not advance in time like a simulation model would;
- The design area demarcates the research, but limits the depth in which the model has been built;
- The boxes in the institutional layer only contain stakeholders, the actual institutions are either represented by arrows or take place in the interfaces;
- The model and the current situation are focussed on households as customers and do not include large consumers;
- There are many details that are not included in the model, it does not cover a lot of detail but it focusses on concepts and high level aspects only;
- The step from going from concepts to using it to represent the current system is quite wide, this could pose difficulties for the usability of the conceptual model.

These limitations should be taken into account when using the general conceptual model for future purposes. The purpose of the conceptual model for this study is to use the conceptual model to develop alternatives. The different implementations of the design choices in the conceptual model are combined into alternative market designs.

In alternative 1, production and retail are open for all who wish to enter. There is a DSO that owns the distribution network, which is a public utility, and there are several producers and retailers that supply heat on these networks. This is combined with a capacity payment mechanism, paying producers to have a certain capacity installed, which can be easily implemented. For this alternative a low temperature network is chosen that lowers the barrier to entry for potential producers. However, this does imply that consumers have to change to different radiators or floor heating, in order to still reach 21 degrees Celsius with a lower supply temperature.

In the second alternative production is open for heat producers, distribution access is limited, due to the single-buyer structure that is implemented. Multiple producers can supply to the purchasing company, who then distributes the heat to consumers. The single-buyer ensures demand is met, either by producing its own heat or by buying it from independent heat producers. The capacity mechanism in place is a capacity market in the form of capacity obligations. Next to the market for heat, a capacity market is introduced. This means that producers are required to buy capacity obligations, which includes the peak consumption and a fixed margin on top of it. Also, in this alternative, a high temperature network is maintained, which avoids the cost-shift to consumers.

In alternative 3, the market is relatively closed. This will be a strict alternative for district heating. Some companies are given the exclusive right and duty to supply in their specific distribution area. They then also own the infrastructure and are responsible for necessary investments. The capacity mechanism in this alternative is a strategic reserve. The strategic reserve is reserve capacity that is, for example, owned and controlled by the government. This is easy to implement and gives old units the opportunity to be reused. In this alternative the supply temperature can vary per local network, so that local sources can be used optimally.

Based on the advantages and disadvantages of each design choice option per alternative, the most promising alternative is a combination of alternatives 1 and 2. To answer the research question: The degree of market opening in alternative 2, the single-buyer model, together with the capacity mechanism and supply temperature of alternative 1, namely capacity payments and a low temperature network, seems the most promising for a new district heating market. However, this judgement cannot be validated further without further research. Therefore, it is suggested that a simulation model of the situation is made, which enables further testing of the alternatives.

In order to facilitate further research, the first transformation steps from alternatives to simulation are also made in this phase. In this case, agent-based simulation is the best simulation method for the district heating system. Agent-based modelling as a method that creates insight into behaviour of the system as a whole, as well as its individual parts. These insights are necessary in order to evaluate the alternatives in case of introducing a new market structure for district heating in The Hague. The model can contribute to the decision making process by simulating different configurations of design choices and their resulting outcome. This outcome is measured in form of the security of supply, the price per MWh of heat, the demand for heat, the number of producers in the market, and the market share per producer. Theory goes a long way, especially in this stage of developing an new market for district heating, but a simulation model can take the results from this research to the next level.

## 13. Recommendations

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This research has shown that there are possibilities to change from the monopoly situation to a more open market for district heating. There are many options to be considered and a lot of work is to be done if such a result is to be achieved. A new market brings a lot of change for all the stakeholders in the market. E.ON Benelux as the problem owner can be given some advice, based upon the conclusions of this research.

- It is of the essence that the proposed agent-based model is made. Without knowing with a greater certainty which combination of market design choices generate the desired behaviour, it becomes very complex to move forward. An agent-based model can give the insights needed for E.ON to move in the strategically optimal direction, creating a place for itself in the new market.
- Incorporating the institutional layer into new plans and advancements for district heating can aid E.ON. The technical and economic aspects are well-covered when looking at new projects. As has become clear during this process, the layers need to change together if a new market situation is to be created. There are often implicit reasons why some solutions may work or not, often institutional. These cannot be ignored if E.ON wants a share in the new system.
- If a district heating market as suggested is put in place, it is advised to diversify production locations and sources. The drive for this change in the market, amongst others, is the 20-20-20 goal. This means that sustainability has a high priority and it is advisable to go along in this trend to ensure a place for E.ON in the district heating market in the Netherlands in the long run.
- In order to secure a place in the market, it could be wise to think further than what Eneco as the client of E.ON wants, but also to think about what Eneco's clients want. Even if in a new market Eneco has a different role, for E.ON there will still be one large party to sell their heat to, who then sells it to consumers. District heating will have to become more accepted if its share is to grow compared with gas and all-electric as solutions for space heating.
- As for the situation in The Hague, it is clear that some of the interests are not aligned as much. The main issue, again, is this image of sustainability. It is important, that some way or another, society's perception alters into E.ON's favour. It is therefore recommended to look into the institutions that form barriers for E.ON and to look into institutional change in order to adjust these barriers.
- If E.ON really want to realise a competitive situation, it should alert the government of the investment risks. None of the stakeholders are prepared to bear the risks and the government will have to propose a plan for investments and offsetting the risks somehow. In what way, is yet to be determined.
- The current distribution network is in the hands of Eneco. It is recommended that it laid out to the Ministry of Economic Affairs and to let them know that if they want consumer price to fall, something must be done to take away this market power from Eneco. Either by regulating how they grant access, or by transferring ownership of the network to a public authority for example.

Apart from recommendations for E.ON, some recommendations for further research are made as well:

- Validation of the conceptual model in terms of multiple workshops in different cities in the Netherlands is recommended if a general simulation model is to be built, instead of a specific simulation model for the situation of E.ON in The Hague.
- For further research, a recommendation is also to develop the proposed agent-based model. This should make for a fine study, that can contribute to accomplishing energy goals and the energy transition in the Netherlands.
- In this research, pricing mechanisms are not included. In the discussion chapter, the importance of a good pricing mechanism has come forward, since the marginal cost approach is causing problems for the electricity market. Other approaches such as the cost-plus method or shadow price method might prove to be more suitable for district heating. More research is needed into this matter.
- Another interesting topic seems to be to look at what a change in cultural norms would mean for the energy transition and district heating. An intriguing example is if the room temperature standard would be 19 or 20°C instead of 21°C. What would this mean for district heating and how would this contribute to the 20-20-20 goals?
- What has not been included in this study is the analysis of change or transition from the current situation to the future situation, looking at institutional change and transition theory. These are very interesting concepts that could be of value when looking at the district heating market.

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# Appendices



# Appendix A – Interviews

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## Interview E.ON

Aris Blankenspoor

### Introductie

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Momenteel ben ik, Lisa van Woerden, masterstudent op het gebied van Technology, Policy and Management aan de TU Delft, bezig met een onderzoek naar het introduceren van meerdere producenten op stadsverwarmingsnetwerken in Nederland. Specifiek wil ik mijn onderzoek richten op stadsverwarming in en om E.ON, omdat hier veel potentie is voor een dergelijke warmtemarkt en er nu een zogeheten ‘window of opportunity’ zich voordoet.

De eerste fase van mijn onderzoek is een systeemanalyse, waarbij ik de gehele keten in kaart wil brengen, op zowel technisch, fysiek, economisch als institutioneel vlak. Natuurlijk zijn er veel stakeholders betrokken met het warmtesysteem, waar u er een van bent. Ik zou dan ook graag met u een interview plannen, waarin ik de systeemanalyses die ik tot nu toe heb gedaan met u door kan nemen. Ik ben benieuwd naar de doelen van uw organisatie met stadsverwarmingsnetwerken en de middelen die uw organisatie heeft om deze doelen te bereiken. Evenals hoe u tegen het introduceren van meerdere warmte producenten op een netwerk aankijkt. Natuurlijk is er ook de gelegenheid om over andere, voor u relevante, aspecten van het warmte systeem te praten.

### Onderwerp interview

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Zoals ik aangaf, wil ik graag de analyses die ik tot nu toe heb gedaan met u bespreken om te verifiëren of u dit ook zo ziet en om nieuwe inzichten te verkrijgen. De voorlopige conclusies van mijn analyse is als volgt.

Het doel dat ik zie voor E.ON met betrekking op stadsverwarming is: ‘To become Nr.1 in management of district heating systems’. Er zijn meerdere middelen nodig om dit doel te bereiken. Om dit doel te bereiken zijn de volgende factoren/doelen en de middelen die daarvoor in te zetten zijn van belang:

- Meer aansluitingen tussen productie installaties en stadsverwarmingsnetwerken creëren
  - o De verbinding van MPP3 met het netwerk bewerkstelligen
  - o Meerdere productie installaties overwegen als warmtebron
- De warmterotonde verder helpen, met toegang voor E.ON als producent
  - o Ruimte creëren voor andere producenten op het netwerk
  - o Meer investeren en mankracht beschikbaar stellen voor de warmterotonde ontwikkelingen
- Optimaliseren van de STEG dispatch
  - o Meer elektriciteit produceren als de e-prijs hoog is
  - o Meer warmte produceren als de e-prijs laag is
  - o Flexibiliteit rond warmte productie vergroten (must-run voorkomen)
- Participatie in nieuwe stadsverwarming in Den Haag vergroten
  - o Meer investeren en mankracht beschikbaar stellen voor Cluster West ontwikkelingen
  - o Meer als netwerkbeheerder ontwikkelen in Den Haag

Bovenstaande voorlopige conclusies zou ik heel graag doornemen door middel van onderstaande vragen.

### Algemeen

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1. Wat is op dit moment de rol van E.ON met betrekking tot stadsverwarming?

E.ON is een grote producent, maar is ook gespecialiseerd in de dispatch en handel in combinatie met elektriciteit.

Doelen

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2. Wat is het algemene doel van E.ON met betrekking tot stadsverwarming?

Het algemene doel is om een grote producent te blijven, groei te realiseren en helpen leveringszekerheid te garanderen. Hierbij is 'people, planet profit' belangrijk. Dit moet zo betaalbaar, groen en betrouwbaar mogelijk. Vooral met betrekking tot het betrouwbare aspect is een rol voor E.ON weggelegd.

3. Waarom wil ze dat bereiken?

Stadsverwarming maakt deel uit van de core businesses van E.ON, en dit wil zij blijven doen.

4. Hoe kan ze dat bereiken?

Participeren! In bijvoorbeeld Cluster West, decentrale initiatieven in Den Haag etc. Het mee doen is belangrijk, en het doen waar je goed in bent.

Middelen

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5. Welke middelen heeft E.ON om deze doelen te bereiken?

E.ON is in veel dingen goed, onder andere: engineering, contracten, bouw, organiseren, technische expertise, dispatch verzorgen, coördinerende rol. Dit zijn belangrijke bouwstenen van stadsverwarming.

6. Welke middelen heeft E.ON niet, maar zijn wel nodig de doelen te bereiken?

E.ON is niet zo zeer afhankelijk, maar andere partijen zijn beter in de organisatie om klanten te bedienen en service te verlenen.

7. Van welke partijen is E.ON afhankelijk voor zijn of haar middelen?

De Nederlandse overheid. E.ON heeft geen leidinggevende functie, hierin heeft de overheid een belangrijke taak, en ook om keuzes te maken voor de hele keten.

Conclusie doelen - middelen

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8. Bent u het eens dat het bovengenoemde doel wenselijk is?

Zie schema einde interview

9. En dat deze bereikt worden door de genoemde middelen?

Zie schema einde interview

Verdere vragen

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Voor de volgende fases in mijn onderzoek ga ik een eenvoudig rekenmodel maken van de warmtemarkt om te kijken of het haalbaar is om meerdere producenten te introduceren en hoe dit dan het beste kan. In dit model zullen zowel technische, fysieke, economische en institutionele variabelen worden meegenomen.

10. Wat zouden jullie graag oplossen met een dergelijk model?

Technisch werkend systeem, en hoe de besturing daarvan georganiseerd kan worden.

11. Wat is er nog onbekend voor jullie om jullie doel te realiseren in de strekking van mijn onderzoek?

Moet er een netbeheerder komen? Hoe werkt dit? Komt er een merit order, en op basis waarvan? Marginale kosten?

12. Waar ligt volgens jullie de uitdaging nu?

De uitdaging ligt vooral bij de tegengestelde (lokale) politieke belangen. Dit zorgt voor veel vertraging, sommige partijen participeren om op de rem te kunnen trappen. De uitdaging is vooral om deze partijen bij elkaar te brengen en één beleid te vormen.

13. Wat zijn jullie ideeën wat betreft een markt, en toetreding van meerdere producenten?

Dat het deels een nutsvoorziening wordt, met een netbeheerdersrol. Meerdere producenten zeker, maar hoe is nog onduidelijk. Betrouwbaarheid blijft heel belangrijk.

14. Hoe ziet u stadsverwarming voor zich over 5 a 10 jaar?

Stadsverwarming zal niet eeuwig doorgroeien. Lokale ontwikkeling van decentrale opwekking (zoals zonnepanelen) zijn belangrijke technologieën die een daling in groei kunnen betekenen voor stadsverwarming. Dus groei is belangrijk waar het kan, maar de algemene vraag naar warmte zal dalen. In de toekomst zal niet 120 PJ worden geproduceerd, maar 80 PJ en dan voornamelijk door duurzame bronnen.

## Interview Eneco

Erik Burgman

### Introductie

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Momenteel ben ik, Lisa van Woerden, masterstudent op het gebied van Technology, Policy and Management aan de TU Delft, bezig met een onderzoek naar het introduceren van meerdere producenten op stadsverwarmingsnetwerken in Nederland. Specifiek wil ik mijn onderzoek richten op stadsverwarming in en om Eneco, omdat hier veel potentie is voor een dergelijke warmtemarkt en er nu een zogeheten 'window of opportunity' zich voordoet.

De eerste fase van mijn onderzoek is een systeemanalyse, waarbij ik de gehele keten in kaart wil brengen, op zowel technisch, fysiek, economisch als institutioneel vlak. Natuurlijk zijn er veel stakeholders betrokken met het warmtesysteem, waar u er een van bent. Ik zou dan ook graag met u een interview plannen, waarin ik de systeemanalyses die ik tot nu toe heb gedaan met u door kan nemen. Ik ben benieuwd naar de doelen van uw organisatie met stadsverwarmingsnetwerken en de middelen die uw organisatie heeft om deze doelen te bereiken. Evenals hoe u tegen het introduceren van meerdere warmte producenten op een netwerk aankijkt. Natuurlijk is er ook de gelegenheid om over andere, voor u relevante, aspecten van het warmte systeem te praten.

### Onderwerp interview

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Zoals ik aangaf, wil ik graag de analyses die ik tot nu toe heb gedaan met u bespreken om te verifiëren of u dit ook zo ziet en om nieuwe inzichten te verkrijgen. De voorlopige conclusies van mijn analyse is als volgt.

Het doel dat ik zie voor Eneco met betrekking op stadsverwarming is: Improve sustainable image 'de duurzame energieleverancier'. Er zijn meerdere middelen nodig om dit doel te bereiken. Om dit doel te bereiken zijn de volgende factoren/doelen en de middelen die daarvoor in te zetten zijn van belang:

- Iedereen van 100% duurzame energie voorzien
  - o Meer producenten introduceren
  - o Meer investeren in innovatie wat betreft technologie
  - o Meer lokale duurzame initiatieven stimuleren
- Meer volume distribueren
  - o Optimaliseren huidig netwerk
  - o Uitbreiden huidig netwerk naar meer wijken
  - o Meer aansluitingen verkrijgen
  - o Meer warmte leveren
  - o Meer producenten introduceren

Bovenstaande voorlopige conclusies zou ik heel graag doornemen door middel van onderstaande vragen.

#### Algemeen

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1. Wat is op dit moment de rol van Eneco met betrekking tot stadsverwarming?

Levering van warmte in o.a. Rotterdam, Utrecht en Den Haag (dit is 90% van de warmtedistributie die Eneco doet).

2. Wat is op dit moment uw rol met betrekking tot stadsverwarming?

Werkzaam bij Eneco Warmte-Koude

#### Doelen

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3. Wat is het algemene doel van Eneco met betrekking tot stadsverwarming?

Duurzame warmte leveren, dat wil zeggen warmte uit hernieuwbare bronnen.

4. Waarom wil ze dat bereiken?

Dit is de missie van Eneco, iedereen 100% duurzame energie leveren, hier valt warmte ook onder

5. Hoe kan ze dat bereiken?

Zie middelen doel-middelen schema

#### Middelen

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6. Welke middelen heeft Eneco om deze doelen te bereiken?
  - Groeien binnen stadsverwarmingsmarkt in volume
    - o Optimaliseren huidig netwerk (bijvoorbeeld lagere temperatuur leveren)
    - o Uitbreiden huidig netwerk naar meer wijken
    - o Meer aansluitingen verkrijgen

- Meer warmte leveren
- Meer producenten introduceren
- Iedereen van 100% duurzame energie voorzien
  - Meer producenten introduceren
  - Meer investeren in innovatie wat betreft technologie
  - Meer lokale duurzame initiatieven stimuleren

7. Welke middelen heeft Eneco niet, maar zijn wel nodig de doelen te bereiken?

Eneco heeft zelf geen bronnen, hier is ze van afhankelijk van andere partijen. Binnen de stad Den Haag is dit de STEG van E.ON, waar nu geen alternatieven voor zijn, zeker niet met hetzelfde vermogen.

8. Van welke partijen is Eneco afhankelijk voor zijn of haar middelen?

Partijen die warmte op grote schaal kunnen leveren, nu E.ON, in de toekomst kan dit verschuiven. En ook kijkt Eneco naar de overheid voor een mogelijke financiële bijdrage om infrastructuur wat betreft transport mogelijk te maken.

Conclusie doelen - middelen

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9. Bent u het eens dat het bovengenoemde doel wenselijk is?

Ja, duurzaamheid is voor ons het hoogste doel

10. En dat deze bereikt worden door de genoemde middelen?

Ja.

Verdere vragen

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Voor de volgende fases in mijn onderzoek ga ik een eenvoudig rekenmodel maken van de warmtemarkt om te kijken of het haalbaar is om meerdere producenten te introduceren en hoe dit dan het beste kan. In dit model zullen zowel technische, fysieke, economische en institutionele variabelen worden meegenomen.

11. Wat zouden jullie graag oplossen met een dergelijk model?

Inzicht in of de warmtemarkt groot genoeg is voor meerdere leveranciers. De verwachting is dat concurrentie op dit vlak geen efficiëntie oplevert voor het systeem als geheel, maar dit is tot nu toe een aanname.

12. Wat is er nog onbekend voor jullie om jullie doel te realiseren in de strekking van mijn onderzoek?

Is de markt er klaar voor om productie op te vangen van de huidige monopolisten (E.ON voor Den Haag)?

13. Waar ligt volgens jullie de uitdaging nu?

Productie van duurzame bronnen voor warmte opschalen, temperatuur van het netwerk verlagen en keuze voor de klant mogelijk maken zijn de belangrijkste uitdagingen.

Momenteel zijn er nog geen alternatieven die de hoeveelheid PJ produceren die nodig is voor de huidige vraag naar warmte via stadverwarming.

14. Wat zijn jullie ideeën wat betreft een markt, en toetreding van meerdere producenten?

Eneco wil graag meerdere producenten om zo de productielast te verdelen en zo veel mogelijk duurzame bronnen toe te laten. Zij wil echter niet dat er een gedwongen afname van elke bron gaat gelden, want de focus ligt voornamelijk op duurzame warmte.

15. Hoe ziet u stadsverwarming voor zich over 5 a 10 jaar?

Stadsverwarming is een onontbeerlijke schakel voor de energieverduurzaming in Nederland.

De grootste kansen voor stadsverwarming liggen in dicht stedelijk bebouwde gebieden. Hier zijn ruimtelijk gezien weinig andere opties zeker zonder afhankelijk te zijn van gas.

Zogenaamde Vinex wijken, nieuwbouw, zijn meer geschikt om warmtepompen te integreren en geen gasaansluiting bij aan te leggen. Het platteland is het meest efficiënt om via groen gas te voorzien.

Voorwaardes om nu verder te kunnen met het verduurzamen van stadsverwarming zijn:

- De temperatuur omlaag. Hierbij is Eneco afhankelijk van de herorganisering van het afgiftesysteem, hier gaan gemeentes/provincie/overheid over.
- Bijdrage overheid om een grote transportleiding aan te leggen. Wellicht het tot een nutsvoorziening bestempellen zou een oplossing zijn, het is duidelijk meer een publiek goed.

## Interview Gemeente Den Haag

Ted Zwietering

### Introductie

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Momenteel ben ik, Lisa van Woerden, masterstudent op het gebied van Technology, Policy and Management aan de TU Delft, bezig met een onderzoek naar het introduceren van meerdere producenten op stadsverwarmingsnetwerken in Nederland. Specifiek wil ik mijn onderzoek richten op stadsverwarming in en om de gemeente Den Haag, omdat hier veel potentie is voor een dergelijke warmtemarkt en er nu een zogeheten 'window of opportunity' zich voordoet.

De eerste fase van mijn onderzoek is een systeemanalyse, waarbij ik de gehele keten in kaart wil brengen, op zowel technisch, fysiek, economisch als institutioneel vlak. Natuurlijk zijn er veel stakeholders betrokken met het warmtesysteem, waar u er een van bent. Ik zou dan ook graag met u een interview plannen, waarin ik de systeemanalyses die ik tot nu toe heb gedaan met u door kan nemen. Ik ben benieuwd naar de doelen van uw organisatie met stadsverwarmingsnetwerken en de middelen die uw organisatie heeft om deze doelen te bereiken. Evenals hoe u tegen het introduceren van meerdere warmte producenten op een netwerk aankijkt. Natuurlijk is er ook de gelegenheid om over andere, voor u relevante, aspecten van het warmte systeem te praten.

### Onderwerp interview

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Zoals ik aangaf, wil ik graag de analyses die ik tot nu toe heb gedaan met u bespreken om te verifiëren of u dit ook zo ziet en om nieuwe inzichten te verkrijgen. De voorlopige conclusies van mijn analyse is als volgt.

Het doel dat ik zie voor de Gemeente Den Haag met betrekking op stadsverwarming is: 'Increase potential of becoming energy neutral in 2050'. Er zijn meerdere middelen nodig om dit doel te bereiken. Om dit doel te bereiken zijn de volgende factoren/doelen en de middelen die daarvoor in te zetten zijn van belang:

- Het gebruik van stadsverwarming ten opzichte van andere alternatieven vergroten
  - o Meer producenten introduceren op het netwerk
  - o Meer geothermie, WKK, Power to heat en restwarmte projecten stimuleren
  - o Meer warmte die al aanwezig is in de stad gebruiken
  - o Meer de kosten efficiëntie van stadsverwarming onder de aandacht brengen
- Het verbruik van warmte verminderen
  - o Meer energie-0 woningen/wijken stimuleren
  - o Meer isolatie van huizen stimuleren

Bovenstaande voorlopige conclusies zou ik heel graag doornemen door middel van onderstaande vragen.

### Algemeen

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1. Wat is op dit moment de rol van De Gemeente Den Haag met betrekking tot stadsverwarming?

Variërend tussen aanjager, regisseur, initiatiefnemer, regisseur, financiering organiseren, enthousiasmeren bewoners, duurzame bronnen stimuleren.

2. Wat is op dit moment uw rol met betrekking tot stadsverwarming?

Haags warmtebedrijf opzetten, samen met andere partijen.

Doelen

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3. Wat is het algemene doel van De Gemeente Den Haag met betrekking tot stadsverwarming?

De energie transitie bevorderen en daarmee de gas afhankelijkheid te verminderen.

4. Waarom wil ze dat bereiken?

Om de toekomstige energievoorziening van Den Haag te verzekeren/veilig te stellen.

5. Hoe kan ze dat bereiken?

Warmte is hierin erg belangrijk. Onder andere is een subdoel om 100.000 aansluitingen te realiseren.

Middelen

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6. Welke middelen heeft De Gemeente Den Haag om deze doelen te bereiken?

Vooral heel veel kennis, van de stad, van de ondergrond en ook heel veel ervaring hiermee.

7. Welke middelen heeft De Gemeente Den Haag niet, maar zijn wel nodig de doelen te bereiken?

Met name technische mensen om goede stappen te maken wat betreft het groeien naar een no regret technologisch slim warmtenet.

8. Van welke partijen is De Gemeente Den Haag afhankelijk voor zijn of haar middelen?

Deels de overheid, maar vooral van mensen met kennis.

Conclusie doelen - middelen

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9. Bent u het eens dat het bovengenoemde doel wenselijk is?

Zie schema.

10. En dat deze bereikt worden door de genoemde middelen?

Zie schema.

Verdere vragen

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Voor de volgende fases in mijn onderzoek ga ik een eenvoudig rekenmodel maken van de warmtemarkt om te kijken of het haalbaar is om meerdere producenten te introduceren en hoe dit dan het beste kan. In dit model zullen zowel technische, fysieke, economische en institutionele variabelen worden meegenomen.



11. Wat zouden jullie graag oplossen met een dergelijk model?

Wanneer is welk markt inrichting voor wie interessant? Wat zijn ieders belangen? Inzicht in de private kant van de markt.

12. Wat is er nog onbekend voor jullie om jullie doel te realiseren in de strekking van mijn onderzoek?

Met name de belangen van andere partijen? What is in it for who?

13. Waar ligt volgens jullie de uitdaging nu?

Zo veel mogelijk projecten starten, en echt stappen maken. Het warmtebedrijf is een middel hiervoor.

14. Wat zijn jullie ideeën wat betreft een markt, en toetreding van meerdere producenten?

Een open net is echt het uitgangspunt en een randvoorwaarde voor een toekomstige markt.

15. Hoe ziet u stadsverwarming voor zich over 5 a 10 jaar?

Als een product dat veel mensen willen hebben. Goedkoop, veilig, meerdere invoer temperaturen mogelijk, alternatief voor gas, een substantieel deel van de energievoorziening. Dan hebben we het wel over duurzame warmte, hierbij is restwarmte second best maar een goede tussenstap mits het wordt uit gefaseerd met de tijd.

## Interview Programmabureau Warmte-Koude Zuid-Holland

Maya van der Steenhoven

### Introductie

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Momenteel ben ik, Lisa van Woerden, masterstudent op het gebied van Technology, Policy and Management aan de TU Delft, bezig met een onderzoek naar het introduceren van meerdere producenten op stadsverwarmingsnetwerken in Nederland. Specifiek wil ik mijn onderzoek richten op stadsverwarming in en om de gemeente Den Haag, omdat hier veel potentie is voor een dergelijke warmtemarkt en er nu een zogeheten 'window of opportunity' zich voordoet.

De eerste fase van mijn onderzoek is een systeemanalyse, waarbij ik de gehele keten in kaart wil brengen, op zowel technisch, fysiek, economisch als institutioneel vlak. Natuurlijk zijn er veel stakeholders betrokken met het warmtesysteem, waar u er een van bent. Ik zou dan ook graag met u een interview plannen, waarin ik de systeemanalyses die ik tot nu toe heb gedaan met u door kan nemen. Ik ben benieuwd naar de doelen van uw organisatie met stadsverwarmingsnetwerken en de middelen die uw organisatie heeft om deze doelen te bereiken. Evenals hoe u tegen het introduceren van meerdere warmte producenten op een netwerk aankijkt. Natuurlijk is er ook de gelegenheid om over andere, voor u relevante, aspecten van het warmte systeem te praten.

### Onderwerp interview

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Zoals ik aangaf, wil ik graag de analyses die ik tot nu toe heb gedaan met u bespreken om te verifiëren of u dit ook zo ziet en om nieuwe inzichten te verkrijgen. De voorlopige conclusies van mijn analyse is als volgt.

Het doel dat ik zie voor programmabureau W-K Z-H is: Het realiseren van een warmterotonde. Er zijn meerdere middelen nodig om dit doel te bereiken. Om dit doel te bereiken zijn de volgende factoren en de middelen die daarvoor in te zetten zijn van belang:

- Uitbreiden van de huidige infrastructuur
  - o Nieuwbouwwijken standaard voorzien van stadsverwarming
  - o Daar waar het gasnetwerk verouderd is, de aansluiting weghalen en vervangen door stadsverwarming
  - o Het huidige netwerk verlengen naar bestaande wijken
- Uitbreiden van het aantal aansluitingen
  - o Nieuwbouwwijken standaard voorzien van stadsverwarming
  - o Daar waar het gasnetwerk verouderd is, de aansluiting weghalen en vervangen door stadsverwarming
  - o Financiële ondersteuning bieden voor stadsverwarming
- Meer restwarmte benutten
  - o Het huidige netwerk verlengen naar bestaande wijken
  - o Meerdere producenten van warmte toelaten op het netwerk
- De vraag naar stadsverwarming verhogen
  - o De bewustwording van de voordelen van stadsverwarming verhogen
  - o Het gebruik van stadsverwarming binnenshuis verhogen
- De leveringszekerheid waarborgen
  - o Meerdere producenten van warmte toelaten op het netwerk

Bovenstaande voorlopige conclusies zou ik heel graag doornemen door middel van onderstaande vragen.

#### Algemeen

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1. Wat is op dit moment de rol van uw organisatie met betrekking tot stadsverwarming?

Het is een overkoepelende organisatie, waarin 25 partijen vertegenwoordigd worden, specifiek in/voor Zuid-Holland.

2. Wat is de aanleiding geweest tot het opzetten van programma bureau warmte-koude Zuid-Holland?

Verduurzamen van warmte kan geen enkele partij alleen, samenwerking is daarvoor nodig.

#### Doelen

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3. Wat is het algemene doel van Programmabureau WKZH?

14% van de gebouwen en kassen te verwarmen met duurzame warmte. Een middel hiervoor is de warmterotonde

4. Waarom wil ze dat bereiken?

Jaren geleden bepaald, gebaseerd op de potentie van warmte uit duurzame bronnen van 20 PJ, dit is 14% van de warmte van Zuid-Holland.

5. Hoe kan ze dat bereiken?

Door de warmterotonde, dit is een middel om de 14% te gaan halen in 2020.

6. Welke middelen heeft Programmabureau WKZH om deze doelen te bereiken?

- Uitbreiden van de huidige infrastructuur
  - o Daar waar het kosten efficiënt is stadsverwarming aanleggen, maar niet forceren. Energie 0 woningen kan bijvoorbeeld ook een optie zijn, wellicht het kleine beetje warmte dat die huizen hebben zou door stadsverwarming opgevangen kunnen worden maar hoeft niet. Het doel is niet isolatie e.d. te verminderen om vraag te verhogen.
  - o Daar waar het gasnetwerk verouderd is, de aansluiting weghalen en vervangen door stadsverwarming
  - o Het huidige netwerk verlengen naar bestaande wijken
- Meer warmte uit alle bronnen benutten
  - o Het huidige netwerk verlengen naar bestaande wijken
  - o Meerdere producenten van warmte toelaten op het netwerk
  - o Meer bronnen stimuleren, aardwarmte, tuinders etc. financieren businesscases
- De vraag naar stadsverwarming verhogen
  - o De bewustwording van de voordelen van stadsverwarming verhogen
  - o De mensen die al stadsverwarming hebben en blij zijn als ambassadeur inzetten
  - o Het gebruik van stadsverwarming binnenshuis verhogen
  - o Transitie naar een vraag-gestuurde markt bevorderen
- De leveringszekerheid waarborgen
  - o Meerdere producenten van warmte toelaten op het netwerk

7. Welke middelen heeft PWKZH niet, maar zijn wel nodig de doelen te bereiken?

PWKZH kan middelen gebruiken van veel aangesloten partijen (25) en bereikt zo haar doelen.

8. Van welke partijen is PWKZH afhankelijk voor zijn of haar middelen?

De 25 aangesloten partijen voor budget en mankracht.

Conclusie doelen - middelen

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9. Bent u het eens dat het bovengenoemde doel wenselijk is?

Ja. De 14% halen is het hoofddoel van het programmabureau. Dit valt samen met het doel om de afhankelijkheid van gas te verminderen, elk deel stadsverwarming is een deel minder gas.

10. En dat deze bereikt worden door de genoemde middelen?

Ja -> zie aanpassingen antwoord vraag 6.

Verdere vragen

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Voor de volgende fases in mijn onderzoek ga ik een eenvoudig rekenmodel maken van de warmtemarkt om te kijken of het haalbaar is om meerdere producenten te introduceren en hoe dit dan het beste kan. In dit model zullen zowel technische, fysieke, economische en institutionele variabelen worden meegenomen.

11. Wat zouden jullie graag oplossen met een dergelijk model?

Niet per se oplossen, maar inzicht verkrijgen in het systeem en de mogelijkheden voor een markt.

12. Wat is er nog onbekend voor jullie om jullie doel te realiseren in de strekking van mijn onderzoek?

Inzicht in restwarmte van kolencentrales. Transparantie is nodig wat betreft een aantal dingen:

- Hoe goedkoop is het nou echt?
- Is het echt afval warmte of zou een kolencentrale kunnen leven op warmte productie als e wegvalt? Ofwel, kan het een hoofdproduct worden zoals het nu is bij sommige AVI's?

13. Waar ligt volgens jullie de uitdaging nu?

De keten zo ver krijgen dat de markt vraag gestuurd wordt in plaats van aanbod gestuurd. En ook de industriële warmte tot stand laten komen, dit wordt nog zo weinig gebruikt, hier ligt echt een kans.

14. Wat zijn jullie ideeën wat betreft een markt, en toetreding van meerdere producenten?

Een handelsmarktplaats voor tuinders, zij handelen nu al op de APX, maar als er ook een warmtehandel op gang komt kan dit zeer veel potentie bieden voor zowel de glastuinbouw als woningen wat betreft warmte.

Certificaten voor hoe duurzaam je warmte is, lijkt ook interessant.

Het doel van het net zou in ieder geval moeten zijn om zoveel mogelijk warmte op te halen en duurzame warmte te stimuleren. Dit is (nog) geen business case, maar zou beter zijn voor de transitie naar een echte warmte markt.

15. Hoe ziet u stadsverwarming voor zich over 5 a 10 jaar?

We zijn er nog lang niet maar als iedereen z'n best doet, kan het zijn dat tegen die tijd de mens stadsverwarming ziet als goed alternatief en als verduurzaming, maar dit gaat niet vanzelf.

## Interview Provincie Zuid-Holland

Robert Geurts

### Introductie

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Momenteel ben ik, Lisa van Woerden, masterstudent op het gebied van Technology, Policy and Management aan de TU Delft, bezig met een onderzoek naar het introduceren van meerdere producenten op stadsverwarmingsnetwerken in Nederland. Specifiek wil ik mijn onderzoek richten op stadsverwarming in en om de gemeente Den Haag, omdat hier veel potentie is voor een dergelijke warmtemarkt en er nu een zogeheten 'window of opportunity' zich voordoet.

De eerste fase van mijn onderzoek is een systeemanalyse, waarbij ik de gehele keten in kaart wil brengen, op zowel technisch, fysiek, economisch als institutioneel vlak. Natuurlijk zijn er veel stakeholders betrokken met het warmtesysteem, waar u er een van bent. Ik zou dan ook graag met u een interview plannen, waarin ik de systeemanalyses die ik tot nu toe heb gedaan met u door kan nemen. Ik ben benieuwd naar de doelen van uw organisatie met stadsverwarmingsnetwerken en de middelen die uw organisatie heeft om deze doelen te bereiken. Evenals hoe u tegen het introduceren van meerdere warmte producenten op een netwerk aankijkt. Natuurlijk is er ook de gelegenheid om over andere, voor u relevante, aspecten van het warmte systeem te praten.

## Onderwerp interview

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Zoals ik aangaf, wil ik graag de analyses die ik tot nu toe heb gedaan met u bespreken om te verifiëren of u dit ook zo ziet en om nieuwe inzichten te verkrijgen. De voorlopige conclusies van mijn analyse is als volgt.

Het doel dat ik zie voor programmabureau W-K Z-H is: Het realiseren van een warmterotonde. Er zijn meerdere middelen nodig om dit doel te bereiken. Om dit doel te bereiken zijn de volgende factoren en de middelen die daarvoor in te zetten zijn van belang:

- Uitbreiden van de huidige infrastructuur
  - o Daar waar het kosten efficiënt is stadsverwarming aanleggen, maar niet forceren. Energie 0 woningen kan bijvoorbeeld ook een optie zijn, wellicht het kleine beetje warmte dat die huizen hebben zou door stadsverwarming opgevangen kunnen worden maar hoeft niet. Het doel is niet isolatie e.d. te verminderen om vraag te verhogen.
  - o Daar waar het gasnetwerk verouderd is, de aansluiting weghalen en vervangen door stadsverwarming
  - o Het huidige netwerk verlengen naar bestaande wijken
- Meer warmte uit alle bronnen benutten
  - o Het huidige netwerk verlengen naar bestaande wijken
  - o Meerdere producenten van warmte toelaten op het netwerk
  - o Meer bronnen stimuleren, aardwarmte, tuinders etc. financieren businesscases
- De vraag naar stadsverwarming verhogen
  - o De bewustwording van de voordelen van stadsverwarming verhogen
  - o De mensen die al stadsverwarming hebben en blij zijn als ambassadeur inzetten
  - o Het gebruik van stadsverwarming binnenshuis verhogen
  - o Transitie naar een vraag-gestuurde markt bevorderen
- De leveringszekerheid waarborgen
  - o Meerdere producenten van warmte toelaten op het netwerk

Bovenstaande voorlopige conclusies zou ik heel graag doornemen door middel van onderstaande vragen.

## Algemeen

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1. Wat is op dit moment de rol van de Provincie Zuid-Holland met betrekking tot stadsverwarming?

Initiatiefnemer van Programmabureau Warmte-Koude Zuid-Holland. De Provincie is hier een van de 25 deelnemers en voorzitter binnen de stuurgroep.

Ook wil de Provincie een warmtefonds oprichten, vanuit een EU fonds voor 'energy and low carbon technologies' samen met de gemeentes Den Haag en Rotterdam om zo de kralen van de warmterotonde te stimuleren.

2. Wat is op dit moment uw rol met betrekking tot stadsverwarming?

Werkzaam binnen de Provincie op het gebied van Warmte, Programmabureau Warmte-Koude, Cluster West.

## Doelen

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3. Wat is het algemene doel van de Provincie Zuid-Holland?

Besparen van energie -> er is veel warmte beschikbaar in de regio = een kostenefficiënte oplossing. Restwarmte benutten kan wat betreft de provincie Zuid-Holland gezien worden als duurzame opwekking.

4. Waarom wil ze dat bereiken?

Deze doelen zijn gesteld voor 2020. De luchtkwaliteit moet worden verbeterd, minder CO2 en NOx uitstoot en onafhankelijkheid van gas moet groter worden. Hierbij is een grootschalig warmtenetwerk de slimste oplossing.

5. Hoe kan ze dat bereiken?

Door krachten te bundelen, niets is zelf of alleen op te lossen.

Middelen

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6. Welke middelen heeft de Provincie om deze doelen te bereiken?

Initiatief nemen, partijen bij elkaar brengen, samenwerkingsverbanden opzetten, netwerken organiseren, (mede)investeren door middel van geld, ruimtelijke en vergunningsmogelijkheden verstrekken, het overrulen van gemeentes door het provinciaal belang te bestempelen.

7. Welke middelen heeft de Provincie niet, maar zijn wel nodig de doelen te bereiken?

Deels bekostiging van de investeringskosten door de klanten die gebruik maken van stadsverwarming.

8. Van welke partijen is de Provincie afhankelijk voor zijn of haar middelen?

Klanten (vraag naar warmte en geld), de Tweede Kamer voor haar plannen en kostendekking. Momenteel komen de baten niet terecht waar de kosten liggen. Wellicht zou er een gelijk speelveld moeten komen voor gas en warmte.

Conclusie doelen - middelen

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9. Bent u het eens dat het bovengenoemde doel wenselijk is?

Ja, onder andere.

10. En dat deze bereikt worden door de genoemde middelen?

Zie doel-middelen schema.

Verdere vragen

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Voor de volgende fases in mijn onderzoek ga ik een eenvoudig rekenmodel maken van de warmtemarkt om te kijken of het haalbaar is om meerdere producenten te introduceren en hoe dit dan het beste kan. In dit model zullen zowel technische, fysieke, economische en institutionele variabelen worden meegenomen.

11. Wat zouden jullie graag oplossen met een dergelijk model?

Maatschappelijk gezien zijn er alternatieven voor stadsverwarming, zoals energie-0 woningen, warmtepomp etc. Ondanks dat deze duurder zijn dan een grootschalig warmtenet is hier veel weerstand tegen. Hoe kan dit opgelost worden?

12. Wat is er nog onbekend voor jullie om jullie doel te realiseren in de strekking van mijn onderzoek?

Hoe de tegenlobby te organiseren om de negatieve ervaring onder klanten te verminderen/om te zetten in een positieve ervaring.

13. Waar ligt volgens jullie de uitdaging nu?

De kosten van de infrastructuur worden nu berekend door middel van het toewijzen wie voor de onrendabele top moet opdraaien. Er zijn meer manieren om hier naar te kijken.

Van de infrastructuur een nutsvoorziening maken zou onder andere een oplossing zijn.

14. Wat zijn jullie ideeën wat betreft een markt, en toetreding van meerdere producenten?

Toegang voor meer producenten is essentieel, een non-discriminatoire netwerk.

15. Hoe ziet u stadsverwarming voor zich over 5 a 10 jaar?

In Zuid-Holland heeft het zeker een toekomst.

- Haven en glastuinbouw (zowel als grootverbruiker als terug leverancier) verbinden met het warmtenetwerk
- De centrale in Den Haag als bron vervangen
- Uitbreiden binnensteden in verband met wijkrenovaties
- Framing is een belangrijk punt. Bijvoorbeeld klanten laten inkopen in het net in ruil voor 'voor altijd' gratis warm water zou een mogelijkheid kunnen zijn
- Het individuele belang moet gelijk getrokken worden met het maatschappelijke belang
- Andere contract vormen moeten mogelijk gemaakt worden

## Appendix B – Systems Analysis

As a result of all the interviews in appendix B, for each stakeholder a means-ends analysis is performed. The diagrams are included in this appendix.

### Means-ends diagram E.ON

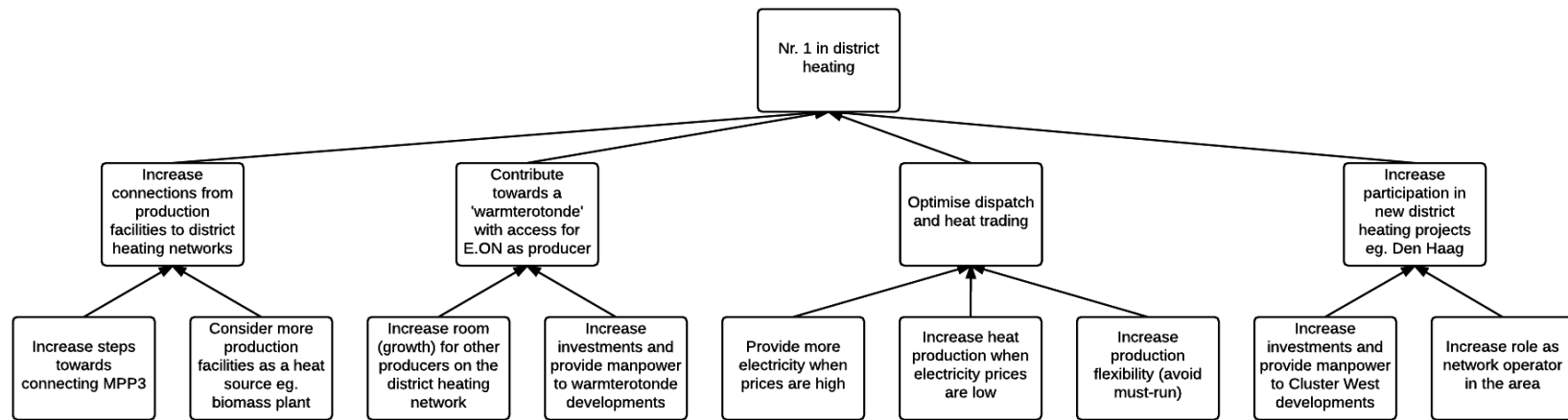


Figure 18: Means-ends diagram E.ON



# Means-ends diagram Eneco

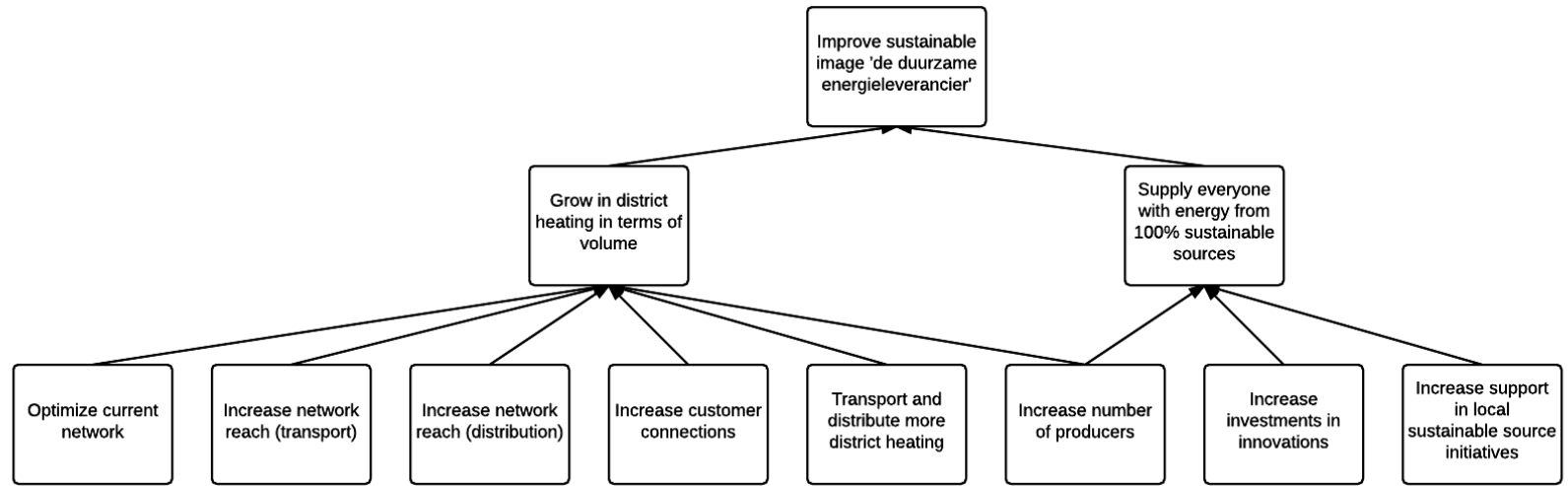


Figure 19: Means-ends diagram Eneco

# Means-ends diagram Municipality The Hague

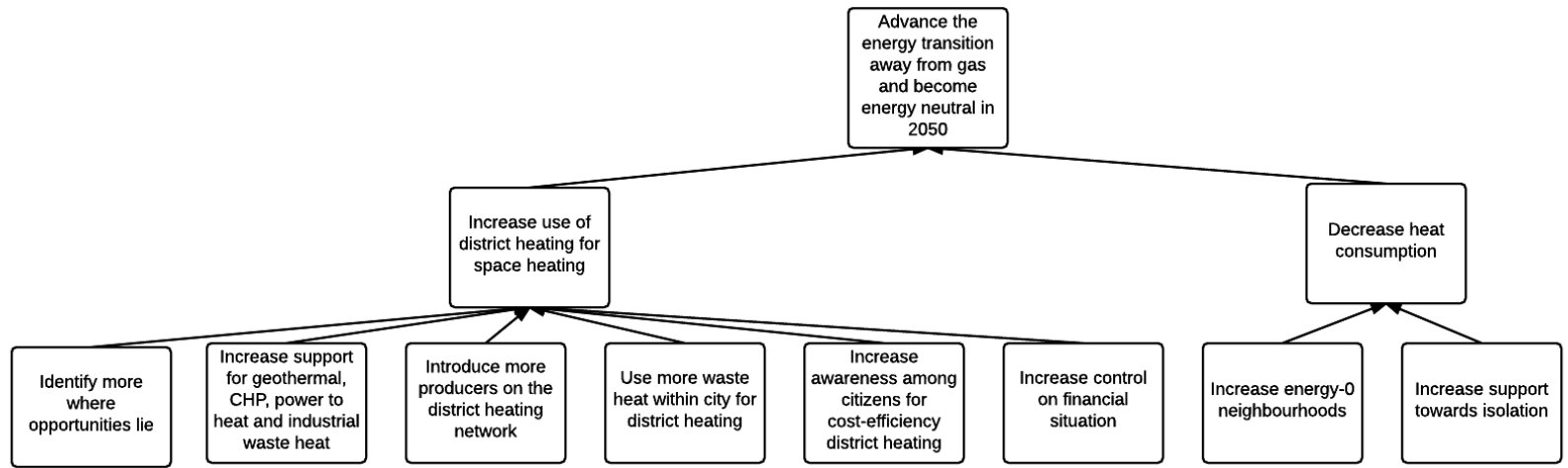


Figure 20: Means-ends diagram Municipality The Hague

# Means-ends diagram Programmabureau Warmte-Koude Zuid-Holland

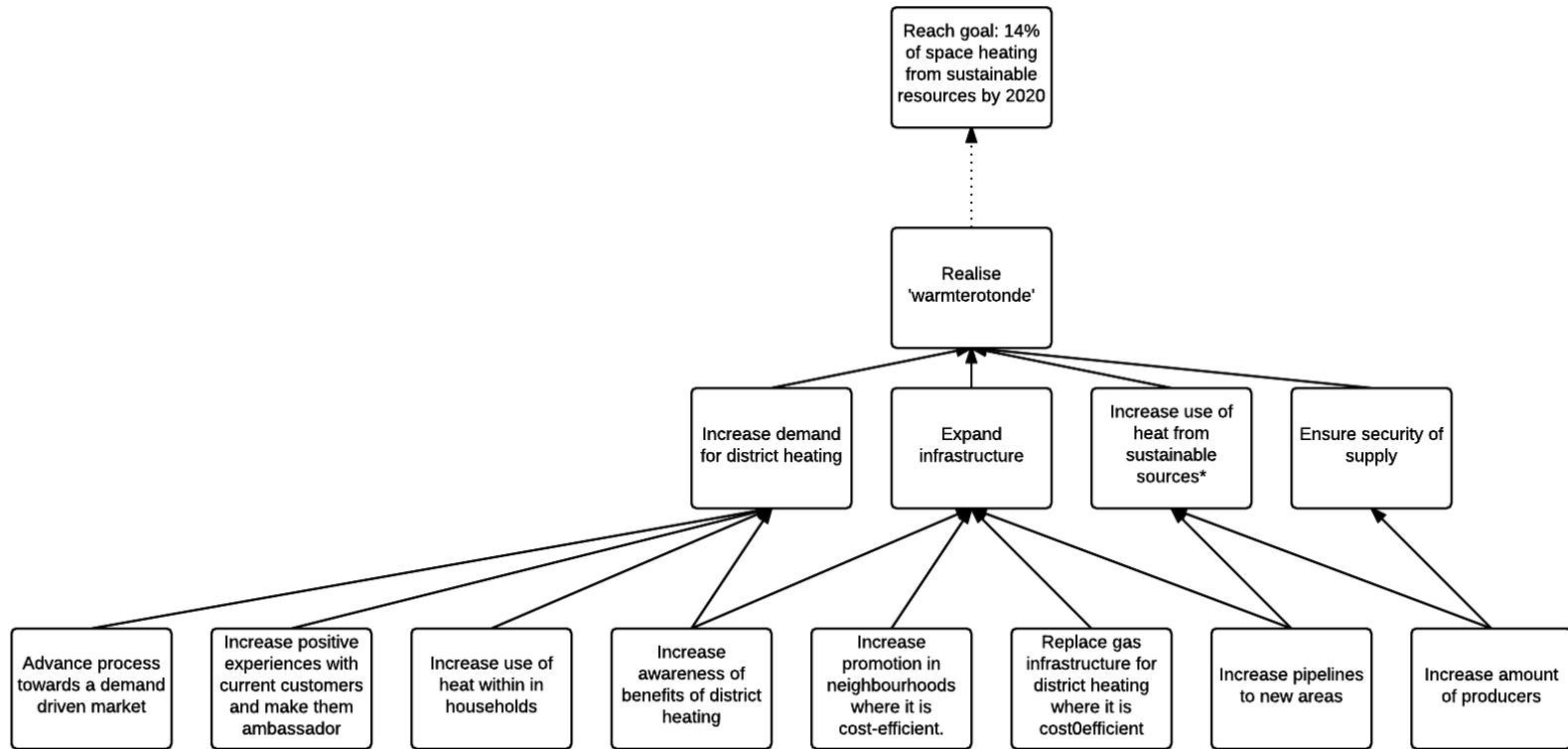


Figure 21: Means-ends diagram Programmabureau Warmte-Koude Zuid-Holland

# Means-ends diagram Province Zuid-Holland

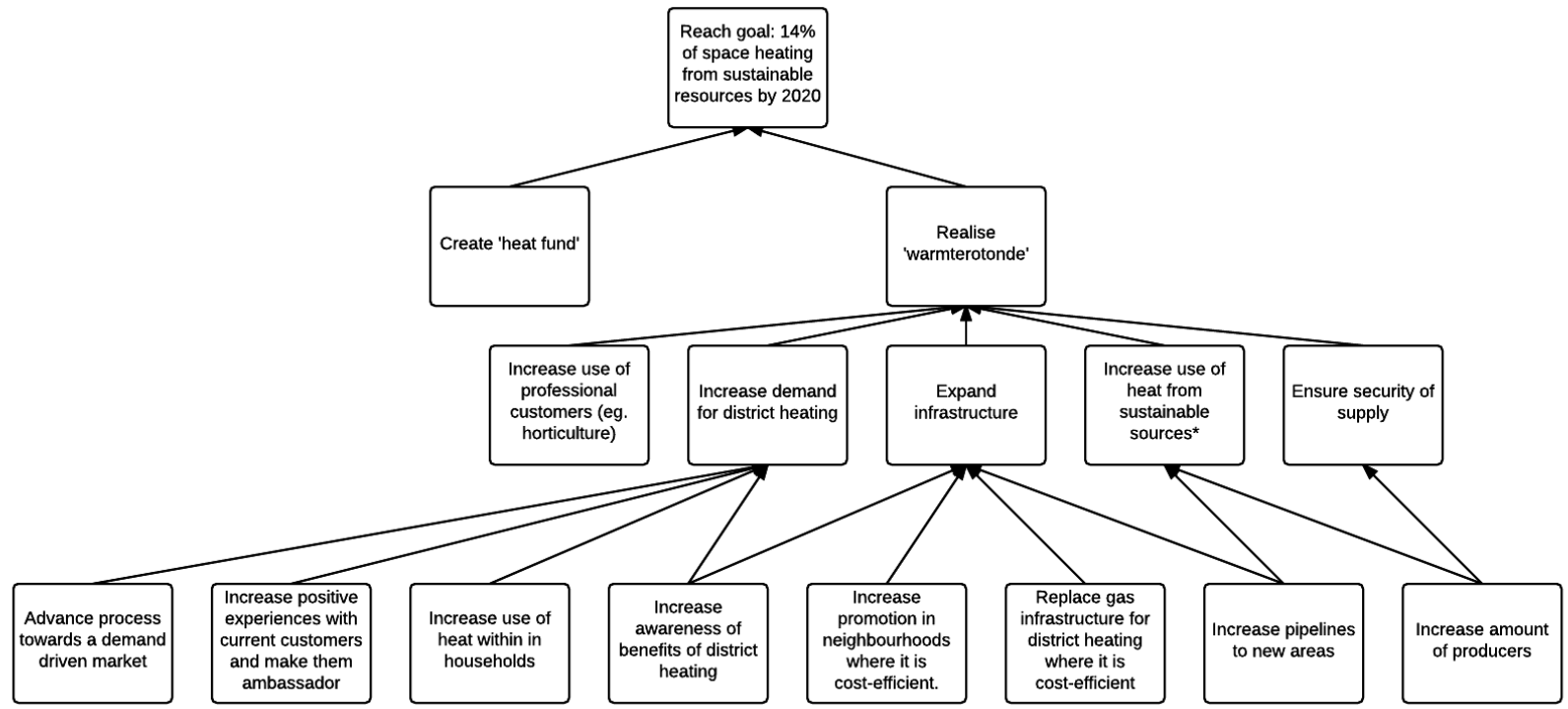


Figure 22: Means-ends diagram Province Zuid-Holland

Means-ends diagram Ministry of Economic Affairs

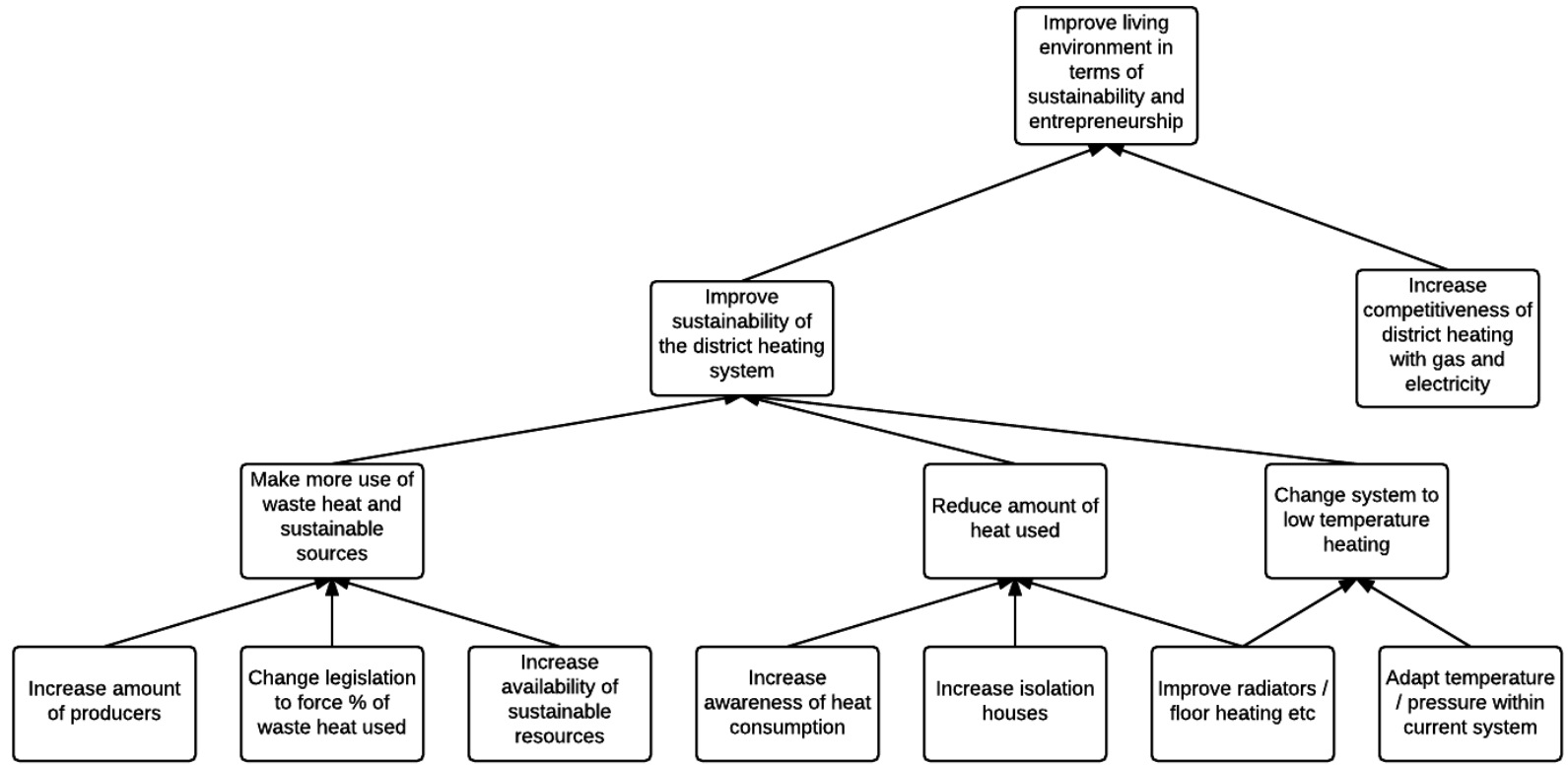


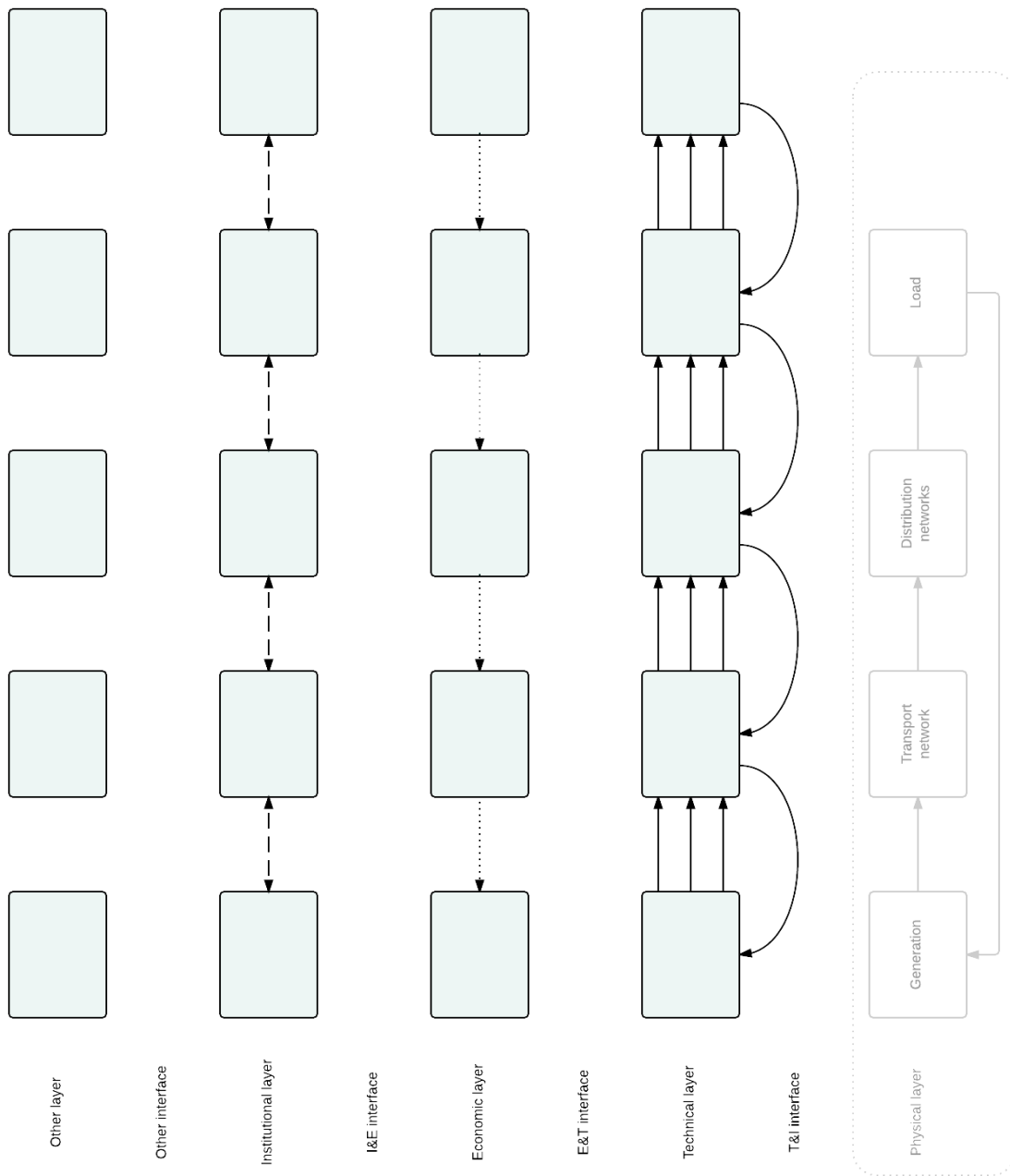
Figure 23: Means-ends diagram Ministry of Economic Affairs

Table 8: Stakeholder bottom means & ends

Stakeholder	Bottom means & ends	Layer/interface
Province & Programmabureau	Advance process towards a demand driven market	institutional
Ministry of Economic Affairs	Change legislation to force sustainable share in district heating	institutional
Gem DH	Increase awareness of benefits of district heating	institutional
Province & Programmabureau	Increase awareness of benefits of district heating	institutional
Province & Programmabureau	Increase positive experiences with current customers and make them ambassador	institutional
Province & Programmabureau	Increase use of heat within households	institutional
Province & Programmabureau	Replace gas infrastructure for district heating where it is cost-efficient	institutional/economic
Municipality The Hague	Use more waste heat within the city for district heating	institutional/economic
Municipality The Hague	Increase control on financial consequences consumers	economic
E.ON	Increase investments and provide manpower to Cluster West developments	economic
E.ON	Increase investments and provide manpower to warmteronde developments	economic
Province & Programmabureau	Increase promotion in neighbourhoods where it is cost-efficient	economic
Eneco	Increase support in local sustainable heatsource initiatives	economic
Municipality The Hague	Increase support in local sustainable heatsource initiatives	economic
E.ON	Consider more production facilities as heat source	economic/technical
Municipality The Hague	Identify more where opportunities lie for district heating	economic/technical
Ministry of Economic Affairs	Increase availability of sustainable resources	economic/technical
Eneco	Increase investments in network innovations	economic/technical
E.ON	Increase production flexibility (avoid must-run)	economic/technical
Eneco	Optimize current network	economic/technical
E.ON	Provide more electricity when those prices are high	economic/technical
Ministry of Economic Affairs	Adapt temperature and pressure within current system to low temperature	technical
Ministry of Economic Affairs	Improve radiators / floor heating and other methods for space heating	technical
Ministry of Economic Affairs	Increase isolation of buildings and houses	technical
Eneco	Increase network reach (distribution)	technical
Eneco	Increase network reach (transport)	technical
Province & Programmabureau	Increase pipelines to new areas	technical
E.ON	Increase steps towards connecting MPP3 to district heating network	technical
Eneco	Transport and distribute more district heating	technical
Eneco	Increase amount of producers	technical/institutional
Ministry of Economic Affairs	Increase amount of producers	technical/institutional
Municipality The Hague	Increase amount of producers	technical/institutional
Province & Programmabureau	Increase amount of producers	technical/institutional
Ministry of Economic Affairs	Increase awareness of heat consumption	technical/institutional
Eneco	Increase customer connections	technical/institutional
E.ON	Increase heat production when electricity prices are low	technical/institutional
E.ON	Increase role as network operator in the area	technical/institutional
E.ON	Increase room (growth) for other producers on the district heating network	technical/institutional

# Appendix C – Conceptual model

## Empty model for validation



# Alternative 1

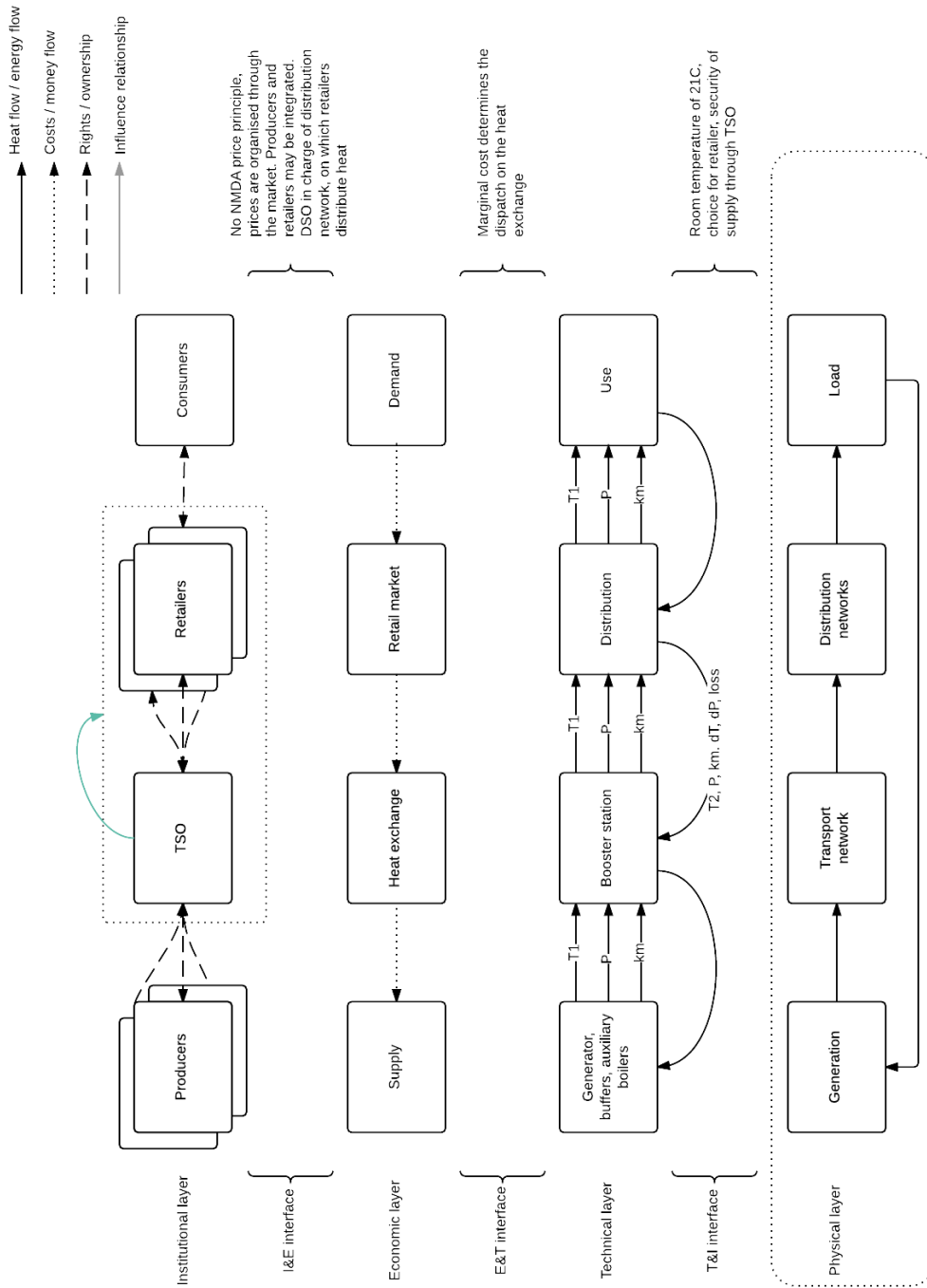


Figure 24: Alternative 1 district heating market



# Alternative 2

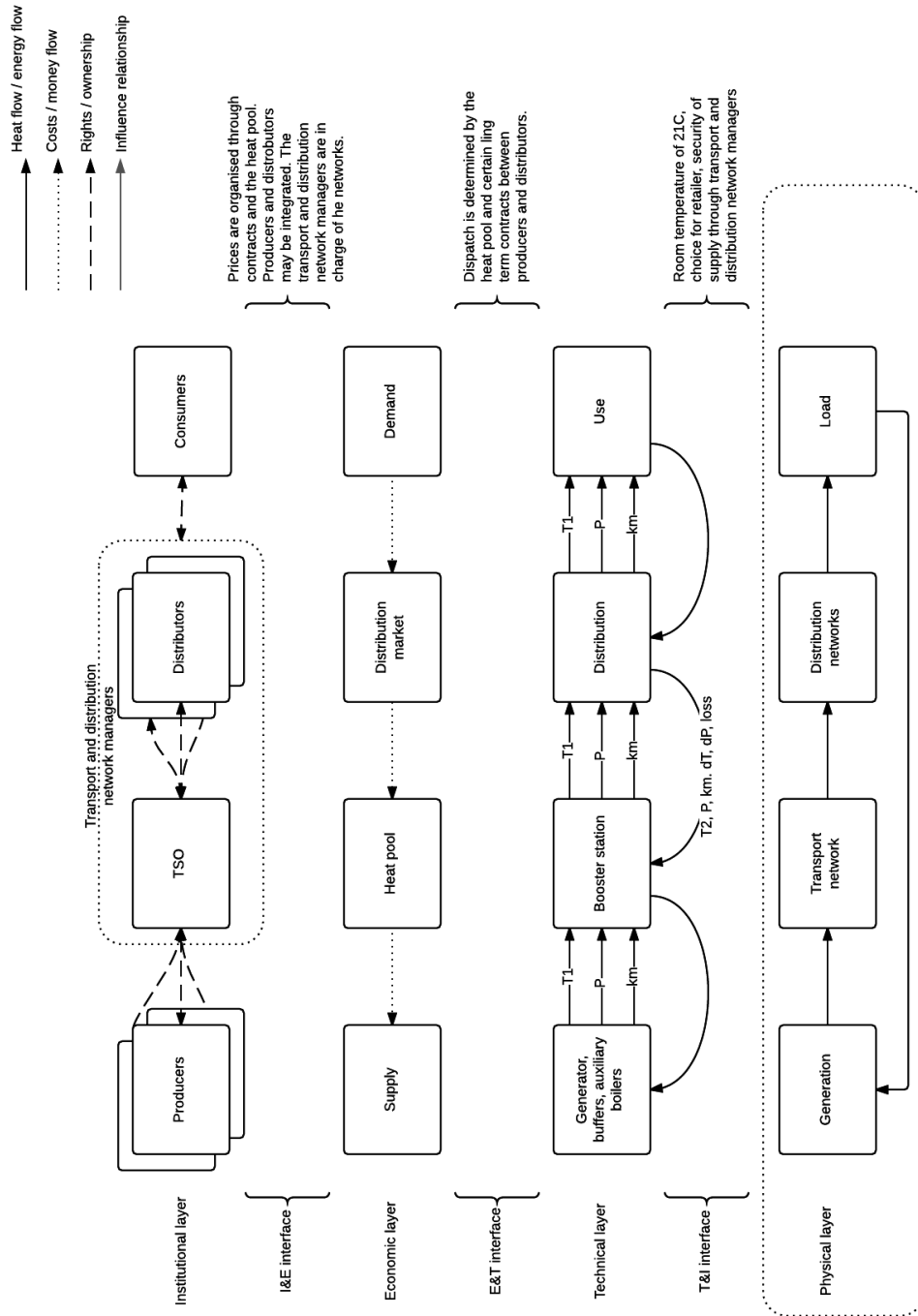


Figure 25: Alternative 2 district heating market

# Alternative 3

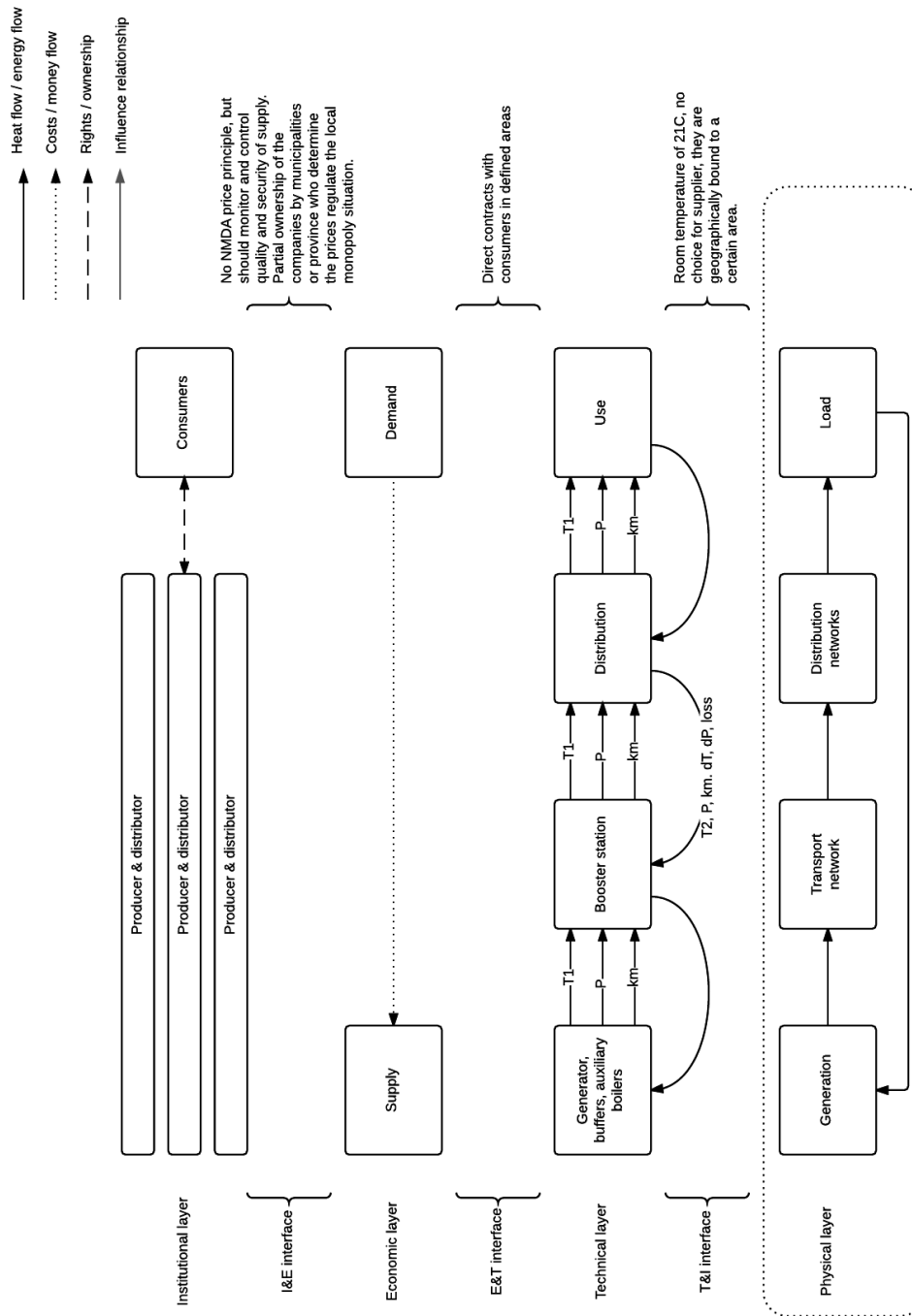


Figure 26: Alternative 3 district heating market

Final alternative

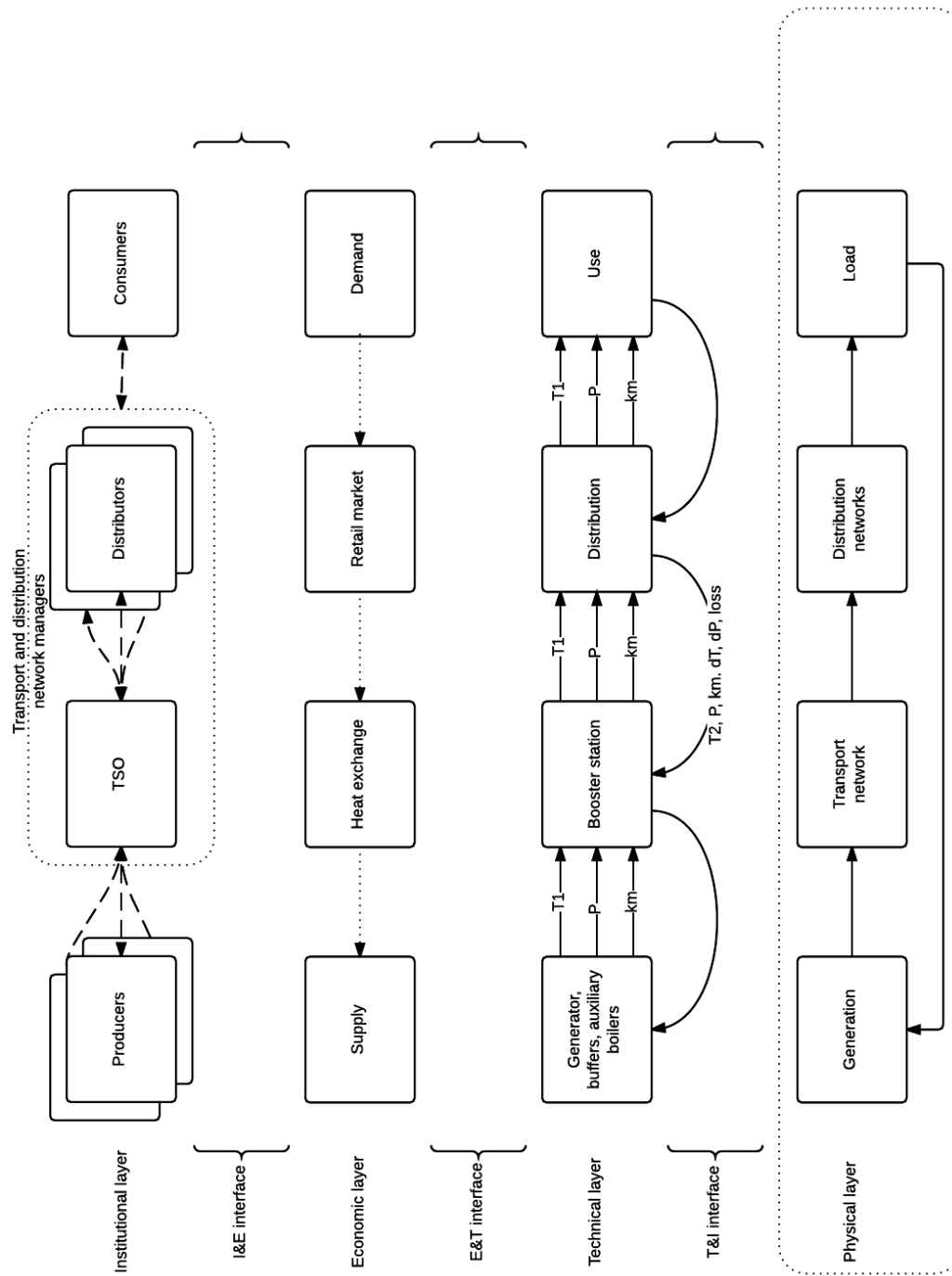


Figure 27: The final alternative to be used for simulation