Upscaling the residential heat provision towards the district scale

Managing geothermal district heating development in the built environment.

P5 report

For the degree of Master of Science in Architecture, Urbanism and Building Sciences track Management in the Built Environment at Delft University of Technology

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Abstract

The world has been facing a detrimental climate change since the beginning of the industrial era due to anthropogenic greenhouse gas (GHG) emissions that are expected to increase exponentially whereas the energy sector is the largest pollutant. Households in the Netherlands are one of the dominant final end users of energy and a transition within this group could contribute to reducing GHG emissions. Local authorities endorse efforts to implement energy policies, but face the complexity in actor networks. This research focusses on how public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands. While measures to reduce the GHG emission for electricity seem decisive, the vast majority of the Dutch households retain a carbon lock-in for heating. A motion towards decarbonisation is an area-based approach in which deep geothermal district heating networks. Although scholars acknowledge the existence of barriers and opportunities of upscaling the residential heat provision to district level, little literature is found on cases where the existing residential building stock is adapted for renewable district scale heat-generating facilities with geothermal energy as source in the Netherlands. This research addresses the knowledge gap on the management of upscaling geothermal district heating networks by public, private and civic actors by performing an actor analysis. The main goal of the research is to gain understanding in the local approaches and efforts of Geothermal District Heating Development (GDHD) and aims to clarify, gather and model the involved actor roles. Empirical research on the managerial actor roles is performed on the development project of Ammerlaan-TGI and Haagse Aardwarmte Leyweg (HAL). The findings on the case study reveal compiled chronologic events managed by a variety of actors. While actors are interwoven with each other by their dependencies, their managerial roles are evaluated on using management aspects in a cross-case setting, indicating how related management aspect variables apply to the GDHD. The outcome is assessed by experts who participated in a two-round Delphi-study from which effective roles for upscaling of geothermal district heating in the coming years is determined. The results show a large public actor integration in GDHD and role segregation among the actors, pointing out the immaturity of the sector. The public actors need to continue using stimulus tools and develop regulatory tools to foster maturation of the sector and evoke competitive advantage. Also their capacity building tools should be used to their full extent to match the heat supply and demand. Consensus between public, private and civic actors is considered most effective in GDHD, where through intensive communication, negotiation and decision making is agreed on the desired environmental quality for the built environment, our built environment.

Key words: Geothermal District Heating Development (GDHD), actor analysis, upscaling, renewable, infrastructure, management aspects, management tools.

Preface

Before you lies the thesis “Upscaling the residential heat to the district scale – managing geothermal district heating development in the built environment”. Literature research and empirical research have been conducted on the actors involved in urban area development and geothermal district heating development. It has been written to fulfil the graduation requirements of the degree of Master of Science in Architecture, Urbanism and Building Sciences track Management in the Built Environment at Delft University of Technology. The research and writing of this thesis took place from Februari 2019 to Oktober 2019.

Having management of the built environment as graduation topic arose from the deeply rooted inspiration for spatial planning, something I first got to know when I was at the age of seven playing SimCity on an old Macintosh computer. At that time I did not yet realise the complexity of urban development, but it came across when I got older. After completing the bachelor’s and master’s courses linked to urban area development the motivation for the topic was still there, but the emphasis shifted to the energy issue due to the decarbonisation trend. From that point in time this thesis was born, with the aim to contribute to GHG emission reduction by doing research on upscaling the residential heat provision. With the emphasis on management this research questioned how public, private and civic actors manage upscaling heat-generating facilities to district scale in the built environment in the Netherlands. The results of the research shows that it takes effort from distinct actors who all have their own personal view on management, but reveals that by joint collaborations mutual targets can be achieved.

I would like to use this opportunity to thank both the first and the second mentor for their support, dedication and patience. Due to the expertise on sustainable urban development projects and public-private partnerships of the first mentor, Erwin Heurkens from the Urban Area Development domain, there was a direct match with the research topic. As experienced researcher in market development of sustainable building concepts and process innovation of the second mentor, Erwin Mlecnik from the housing domain there was a perfect fit for the emphasis on residential real estate. The tutoring periods are characterised by serene and eventful moments where criticism, suggestions, tips, compliments and motivation alternated. Within this unique setting I was able to find my way to achieve a higher quality level, which would not have been possible without the guidance of Erwin Heurkens and Erwin Mlecnik.

I would also like to thank all the respondents, without whose cooperation I would not have been able to conduct the actor and case analyses. At first, my thanks goes out to Bas van Dun and Leon Ammerlaan for their contribution to the research by handing over project specific information about the cases. Second, I want to say thanks to the experts that are engaged in geothermal district heating development which assessed the research findings: policy advisers from the Municipality and Province, geothermal developers and operators, housing organisations, researchers from TU Delft and urban area development managers. The contribution of all the professional respondents led to a greater validity of the results.

At last, I would like to thank my friends, family and fellow students for their support and admiration during the graduation period. Their constant urge to continue and seeing my personal qualities fostered the completion of this thesis. This means a lot to me. Writing a Master thesis is like climbing a mountain: the higher you climb, the harder the wind blows. Courage and confidence are needed to overcome the fear that things will go wrong. Eventually, it came to a good ending.

I hope you enjoy reading.

Daniël C. Brandon

Delft, Oktober 30th, 2019

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Executive summary

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The world has been facing a detrimental climate change since the beginning of the industrial era due to anthropogenic greenhouse gas (GHG) emissions that are expected to increase exponentially whereas the energy sector is the largest pollutant. Households in the Netherlands are one of the dominant final end users of energy and a transition within this group could contribute to reducing GHG emissions. Local authorities endorse efforts to implement energy policies, but face the complexity in actor networks. This research focusses on how public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands. While measures to reduce the GHG emission for electricity seem decisive, the vast majority of the Dutch households retain a carbon lock-in for heating. A motion towards decarbonisation is an area-based approach in which deep geothermal district heating networks are developed. Although scholars acknowledge the existence of barriers and opportunities of upscaling the residential heat provision to district level, little literature is found on cases where the existing residential building stock is adapted for renewable district scale heat-generating facilities with geothermal energy as source in the Netherlands. This research addresses the knowledge gap on the management of upscaling geothermal district heating networks by public, private and civic actors by performing an actor analysis. The main goal of the research is to gain understanding in the local approaches and efforts of Geothermal District Heating Development (GDHD) and aims to clarify, gather and model the involved actor roles. Empirical research on the managerial actor roles is performed on the development project of Ammerlaan-TGI and Haagse Aardwarmte Leyweg (HAL). The findings on the case study reveal compiled chronologic events managed by a variety of actors. While actors are interwoven with each other by their dependencies, their managerial roles are evaluated on using management aspects in a cross-case setting, indicating how related management aspect variables apply to the GDHD. The outcome is assessed by experts who participated in a two-round Delphi-study from which effective roles for upscaling of geothermal district heating in the coming decennia is determined. The results show a large public actor integration in GDHD and role segregation among the actors, pointing out the immaturity of the sector. The public actors need to continue using stimulus tools and develop regulatory tools to foster maturation of the sector and evoke competitive advantage. Also their capacity building tools should be used to their full extent to match the heat supply and demand. Consensus between public, private and civic actors is considered most effective in GDHD, where through intensive communication, negotiation and decision making is agreed on the desired environmental quality for the built environment, our built environment.

Key words: Geothermal District Heating Development (GDHD), actor analysis, upscaling, renewable, infrastructure, management aspects, management tools.

1. Introduction

1.1 Trends

The energy transition is a key urban challenge of 2050 which is defined as “a pathway towards transformation of the global energy sector” (IRENA, 2018). The main goal is to make a transition from energy derived from fossil fuels such as gas, nuclear energy and coal to energy from renewable sources by 2050 (EC, 2019).

To manage the adverse effects of climate change an active governance role is necessary. Increasing anthropogenic emissions due to global economic activity, carbon intensity and airborne fraction (Canadell et al., 2007) caused fluctuations in CO_2 concentration and temperature over the course of time. Evidence shows that the that this increase enhances the greenhouse effect, causing global warming (Bolin & Doos 1988; Nordhaus, 1991). The increasing global temperature anomaly results in relative changes in the rainfall intensity, sea level rises, floods and droughts (KNMI, 2017; IPCC, 2007). As a reaction, governments have the necessity to minimize the damage of climate change toward cities. On the different spatial levels an active role of actors from multiple governmental levels (supra-national, national, regional and local) is required.

The growing population and energy demand emphasizes the need for energy strategies. In 2016, the Netherlands had a population of approximately 17 million people divided among 7.7 million households (CBS, 2018a). According to the prognosis made by Van Duin & Stoeldraijer (2014) the number of households will rise to 8.5 million by 2040. The number of households is expected to increase partly due to the expected population growth and partly due a further decline in the average household size. Due the lock-ins made in the past, the Dutch natural gas and coal are the primary energy source in the Netherlands (CBS, 2017c) and natural gas accounts for 93% of the total thermal energy demand of households according to NAM (2018). The total demand of natural gas can be lowered by efficiency measures and energy conservation of the existing residential stock by quality improvements of the buildings (isolation of walls, floors, roofs and windows) and the use of energy saving heat-generating facilities (Ministerie van Economische Zaken, 2016; Mlecnik, 2018). Although the gas use per dwelling decreases, the natural gas demand for space heating increased (Ministerie van Economische Zaken, 2016; p69). The growing demand of energy due a growing population emphasizes the need for energy strategies and efforts to reduce the demand and consider the supply.

Implementing energy strategies and policy requires comprehensive action by various actors, scales and disciplines according to Petersen & Heurkens (2018). A multitude of global governmental efforts on various scales, such as the Kyoto Protocol (1997) and Paris Agreement (2015) anticipate on the adverse effects of climate change by forming binding climate commitments to minimize the CO_2 emission. In contrast with strategies for renewable electricity there were little concrete policy objectives for renewable heat solutions at national or European level according to CBS (2017d), but this is about to change. The Dutch action plan is to have 9% of the total heat demand fulfilled with renewable heat solutions by 2020, which was only 5,9% in 2017 (CBS, 2017d). Even more, the letter to Parliament from the Minister of Economic Affairs and Climate Policy suggests to seek for gas alternatives, such as geothermal energy, which has a potential to fulfil 14% of the total heat demand of the built environment by 2050 (Wiebes, 2018). In the Netherlands, an emerging political pressure to shift from energy derived from gas as fossil fuel is enforced due to earthquakes on Groningen Gas Field (NRC, 2013). As a result of the decreasing production, the import and costs of natural gas increases and jeopardizes the energy security of the Dutch households. From 1 July 2018 on, the amendment to abolish the mandatory gas connection in dwellings came into force in order to reduce the use of natural gas by households (Ministerie van Economische Zaken en Klimaat, 2018). The implementation of energy strategies in urban development seems to be a complex process in which comprehensive action by various actors, scales and disciplines is required (Petersen & Heurkens, 2018). The market behaviour is influenced in a way that governments can steer on desired developments, which need further investigation for the development of renewable thermal energy strategies.

There are alternatives for residential heating to consider that entail the potential to meet binding climate commitments. Prominent alternatives are all-electric, district heating or biogas/hydrogen. The first proposed solution, all-electric, will impact the electricity demand considerably, of which the supply is considered to be 13,8% renewable in 2017 (CBS, 2017d; p22), meaning that this solution fosters the GHG emission even more. The third alternative is having green gas that can reduce the GHG emission with 30% (Scharlemann & Laurance, 2008), but these technology is not sufficiently developed yet and is not a renewable source thus is limited in supply (Tempelman, 2012, p19; Schepers, Naber, Rooijers & Leguijt, 2015, p16). Since it is thought that the all-electric solution will foster GHG emission and green gas is scarce, it is assumed that district heating has the largest potential to reduce the GHG even more, although it is thought that the alternatives for heat in the future can consist of a mix of alternatives (Schepers et. al, 2015). Decision making of actors between the alternatives for heat can depend on many variables. A shift of heat generation from household scale and building scale to district scale offers opportunities to meet binding climate commitments, but for the technical and financial implication of such systems various actors and disciplines are required. Existing district heating in cities that have already been laid down in urban infrastructure and dwellings mainly use fossil fuels (e.g. CCGT, Combined-Cycle Gas Turbines) and renewable sources only accounted for 25% (ECN, 2017) of the total heating production in 2015. These existing heat networks do have certain predefined actors that manage the supply of heat, but for the implementation of renewable district heating additional actor involvement is necessary. Considering the existing district heating networks cover less than 5% (ECN, 2017) of the total heat demand, there are managerial challenges in implementing renewable district heating in the already built environment.

Changing roles in urban development associated with the management of renewable district heating development that needs to be considered. Urban area development requires "management on different (spatial) levels, different development stages (initiative, plan development, financial feasibility, realisation, and maintenance), and different sectors and professions (public, private, civic actors)" according to Heurkens (2012). There is an urban governance shift noticed over time by (Heurkens, 2012) that indicates the private sector development roles where property development is led by the market and facilitated by local planning authorities to implement planning and market objectives.

1.2 Problem and purpose

The main challenge were is responded to in this research is the "management of geothermal district heating development in the built environment in the Netherlands". It is found that local authorities endorse efforts to implement energy policies, but face the complexity in networks of various actors, scales and disciplines (Petersen & Heurkens, 2018). Therefore it is important to define 'who' does 'what' in the management of district scale heat-generating facilities and infrastructure development. While scholars and public planners acknowledge the existence of barriers and opportunities of upscaling residential heat to district level (Sandick, 2010; Thorsteinsson & Tester, 2010; Colmenar-Santos, Rosales-Asensio, Borge-Diez & Mur-Pérez, 2015), little literature is found on cases where the existing built environment and infrastructure in the Netherlands is adapted for renewable district heating networks. This research addresses the knowledge gap on the managerial roles of public, private and civic actors in upscaling residential heat to a district scale from renewable sources.

1.3 Research questions

The main research question is "*How do public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands?*" and has the purpose to gain understanding in, clarify, gather and model the local approaches and efforts in developing renewable district scale heat-generating facilities. The research is intended to broaden the understanding of what public, private and civic actors are involved, what their roles and dependencies are in upscaling the residential heat provision to a district level in the existing built environment and aims to determine the effectivity of actor roles in such developments. The research sub questions address the managerial roles and dependencies of public, private and civic actors in implementing energy policies, district scale heat-generating facilities and infrastructure in the built environment from literature (1) and practice (2), where after the roles that are effective for upscaling (3) are elaborated on.

1.4 Readers' guide

The executive summary is structured as follows.

- Part I (Section 1-2): Introduction of the research, discussing trends, definitions, problems, purpose, expectation, research questions and methodology.
- Part II (Section 3): Examines the literature on urban development actors and identifying the roles of public, private and civic actors in urban development management, implementing heat-generating facilities and infrastructure.
- Part III (Section 4): Covers a study of two cases on the roles of public, private and civic actors managing geothermal district heating development (GDHD).
- Part IV (Section 5): Explores the roles effective for upscaling GDHD using expert assessments.
- Part V (Section 6): Considers the results of the research in the conclusions, reflects on the research and discusses the recommendation for further research.

2. Methodology

Well begun is half done: without proper methods a research can easily fail. The research methodology is elaborated on in this second section to explain what techniques are used to find answers to the main research question and research sub questions. The main research question tends to answer ("how to") operation-related problems, but the research can be classified as 'empirical' since the question is knowledge-related (Barendse, Binnekamp, De Graaf, Van Gunsteren & Van Loon, 2012). The goal is to understand managerial roles on urban area development with upscaling the residential heat provision in particular (theory) but also to aims clarify, gather and model the effective managerial roles in urban area development with upscaling the residential heat provision from practice (empirical). Since the research question can be classified as empirical, empirical research methods are used to come to an answer to the main research question, but literature research is needed to support the empirical research. A research model showing the research phases, the data collection instruments and processing tools is supported *(Figure 1)* and elaborated on in the following subsections.

2.1 Data collection instruments

Literature is used as a source for data in the research. In the first part, literature is used for trend analyses for the research proposal. In the second part it is used to form a basic understanding of public, private and civic actor roles and management aspects.

An actor analysis based on Koppenjan & Klijn (2004) is used to analyse literature to determine public, private and civic actor roles and dependencies. In subsequent steps problem definition, actor inventory, means and dependencies are determined. The actor analysis fits the aim to gain understanding in the local approaches and efforts managing district scale heat-generating facilities and infrastructure development in the Netherlands because it can provide insights in the relations that exist between actors and what means are being used.

Case study methods are used to study selected cases in depth (Bryman, 2012; p12). From the trend analysis is concluded that the management by actors in renewable district heating development for the existing built environment is not discussed in literature as such yet, which is why these cases are revelatory.

The revelatory case exists when there is an "opportunity to observe and analyse a phenomenon previously inaccessible to scientific investigation" (Yin, 2009; p48). A selection of two Dutch cases is made, which are individually analysed with an actor analysis and actor dependency analysis using uniform analysing tools that prevents comparing apples and oranges. A limitations is the selection of Dutch cases is the lack of international examples from which can be learnt from. However, the danger of comparing international cases is the limitation of policy transferability, development behaviours and path dependencies in different countries according to Squires & Heurkens (2016).

2.2 Processing tools

To process all the data that is acquired using data-collecting instruments, a broad selection of instruments for data processing is used.

At first the framework on managerial roles *(Table 1)* based on the research of Heurkens & Hobma (2014) is used for recognition and categorisation of roles, which originated from different management theories. Applied a lot is the categorisation of management tools – that are being used by public actors to induce market behaviour towards desired outcomes - in shaping, regulating, stimulating and capacity building which derived from Adams & Tiesdell (2012). It is thought that this leads to "a more comprehensive perspective on, and understanding of, actor roles" according to Heurkens & Hobma (2014, p356). The framework on managerial roles, aspects and variables is used in the analysis on actor dependencies in the cases.

Roles	Aspects	Variables
Managerial	Project management	Initiating, designing, planning, operating
	Process management	Negotiating, decision-making, communicating
	Management tools	Shaping, regulating, stimulating and capacity building
	Management resources	Land, capital, knowledge

Table 1 The managerial roles in urban area development (Source: Heurkens & Hobma, 2014, own edit).

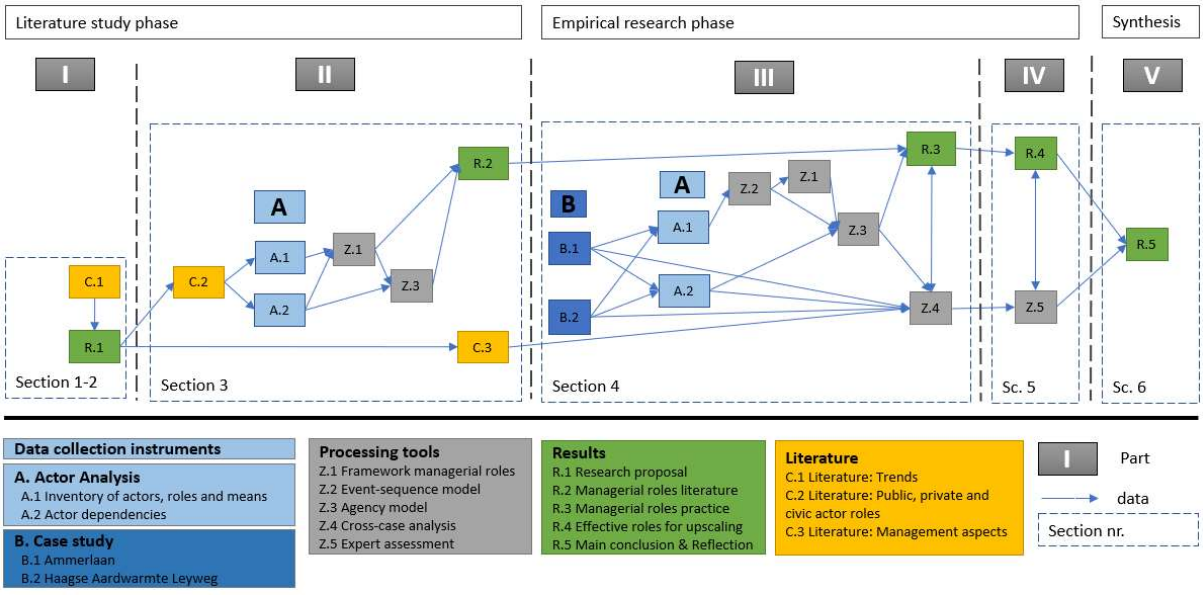

Figure 1 The research model that shows the research phases and parts, data collection instruments and processing tools subsequently used in the research on how public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands (own design)

Second, an event-sequence model or event-sequence table is necessary to structure the development that is carried out by actors in the different phases. According to Adams & Tiesdell (2012; p75) an event-sequence model can be used as a real estate development paradigms to categorise the process in order to 'reduce the complexity' of real estate development. The even-sequence model will consist of a tabulation where task number, name of the activity, main tasks, time(-span) and involved actors are mentioned.

Third, an agency model is made to position the actors to show dependency relations that exist between actors. The agency model is a 'diagrammatic representation' as defined by Adams & Tiesdell (2012; pp 75-76) and is used to show 'essential components' involved in urban development processes. The visualisation of the actor dependencies with the agency model fits the intended purpose of clarifying, gathering and modelling the actor positions and their dependencies. The agency model will show the actors and their roles in boxes, while the dependencies between actors are shown with an arrow. The single arrow can indicate an exchange of multiple dependencies: exchange of money, information and knowledge and mutual agreements. These arrow is labelled with a character (a-x) of which the definition can be found in the supported legend.

Fourth, cross-case analytical methods as part of the case study method is used to process data. It is aimed to to match patterns (Yin, 2009) and can be applied when there are two or more cases. According to Yin (2009; p156) an increase of cases "could strengthen the findings even further". The aim for the use of a cross-case analysis is to define similarities and differences in the cases. According to Yin (2009: p156) individual data from the cases need to be displayed according to "some uniform framework". For an uniform framework there is chosen to devote this to management aspects. The comparison of the important similarities and differences are the results of the empirical findings from the cases.

Fifth, an expert assessment is conducted to enhance the validity of the results from the empirical findings (Bryman, 2012; p.171). Therefore an Delphi study is being held, in which experts familiar with the particular issue assess statements that are based on literature and empirical findings. The Delphi technique is a method characterised by anonymity to reduce the effect of dominant individuals (Dalkey, 1972) that combines opinions of a group of experts on selected subjects (Hsu & Sandford, 2007; Jones, 1975): the management aspects money, organisation, time, information and quality (MOTIQ). The Delphi technique exposes assumptions or information leading to different judgements, educates the respondent group on the different topics and makes it possible to correlate the judgements (Hsu & Sandford, 2007), which is needed to have a grounded conclusion. A second round is held where judgements of experts are summarised and returned for feedback by the experts.

2.3 Selection

A selection of cases is made to demarcate the research topic. In this qualitative research purposive sampling is chosen over probability sampling: interviewing all the people participating in all heating alternatives would add a great deal to the time and cost of doing research. To deal with this problem is to employ purposive sampling (Bryman, 2012; p416) in which a selection of cases is made based on criteria. Purposive sampling is utilised in levels (Bryman, 2012, p417): in the first level the cases are sampled by context and in the seconds level sampled by participants.

In first level sampling there is decided on weighing district heating alternatives for the research *(Table 2)* on criteria: The alternative must be (1) Renewable and climate neutral, (2) must be able to provide heat on a district scale, (3) an urban redevelopment project in which infrastructure and existing dwellings were adapted, (4) competitive with fossil fuel sources in terms of The Leveled Cost Of Energy (LCOE) and the project must already be or been operational. In the table the 'x' marks when the selection criteria is met.

Category	Source	Selection criteria*				
		1	2	3	4	5
2nd generation Pressurised high-temperature water systems (>100 C)	Industrial waste heat	x	x		x	x
	Biomass		x		x	x
	Combined Heat Plant (CHP)		x		x	x
	(Ultra) Deep geothermal	x	x		x	
3th generation Pressurised medium-temperature water systems (<100 C)	Industrial waste heat	x	x	x	x	x
	Waste-to-energy		x	x	x	x
	Biomass		x		x	x
	Combined Heat Plant (CHP)		x		x	x
	Deep geothermal	x	x	x	x	x
4th generation: Low-temperature water systems (~30-70 C)	Low-temperature waste heat (data centers, greenhouses, supermarkets, etc.)	x	x	x	x	x
	Water (Sewage)	x	x	x	x	x
	Deep and Shallow geothermal					

Table 2 An overview of alternative energy purposes for heating dwellings and selection criteria (Source: Energy Storage, 2018; Keutel, 2018, Sayegh, Jadwiszczak, Axcell, Niemierka, Bryś & Jouhara, 2018; own edit).

** 1=Renewable and climate neutral, 2=Scale and capacity, 3=Urban redevelopment, 4=competitiveness, 5=project phase*

x = Indication for when a selection criteria is met.

Because there are multiple sustainable solutions a choice is made based on interest and literature gap. That leaves the research demarcation on context criteria to deep geothermal energy as weighted alternative to household scale and building scale heat generating-facilities. Only two cases were found to do case study about: Ammerlaan in Pijnacker-Nootdorp and Haagse Aardwarmte Leyweg (HAL) in The Hague.

In second level sampling the participants (Bryman, 2012; p417) in the cases are selected based on the actor group where they belong in. There is no second-level sampling made on the documents for data-collection, because excluding documents could limit the findings of results. Heurkens (2012) defined the three actors groups in urban governance which are going to be used as criteria in the selection of interviewees. At first the private actors who developed the project are going to be interviewed and snowball sampling will be applied (Bryman, 2012; p424). In snowball sampling the first participant can propose other participants, from the actor groups that are relevant for the research.

2.4 Administration

For the case study interviews are being held to gather actor information from actors using concepts related to actor identification, positions and dependencies derived from Koppenjan & Klijn (2014). The interviews are being held face-to-face, by email or by phone, depending on what measurement method is preferred. The interviews are being recorded by means of a microphone and digitally stored.

Additional document studies are performed to acquire all the information about the cases for triangulation purposes. To prevent the problem of accumulation of transcript data in the appendices of the thesis there is chosen not to include these in the appendices for two reasons. The first reason is that the majority of the interviewees did not want to have all the transcript data published. That brings us two the second reason: privacy. After the actor analysis and dependency analysis is made from case information, a verification by the interviewees is requested and performed to ensure correctness.

3. Literature study

3.1 Inventory of actors

At first an inventory of (public, private and civic) actors, their roles and means in urban development management is made before determining dependencies.

The key public actors in urban development concerning district scale heat-generating facilities are considered The State and Ministries, the Province and the Municipality. Their main roles have to do with consumer protection, social aims and licencing safety, construction and environmental issues (RVO, 2014). Important in the inventory of public actors, roles and their means is a categorisation of the management tools that are at their disposal to steer on urban development as defined by Adams & Tiesdell (2012): shaping, regulating or stimulating market behaviour or building capacity. These instruments are used to induce market behaviour towards desired outcomes by public actors and categorisation of the instruments is relevant for understanding the management tools carried out by public actors in urban development projects. An overview of the management tools that can be used is provided *(Table 3).*

The private actors in urban development are legal entities that are not (completely) in the hands of public actors. Out of literature actors relevant for the actor analysis on the managerial roles of private actors a distinction is made between developers, financiers, communities, investors and corporations.

Developers (1) in urban development practice are traditional real estate industry agencies and can be financial-organisationally linked to banks, investors, construction companies, or be independent companies according to Heurkens (2017a). Developers as non-independent actors do not have the in-house capabilities as they can be at the heart of multiple linked private actors from different disciplines in real estate development according to Adams & Tiesdell (2012; p80). Based on their field of expertise, developers tend to put more emphasis on a certain discipline due to the sector-division of real estate (Heurkens, 2017c). In project development a Special Purpose Vehicle (SPV) is often used. An SPV is defined as “a legal entity created by a firm by transferring assets to the SPV, to carry out some specific purpose or circumscribed activity” in order to limit the risk of the shareholders to the project and offers opportunities for financiers and sponsors to participate with limited risks (Gorton & Souleles, 2007 p550; RVO, 2014, p44; Vlek, van Oosterhout, Rust, van den Berg & Chaulet, 2016). The management resources as defined by Heurkens & Hobma (2014) being used could be land, capital and knowledge which is exchanged between actors in the SPV.

Financiers (2) are an essential part in the development as they provide capital for investment and costs (RVO, 2014; p43). The capital is transferred to an SPV or other legal entity which holds the risks, cash flows etc. that are disconnected from the financiers’ own activities according to RVO (2014; p44).

Communities (3) are defined by Heurkens (2017b; p2) as “non-traditional real estate industry agencies as their core expertise often is not real estate” which are “locally-rooted actors such as property owners, entrepreneurs, or local citizens that engage in urban development. Two types of community organisations are defined in this thesis: energy cooperatives and homeowner associations. Energy cooperatives are typical locally rooted are citizen-led energy communities that and have a formal cooperative form or foundation as a legal entity that educate on energy use, collective procurement of renewable energy for consumption by inhabitants, participants or members that are living in the vicinity of the place where the renewable energy is generated (Boon & Dieperink, 2014). A Homeowner association (HOA) is a community of homeowners, that has a legal entity and acts as a representative for the homeowners. Single homeowners are involved with maintenance and improvement of their property, while apartment owners are often acceded as members in homeowner associations (Eigenhuis, 2019).

Investors (4) are also real estate industry agencies which can be categorised as institutional investors, investment banks and development investors (Heurkens, 2017b). Institutional investors are characterized by the purchase or real estate from developers and earn return during the operation according to Heurkens (2017b; p2). Energy industry agencies are defined as corporations but could have publicly tradeable shares that are owned by institutional investors.

Corporations (5) are defined by Heurkens (2017b; p2) as “non-traditional real estate industry agencies, as their core business is not real estate. Corporations like technology and energy companies can be influential in urban development and are characterized by their long-term involvement (Heurkens, 2017b). In the operation phase of district heating networks, tasks are not always performed by the same actor since actors can fulfil multiple roles and roles can be fulfilled by multiple parties (van Vliet, van der Voordt & Den Heijer, 2004; p82). This is confirmed in research of Schepers & Valkengoed (2009, pp. 34-35) in which is shown that the heat production company is not often found in the possession of the distribution network and supplying company thus different companies can have the role as producer, distribution service operator (DSO), heat storage role and supplier role performing the tasks in the value chain of heat exchange.

The civic actors can perform a role as homeowner and tenant instead of from a legal entity (consisting of homeowners and tenants) which is why they differ from a private sector actor, but do have a voice in the development. Housing associations have private actor means, but the core missions and values are social and therefore these are characterised as ‘hybrid organisations’ by Czischke, Gruis & Mullins (2012). The national Association of Housing Associations Aedes agreed in the Climate Agreement on having the heat provision of the current social housing stock carbon neutral by 2050 (Aedes, 2018) and therefore seem relevant in the renewable district heating development.

3.2 Actor dependencies

The position of actors and their dependency relation is clarified according to literature. The actor dependencies is about what means each actor has at their disposal to solve managerial problems according to Koppenjan and Klijn (2014). In between heat exchange projects it differs when or how these means are being used and that is why there is no consistent role division for the actors involved since different projects are elaborated on in the consulted literature, which could result in an incomplete overview of the dependency relations. Viewing the agreements *(Figure* 2) that are generally made between the aforementioned actors in the Netherlands, is the result of management processes: communication, negotiation and decision-making.

The first agreement noticed is the *shareholder agreement* (a) withholds an agreement between any real estate developer and Special Purpose Vehicle (SPV) in the development of real estate. Developers can bring in their financial means (e.g. equity) and receive dividend in return according to Vlek et al. (2016). The shareholder agreement can be made between private actors or between private and public actors.

The *financing agreement* (b) is the contractual relation between the financer and the SPV. Acccording to Vlek et al. (2016) developers prefer interest-bearing dept or loan capital in order to cover (a part of) the development costs.

The *purchase agreement* (c) is made between the project SPV and the investors or corporations which have an important role in the operation phase. The developed real estate objects are transferred from the SPV to the actors involved on the long-term (RVO, 2014). In these agreements there are writings about the financial arrangements, program, planning and phasing and division of the risks.

Key public actors	Management roles	Means
State and Ministries	Regulatory, shaping, supervisory.	*Regulatory:* Spatial Planning Act, Order in Council, The Building Decree and Crisis and Recovery act, Heat Act (Consumer protection), licence granting, supervision on and enforcement of environmental law, sustainable policy. *Shaping:* Climate agreement *Stimulus:* Direct state grants, State body RVO subsidy
Province	Regulatory, supervisory, shaping.	*Regulating:* Provincial-Bye law, environmental permit licencing, supervision on and enforcement of permits *Shaping:* Structure plans, publication of (sustainable) plans. *Stimulus:* Subsidies and guarantees.
Municipality	Public law roles: Regulatory, supervisory, shaping observer (facilitatory) or initiator, consultant. Private law roles: Partner, contractor, owner.	Public law instruments: *Regulatory:* Environmental permit assessment, concessions land acquisition, *Shaping:* Publications of plans, strategies and visions, land use plans, Municipal heat plans. *Stimulus:* Subsidies, development grants (subsidies) and loan, guarantees. *Capacity building:* Setup of popups & interaction arenas for communication. Private law instruments: Contracts or involvement in legal entity.

Table 3 The key public actors in the Netherlands and their roles and means regarding urban development (Based on findings from: Adams & Tiesdell 2012; RVO, 2014; Heurkens, 2012; Hobma & Jong, 2016; van Vliet et al., 2004; Rijksoverheid, 2019; ACM, 2019; Provincie Zuid-Holland, 2019; Schilling et al., 2018)

There is a variety of *public-private partnerships* (d) possible, which are the contractual agreements between public and private actors: building rights model, joint venture and concessions (Heurkens, 2017c; p22). Arrangements such as private realization or public realization are not considered partnerships but as "an operation agreement between public and private actors" according to Heurkens (2012; p154).
The heat *delivery agreement* (e) is made between the performer of the DSO role or supplier role and the (semi-)private actors that receive heat such as the housing associations, homeowner associations and energy cooperatives in heat (RVO, 2014).
The *heat supply contract* (f) exist when the heat producer role is not executed by the same actor that executes the roles of distribution operator.
The *service contract* (g) for residential heat in district heating networks is agreed on in between suppliers, homeowners and tenants. The service contract can also be made from indirect suppliers such as the housing associations to tenants. For a service contract, tenants, homeowners, tenants and indirect suppliers will, when pursuing affordably, prefer lower costs for heat (RVO, 2014). In case of dispute or shortcomings by the heat supplier, the end-user of heat can claim compensation (Geschillencommissie, 2019).

The *membership agreement* (h) is a typical arrangement that is made between homeowners and their HOAs. When homeowners, in this case apartment owners, purchase apartment rights which withholds that a share in the building is bought with the exclusive right to use the apartment. Together with the other apartment owners, the buyer will become the owner of the entire building (NederlandVVE, 2019).

Since no role distribution over the actors can be elaborated on due the lack of specific project data, there is an agency model made for the dependency analysis that limits the conclusion on contracts that are agreed on as dependencies. To conclude on the agreements between the roles it is found from the majority of the agreements is based on an exchange of resources (finance, material and human resources). The emphasis of the research lies on the analysis of revelatory cases, which means that there is a gap in literature regarding the management of GDHD. Reflecting on how the management aspects influence the actor roles and actor dependencies found in literature does not lead to an answer to the research question, but provides important characteristics of the roles that actors perform in the cases.

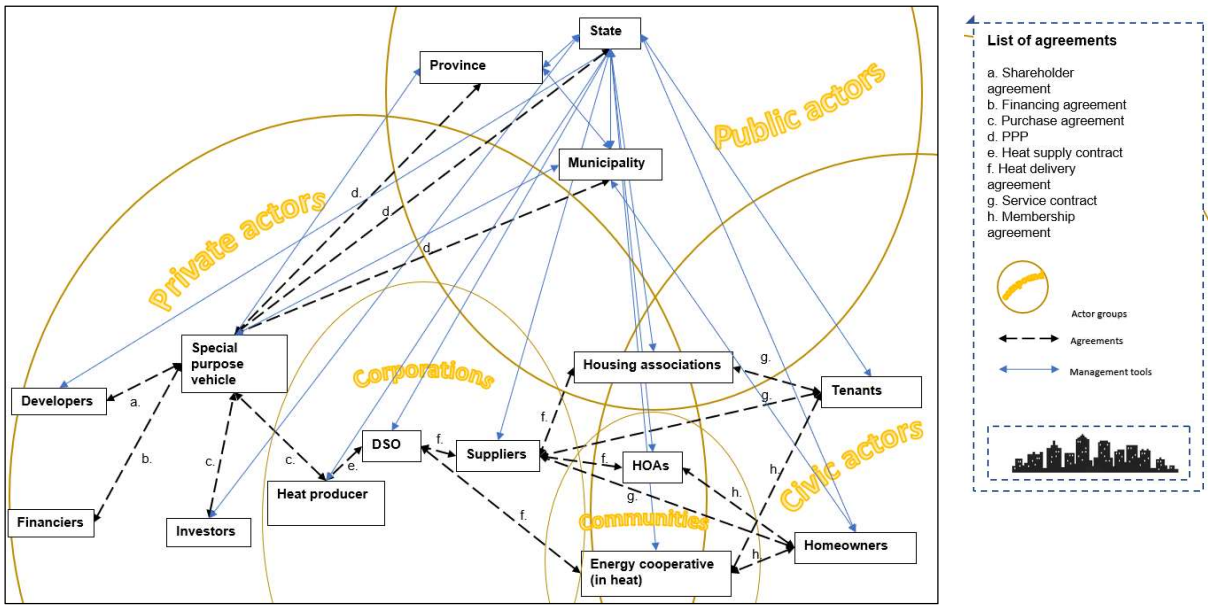

Figure 2 An agency model to position the roles of the public, private and civic actors that actors actively involved in, have the means to, have the knowledge of, are expected to be involved or are affected by the management of heat-generating facilities and infrastructure development in the built environment (Source: Own design, based on literature).

3.3 Management perspectives

Management in general is defined by Black & Porter (2000, pp. 19-24) as the process of assembling and using resources in a goal-orientated manner to accomplish tasks in an organisation. To be more specific, management is a process (that involves a series of activities and operations, such as planning, deciding and evaluating), involves assembling and using a variety resource types (means and assets such as finance, material and information) to accomplish tasks in a goal-directed manner within a certain organisational setting (Bruil, Heurkens & Lousberg, 2015, p6). Management is versatile and many and often contradictory perspectives on how urban development projects should be managed exist. The roles of public, private and civic actors, interpreted as 'management' activities performed by a certain actor, are evaluated on two management perspectives: management through levels and management through aspects.

Management in urban development can occur at different levels. Black and Porter (2000) make a distinction between strategic plans, tactical plans and operational plans *(Figure 3.4)*. According to Bose & Pal, (2015; p103) the more plans shift from strategic to tactical to operational, the smaller the planning horizon becomes. Also the number of people that are involved and the detail of plans increases.

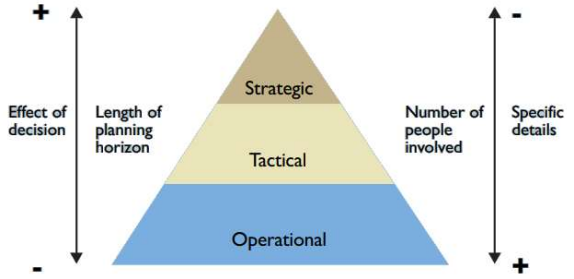

Figure 3 The triangle that represents the different levels at which management occurs (Source: Bose & Pal, 2015; p103)

Also Black and Porter (2000) mentioned the decreasing time horizon when strategic plans shift to tactical and operational plans. At first, strategic plans are characterised by their long time horizon (3-5 years), focus on the broad future of the organisation and high interdependence in which the resources and capabilities of the entire organisation are considered according to Black and Porter (2000). In strategic planning governments can reach consensus with private and social actors about policies and projects (Biffarello, 2014) at an early stage. With the shift to tactical plans (1-2 years) the strategic plans are translated into specific goals for specific parts of the organisation according to Black and Porter (2000). Operational plans cover 12 months or less and contain tactical plans translated in specific goals influencing a small unit of the organisation according to Black and Porter (2000).

Management through aspects relates to how geothermal district heating projects are managed viewed from the management aspects of money, organisation, time, information and quality (MOTIQ) as mentioned in Bruil et al. (2015, p47). The management aspects are linked to the activities performed in geothermal district heating development and lead to relevant topics to be discussed as underlying variables in the cross-case analysis on the cases in the empirical phase. The aspects and relevant topics that are discussed are provided *(Table 4)*.

Management aspect	Relevant topics
Money	lock-in costs, development costs, end-user affordability, heat sale opportunity, competitiveness of alternatives, financial risks, subsidies.
Organisation	Organisation types: line management (top-down hierarchy, with repetitive activities), project management (multidisciplinary and temporary organisation), organisation complexity, organisation fragmentation, degree of actor dependency (joint collaboration).
Time	Project duration, project planning, timing of activities between geothermal district heating development and urban development management, operating time of the geothermal well, time overruns.
Information	Dispersion of specialized information, techniques used to foster learning, information provision to tenants and homeowners, involvement of education, science and technology.
Quality	Geothermal well and location; environmental, health and safety quality; Spatial quality (utility, experience, future value); social values; steering on quality.

Table 4 Relevant topics extracted from the MOTIQ management aspects (Source: own design, based on literature findings)

3.4 Conceptual model

A conceptual model can now be produced *(Figure 4)* showing variables that are used to elaborate on GDHD management. At first actor roles are defined from literature and later evaluated on within the GDHD cases of Ammerlaan and HAL. Further there is determined to what extend various managerial roles and aspects are present among the roles GDHD actors perform. Eventually the results are assessed by experts before conclusions are made on effective managerial roles for upscaling GDHD.

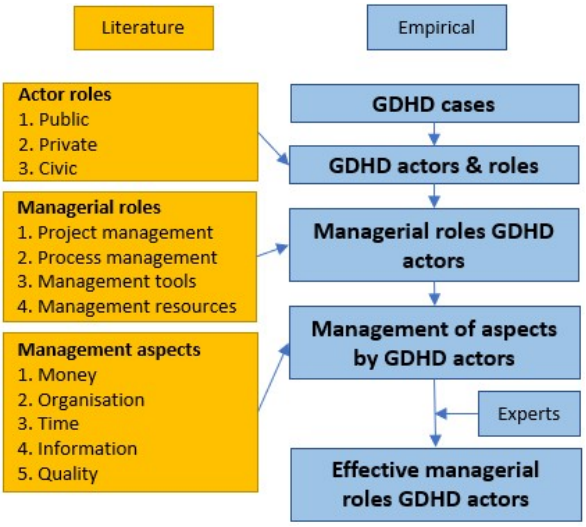

Figure 4 Conceptual model (Source: own design)

4. Case study: managerial roles

The case study performed in answers the research sub question on what the managerial roles & dependencies of public, private and civic actors are in implementing energy policies, district scale heat-generating facilities and infrastructure in the practice of urban development in the built environment in the Netherlands. A combination of data-collection instruments and processing tools with literature support led to the thorough analysis of the Ammerlaan and Haagse Aardwarmte Leyweg (HAL) cases. In both cases an actor inventory is made based on events that are chronologically ordered in an event-sequence table, showing task number, name of the activity, main tasks, time(-span) and involved actors, but is excluded from the executive summary. As stated in the conceptual model, the managerial roles of the inventoried actors are analysed and the first thing to notice is that these roles are intertwined. The variables that are analysed are project management, process management, management tools and management resources are narrated alongside the agency model per case. The agency model of the Haagse Aardwarmte Leyweg (HAL) case is provided in this summery for clarification purposes (*Figure 5)*. The figure forms the basis of the organisation in the project in which the dependencies between actors is shown with an arrow. The single arrow can indicate an exchange of multiple dependencies: exchange of money, information and knowledge and mutual agreements

The project management variables relate to the phases in which the events of the development occurs: initiative, planning, realisation or operation phase. In the initiative phase of the project the Municipality draws up a heat plan **(x)** which is a recognised shaping instrument. In the planning phase of the project several technical and financial feasibility studies are made on the base of external consultancy **(f)** or internal knowledge **(j)**, capital is attracted **(a-d, z1)**, several licences (exploration, extraction and environmental) are arranged **(w)** and capacity building (networking and information provision) is enabled **(y)**.

In the realisation phase the planned activities are executed: (re)development of the geothermal well, infrastructure development and residential adjustments.

In the operating phase, managerial roles for heat production, distribution services, supply, use and maintenance are performed **(l-o)**, production subsidy is provided **(z3)**.

Looking at the process management variables communicating, negotiating and decision-making, there can be concluded hthat these variables occur throughout the whole development of which the (intentional) agreements are the result. These agreements are made between actors and are indicated with a black dashed arrow **(a-o)** in the figure.

The management tools are indicated with the blue arrows and shows the management tool categorisation enabled between public and private/civic actors in the organisation **(w-z).**

As mentioned before the arrows indicate several dependencies that can be seen as management resources.

Important conclusions on the managerial roles and dependencies of public, private and civic actors are elaborated on. Conspicuous in the GDGH organisation is the large public actor role integration: not only do they provide the regulatory framework as in every project, but also play an important role in stimulating (e.g. capital-raising) the development. There is concluded that the lower the governmental level is, the larger the variety of management tools are used: Capacity building tools only found applied on the level of the Province and Municipality. An important finding is the capacity building tools used by the Province in the cases, which was not found in literature before. The reason for this is that the Province of South Holland is leading in geothermal energy, where they have an overarching role in building capacity between GDHD projects in the Province. Another noticeable fact is that there is a large role segregation among the actors, pointing out that there is no GDHD agency that has all the in-house capabilities of developing a geothermal well, district heating infrastructure and residential adjustments together.

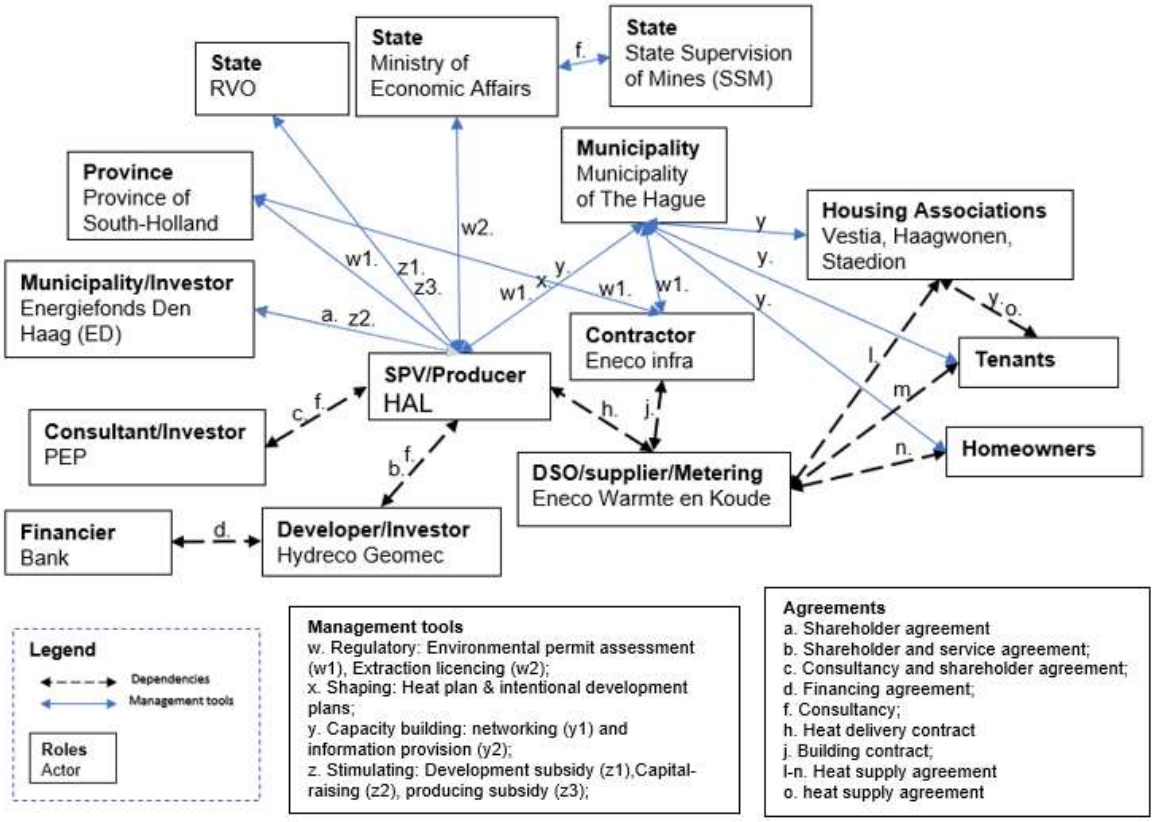

Figure 5 An agency model of the that indicates the dependencies between the roles of actors in the Haagse Aardwarmte Leyweg (HAL) project (Source: own design, based on empirical findings).

5. Case study: management of aspects and levels

The cases Ammerlaan and Haagse Aardwarmte Leyweg (HAL) were placed in relation to the relevant topics of the management aspects as described in the conceptual model, in a cross-case comparison. The conclusions are discussed in the following paragraphs in the order of the management aspects money, organisation, time, information and quality.
From the aspect of money relevant topics for GDHD are high investments, long payback periods and uncertainty of heat sales that private actors are dependent of. Although civic actors are dependent on justified individual costs and lock-in, for all the adjustments to dwellings and geothermal well development additional public actor stimulus seemed necessary.
The organisational setting of GDHD is elaborated on and there are found multiple organisation types and actor dependencies. Not all the actors found in the literature study seem actively involved in the development of the cases. The civic actors such as homeowners or tenants often seem less involved in the planning and realisation, but can be involved from a community role from a homeowner organisation or energy cooperative. But even those organisations seem minor in GDHD.
Time management can reduce the costs of the development by preventing delay or by coinciding processes needed for GDHD development. Important moments in time to reach legal consensus between the supply and demand side can reduce the risks in GDHD.
The provision of information from the supply side of GDHD to the demand side is important to foster the adoption. Through capacity building tools public support can be acquired, but informing tenants and homeowners by informational letters and frequent meetings could increase the civic actor support.
For GDHD development a minimal environmental quality standard is opposed from the different governmental layers and are considered minimal (regulatory) requirements. The spatial value is considered subjective as this is perceived differently for each actor. Lastly the social value is a determent of spatial quality. Variations on these could influence the acceptance of plans for GDHD.

Management of urban area development is happening on strategic, tactical and operational level. It is found that Management through levels concerns the development and execution of plans, which means that this is related to the management aspect of time. However, it is assumed that the management aspects money, organisation, information and quality are also linked to strategic, tactical and operational planning and can be specified for each actor in the development and is therefore hard to indicate in this organisational setting. In Bose & Pal (2015; p103) is found that the number of people that are involved increases during the shift from strategic to operational plans, which can be proved by looking at the role the Municipal council performs by shaping plans. An important conclusion is that strategic plans for GDHD are made by public actors through shaping instruments in case of top-down developments and that during the shift to tactical and operational plans private and civic actors are involved through capacity building.

6. Delphi study

A two-round Delphi study is organised to hear from experts how is thought about results of the literature and empirical research. At first a list of ten experts from varying disciplines is made: policy advisors from the Municipality and Province, geothermal developers and operators, district heating experts, housing associations, researchers Delft University of Technology and area development managers. The experts were asked to fill in a statement document showing six statements from research findings that relate to the MOTIQ (Money, Organisation, Time, Information and Quality) management aspects. Before each statement a sort of context is attached to clarify the origin of the statement. The responses of the results of the Delphi study and the statement documents are merged and elaborated on in the following paragraphs.

1. The sales of heat to private and civic actors is insufficient to cover the development costs: without the availability of subsidies and grants, the development of geothermal district heating will not happen.

Important findings on the assessment by experts on the management aspect money is that the statement can be misleading and partly incorrect and paints a misleading picture because

1. The need for subsidies is not only determined by the sales of heat or heat potential, it is the sum of uncertainties related to geothermal development, but heat sales remains an important factor (Expert 4).
2. Competition is not possible without subsidy: the alternative of geothermal heat (natural gas) is subsidised as well since the costs and risks of maintenance and installation of natural gas networks by regulated companies are embedded in the social system (Expert 3).

For now it seems that the development of geothermal district heating is not feasible without subsidies and grants, which is caused by many reasons:

1. First of all there is a competition with other alternatives (for heat). The most important competitor found is natural gas (Expert 1; Expert 9): the extraction of geothermal heat is only sold on the local market while extraction of natural gas can be sold on a worldwide market. Another example for competition variables are that individual heat-generating alternatives suit the demand better (Expert 5), have less risk and upfront investments that are included in the purchase price of a dwelling (Expert 7). There is no fossil free alternative for large scale winter heating except for storage (Expert 5).
2. The financial crisis resulted in a more cautious approach of developers and loan capital provides/banks (Expert 6, Expert 9): meaning large risks, high upfront investment with uncertainty of heat sale potential and uncertain growth potential. Risk are partly covered by local funds such as ED (Expert 9).
3. The failure of local governments to translate views and planning to concessions (Expert 4)
4. The geothermal heating market is in the initiative phase, immature, insufficiently developed and that there is no best practice yet (Expert 6; Expert 4; Expert 2), which is made harder due to different local subsurface conditions.
5. Not only the geothermal well and infrastructure development needs to be subsidised: the severe adjustments to dwellings are accompanied with an unprofitable margin that are covered with subsidies and grants (Expert 8).

Subsidising geothermal developments common and practical way to bridge the uncertainties (Expert 4). An important argument is that subsidising leads to more research in a short period of time, resulting in better techniques and materials being developed and occurrence of scaling up (Expert 6). In the future there might be solutions that can make GDHD feasible without grants and subsidies:

1. A competitive advantage arises when there is a CO2 tax (Expert 1; Expert 3;)
2. The adoption of appropriate legislation and regulation (Expert 1, Expert 4)
3. The development of a firm view (and planning) on the heat transition to create growth potential could cover the uncertainties of heat sales (Expert 4);
4. The underlying factors of heat demand should be considered: although cities densify and the demand per grid investment increases, heat-insulation decreases the heat demand (Expert 5);
5. Development of the sector towards maturity: techniques and organisation, becoming a ‘regular business’ with cost reductions (Expert 10; Expert 6).

2. An area-based approach that is steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor (homeowners & tenants) initiatives (bottom-up).

The assessment on the management aspect organisation by the experts led to a tendency to be for the statement, which suggests that an approach steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor initiatives (bottom-up). The arguments against the statement imply that the effectivity depends on the policy-based market context (Expert 1), resistance against public plans and the access to expertise by civic actors (Expert 5). Bottom-up initiatives are driven by the reduction of money (savings of natural gas) and carbon reduction and are more common in the greenhouse area (Expert 9), considering that horticultural companies are developing for themselves.
Arguments for the statement suggest that the scale of geothermal development is too large to by led bottom up (Expert 3; Expert 5) and therefore public actor engagement can lead to better coordination of plans in neighbourhoods to achieve the scale needed in a shorter time (Expert 8; Expert 4). A top-down approach leads to sharing experiences, knowledge and the preservation of quality and organisational processes (Expert 10). Also, the interest of civic actors are lower costs for heating, cooling and comfort for which the management role is expected to be taken care of by private and public actors (Expert 7; Expert 3). As suggested by (Expert 6) the Municipal positive-critical attitude towards such sustainable developments reflects the opinion of the municipal community. Although top-down approaches are found more effective, the combination of bottom-up and top-down approaches are found necessary for receiving support and reaching the scale needed for a successful business case (Expert 10; Expert 2; Expert 4; Expert 3).

3.a The connection of dwellings to geothermal district heating can only happen before the end user's current heat-generating facilities are past due and municipal soil excavation works are planned.

The statement probably suggests the most desired situation or extra opportunity in the development of geothermal district heating (Expert 4; Expert 9). From the perspective of the urban area development manager this situation is necessary for a step by step controlled development approach to reduce uncertainty: risk and interest surcharge (Expert 6). The past due time of heat-generating facilitates and planned municipal excavation works are found factors for the GDHD business case optimisation (Expert 3), such as prioritising the neighbourhoods as first areas where natural gas will be replaced (Expert 10). Unfortunately, the exploitation period of the heat-generating facility is different for each homeowner or tenant in practice (Expert 3; Expert 4; Expert 8; Expert 10). Due to the CO2 targets and concept climate agreement there might be a need to replace the heat-generating facilities in place prior to the due date (Expert 10). However, heat-generating facilities can also pass their due date. Solutions to deal with this problem are the existing service of temporary lease of a heat-generating facility in case of breakdown of the current before planned switch to district heating (Expert 3; Expert 5).

3.b Before the start of geothermal well and infrastructure development legally binding agreements with the end-users regarding dwelling adjustments and grid connections are necessary.

The statement shapes the image that a legally binding agreements with the end-users are a precondition for GDHD.
There seems to be a difference in opinion for who and what the precondition applies to. From the arguments against the statement is found that gathering the necessary contracts is not possible due the large number of costumers and unfamiliarity with the development (Expert 7; Expert 8) and that a serious expression of interest or potential for development provides enough incentive for an investor (Expert 3). This is in contrast with the findings of the experts that are for the statement: the investments are usually that high that developers can not afford having no legal certainty (Expert 6). It is of importance to make clear agreements about responsibilities: who does what and when (Expert 10). Long-term planning, development of infringement locations with many stakeholders, long lead times harm the return and becomes less manageable without certainty (Expert 6).
The moment of legally binding agreements are found necessary are at the financial investment decision (Expert 4), which is the moment that all permits and financial arrangements and construction works contracts are ready. Even more, it is found that no bank loan will be provided without completed permits, granted subsidies and given guarantees on heat sales (Expert 9). Important solutions to this problem are given: business to business (B2B) contracts where the risks of heat sales is transferred to the heat supplier, contractors or other developers who pass through agreements to the end-users (Expert 9; Expert 7). But that does not cover all the risks: it seems that only a B2B contract is insufficient to secure future cashflow because the SDE+ subsidy is based on the real heat supply, which means that production of heat is not subsidised when there is no heat delivered.

4. The provision of development information (planned and ongoing) and civic participation through capacity building tools leads to more acceptance, cooperation and fosters adoption by civic actors.

The majority of the experts have indicated to be for the statements. GDHD is characterised by mining activities in the neighbourhood causing nuisance (Expert 4)., which relates the most to the HAL case compared to the case of Ammerlaan. IN the HAL case HAL and the and Eneco wanted to inform the neighbourhood on the plans (Expert 9). Important reasons for the provision of development information is reducing resistance against plans, increasing acceptance and cooperation, but does not necessarily lead to acceptance (Expert 1; Expert; Expert 10). Civic actor behaviour is an important consideration. Sustainability is a hot topic people have interest in, people like to be heard, want to be included in the process and might even act as a 'representative' of your project when a the right approach is executed (Expert 7; Expert 6; Expert 8). A certain quality level of the information provided is needed. The information must be completely transparent, honest, reliable, has to be factual and must promote trust, what can be done by using capacity building tools (Expert 5; Expert 10; Expert 4). However, it is thought that the provision of development information can be perceived wrongly, is lacking or can be 'biased', resulting in uncertainty, suspicion, resistance and speculation about risks that are not applicable (Expert 3; Expert 5; Expert 6). It is therefore necessary the respond adequately with appropriate information.

5. Meeting the environmental quality standards will only lead to geothermal district heating development if the desired spatial quality and social values are met.

The statement described a precondition that expects that the spatial quality and social values have to be met to come to GDHD. It is thought that it would be more interesting to see if there are opportunities for GDHD if the desired spatial quality and social values are not met (Expert 6). Although spatial quality is subjective, there can be a difference in perception of how spatial quality is perceived considering that GDHD consist of multiple elements in a system: infrastructure, residential building installations and the geothermal well. Some elements are perceived as adding value while others harm the spatial quality. For instance the piping and installations are not visible after realisation and only cause temporary nuisance (Expert 8) and provide future sustainability. For the geothermal well, the space loss and impact on spatial quality is significant,

given that about 10.000m² has to be reserved for at least 30 years (Expert 4). In certain cases the spatial quality is declined, due to green areas has been replaced by parking lots (Expert 3). Therefore, the location of the geothermal well development could influence the resistance: urban areas might experience a larger loss of space compared to developments outside the urban area. Existing neighbourhoods are much more organised for resistance and the opposition against GDHD becomes stronger if it is associated with loss of space (Expert 5; Expert 3). This is also referred to as the NIMBY-phenomenon, in which people do want a more sustainable solution, but do not prefer this to be placed in their vicinity (Expert 2). The resistance arises if the spatial and social values are insufficiently met, resulting in objection procedures which makes the development politically and legally impossible (Expert 1). It is found that the renewable objective as social value is the focal point (Expert 4), but could that outweigh the loss of spatial quality? It is found that the choice for and an acceptance of a solution is based on quality (proper functioning) and price first (Expert 7; Expert 2), after which the environmental impact follows. Having a higher quality than is needed for the environmental quality standards (e.g. GRE-lined casings), improves the spatial quality on the topics of durability and continuity (Expert 9) and might balance the loss on other aspects of spatial quality. It is important that there is at least support on all the environmental quality aspects regardless if they outweigh each other and therefore there is frequently communicated to the surrounding of the project (Expert 10; Expert 9).

7. Conclusion

Public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands by forming a strategic plans, making deliberate decisions and executing several processes.

- A large actor integration is noticed in the cases, indicating that steering from several governmental levels is necessary to induce the market behaviour towards desired outcomes by using management tools. Regulatory instruments from different governmental layers foster the safety and feasibility of such developments through multidisciplinary assessments. Strategic plans for GDHD are recognised as shaping instruments in the form of heat plans. Local authorities can build capacity: performing a facilitating or directory role in the implementation of these plans as shown in the case study on Ammerlaan and HAL. The role they perform eventually determines which stimulus tools are used by them: in the facilitating role performed in the Ammerlaan case local subsidies are granted while in the directory role in the HAL case a revolving energy fund was in place. Stimulus for the production of geothermal heat was subsidised as well from the State body RVO and for the adjustment of the dwellings stimulus instruments were in place to cover the unprofitable margin, since GDHD links up with the sustainable public actor ambitions (for which budgets are allocated). In between public, private and civic actors there is communicated, negotiated and decided on desired outcomes, settled in (intentional) agreements, which provide certainty for feasible development.
- There is a large role segregation among the actors, pointing out that there is no GDHD agency that has all the in-house capabilities of developing a geothermal well, district heating infrastructure and residential adjustments together. In the Ammerlaan case there was a larger role integration by the development actor Ammerlaan, compared to the developer in the HAL case: Ammerlaan managed to fulfil the role as developer, corporation (producer, distributor) and investor.

On the management aspects of money, organisation, time, information and quality conclusions are made:

- GDHD is characterised by large competition, immaturity of the sector, reticence of loan capital providers, failed concessions and unprofitable margins, high investments and long payback periods and is public actor stimulus dependent.
- Organisationally the developments show top-down initiatives where public and private actors initiate the development.
- Optimising timing or coinciding development activities are necessary to acquire certainty, especially on the topics of the replacement of current heat-generating facilities and legal agreements with end-users. Without certainty GDHD becomes less manageable.
- Information provision to civic actors and neighbourhood is key for GDHD in order reduce public resistance against plans, increasing acceptance and cooperation, but does not necessarily lead to acceptance.
- The management of quality of GDHD should be taken into consideration by looking at the several aspects of environmental quality, that can outweigh each other.

Probably the most effective solution for upscaling GDHD is consensus between public, private and civic actors, where through intensive communication, negotiation and decision making is agreed on the desired environmental quality for the built environment, our built environment.

8. Discussion & recommendations

The research on actor roles and dependencies of GDHD has its limitations is limited to two cases with certain actors involved in the Province of South Holland. Why cities in other Provinces don't explore GD but focus on other solutions is not clearly explained. Also international cases could show a different role dispersion, where public actors are developing actors, when heating dwellings is expected to be a social responsibility of the public actors. Both the cases are development projects that were initiated ten years ago, indicating that new techniques open opportunities to reach higher formation water temperatures that could not only be used for direct heating, but also for electricity production. The aforementioned technical innovations could change the organisation structure drastically.

For the GDHD practice recommendations are made relating to actors roles, exploration, anticipation to CO_2, and acceleration of processes: (1) The public actors need to continue using stimulus tools and develop regulatory tools to foster maturation of the sector and evoke competitive advantage. Capacity building tools should be used to their full extent to match the heat supply and demand. (2) Subsurface surveys and exploration near dense urban areas need to be conducted in an early phase to see whether GDHD is feasible in specific regions. (3) Anticipation on the CO_2 tax: looking for geothermal development feasibility. (4) Determining the effects of technological innovations: questioning whether shorter procedures and enhanced production period leads to a higher financial feasibility.

Further research is on GDHD is recommended: (1) An analysis on the actor organisation and GDHD of (international) cases can indicate the existence of less or more public actor integration and role dispersion among actors and explain what the reason for this is. (2) Comparable studies on countries that have a mature geothermal sector (e.g. USA, Germany, Iceland) could have important and relevant lessons to learn from. Further research could be conducted on the transferability of international practices. (3) From each actor, several departments within the actor organisation are also worth investigating. For instance: in the research the environmental license is discussed to a certain extent, but in reality this covers over 40 different licenses that might require a certain discipline within the organisation.

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1. Introduction

In this chapter the background and motivation for this thesis will be discussed. The report focusses on the topic of sustainable area transformation within the theme of Urban Development Management (UDM). An issue to be addressed are the trends in energy and urban development **(1.1)**. After this introduction, the conceptualisation of definitions follows **(1.2)**. Following the definitions section the research problem will be formulated **(1.3)**. In the section after is explained what the goals and objectives are for the thesis **(1.4)**. In the fifth section the main research question and sub questions are elaborated on **(1.5)**. In the sixth section of this chapter the expected outcome, dissemination and audiences are briefly discussed **(1.6)**. On the seventh and last section of this chapter the conceptual framework is presented **(1.7)**.

1.1 Trends

Jump in the bandwagon: the trends in energy and urban development show an emerging transition. One of them is the energy transition, a key urban challenge of 2050 which is defined as “a pathway towards transformation of the global energy sector” (IRENA, 2018a). The main goal is to make a transition from energy derived from fossil fuels such as gas, nuclear energy and coal to energy from renewable sources by 2050 (EC, 2019). First, to manage the adverse effects of climate change an active role of national, regional and local governance is necessary **(1.1.1)**. Second, the growing population and energy demand emphasizes the need for energy strategies and efforts to reduce the demand **(1.1.2)**. Third, implementing energy strategies in urban development from different government scales requires comprehensive action by various actors, scales and disciplines **(1.1.3)** according to Petersen & Heurkens (2018). Fourth, alternatives such as the decentralization of electricity and centralisation of heat entail the potential to meet binding climate commitments **(1.1.4)**. Fifth, the changing roles in urban development that is associated with the management of renewable district heating development needs to be considered **(1.1.5)**.

1.1.1 Climate change

The world has been facing detrimental climate change since the beginning of the industrial era in 1850. Increasing anthropogenic emissions due to global economic activity, carbon intensity and airborne fraction (Canadell et al., 2007) caused fluctuations in CO_2 concentration and temperature over the course of time. Evidence shows that the that this increase enhances the greenhouse effect: emission gasses trap infrared radiation energy from the sun, causing global warming (Bolin & Doos 1988; Nordhaus, 1991). The increasing global temperature anomaly results in relative changes in the rainfall intensity, sea level rises, floods and droughts (KNMI, 2017; IPCC, 2007). As a reaction, governments have the necessity to minimize the damage of climate change toward cities.

In the Netherlands the aforementioned adverse effects of the climate change is well managed by Ministry of Infrastructure and Water Management and Water Authorities. The Delta Works (*Figure 1.1*) are examples of structures that provide protection against sea level rise, tidal effects and storm surge. Under the Ministry of Infrastructure and Water Management is the Royal Netherlands Meteorological Institute (KNMI) worth mentioning. The institute has a primary role in forecasting and monitoring the weather, climate air quality and seismic activity (KNMI, 2018). Even on regional and local level management tools were used, such as the implementation of rain buffers in urban areas in land use plans. In order to adhere to the increased rainfall intensity, rainwater discharge pipe uncoupling was stimulated by means of subsidies (HDSR, 2019).

However, according to Strengers (2018) the dangers of climate change should not be neglected: the adverse effects of climate change elsewhere in the world could also radiate on to The Netherlands.

Figure 1.1 A photograph of the eastern Scheldt storm surge barrier in Zeeland that protects the land from sea level rises and floods. The hydrological construction shown in the picture is part of the Delta Works in the Netherlands (Source: Rijkswaterstaat, 2007).

1.1.2 Growing population and energy demand

A growth in the population constitutes an energy challenge for the future. In 2016, the Netherlands had a population of approximately 17 million people divided among 7.7 million households (CBS, 2018a), given that many urban regions continue to grow significantly and the rural areas experience population shrinkage (PBL/CBS, 2016). According to the prognosis made by Van Duin & Stoeldraijer (2014) the number of households will rise to 8.5 million by 2040. The number of households is expected to increase partly due to the expected population growth and partly due a further decline in the average household size.

The total thermal energy demand of households is provided by means of natural gas and accounts for 93% of the total amount of households according to NAM (2018) which means the electricity demand for heating is limited (Hekkenberg et al.; 2009). The total demand of natural gas can be lowered by efficiency measures and energy conservation of the existing residential stock (Mlecnik, 2018). Certain local authorities create pop-ups and consultancy centres that could accelerate the energy performance through the renovation of owner-occupied housing according to Meijer et. al (2018). In the course of time, natural gas is used more efficiently due the quality improvements of the buildings (isolation of walls, floors, roofs and windows) and the use of energy saving heat-generating facilities (Ministerie van Economische Zaken, 2016) which led to a decrease of the average natural gas use per dwelling. Unfortunately, the growth of the amount of households caused an increase in the total natural gas demand for space heating from 720 PJ in 1990 to 800 PJ in 2012 (Ministerie van Economische Zaken, 2016; p69). Research on the energy performance of the social housing stock done by Filippidou et al. (2017) showed that the energy performance improvement pace is too slow to fulfil the EU-targets for energy efficiency. When energy improvements are difficult to implement in the regulated, non-profit housing sector, it might even be more difficult for the non-regulated housing sector (Filippidou et al., 2017). This indicates that the measures to improve should accelerate and that *upscaling* the current effort is urgent.

1.1.3 Political pressure

A multitude of global governmental efforts on various scales, such as the Kyoto Protocol (1997) and Paris Agreement (2015) anticipate on the adverse effects of climate change by forming binding climate commitments to minimize the CO_2 emission. These commitments led to strategy development, for instance the strategy development of the European Commission (EC) towards a low-carbon economy, with a cut of 80% in Greenhouse Gas (GHG) emissions below 1990 levels by 2050 (EC, 2018).

In the EU, the existing buildings are responsible for approximately 40% of the energy consumption and 36% of CO_2 emissions (EC, 2018). To cut the GHG emission of existing buildings, the European Commission lays down the legislation framework for its member states through its European Directives. These Directives are adopted for improving energy efficiency (2002/91/EC), requiring minimum energy performance and certificates (2002/91/EC), increasing minimum energy performance (2010/31/EU) in order to reduce the energy demand of buildings and to foster the use of energy from renewable sources (2009/28/EC). From January 2020 on, the Nearly Zero Energy Building (NZEB) regulation is implemented for newly developed buildings (already for new public building in 2018), which is requested in the recast of the energy performance of buildings (2010/31/EU) to reduce the energy demand even more. Due to the temperature dependence, both electrical and thermal energy demand are influenced by the changing climate and weather conditions (Hekkenberg, Benders, Moll & Uiterkamp; 2009) which is one of the reasons to regulate the energy market. Due to the European Directive on Electricity (96/92/EC) the Electricity Act 1998 was adopted in the Netherlands which abolished the monopoly positions of energy companies in the Netherlands and enabled cross-border trade of electricity. In contrast with strategies for renewable electricity there were little concrete policy objectives for renewable heat solutions at national or European level according to CBS (2017), but this is about to change. The Dutch action plan is to have 9% of the total heat demand fulfilled with renewable heat solutions by 2020, which was only 5,9% in 2017 (CBS, 2017). Even more, the letter to Parliament from the Minister of Economic Affairs and Climate Policy suggests to seek for gas alternatives, such as geothermal energy, which has a potential to fulfil 14% of the total heat demand of the built environment by 2050 (Wiebes, 2018). In the Netherlands, an emerging political pressure to shift form energy derived from gas as fossil fuel is enforced due to earthquakes on Groningen Gas Field (*Figure 1.2*). The extraction of natural gas from the soil causes earthquakes (NRC, 2013) in the Groningen region.

Figure 1.2 The Gas bubble found in Slochteren, Groningen, led to an emergency construction rate of natural gas pipe networks throughout the Netherlands. From left to right: (1) Picture of the construction of the drilling rig at Slochteren in 1959, (Source: Historisch Archief Midden-Groningen, 2018), (2) Photograph taken of the gas pipelines being laid down in the Dutch soil in 1963 (Source: NOS, 2016), (3) The preparation of gas boilers and gas cooking appliances by the Municipal Energy Company (GEB) in 1963 (Source: Vernieuwbouwd, 2018)

Whereas the natural gas revenue benefits were partly held by State of The Netherlands through a concession (in accordance with the Mine Act 1903) to improve the Dutch welfare and economy (e.g. development of the Deltaworks), the decrease in the gas production and shrinking benefits now draws the attention of the Dutch company NAM that currently owns the land rig (CBS, 2017).

Due the lock-ins made in the past, the Dutch natural gas and coal are the primary energy source in the Netherlands (CBS, 2017c). A total of 93% of the Dutch households are dependent on natural gas for space heating, water heating and cooking (NAM, 2018; CBS, 2018). As a result of the decreasing production, the import and costs of natural gas increases and jeopardizes the energy security of the Dutch households. There is an urgent by the need to alter this energy source by reason of energy security and also because of binding climate commitments made. The European Directive on Natural Gas (98/30/EC) precipitated the adoption of the Natural Gas Act in the Netherlands, but now that there is a shift towards an economy that is free of natural gas new legislation is adopted. From 1 July 2018 on, the amendment to abolish the mandatory gas connection in dwellings came into force in order to reduce the use of natural gas by households (Ministerie van Economische Zaken en Klimaat, 2018).

Besides the national and supranational policies, local governments have the ability to stimulate the urban development of energy efficient (residential) buildings to reduce the energy demand. As a matter of fact the research done by Meijer, F., Straub, A., & Mlecnik, E. (2018) shows local authority policy instruments for the adoption of energy efficiency measures by homeowners. Financial, decision-making and informational barriers and incentives for homeowners to improve the energy efficiency have been widely investigated in literature (Hoppe, T., 2012; Gorter & van Zessen; 2018) and provide opportunities to reduce the increasing demand of energy. Regional and local authorities use policy instruments to motivate and stimulate homeowners by “tackling the existing regulatory, economic, informational and organisational barriers” of energy efficiency measures according to Meijer et al. (2018). However, the implementation of energy strategies in urban development seems to be a complex process in which comprehensive action by various actors, scales and disciplines is required (Petersen & Heurkens, 2018). Implementing these strategies is a challenge for implementation agents (e.g. community and private actors) and urban planners since public planners are not often in the position to influence the implementation of urban development targets according to Petersen & Heurkens (2018). Although the land-use planning, binding stipulations and abstract energy policies (in the Building Decree) are powerful regulatory tools for influencing energy-use, public actors are dependent on private actors and the community for the actual implementation of energy measures in practice.

1.1.4 Alternatives for heating

The first alternative for conventional heating on natural gas is found all-electric *(Table 1)*. This proposed solution will impact the electricity demand considerably, of which the supply is considered to be 13,8% renewable in 2017 (CBS, 2017d; p22), meaning that this solution fosters the GHG emission even more. However there is a trend noticed were the electricity supply is becoming more renewable: since medium and micro scale generating-facilities have become available, end users have been able to produce energy themselves and convey the surplus over the power grid (Pagani & Aiello, 2011). The development of photovoltaic (PV) technology resulted in a major growth of PV industries and adoption of individual renewable energy generation in the Netherlands (Verhees, Raven, Veraart, Smith, & Kern, 2013). Subsidies from ‘Stimuleringsregeling Duurzame Energie (SDE+)’ and tax incentives to promote green energy are found stimulating tools in order to foster the development of renewable energy production according to BDO (2018).

In the Netherlands the households that are dependent on natural gas to heat their dwelling, are using micro or condominium building scale heat generating-facilities. These prolonged decentral heating facilities on natural gas could be replaced by heating alternatives *(Table 1)* if the shift towards a low-carbon economy by 2050 is pushed through. Due to energy security, the reliance on natural gas for heating dwellings is an important reason to accelerate the adoption of renewable heating systems according to Kieft, Harmsen & Wagener (2015).

Alternatives to heat	Category	Source
All-electric	Heat exchange through circular pump	Air, Soil, Water (Heat tubes)
	Storage	Pumped Heat Electrical Storage (PHES) Hydrogen Energy Storage (HES) Liquid Air Energy Storage (LAES)
District heating	3th generation Pressurised medium-temperature water systems (<100 C)	Industrial waste heat Waste-to-energy Biomass Combined Heat Plant (CHP) Deep geothermal
	4th generation: Low-temperature water systems (~30-70 C)	Low-temperature waste heat (data centers, greenhouses, supermarkets, etc.) Water (Sewage) Deep and shallow geothermal
Green Gas		Biogas from waste, Biogas from sewage sludge,H_2

Table 1.1 A list of alternative energy purposes for heating dwellings that could possibly replace micro (e.g. heaters, boilers) and building scale (collective boiler) heat generating-facilities (Source: Energy Storage, 2018; Keutel, 2018, Sayegh, Jadwiszczak, Axcell, Niemierka, Bryś & Jouhara, 2018; own edit).

The alternative for natural gas is having green gas that can reduce the GHG emission with 30% (Scharlemann & Laurance, 2008), but these technology is not sufficiently developed yet and is not a renewable source thus is limited in supply (Tempelman, 2012, p19; Schepers, Naber, Rooijers & Leguijt, 2015, p16). Since it is thought that the all-electric solution will foster GHG emission, it is assumed that district heating has the potential to reduce the GHG even more, although it is thought that the alternatives for heat in the future can consist of a mix of alternatives (Schepers et. al, 2015). Regarding the district heating, the third generation networks are prospected to be the best available technologies between 1980-2020 according to Lund, Werner, Wiltshire, Svendsen, Thorsen, Hvelplun & Mathiesen (2014). In the research of Lund et al. (2014), the fourth generation district heating networks is expected the best available technology between 2020-2050. The third generation networks is applicable for apartment and service sector buildings including single-family houses (100-200 kWh/m²). The fourth, would only be applicable to new buildings (<25kWh/m²) or existing buildings (50-150kWh/m²) with higher energy efficiencies.

However, decision making of actors between the alternatives for heat depends on many variables. For instance, the heat from waste and biomass is limited (Lund et. al, 2014) due to the availability of the source. The environmental conditions, such as a listed Monumental status or insufficient roof surface of homeowners and tenants (e.g. for heat tubes) could also narrow the solutions proposed.

Also the available technologies and their working temperature *(Figure 1.3)* influence decision making according to the research of Sayegh, Jadwiszczak, Axcell, Niemierka, Bryś & Jouhara (2018; p126). The arrow on the left indicates the environmental friendliness of the solutions proposed but there is no strong argument that proves geothermal to be less environmental friendly than solar tubes in this research.

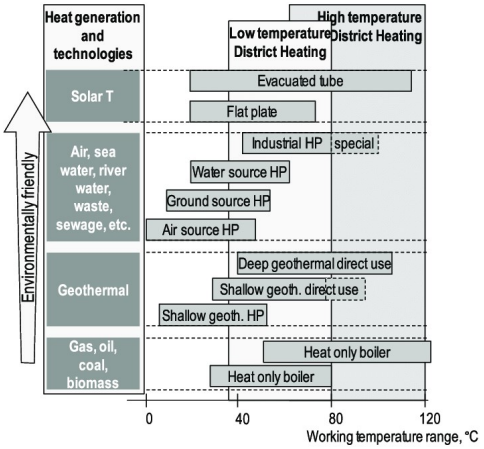


Figure 1.3 A diagram that shows the working temperature range of available heating technologies (Source: Sayegh et al. 2018; p126, own edit).

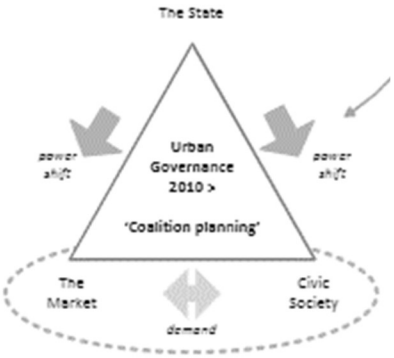
The micro or condominium building scale heat generating-facilities in the majority of the residential stock uses natural gas with a maximum working temperature of 300 C, which means that it can cover all the heat loads. The current district heating in The Hague is fed with temperatures ranging from 70 C tot 90 C (Gemeente Den Haag, 2018) which seems sufficient. Such high working temperatures are often not needed after retrofitting. In the research of Lund et al. (2014; p10) an evolution of various district heating generations shows an increase in applied technologies and a decrease in temperature of district heating steam/fluids in the course of time. In recent research of Østergaard, & Svendsen (2016) is shown that 1930s single-family houses which used high-temperature heat-generating facilities have potential for low-temperature district heating.

Not only building performance but also the performance of the available technologies, expressed as the Coefficient of Performance (COP) will influence the decision making for energy producers. Shallow geothermal heat pumps can have a COP ranging from 3 to 6 while Deep Geothermal heat pumps can reach a COP of 11 (Sayegh et al. 2018; p126; Das, 2019; p6). This results in actors that compete with energy solutions and have the tendency to reduce energy production costs according to Bakker (2016), Verbong and Geels (2010) and den Ouden, Duivenvoorde & Kooiman (2016).

Existing heating networks in cities that have already been laid down in urban infrastructure and dwellings mainly use fossil fuels (e.g. CCGT, Combined-Cycle Gas Turbines) and renewable sources only accounted for 25% (ECN, 2017) of the total heating production in 2015. These existing heat networks do have certain predefined actors that manage the supply of heat. The production of heat is done by heat-generating facility owners (corporations) that are cooperating with suppliers who sell the energy to end-users. The distribution of heat is the responsibility of Distribution Service Operators DSOs (e.g. Liander, Enexis, etc. that also have the responsibility of electricity and gas at their disposal). Compared to the electricity supply chain, heating networks do not have a national grid where TSOs operate since it is a regional business according to Brugman (2019). Considering the existing district heating networks cover less than 5% (ECN, 2017) of the total heat demand and the emerging growth of independent suppliers, there are managerial and organizational challenges in implementing heat networks in the already built environment.

1.1.5 Changing and integrating roles in managing urban development

Urban area development requires "management on different (spatial) levels, different development stages (initiative, plan development, financial feasibility, realisation, and maintenance), and different sectors and professions (public, private, civic actors)" according to Heurkens (2012). Heurkens (2012, p140) stresses that urban governance requires "interaction between the three actor-groups": (1) the State, (2) the market and (3) civic society and is experiencing an emerging urban governance shift over time *(Figure 1.4)*. The shift stated by Heurkens (2012) explains the private sector-led urban development role where property development is led by the market and facilitated by local planning authorities to implement planning and market objectives.



In between The Market and Civic Society an arrow indicates the demand and supply between the actor groups. This interaction indicates the balancing process (van Vliet, van der Voordt & den Heijer, 2004;p) where market actors supply (e.g. energy, housing etc.) and civic society actors demand (e.g. affordability, supply certainty etc.).

Figure 1.4 The interaction between the State, the market and civic society. (Source: Heurkens, 2012; p140)

The important role of the civic society in services such as energy is also discussed by Dóci, Vasileiadou, & Petersen (2015). Individual households in renewable energy generating systems whereas energy generation initiated of households, from community-led initiatives (e.g. energy cooperatives) could contribute to a to the energy transition in the Netherlands (Boon & Dieperink, 2014; Bakker, 2016). According to Dóci, Vasileiadou, & Petersen (2015) scaling up to community level is a more efficient way for producing renewable energy compared to individual actions. Scaling up to the district scale could even bring more economies of scale.

The push through of decarbonization and centralization of heat could result in the involvement of energy management roles in urban development. Especially the social and environmental implementation require consensus and changes in existing urban infrastructure (transmission, distribution) and adaptation of dwellings and buildings (metering, heating installations, energy characteristics) that are owned by different actors. On top of that, implementing renewable heating generating-facilities for the district scale demands for actors that are capable of fulfilling the managerial and organizational roles. Due the shift in power in urban governance mentioned by Heurkens (2012) it is unlikely that the implementation of heating networks will be carried out by public actors solely, which was the case 55 years ago when the natural gas piping infrastructure was laid down and household appliances were adapted by the Municipal Energy Company (GEB). Urban development actors include and manage the roles of energy actors and therefore the role of the different actors involved should be further investigated. The energy management actors can be categorised in the energy source that is provided through the energy supply chain *(Table 1.2).* When analysing the current supply chain of natural gas and electricity there can be concluded that these are highly regulated and the actors involved in the supply processes are predefined and categorised. As a contrast, the roles in the renewable heat supply chain often do not have clear predefined actors. Large companies of non-renewable heat in district networks operate the majority of the supply chain while medium and small sized networks show a separate ownership that operate the processes in the supply chain.

		Gas Supply	*Electricity supply*	*Renewable district scale heat supply*
Processes	***Actor***			
Generation	Production company	The main producer of gas (NAM).	Producer of electricity The production of electricity can be locally, regionally or internationally.	Producer of renewable heat. The renewable heat produced in heating networks only accounted for 25% out of the total supply in 2017. The supply of heating networks fulfils only 5% of the total heat demand.
Trading	Program responsible party	The business trader of natural gas (VEMW)	Stock market exchange of bulk electricity (APX Power spot, ENDEX Dutch power, etc.), sustainable electricity through the exchange of Guarantees of Origin (GO).	Renewable heat is not traded nationally. The trade of heat happens between producers, distributers, suppliers and end-users, on the regional and local scale.
Transmission	Transmission System Operator (TSO)	Manager for the national main transport network of gas (Gasunie Transport Services B.V).	Manager for the national main transport network for electricity (TenneT)	There is not a national main network for heat, but for transmission pipes that are little branched out and facilitate transport over large distances are seen as transmission systems.
Distribution	Distribution System Operators (DSOs)	Manager for the regional main transport network of gas and electricity (Coteq Netbeheer, Enduris, Enexis, Liander, RENDO Netwerken, Stedin, Westland Infra).		A little amount of DSOs distribute heat from renewable sources. The majority of existing non-renewable district heating networks are local or at building block scale.
Metering	Metering company	In the Netherlands the DSOs are responsible for the installation of meters for monitoring gas and electricity		Metering is done by the DSOs.
Supply	Supplier	In 2018 there were approximately 47 energy suppliers active in the Dutch energy market which are categorised in (1) large suppliers (Innogy, Eneco Holding, Vattenfall, NUTS groep, Energie Concurrent BV, ENgie) , (2) independent suppliers (OM, vandebron, zelfstroom) and (3) independent suppliers for the business market.		Large heat suppliers often are affiliate legal entities from the heat producer in existing non-renewable heat networks, while small and medium sized renewable heat suppliers are owned by different companies than the producing companies.
Use	End-user	Households, offices, industry etc.	Households, offices, industry etc.	Households, offices, industry etc.

Table 1.2 *A schematic composition of the different processes and energy actors that are involved in the electricity, gas and heating supply. (Source: Bakker 2016; Keutel,2018; Energievergelijk, 2018; PBL, 2017, p8; ECN, 2017; own design&edit)*

To conclude on the trends noticed, a few remarks can be made. The climate change affects the environment considerably and therefore demands an approach that can be executed on the different spatial levels which requires active roles of actors from multiple governmental levels (supra-national, national, regional and local). The political pressure as a result of the changing climate needs to be implemented through energy strategies and policy on the different government scales to which the market can respond to. The market behaviour is influenced in a way that governments can steer on desired developments, which need further investigation. The growing demand of energy due a growing population emphasizes the need for energy strategies and efforts to reduce the demand and consider the supply. Reducing the energy demand concerns the civic actors and therefore their roles are worth investigating. The shift from heat generation from household scale and building scale to district scale offers opportunities to meet binding climate commitments, but for the technical and financial implication of such systems various actors and disciplines are required. Appropriate district scale heating systems are already being operated by energy managers for a minor share of the total residential stock. When the existing residential housing stock is expected to be connected to district heating networks, it requires the cooperation urban development actors that are capable of fulfilling this task. The power shift from state actors to market actors in urban development, requires appropriate coordination on the execution of tasks that once were state organised and managed and now become market organised and managed. The aforementioned trends demonstrate the need of various actors, disciplines and governmental levels that are accompanied in the transition towards a carbon neutral economy for 2050. The heat generation scale shift mentioned can be executed effectively when the urban area development actors are able to manage the roles in district heating networks and renewable heat generating-facilities. The involvement of actors for performing roles in renewable district scale heat-generating facilities and infrastructure in urban development management is found not fully investigated in the field of urban area development. For so far the trends are elaborated on, the selection on which alternatives fit best is done in the methodology section **(2).**

1.2 Definitions

In order to understand what is meant with terms used in this thesis a short definition list is made. This list is made aims to prevent ambiguity and indistinctness.

Actor. The term actor defined by Heurkens (2012, p57) and will be used throughout the report: *An actor is defined as "an organisation or representative individual that is actively involved" in urban (re)development or implementing heat-generating facilities and infrastructure.* An actor performs an active managerial role in the development.

Agency model. The agency model is defined by Adams & Tiesdell (2012; p. 76) as: *A model that focusses on actors in the development process, the role they play and the interests which guide their strategies.*

Effectiveness. Through extensive literature review the effectiveness is conceptualized and defined by Heurkens (2012, p108) and will be used throughout the report: *Effectiveness is defined as: "the degree to which the cooperation process"* leads to *"achievement of intended public and private actor's objectives and resolved problems".*

Event-sequence model. The event-sequence model is defined by Adams & Tiesdell (2012; p. 76) as: *A model that seeks to specify the various stages of a development project and identify the order in which they take place;*

Geothermal energy. Geothermal energy is defined as the extraction of formation water from the subsurface to heat buildings, greenhouses and the industry, in which the deeper you drill into the earth, the higher the temperature becomes (Ammerlaan-TGI, 2018). The advantage of geothermal energy is that the source is inexhaustible and the production of heat does not rely on fossil fuels.

Geothermal District Heating Development (GDHD). The urban area development in which a geothermal well, district heating infrastructure and necessary adjustments to the building stock are executed.

Integration
The ambiguous term integration in the context of the research is defined as actors becoming part of, disciplines and governance sectors brought together in the geothermal district heating development organisation. Integration management is the management of bringing together actors to act as an organisation as a whole.

Local. Local government can refer to various government scale within a city and is an ambiguous term (Hoppe, Graf, Warbroek et al., 2015). It could refer to the government the building block, neighbourhood, district or city division and even the city itself. To prevent confusion the following scales are used in this thesis:

Household/dwelling scale:	One individual household/dwelling.
Building scale:	A group of households of which the dwellings are connected as one building.
Neighbourhood scale:	A neighbourhood is an urban area that is characterised by multiple building types and functions.
District scale:	A district consists of multiple neighbourhoods. Also known as the municipal administrative division of the urban area (e.g. Wippolder). In this urban scale the 4 digits of the zip code are similar.
City division scale:	A city can be divided in multiple divisions. The term city division will be used to point a city part that consists of multiple districts.

Local Renewable Heat Organisation. Local Renewable Heat Organisations (LRHOs) are defined as: *local organisations where public, private and civic actors cooperate in the generation, consumption distribution, storage or supply of heat from renewable sources, wherein cooperation is seen the working or acting together for the underlying benefit of decarbonising.*

Role: Actors such as local authorities and private-sector actors in urban development play a certain role. A role is defined by Heurkens (2012, p57) and will be used throughout the report:
A role is defined as "a coherent set of organizational tasks and related management measures carried out by actors" that are involved urban (re)development.

Stakeholder: In this thesis the definition of actor is different from the definition of a stakeholder. In this thesis a stakeholder is *a person, group or organisation that can affect or is affected by a business.* From this definition a stakeholder can also be not actively involved in the management but can be influenced by it.

Upscaling: Scaling up is seen as enlarging certain indicators into a larger number or amount of that indicator. *In this research upscaling is defined as the enlargement of the heat supply towards the district scale.* From this definition the single heat-generating facility should be capable of replacing all the individual heat-generating facilities. Upscaling can also refer to scaling up a sector, such as the geothermal sector and therefore will be used in a certain context to prevent confusion. Upscaling the heat supply also affects upscaling of the actor network, dependencies, operational area and other aspects, as the organisation grows.

1.3 Problem

The main challenge were is responded to in this research is the "management of geothermal district heating development in the built environment in the Netherlands". It is found that local authorities endorse efforts to implement energy policies, but face the complexity in networks of various actors, scales and disciplines (Petersen & Heurkens, 2018). Therefore it is important to define 'who' does 'what' in the management of district scale heat-generating facilities and infrastructure development. While scholars and public planners acknowledge the existence of barriers and opportunities of upscaling residential heat to district level (Sandick, 2010; Thorsteinsson & Tester, 2010; Colmenar-Santos, Rosales-Asensio, Borge-Diez & Mur-Pérez, 2015), little literature is found on cases where the existing built environment and infrastructure in the Netherlands is adapted for renewable district heating networks **(1.1)**. This research addresses the knowledge gap on the managerial roles of public, private and civic actors in upscaling residential heat to a district scale from renewable sources. Together the public, private and civic actors can assure the implementation of renewable heat, which is why they can be seen as a large network of actors wherein the dependency of actors defines to what extend decarbonising targets are accomplished.

1.4 Purpose

The main goal of the research is to gain understanding in the local approaches and efforts towards renewable district scale heat-generating facilities in the Netherlands replacing one single household or building scale heat-generating facilities. The research is intended to broaden the understanding of what public, private and civic actors are involved, what their roles and dependencies are in upscaling residential heat to a district level in the existing built environment. The research focusses on how public, private and civic efforts can bring about a local energy transition and is intended to clarify, gather and model the roles in managing district scale residential heat-generating facilities and infrastructure development in the Netherlands and aims to determine the effectivity of such developments.

1.5 Questions

The main research question is derived from trends in energy and urban development. The organisations that perform managerial roles in the development seem to be a solution to stem the GHG emission, but these organisations are minor in upscaling residential heat to a district scale in contrast to organisations that cooperate in acquiring residential renewable electricity. Organizational and managerial barriers are faced by public and private actors when managing development of district heating in the existing built environment and moreover the civic society is becoming more eager to cooperate in decarbonisation measures. Therefore the main research question is as follows:

> *How do public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands?*

The first research sub question concerns a literature review on the managerial roles of public actors in urban development and what means they have at their disposal to implement energy policies. For private and civic actors management it is important to define how the heat-generating facilities and infrastructure are implemented. LRHOs are formed by dependency relations between the actors and therefore it is necessary to investigate in which way this happens. Therefore the first sub question is:

1. *What are the managerial roles & dependencies of public, private and civic actors in implementing energy policies, district scale heat-generating facilities and infrastructure in the literature on urban development of built environment in the Netherlands?*

The second research sub question is an attempt to have an understanding of the current management practices in upscaling the residential heat-generating facilities to district scale. The empirical research performed for this question is intended to define the managerial roles of public, private and civic actors in upscaling residential heat to district scale. The following questions are answered in the empirical research phase:

2. *What are the managerial roles & dependencies of public, private and civic actors in implementing energy policies, district scale heat-generating facilities and infrastructure in the practice of urban development in the built environment in the Netherlands?*

The third research sub question is combining the results of the first two sub questions to clarify, gather and model the managerial roles in implementing residential district heating in the Netherlands and determine which are effective. With effective is meant to what degree the management activities performed by public, private and civic actors "leads to the achievement of intended objectives" (Heurkens, 2012; p107).

3. *What managerial roles are effective for upscaling residential heat-generating facilities and infrastructure to a district scale in the Netherlands?*

1.6 Expectation

After completing the bachelor's and master's courses linked to urban area development with pleasure, my preference was to have Urban Development Management my main graduation theme with sustainable area transformation as a subsidiary subject. In each of the courses, but mainly during the management game course, I was tended to focus on various technical and financial tools available for energy performance and production on an urban area scale. The current energy supply is largely generated from finite sources and fossil fuels that emit greenhouse gasses (GHG's). The legal standards for energy performance for new residential buildings are becoming stricter (2020> NZEB) and the existing stock is subject to the necessary energy performance improvements. There is a trend emerging wherein the residential stock tends to be self-sufficient in various respects. From the perspective of energy, the residential stock is deemed to reduce its energy consumption and is households are sometimes even attracted to produce (renewable) energy. While there is a strong demand in residential markets, particularly in already urbanised parts of the country, there also is a growing demand for energy. The key challenge in the urban development is the energy transition towards low-carbon cities by 2050. I therefore see an opportunity to deepen my understanding of and propose solutions for the energy transition for existing dwellings in urban areas.

An analysis of the public, private and civic actor roles in GDHD can provide an understanding in the dynamic patterns of an energy transition. 'Implementing agents' such as households, have potential to participate in energy cooperatives and could represent a larger number of households, so the decision making process to implement is eased and more democratic. The intervention of intermediaries and change agents could be the missing link in the cooperation between actor groups.
For both private actors and local authorities this research on actor involvement can contribute to effective management of upscaling residential heat-generating facilities to a district scale. Therefore this research can contribute to the pace at which the energy transition towards a larger share of renewable heat production in the Netherlands takes place. Insights and analysis of cases where the built environment is adapted could inspire the housing sector from (member) magazines for home-owner unions and housing association newsletters. Whereas national, regional and local authorities can adopt strategies and utilise effective management tools to steer on the energy transition, 'implementing agents' such as private actors and households can cooperate to adapt the built environment.

1.7 Readers' guide

As a readers guide there is chosen to provide an overview of the sequence of chapters:

- Part I (Chapters 1-2): Introduction of the research, discussing trends, definitions, problems, purpose, expectation and research questions.
- Part II (Chapters 3): Examines the literature on urban development actors and identifying the roles of public, private and civic actors in urban development management, implementing heat-generating facilities and infrastructure.
- Part III (Chapter 4): Covers a study of two cases on the roles of public, private and civic actors managing geothermal district heating development (GDHD).
- Part IV (chapter 5): Explores the roles effective for upscaling GDHD using expert assessments.
- Part V (Chapter 6): Considers the results of the research in the conclusions, reflects on the research and discusses the recommendation for further research.

2. Research methodology

Well begun is half done: without proper methods a research can easily fail. The research methodology is elaborated on in this second chapter to explain what techniques are used to find answers to the main research question and research sub questions. The main research question is supported again and is as follows:

> *How do public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands?*

The main research question is a response to the trends that are mentioned in literature **(1)**. This question tends to answer ("how to") operation-related problems, but the research can be classified as 'empirical' since the question is knowledge-related (Barendse, Binnekamp, De Graaf, Van Gunsteren & Van Loon, 2012). The goal is to understand managerial roles on urban area development with upscaling residential heat in particular (theory) but also to aims clarify, gather and model the (effective) managerial roles in urban area development with upscaling the residential heat provision in particular from practice (empirical). Since the research question can be classified as empirical, empirical research methods are used to come to an answer to the main research question, but literature research is needed to support the empirical research. The first steps to come to an empirical research method is treated in the approach section of this chapter **(2.1).** After expansion and refinement of the former steps a final research design **(2.2)** is made, which also functions as a navigation pane for the thesis. The research design is made to clarify how and by which means the answers for the main and sub questions are acquired. After the research design section there is further elaborated on the instruments that are used for data collection **(2.3)**. Subsequently a selection based on two-level purposive sampling method is applied in order to make a selection of cases and participants **(2.4)**. The semi-structured interviews are administrated using phone, email, recordings and transcripts **(2.5)**. In order to process all the data that is acquired using data-collecting instruments, a broad selection of instruments for data processing is used **(2.6)**

2.1 Approach

An approach for empirical research is chosen. The steps followed in an empirical research process *(Figure 2.1)* are defined by Kumar (2011) as:

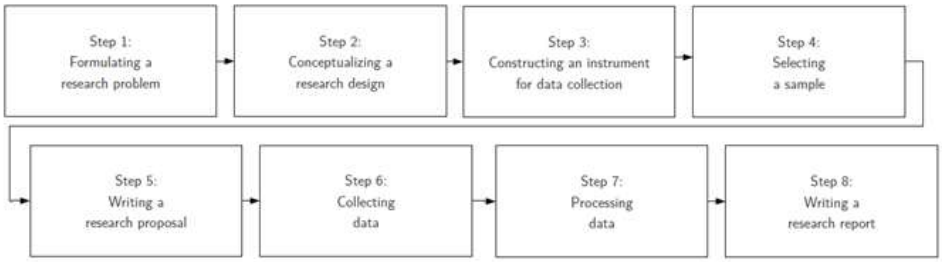


Figure 2.1 Steps of an empirical research process (Source: Kumar, R., 2011 p. 22, own edit)

The research framework of Kumar (2011) follows eight steps in chronological order and was the basis to find out how to come to a research. The steps were a research design, instrument for data collections, selection of a sample and data processing tools are suggested are refined further in this methodology section.

2.2 Design

A research design *(Figure 2.2)* is made to link the research methods, research sub questions and phases. There is chosen for three phases because the is always literature needed for a base understanding of a topic. The empirical phase is there to understand how management is performed in practice and the synthesis phase is needed to conclude on the findings. The arrows indicate the direction in which the research takes place: the output of each phase is the input for the next phase. In the first phase a literature study is performed on theories to answer the first research sub question. In the first phase is attention is paid to urban area management perspectives where theories concerning management through levels and management through aspects is elaborated on. The literature phase comprises chapter three. In the second phase the actor analysis **(2.3.1)** acts as a backbone to clarify the actor roles and dependencies in the empirical study. The empirical phase consists of two chapters. In chapter four a case study is executed in which various data processing tools are used in combination with an actor analysis. A case study **(2.3.2)** is the best choice since the demarcated subject of the study **(2.4)** is not yet performed in literature. Having multiple cases comparison between the cases is possible from which conclusions can be drawn about the similarities and differences of two projects that were completed by performing a cross-case analysis **(2.6.4)** further in the chapter. The second part in the empirical phase, accommodated in chapter five, is the Delphi study **(2.6.5)** that functions as verification of the findings and assessment of the effective roles in the management of upscaling residential heat, which is questioned in the third research sub question. This method fits the research best because experts know the best how management is performed in practice and by using this method consensus on findings is reached. In the third phase, the synthesis phase, conclusions are made based on the findings, a reflection of the process and methods is made and further research suggestions are elaborated on in the discussion section.

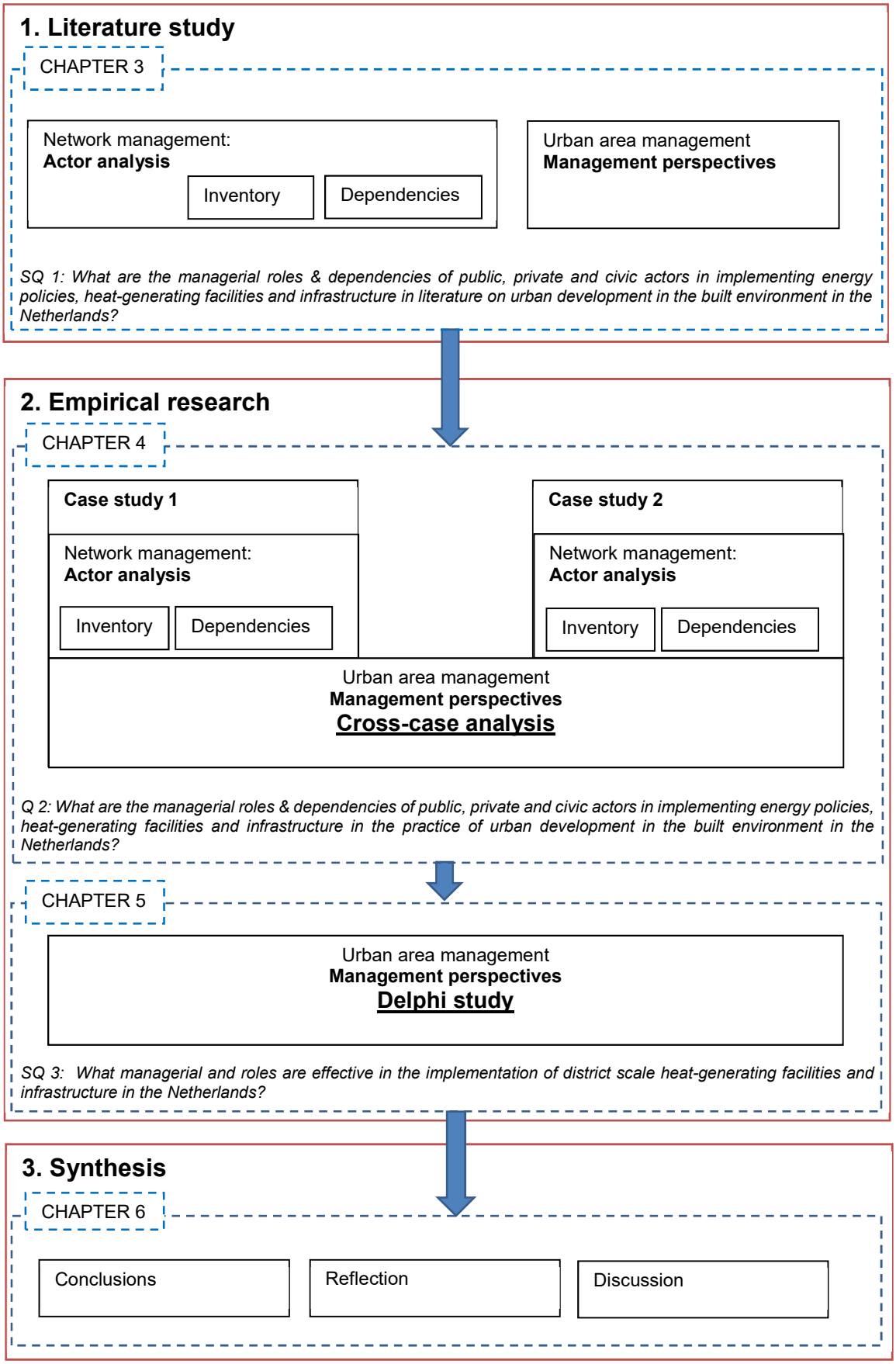


Figure 2.2 Research design (own illustration, inspired by Heurkens, 2012; Veenhof, 2018)

2.3 Instruments

As mentioned in the research design there are multiple instruments used for the collection of data in order to find answers to the main research question and research sub questions. Instruments for data collection are important tools to acquire the desired data which can be processed **(2.6)** such that it leads to clarifications. The first instrument to gather actor specific information and dependencies about public, private and civic actors is an actor analysis **(2.3.1)**. The actor analysis is used in the literature phase as well as in the empirical phase. The second tool to acquire information is the case study **(2.3.2)** method in which two cases provide information concerning the roles and dependencies of public, private and civic actors in practice.

2.3.1 Actor analysis

The data collection instrument that is used to analyse actors involved in upscaling residential heat-generating facilities is the actor analysis based on Koppenjan & Klijn (2004). In an actor analysis defined by Koppenjan & Klijn (2004; p134) "the actor field involved in a problem situation" is mapped. Determining who the most important actors are, what problem perceptions they hold and what their position is regarding the problem are the first steps of an actor analysis (Koppenjan & Klijn, 2004; p135). The actor analysis fits the aim to gain understanding in the local approaches and efforts managing district scale heat-generating facilities and infrastructure in the Netherlands. In this thesis the actor analysis is supported with additional processing tools **(2.6)** for to clarify and model the actor roles. Other theoretical frameworks such as the supply chain framework may limit the research since it demonstrates subsequent processes and underexposes the mutual relations and dependencies between actors. The analysis of public, private and civic actors and their interdependencies are intended to be analysed and therefore the actor analysis of Koppenjan & Klijn (2014) suits the research most. The limitations of the actor analysis are that the relations between actors are only investigated onto a certain extent. It does not provide solutions to network problems, improvements for stagnation of interactions between actors or for institutional rules of the game. However the framework fits the research because it can provide insights in the relations that exist between actors and what means are being used. From that it can provide opportunities for strategic choices and insight into possible obstacles for certain initiatives (Koppenjan & Klijn, 2014; p158).

The starting point in the actor analysis is the determination of the problem: management of developing district scale heat-generating facilities and infrastructure in the built environment.

The second step is the inventory of actors: the actors involved in urban area development and actors involved in district heating development. Hereby the actors actively involved in, have the means to, have the knowledge of, are expected to be involved or are affected by urban area development and district heating development regarding the existing built environment are identified using literature. As a starting point the State-Market-Society triangle is used to categorize the actors. To deal with the problem of "compound actors" (Koppenjan & Klijn, 2004; p139), the relevant units involved within a compound are tried to be labelled as a separate actor (e.g. for civic actors all relevant civic actors will be seen as a separate actor). By doing so, the information quality of the analysis is enlarged, but could form clutter when separated too much.

The third step in the analysis is making an inventory of the problem perceptions, determine the objectives and interests of actors (Koppenjan & Klijn, 2004; p140). From literature general problem perceptions are acquired from all the actors involved but there is a risk that perceptions are not corresponding with the real actor perceptions. Therefore the objectives and interests of the inventoried actors from literature are generally determined by actor categorisation. Since the research has a management perspective the term 'objectives' used by Koppenjan & Klijn (2004) will be replaced by the term 'roles' to describe "a coherent set of organizational tasks and related management measures" as defined by Heurkens (2012, p57). In the first phase of the research the roles and interests are based on literature but due insufficient deepening or categorisation additional actors could be involved in the cases. For that reason the interests and objectives of the actors involved are open for reconstruction.

In the fourth step of the actor analysis, the positioning of actors determined by the means and dependency relations between actors. According to Koppenjan & Klijn (2004; p144) the dependence between the actors can be viewed by looking at the types of resources actors have at their disposal to perform their role. For this the theoretical framework on managerial roles as defined by Heurkens & Hobma (2014) is utilised to process the information **(2.6)**.

2.3.2 Case study

The second instrument that is used for data collection is case study research because it focuses on the 'how' and 'why' of contemporary events as written in the main research question. In case study research the aim is to study the selected case in depth (Bryman, 2012; p12) & will be selected on the basis of criteria **(2.4)**. The trends analysis **(1.1)** shows that there is much to find about district heating as heat-generating facility, but uses natural gas as a source. The management of actors in the cases that are selected are not discussed in literature as such yet, which is why these cases are revelatory. The revelatory case exists when there is an "opportunity to observe and analyse a phenomenon previously inaccessible to scientific investigation" (Yin, 2009; p48). There is a choice for using two cases that are individually analysed with an actor analysis and actor dependency analysis **(2.3.1)**. Using uniform analysing tools prevents comparing apples and oranges. In the case study data concerning the actors will be acquired from semi-structured interviews, document studies and symposia **(2.5)**. According to Yin (2012) the limitations of such case study research is that the results cannot generalize the outcome for the whole population but noted that case studies are generalisable to theories. Another limitations is the selection of Dutch cases in which important findings from international examples from which can be learnt from are lacking. However, the danger of comparing international cases is the limitation of policy transferability, development behaviours and path dependencies in different countries (Squires & Heurkens, 2016)

2.4 Selection

A selection of cases is made to demarcate the research topic. In this qualitative research purposive sampling is chosen over probability sampling: interviewing all the people participating in all heating alternatives would add a great deal to the time and cost of doing research. To deal with this problem is to employ purposive sampling (Bryman, 2012; p416) in which a selection of cases is made based on criteria. Purposive sampling is utilised in levels (Bryman, 2012, p417): in the first level **(2.4.1)** the cases are sampled by context and in the seconds level **(2.4.2)** sampled by participants.

2.4.1 First-level sampling

As mentioned before, decision making between the alternatives for heat depends on many variables **(1.1)**. Selection criteria should guide the research towards solutions to the problem statement of the implementation of renewable heat for decarbonisation purposes. In first level sampling the following criteria are used:

1. Renewable and climate neutral: The energy that is produced must come from renewable heating sources and should not emit GHGs.
2. Scale and capacity: The heat source must be able to provide heat on a district scale since the other options (e.g. all electric and green gas) found less effective already **(1.1)**.
3. Urban redevelopment: The developed district heating network is an urban redevelopment project in which infrastructure and existing dwellings were adapted. This criteria is made in order to draw lessons from adjustments to the existing built environment.
4. Competitiveness: The Leveled Cost Of Energy (LCOE) must be competitive with fossil fuel sources.
5. Project phase: The project must have been operational, so to say there is already heat delivered to dwellings and used for space heating and water heating in the Netherlands.

In order to weigh the alternatives on the aforementioned criteria a table is made where the 'x' marks when the selection criteria is met *(Table 2.1).* The reason to incorporate this criterium is that higher efficiencies, economies of scale and more heat storage possibilities can obtained (Agrel & Bogetoft, 2005; Powell, Sriprasad, Cole & Edgar, 2014).

Alternative	Category	Source	Selection criteria*				
District heating			1	2	3	4	5
	2nd generation Pressurised high-temperature water systems (>100 C)	Industrial waste heat	x	x		x	x
		Biomass		x		x	x
		Combined Heat Plant (CHP)		x		x	x
		(Ultra) Deep geothermal	x	x		x	
	3th generation Pressurised medium-temperature water systems (<100 C)	Industrial waste heat	x	x	x	x	x
		Waste-to-energy		x	x	x	x
		Biomass		x		x	x
		Combined Heat Plant (CHP)		x		x	x
		Deep geothermal	x	x	x	x	x
	4th generation: Low-temperature water systems (~30-70 C)	Low-temperature waste heat (data centers, greenhouses, supermarkets, etc.)	x	x	x	x	x
		Water (Sewage)	x		x	x	x
		Deep and Shallow geothermal	x	x	x	x	x

Table 2.1 An overview of alternative energy purposes for heating dwellings and selection criteria (Source: Energy Storage, 2018; Keutel, 2018, Sayegh, Jadwiszczak, Axcell, Niemierka, Bryś & Jouhara, 2018; own edit).
** 1=Renewable and climate neutral, 2=Scale and capacity, 3=Urban redevelopment, 4=competitiveness, 5=project phase*

The research is delineated on one heat source to do research on. The alternatives are now compared and evaluated. The district heating of the 3th generation (industrial waste heat and deep geothermal) and 4th generation (low-temperature waste heat and shallow geothermal) categories meet the selection criteria. According to the research IRENA (2018b) the energy sources geothermal and biomass are competitive with fossil fuels when looking at the Levelled Cost of Energy. While there are cases where there are existing district heating networks on industrial waste heat (e.g. Maasvlakte Rotterdam) and Waste-to-energy (e.g. Westelijk havengebied Amsterdam), these did not became operational after adaption of existing dwellings (yet). As mentioned before, only 25% of the existing district heating networks are actually from renewable sources. Whether biomass is renewable is questioned: it contributes to depletion of natural resources and deforestation, although some of the woods chips utilised in the plant are acquired from sustainable forest management from the Foresty Commision (Staatsbosbeheer). It is also questioned whether low temperature water systems – which requires high energy performance buildings - are actually capable to fulfill the heat on district scale since different neighbourhoods in districts could have a broad range of energy performances of buildings. The advantage of 3th generation district heating over the 4th generation is the larger applicability over the existing dwellings that have a variance in energy performance. Just as in industrial waste heat and waste-to-heat alternatives, cascading heat offers the supply of a broad range of temperature which increases the system efficiency (Fang, Xia, Zhu Su & Jiang, 2013). Therefore, deep geothermal heat as a source is worth investigating, so a broad range of the existing building stock with various energy performances could be supplied with heat, with or without cascading. Because there are multiple sustainable solutions a choice is made based on interest and literature gap. In Keutel (2018) is shown that low temperature waste heat for residential purposes is already investigated.

This leaves the research demarcation on context criteria to deep geothermal energy as weighted alternative to household scale and building scale heat generating-facilities. But what is geothermal energy and how does it work?

In geothermal energy, hot water is extracted from the soil to heat buildings, greenhouses and industry. The deeper you drill into the earth, the higher the temperature becomes (Ammerlaan-TGI, 2018). The temperature >70 C is reached beyond a depth of 2.1 km at the location of Ammerlaan in Pijnacker-Nootdorp.
In order to extract the heat from the soil, the water that is stored in sand layers at the aforementioned depth is escaping due the heat and pressure. The extraction of geothermal water is normally done using two wells connected to the surface by two doublets. The hot water is pumped up via the first well and passed through above-ground heat exchangers. The cooled water that has been used for heating buildings is pumped back into the soil and is warmed up again due the constant heat at 2.1 km depth and can be re-used at a later stage.

Figure 2.3 An image of a geothermal drilling rig during the construction. To reach the 70 C formation water at depth of 2.1 km, extensive drilling is required (Source: Energieoverheid, 2016).

There are actually very little geothermal projects finished and operational that fulfil the residential heat demand in the Netherlands. Although two cases have been found to perform a case study and cross-case analysis on: Ammerlaan **(I.)** & Haagse Aardwarmte Leyweg **(II.)**. The first case was found on the website of VB-group, which is an conglomerate of various specialisms in (agricultural) technology, of which the companies operating independently, but benefiting from sharing their expertise on a regular basis (VB-group, 2018).

Ammerlaan	**Haagse Aardwarmte Leyweg (HAL)**
 *Figure 2.4 Geothermal plant Ammerlaan (Source: Energievastgoed, 2016)*	 *Figure 2.5 Geothermal plant HAL (source: energienieuws, 2017)*
Ammerlaan invested in a geothermal heat source in 2010. This made Ammerlaan the first floriculture company in the Netherlands with a geothermal heat source (Ammerlaan-TGI, 2018). In 2012, Ammerlaan negotiated with the municipality of Pijnacker-Nootdorp and the housing association Rondom Wonen about supplying 16 apartment buildings consisting of 470 apartments with geothermal heat to improve the current heating method (Hierverwarmt, 2018).	From 2018, the HAL will supply the district Southwest with sustainable heat from wells that are more than 2 km below ground level. The geothermal heat project is making a relaunch since the company HAL took over the two doublets that were drilled in 2010 (Energienieuws, 2017). The project is unique since it is the first inner-city geothermal plant in the Netherlands.
Important actors: Ammerlaan B.V., Municipality Pijnacker-Nootdorp Housing association Rondom Wonen.	*Important actors:* Municipality of the Hague, Haagse Aardwarmte Leyweg (HAL), Hydreco Geomec B.V. Perpeetum Energy Partners B.V. (PEP) & Energiefonds Den Haag C.V. (ED)
Status: Operational from 2010-2017	*Status:* Operational in 2020

2.4.2 Second-level sampling

For the second level sampling, the participants (Bryman, 2012; p417) in the cases are selected based on the actor group where they belong in. There is no second-level sampling made on the documents for data-collection, because excluding documents could limit the findings of results. Heurkens (2012) defined the three actors groups in urban governance which are going to be used as criteria in the selection of interviewees. At first the private actors who developed the project are going to be interviewed and snowball sampling will be applied (Bryman, 2012; p424). In snowball sampling the first participant can propose other participants, from the actor groups that are relevant for the research. In the Ammerlaan case the developer in the project, Leon Ammerlaan is asked to cooperate in the research. Contact information of the housing manager of the housing association Rondom Wonen was acquired by snowball sampling. After repetitive request for cooperation from the Municipality of Pijnacker-Nootdorp, I failed to come in contact. Therefore Municipal documents, such as council meetings, that where published at that time are consulted. Desk-research led to the discovery of the involvement of TU Delft in the Ammerlaan project. By contacting the guest speaker of the DAP symposium, Phil Vardon at on April 16th, contact information of Wolf, K.H. was acquired, who's students were involved in the Ammerlaan project that time. In the HAL case the developer Hydreco Geomec was contacted first and the other involved private actors where contacted from publicly available contact information. Document studies were performed on Municipal documents, because in both cases there was little interest in cooperating in the research. Interviews with the Municipal actors were lacking so the research limitation is that acquired information from Municipal documents is not verified by Municipal workers (triangulation).

2.5 Administration

For the case study interviews are being held to gather actor information from actors. The interviews are being held face-to-face, by email or by phone, depending on what measurement method is preferred. The interviews are being recorded by means of a microphone and digitally stored. Later a transcript is made, but is left out of the report for privacy reasons. Out of the recorded interviews and relevant data the report is made up and verified by the actors that were interviewed. Concepts are derived from the theoretical framework **(2.3)** for an actor analysis. The interview questions will be based on actor identification, positions and dependencies. These concepts are ordered in an operationalisation scheme to define the open questions for the semi-structured interviews *(Table 2.C).*

Actor analysis	Questions	
Identification	To what extent is the actor involved in the project? In what project phase(s) was, is and will the actor be involved? What are the goals the actor want to achieve in this project? Which actors in the actor network are important to realize the goals in the project? Which other actors have interest in the project?	
Actor positions and dependencies	What means/ instruments does the actor have at their disposal in the project (in order to solve managerial/organizational/cooperation problems? What are the important means? When or in which phase are these means used? Is the actor dependent on other actors in the project? To what extend?	
Event analysis	What were important events during the period that the actor was active, considering the project development phases.	

Table 2.2 An overview of the concepts and questions related to the actor analysis (Source: Koppenjan & Klijn, 2014, own edit)

These questions relate to the sub question as they define the roles actors have in the development. The operationalisation scheme is used as a guidance during the interviews, but is limited because of time. Additional document studies are performed to acquire all the information about the cases. To prevent the problem of accumulation of transcript data in the appendices of the thesis there is chosen not to include these in the appendices for two reasons. The first reason is that the majority of the interviewees did not want to have all the transcript data published. That brings us two the second reason: privacy. Specific case information is collected from aforementioned instruments and processed **(2.6)**. After the actor analysis and dependency analysis is made from case information, a verification by the interviewees is requested to ensure correctness.

2.6 Processing tools

An ounce of prevention is worth a pound of cure: without the right processing tool it might be very hard to digest all the information available. When all the information is gathered, through the actor analysis and case study, the information is processed to a desired output. The aim of processing data is to shape it into an output that can be used for clarification purposes. In both the literature study and empirical study the actor analysis is performed in order to create coherence during the research. There is chosen to use various processing tools in the actor analysis on which is elaborated on in this section. At first, when the actor inventory and actor dependency analysis is being made, it is important to have an overview of the organisational and managerial roles, aspects and variables **(6.2.1)**. There are many documents to be found that describe the initiative, planning, realisation and operation phases of the projects in the cases. To have an overview of al the activities in the cases in a logical order an event-sequence model **(6.2.2)** is used. After the actor inventory, the dependency of actors is supported by an agency model to arrange the actor positions **(2.6.3)**. As important part of the case study, a cross-case analysis **(2.6.4)** is performed to match patterns between cases **(2.6.4).** Verification of the literature and empirical study concerning the management aspects are verified by conducting a two-round Delphi study **(2.6.5)**.

2.6.1 Framework on organisational and managerial roles

In the research of Heurkens & Hobma (2014) organisational and managerial roles of actors were conceptualised on the basis of different management and organisation theories. It is thought that this leads to “a more comprehensive perspective on, and understanding of, actor roles” according to Heurkens & Hobma (2014, p356). For that reason the framework on organisational and managerial roles, aspects and variables is used in the analysis on actor dependencies in the cases *(Table 2.3).*

Roles	Aspects	Variables
Organizational	Organizational	Tasks, responsibilities
	Financial	Risks, revenues
	Legal	Rules, requirements
Managerial	Project management	Initiating, designing, planning, operating
	Process management	Negotiating, decision-making, communicating
	Management tools	Shaping, regulating, stimulating and capacity building
	Management resources	Land, capital, knowledge

Table 2.3 The organisational and managerial roles in urban area development (Source: Heurkens & Hobma, 2014).

According to Heurkens & Hobma (2014; p355) the roles performed use “a combination of organisational and managerial roles” to realise urban projects. Also, the organisational role division in close public-private cooperation is often unclear and less separated then theory suggested according to Heurkens & Hobma (2014; p359). Nevertheless, the roles that certain actors have in the development are identified and discussed in the dependency analysis of each of the cases.

2.6.2 Event-sequence model

In an actor analysis it is necessary to structure the development that is carried out by actors in the different phases. According to Adams & Tiesdell (2012; p75) an event-sequence model can be used as a real estate development paradigms to categorise the process in order to ‘reduce the complexity’ of real estate development. The data that is acquired through the actor analysis can be processed such that the several development stages of the project are recognised and the order in which activities take place by which actors can be identified. The structuring of events and tasks is necessary to show actor involvement in managing upscaling residential heat. The even-sequence model will consist of a tabulation where task number, name of the activity, main tasks, time(-span) and involved actors are mentioned. The event-sequence model is used at the inventory section of the case study **(4)** in the empirical phase.

2.6.3 Agency model

After an inventory of actors is made with an actor analysis and supporting event-sequence model, the positioning and dependency relations between actors are analysed. In order to position roles of public, private and civil society actors in urban (re)development management an agency model is used. The agency model is a ‘diagrammatic representation’ as defined by Adams & Tiesdell (2012; pp 75-76) and is used to show ‘essential components’ involved in urban development process. The visualisation of the actor dependencies with the agency model fits the intended purpose of gathering and modelling the actor positions and their dependencies. The agency model shows the actors and their roles in boxes, while the dependencies between actors are shown with an arrow. The single arrow can indicate an exchange of multiple dependencies: exchange of money, information and knowledge and mutual agreements. These arrow is labelled with a character (a-x) which is referred to from the text. The agency model is used in the dependency analysis of the case study to explain the dependency relation between actors supported by the framework on organisational and managerial roles **(2.6.1)**.

2.6.4 Cross-case analysis

As a processing aid for the comparison of cases in the case study a cross-case analysis **(4.3)** is introduced. The cross-case is an analytical technique that has the aim to match patterns (Yin, 2009) and can be applied when there are two or more cases. According to Yin (2009; p156) an increase of cases “could strengthen the findings even further”. The aim for the use of a cross-case analysis is to define similarities and differences in the cases. According to Yin (2009: p156) individual data from the cases need to be displayed according to “some uniform framework”. For an uniform framework there is chosen to devote this to management aspects **(3.4)**, considering the management emphasis in this report. From management aspects relevant topics are elaborated on in each case, supported by former used analytical instruments and processing tools that clarified, gathered and modelled actor roles. The comparison of the important similarities and differences are the results of the empirical findings from the cases.

2.6.5 Two-round Delphi study

For the validity of the results from the empirical findings experts can be asked make a judgement (Bryman, 2012; p.171). Therefore an Delphi study **(5)** is being held, in which experts are able to assess statements that are based on literature **(3)** and empirical findings **(4)**. The Delphi technique is a method for combining opinions of a group of experts on selected subjects (Hsu & Sandford, 2007; Jones, 1975). The selected subjects are the management aspects money, organisation, time, information and quality of GDHD. The technique is characterised by anonymity of the experts involved to reduce the effect of dominant individuals (Dalkey, 1972) so all voices and perspectives can be heard. Although the aim is to verify the findings from literature and empirical study, the use of the Delphi technique exposes assumptions or information leading to different judgements, educates the respondent group on the different topics and makes it possible to correlate the judgements (Hsu & Sandford, 2007), which is needed to have a grounded conclusion. Instead of four iteration rounds and questionnaires normally being held in a Delphi study (Hsu & Sandford, 2007), a modification is made in which statements (that are the result of intensive literature and empirical study) are used. In two rounds in which experts are able to respond to statements is found acceptable (Kerlinger, 1973 as found in Hsu & Sandford, 2007) because it still leads to relevant findings to the management aspects in relation to GDHD and offers the expert the opportunity to respond on the outcome. The actors nominated for participation need to be familiar with the particular issue (Ludwig, 1994: Jones, 1975; Anderson, 1993 as found in Hsu & Sandford, 2007, p3). Therefore the involved experts for the assessment of the statements are actors in geothermal district heating development: policy advisors from the Municipality and Province, geothermal developers and operators, housing organisations, researchers from TU Delft and area development managers. In the second round the judgements of experts are summarised and returned for feedback by the experts. The limitation of a two-round Delphi study is that consensus might not be reached because less iteration round are being held. Therefore it is tried link conflicting arguments to variables necessary for that argument to be true.

3. Literature study

In the first phase a literature study is performed. The purpose of this chapter is to position the research within urban development and identifying the roles of public actors, private and civic actors in urban development management and heat-generating facilities and infrastructure. The characteristics of spatial development and area development are that many different actors from different disciplines are involved. In order to understand the actors and their roles in urban (re)development – specifically in implementing heat-generating facilities and infrastructure – a literature study on urban development actors regarding Geothermal District Heating Development (GDHD) is performed. At first GDHD is positioned in urban development management **(3.1)**. In the second section of this chapter, an inventory of the relevant public, private and civic actors, their roles and their means are defined **(3.2)**. Third, the dependency relations and cooperation between actors and roles actors are defined and envisioned using an *agency model* **(3.3)**. The follow up on the literature study focusses on the perception on management of GDHD through levels and through aspects **(3.4)**. Conclusions on literature are included and briefly evaluated **(3.5).** At the end of the literature study the complete research model and conceptual model is added **(3.5)**.

3.1 Position

Urban development is unique in its scale as it is positioned between development at city scale and parcel and building scale (Daamen, 2005). While developments on parcel and building scale are considered real estate development, the city, regional and national scale are considered spatial planning, so urban development management is found a multifunctional task (Heurkens, 2017c; p4). The main characteristics of urban development are the public-private actor involvement and integrated management orientation (Heurkens, 2017c; p13). While real estate development is defined by Adams & Tiesdell (2012; P94) as an 'intensely social process' where the interrelation between people determines outcomes. Real estate development is characterized by a sector-division (while mixed-use also exists) and has primarily private actor involvement with a financial and management orientation (Heurkens, 2017c; p13). Having spatial planning combined with real estate development demands a multi-dimensional approach. Looking from a management perspective to urban development, Bruil, Hobma, Peek & Wigmans (2004) found that urban development demands aligning of and steering on different spatial levels (national, regional, local, district, area and parcel) through the different phases (initiative and planning, location preparation, realisation, exploitation and operation), integrating the different governance sectors (spatial planning, economy, education and culture) and disciplines (architecture, real estate, planning, law, public administration etc.).

Developing heat-generating facilities and infrastructure to provide dwellings of heat can be positioned as urban development management since it tends to seek for an integrative approach at the city, district and area scale through the different phases integrating specific governance sectors and disciplines. The elements of district heating networks and facility all fall under different subclasses of real estate as defined by van Vliet, van der Voordt & Den Heijer (2004): infrastructure (civil and hydraulic sector), functional real estate (residential and commercial) and the facility itself is characterized as industrial real estate. In the case of geothermal heat-generating facilities even mining as real estate division is touched upon.

3.2 Inventory

An inventory of actors, roles and their means in urban development management is made. In the first subsection of the chapter **(3.2.1)** the roles of public actors in urban (re)development is discussed as well as how is steered on implementing energy policies. In the second section of the chapter **(3.2.2)** the roles of private actors in urban (re)development are explained. In the third section **(3.2.3)** the roles of civic actors are discussed.

3.2.1 Public actors and management tools

The relevant public actors in urban development concerning district scale heat-generating facilities are considered The State and Ministries **(3.2.1.a)**, the Province **(3.2.1.b)** and the Municipality **(3.2.1.c)**. Their main roles have to do with consumer protection, social aims and licencing safety, construction and environmental issues (RVO, 2014). Important in the inventory of public actors, roles and their means is a categorisation of the management tools that are at their disposal to steer on urban development. Adams & Tiesdell (2012) define four types of management tools to shape, regulate or stimulate market behaviour or build capacity. These instruments are used to induce market behaviour towards desired outcomes by public actors. The categorisation of the instruments is relevant for understanding the management tools carried out by public actors in urban development projects.

3.2.1.a The State and Ministries

The State of the Netherlands is a parliamentary democracy in which the rule of law applies. This means that the state is bound by its own laws and this protects citizens against arbitrariness. The Netherlands is decentralized (Hobma & Jong, 2016), but also a unitary state, so local authorities are subject to the provisions of higher authorities. Provinces and municipalities carry out many tasks in commission and according to the rules of the higher government (Oosten, 2009). The general provisions are laid down in legal norms and partly in stipulations and informal administrative consultations. Examples of the legal norms that are adopted by The State are Constitution, Law (in a formal sense), Order in Council (Dutch: Algemene Maatregel van Bestuur) etc..

The roles of the State and ministries in heat exchange projects are licence granting, consumer protection, surveillance and enforcement of environmental law and execute sustainable policy according to RVO (2014; p11). By means of management tools, primarily shaping and regulating tools are found with which the State and Ministries influence market behaviour. In Environmental Law the Spatial Planning Act, Order in Council, The Building Decree and Crisis and Recovery act are important regulations adopted by The State (Hobma & Jong, 2016). With respect to regulation concerning heat the Dutch heat Act is an example of where rules regarding consumer protection are laid down. In this Act, the utility costs that come along with heating the dwellings (heat tariffs) are determined by the Authority for Consumer and Markets (ACM). Due to the fact that there is no market competition between heat suppliers, the ACM sets maximum heat tariffs that suppliers are allowed to charge for fixed-costs, variable tariffs (in € per GJ) and one-off connection fee (ACM, 2019).
Besides shaping and regulating tools, stimulating tools for development and sustainable energy production exist, executed by The Netherlands Enterprise Agency (RVO) which operates under the auspices of the Ministry of Economic Affairs and Climate Policy (RVO, 2019). RVO stimulates entrepreneurs in sustainable business by funding and networking,

3.2.1.b Province

In the Netherlands the regional government is divided among 12 Provinces, each consisting of the Provincial Council (Dutch: Provinciale Staten), Provincial Executive (Dutch: het College van Gedeputeerde Staten) and the King's Commissioner (Dutch: de Commissaris der Koning) according to Hobma & Jong (2016; p6).
The Province has many roles (which are their assigned interest defined by law) such as making structure visions, translating spatial policy of the central government to the regional level, planning municipal expansion, developing plans for road, rail and industry and is also responsible for development and maintenance of Provincial roads, bicycle roads and bridges (Louw, van der Krabben & Priemus, 2003). Important in planning municipal expansion is solving planning issues that cross municipal boundaries (Louw et al., 2003). According to Hobma & Jong (2016) the Province also assesses the abidance of Environmental law and has the supervision over the Municipalities and Water authorities.

The general tasks of the Province in heat exchange projects are licencing environmental permits (e.g. water extraction), supervision and enforcement of permits to reduce environmental risks and executing a sustainable policy according to RVO (2014). To what extend the Provinces are involved in the development of heat-generating facilities and infrastructure varies. The Province of South Holland is considered active in the development and realisation of heating infrastructure as they work from a "shaping role" on further development of heating networks (Provincie Zuid-Holland, 2019).

One of the management tools to shape markets is the publication of plans (Adams & Tiesdell, 2012). The Province fulfils the obligatory role to propose development plans and does that by drawing up structure visions that contain the development plans of (a part of) the Province and by adapting General rules in the Provincial Bye-Law (Hobma & Jong, 2016; p67-68). The Provincial structure visions and General rules are examples of provisions that not only affects the market but also the local authorities. For instance, when the Municipal Executive grants an environmental permit the Province is allowed to appeal if these are in conflict with the General rules. In urban development the Province in the Netherlands is able to use stimulus tools such as subsidies, guaranties and capital-raising instruments (Provincie Zuid Holland) as identified by Adams & Tiesdell (2012; p134). These aim to encourage both public and private sector developers, to undertake development projects on sites with the aim to promote development. Capital-raising instruments can be deployed from a revolving energy fund (Provincie Zuid-Holland, 2019).

3.2.1.c Municipality

Important roles of the Municipality concern the creation and enlarging of the public values and uses policies and programs to achieve this according to van Gameren (2011). These values can be of social, economic, and environmental nature such as the aims for more employment and environmental quality according to (Daamen 2005; p30; Schilling, Burger & Schep, 2018; p40). Concerning urban development The municipality has a division of tasks that are carried out by the several municipal bodies. Hobma & Jong (2016; p136) define the civil servants (Dutch: Ambtenaren), public servants, city architect, External Appearance Committee (Dutch: Welstandscomissie), Local Building Control (Dutch: Bouw- en Woningtoezicht), Town Planning Consultant, Town Planning Department. Actors can fulfil multiple roles and roles can be fulfilled by multiple parties (van Vliet, van der Voordt & Den Heijer, 2004; p82). In urban development the Municipality can act as building contractor, funder, infrastructure provider, investor, land developer, landowner, occupier, parcel developer, politician and regulator according to (Adams & Tiesdell, 2012; p131).

The Municipality as infrastructure supplier concerns the supply (and maintenance) of certain municipal services and public facilities such as public municipal roads, sewerage, public lighting etc. (Hobma & Jong, 2016; p48). Notably, the actors involved in the electricity, gas and heat supply chain are found to be private actors *(Bakker, 2016, p16; NAM, 2018)*.

The roles municipalities have in implementing heat-generating facilities and infrastructure depends on the responsibility of realising energy infrastructure, the degree to which the municipality is willing to accept risks and knowledge and capacity that is present at the municipality (Schilling et al., 2018). The risk that are willing to be accepted determine the facilitating, partnering, contractor or owner roles of municipality (van der Steenhoven, 2019). In any way they have the obligation by law (Hobma & Jong, 2016) to perform certain roles in case of a (heat exchange) project development, in which the development department and land department could be involved as separate actors within the Municipality. For the Municipality there is the legal obligation of licencing an environmental permit (e.g. line permit, logging permit, construction permit etc.) and making concessions with district heating operators but also supervision and enforcement of permits to ensure safety while executing a sustainable policy that is in favour of the social values (RVO, 2014). In the research of Schilling et al. (2018) is found that municipalities have an observing attitude when there are private heat actors involved and are having an initiating or encouraging role in the majority of the newly realized heat networks. In order to react to social values such as climate change awareness and decarbonizing cities and to meet binding climate conditions, the local authorities develop energy strategies. Petersen & Heurkens (2017) fount that the local authorities endorse efforts to implement energy policies, but face the complexity in networks of various actors, scales and disciplines. Local authorities and public planners are not often in the position to influence the implementation of urban development targets according to Petersen & Heurkens (2017). Therefore the province and Municipality should and will use several management tools that are at their disposal to steer on the implementation of energy infrastructure such as heating networks in order to enable a feasible sustainable business case (Adams & Tiesdell, 2012; RVO, 2014).

Shaping instruments of municipalities are the publications of plans, strategies and visions. In urban expansion or deep renovation of residential areas the municipality is allowed to compel a connection to a heat grid through the Municipal heat plan (Schilling et al., 2018). In the Municipal heat plan, certain areas are appointed for a maximum period of ten years in which exemption is only possible if equal energy efficient and environmental benefits are reached. For existing residential areas there are little opportunities for municipalities to legally foster the connection to heat networks according to Schilling et al., (2018).

Regulatory instruments that influence development are the land-use plan, building aesthetics supervision, (municipal) building bye-law, site development plan, structure vision, codes regarding the external appearance of buildings, joint regulation, management regulation, preliminary Decree, project decision and reasonable requirements of external appearance (Hobma & Jong; p136). The municipality decides on environmental permit applications and assesses whether these are in conflict with the aforementioned (public) law instruments. Predefined conditions for development implied by municipalities adopted in land-use plans or contractual agreements are found “often resulting in too detailed and inflexible contractual conditions for private actors to work with” according to Heurkens (2012; pp.217-218). Besides the aforementioned public law instruments, Municipalities are allowed to use private law instruments if similar results are not achieved by public law instruments (=thwarting doctrine) according to Hobma & Jong (2016; p72). To clarify, municipalities can carry out the private actor roles, ranging from having agreements to “incorporating a company together with other parties, in which it holds shares” (Hobma & Jong, 2016; p84).

Stimulating instruments often used by municipalities could range from direct state-actions (by which the state can directly influence the development) to price-adjusting actions (which impact projected costs and revenues in a development), risk-reducing actions (Impacts initial capital value) and capital-raising actions. Examples are land acquisition, grants (subsidies) and loan guarantees (Adams & Tiesdell, 2012; p134).

Capacity building tools being used are the improvement of actor relationships by providing arenas for interaction and networking, making social capital partnerships and enabling cultural perspectives according to Heurkens (2012; p87). The purpose of capacity building is seeking collaboration from local residents and communicate well in order to increase public support (RVO, 2012, p12; Heurkens, 2012, p207). Arenas for interaction and networking that are recognized by Meijer et al. (2018) are the setup of pop-ups and consultancy centres in order to create social awareness, especially for homeowners. Capacity building efforts help to shape effective communication programs according to Grimm (2018; p3)

Government actors such as the Municipality, Province of South-Holland and the State can influence development by using policy instruments that are categorised as shaping, stimulating, regulating and capacity building tools by Adams & Tiesdell (2012). The Municipality and Province draw up land use plans and structure plans that can restrict developments, while on the other hand subsidies and guarantees can stimulate the development *(Table 3.1)*.

Key public actors	Management roles	Means
State and Ministries	Regulatory, shaping, supervisory.	*Regulatory:* Spatial Planning Act, Order in Council, The Building Decree and Crisis and Recovery act, Heat Act (Consumer protection), licence granting, supervision on and enforcement of environmental law, sustainable policy. *Shaping:* Climate agreement *Stimulus:* Direct state grants, State body RVO subsidy
Province	Regulatory, supervisory, shaping.	*Regulating:* Provincial-Bye law, environmental permit licencing, supervision on and enforcement of permits *Shaping:* Structure plans, publication of (sustainable) plans. *Stimulus:* Subsidies and guarantees.
Municipality	Public law roles: Regulatory, supervisory, shaping observer (facilitatory) or initiator, consultant. Private law roles: Partner, contractor, owner.	Public law instruments: *Regulatory:* Environmental permit assessment, concessions land acquisition, *Shaping:* Publications of plans, strategies and visions, land use plans, Municipal heat plans. *Stimulus:* Subsidies, development grants (subsidies) and loan, guarantees. *Capacity building:* Setup of popups & interaction arenas for communication. Private law instruments: Contracts or involvement in legal entity.

Table 3.1 The key public actors in the Netherlands and their roles and means regarding urban development (Based on findings from: Adams & Tiesdell 2012; RVO, 2014; Heurkens, 2012; Hobma & Jong, 2016; van Vliet et al., 2004; Rijksoverheid, 2019; ACM, 2019; Provincie Zuid-Holland, 2019; Schilling et al., 2018)

These means above influence the behaviour of market actors, who are bound to the regulatory and shaping instruments. Stimulus and capacity building can influence developments in a positive way. Further analysis on private actors is performed.

3.2.2 Private actors

The private actors in urban development are legal entities that are not (completely) in the hands of public actors. In recent research of Heurkens (2017a) on strategies for sustainable private sector-led urban development projects in the Netherlands four typologies (and their characteristics) that can perform a leading in urban development are recognized. The term 'led' is related to actors performing a directive role in the management of projects (Heurkens, 2012; p59). These typologies are developer-led urban development, investor-led urban development, community-led urban development and corporation-led urban development. When these actors not taking a leading role, it is not a matter of course but still possible that actors are involved in different phases of urban development. Therefore these actors will be relevant for the actor analysis of urban development. For the analysis on the managerial roles of private actors a distinction is made between developers **(3.2.2.a)**, financiers **(3.2.2.b)**, communities **(3.2.2.c)**, investors **(3.2.2.d)** and corporations **(3.2.2.e)**. First attention is paid to actor involvement. Actor involvement in urban development can be illustrated using the relation between the degree of involvement and development strategy according Heurkens (2017b; p2) as displayed below *(Figure 3.1)*.

Figure 3.1 Degree of Actor involvement and development strategy (Source: Heurkens, 2017b; p2).

Out of the actors in the figure can be concluded that investors and corporations focus on long term yields, have a long-term involvement in urban development as they have an important role in the operation phase (after completion) of projects according to Heurkens (2017b). Developers focus on short-term profits, are involved in the realization and have limited their responsibility until delivery. Community efforts in urban development are found limited in scale and risk according to Heurkens (2017b). In existing heat networks, the private actors involved are large heat corporations (e.g. Eneco, Essent, Nuon, Stadsverwarming Purmerend, Wamob), (social) housing associations, home owner associations (HOAs) according to Schepers & Valkengoed (2009; p20). Large heat companies can be seen as corporations with energy management as core-business, while housing associations have real estate as their core business.

3.2.2.a Developers

Developers in urban development practice are traditional real estate industry agencies and can be financial-organisationally linked to banks, investors, construction companies, or be independent companies according to Heurkens (2017a). Developers as non-independent actors do not have the in-house capabilities as they can be at the heart of multiple linked private actors from different disciplines. Adams & Tiesdell (2012; p80) define the following actors from different disciplines *(Table 3.2)* in real estate development:

Discipline	*Managerial*	*Technical*	*Legal*	*Economist*	*Financial*	*Design*	*User*
	Project manager	Civil Engineer	Solicitor	Valuation surveyor/ estate agent	Accountant or financial consultant	(Landscape) Architect	Residents
		Mechanical and electrical engineer			Property market analyst or economic consultant	Interior designer	
		Structural engineer			Construction economist or quantity surveyor	Planning consultant	
						Urban designer	

Table 3.2 The actors of different disciplines that are involved in real estate development (Source: Adams & Tiesdell, 2012; p80)

Each of the actors that are linked to a developer have their own interests in a project. These interests of actors can vary per project and can even change during projects because of dynamics in problem formulation and appropriate solutions set by actors (Koppenjan & Klijn, 2004; p47). Based on their field of expertise, developers tend to put more emphasis on a certain discipline due to the sector-division of real estate (Heurkens, 2017c). Where management emphasis lies on the adjustment or expansion of urban areas with many owners, multiple developers, process managers and project managers with an industrial, infrastructural or functional real estate specialism could be involved, each having their emphasis on certain disciplines (Heurkens, 2017c; p81). There could be developers that are specialized in the development of the heat-generating facility, but also developers that are specialized in developing heating infrastructure, which both tend to emphasise on the technical discipline and to less extend on the design and user discipline. In contrast, developers of functional real estate such as residential real estate tend focus their development on the user and provide solutions that are agreed on with residents (Heurkens, 2017c; p32). In this case, it depends on the development project, in which actors are involved. Therefore the development actor role will solely be added to the (general) agency model and the multiple linked private actors such as contractors are considered part of or linked to the developer.
In heat exchange projects, the developers of heat-generating or production facilities and infrastructure are interested in covering the development risks and sale opportunity according to PBL (2017; p11). Trader-developers do this by selling the developed real estate (e.g. production facility and infrastructure) by means of a purchase agreement at the delivery (when the realization is complete and the operation phase is entered) according to Heurkens (2017b). At this point the developer sells the property in accordance to the contractual terms agreed on by the seller and buyer of property, which confirms the short-term involvement of developers in Heurkens (2017a). However, there are cases in which the development is performed by large corporations **(3.2.2.e)** that develop, distribute and supply heat from affiliates. On the other side heat exchange projects can have partition of the developments over different legal entities. In the latter the interests in project development are covering the risk and one solution to that is the Special Purpose Vehicle (SPV). An SPV is defined as “a legal entity created by a firm by transferring assets to the SPV, to carry out some specific purpose or circumscribed activity” in order to limit the risk of the shareholders to the project and offers opportunities for financiers and sponsors to participate with limited risks (Gorton & Souleles, 2007, p550; RVO, 2014, p44; Vlek, van Oosterhout, Rust, van den Berg & Chaulet, 2016). Regarding the organizational and managerial roles of developers, a broad range of organizational, financial and legal aspects are used throughout the different initiating, designing, planning and operating phases of the project. The management resources as defined by Heurkens & Hobma (2014) being used could be land, capital and knowledge which is exchanged between actors in the SPV.

3.2.2.b Financiers

The financiers are an essential part in the development as they provide capital for investment and costs (RVO, 2014; p43). The capital is transferred to an SPV which holds the risks, cash flows etc. that are disconnected from the financiers’ own activities according to RVO (2014; p44). The project finance can consist of private equity of the intended owners but could also consist of interest-bearing dept or loan capital from for instance banks. The means of private equity financiers come with investments in the SPV having dividend in return, while the loan capital financiers receive interest in return RVO (2014; p45). The advantage of a SPV is that all the actors involved, such as the developer, producer, distributor and supplier can financially contribute to the project and receive a return on investment. The barriers of the financiers are the uncertainties that are accompanied by developments. In heat provision on the district scale there are large investments but low interest rates that form a risk, that should be balanced to acceptable risk-interest ratio (RVO, 2014).

3.2.2.c Communities

Communities are defined by Heurkens (2017; p2) as “non-traditional real estate industry agencies as their core expertise often is not real estate” which are “locally-rooted actors such as property owners, entrepreneurs, or local citizens that engage in urban development”. Often they operate on a building scale and adopt incremental strategies to optimise real estate operation and building and public space and infrastructure use. Two types of community organisations are defined in this thesis:

1. Energy cooperatives;
2. Homeowner associations.

Ad 1 Energy cooperatives

Typical locally rooted community actors in energy are the energy cooperatives, which are citizen-led energy communities that and have a formal cooperative form or foundation as a legal entity. The roles and interests of such an organisation is educating on energy use, collective procurement of renewable energy for consumption by inhabitants, participants or members that are living in the vicinity of the place where the renewable energy is generated (Boon & Dieperink, 2014). The energy cooperatives generate enough electricity to provide 140.000 households of renewable electricity from wind turbines and solar (Hieropgewekt, 2018). Although findings in the report of Boon & Dieperink (2014) show that the emerging and developed energy cooperatives is experiencing a growth over the past decennia, little heat cooperatives are now operational. One example of an operational heat cooperative that operates a district heating network distributes heat for 220 dwellings and other buildings from geothermal heat produced by the drinking water production company Vitens B.V. in Culembourgh (Thermobello, 2019). In this case the possibility to exploit a local renewable source was an important influencing factor for the emergence of a heat cooperative, which is also proven significant by Boon (2012). Energy cooperatives seem to be dependent of financiers, professional actors for planning and execution (developers, corporations) since high up-front investments, administrative responsibilities and low degree of professionalism is recognised within this group (Bakker, 2016; Boon, 2012). Also, the presence of government support significantly influences such initiatives (Boon, 2012) in a way that their success is dependent on it.

Ad 2 Homeowner associations

A homeowner association (HOA) is a community of homeowners, that has a legal entity and acts as a representative for the homeowners. Single homeowners are involved with maintenance and improvement of their property, while apartment owners are often acceded as members in homeowner associations (Eigenhuis, 2019). The association has a democratically chosen board and regularly meetings are being held between the members. Each member pays monthly contributions for the maintenance and improvement of the apartment building and related services according to Eigenhuis (2019). The HOA must have a reserve fund to carry out major maintenance (e.g. façade, roof or lifts) or sustainable measures (e.g. insulation) in accordance with a long-term maintenance plan (Rijksoverheid, 2019b). When important or large improvements need to be made, decisions are taken democratically by a majority of the votes in which at least two third of the members should be present at the meeting, of which the decision is found valid when at least two thirds of the votes reach consensus. In a research on existing heating networks done by Schepers & Valkengoed (2009) is found that besides large heating companies owning the majority of the heating networks, there is a variety of actors operating small-scale heat networks (<5000 residents) such as HOAs. HOAs operate the heating facility and are accompanied by companies that invoice the heat distribution cost (e.g. producing and supplying heat to consumers) according to Schepers & Valkengoed, (2009; p9). The homeowner associations (HOAs) have the aim to reduce the energy costs of their members and still have a reasonable financial efficiency on their heat supply (Hoogervorst, 2017; p48). The HOA is a formal community of which the board is attributed with organizational and managerial roles. There is jointly decided on where the management resource of capital (e.g. reserve fund) is used for. Also process management activities are recognized among the community members such as the regularly meetings and democratic decision-making concerning maintenance and improvements. This means that available budget and consensus about expenses is a challenging barrier for the implementation of sustainable solutions.

3.2.2.d Investors

Investors are also real estate industry agencies which can be categorised as institutional investors, investment banks and development investors (Heurkens, 2017b). Institutional investors are characterized by the purchase or real estate from developers and earn return during the operation according to Heurkens (2017b; p2). Energy industry agencies are defined as corporations but could have publicly tradeable shares that are owned by institutional investors. Some examples are:

1. NUON as part of Vattenfall NV;
2. Essent NV as part of RWE AG;
3. Eneco B.V. in which 44 municipalities hold shares.

The earlier mentioned project financiers could also be investment banks or development investors who are involved in the operational phase as well. These actors are characterized by their long-term involvement in the project and could “develop real estate for their own investment portfolio” according to Heurkens (2017b; p2).

3.2.2.e Corporations

Corporations are defined by Heurkens (2017; p2) as “non-traditional real estate industry agencies, as their core business is not real estate. Corporations like technology and energy companies can be influential in urban development and are characterized by their long-term involvement (Heurkens, 2017). Since their core business is not real estate, energy corporations outsource developers (with short-term involvement) to realize their real estate and use real estate as a mean to perform their core business. Remarkably, large heat companies sometimes have affiliate legal entities to fulfil the roles in the heat supply chain as shown in the research of Schepers & Valkengoed (2009). The economic issue these large corporations had in the past, was questioning whether the investment, connection fee, fixed costs and energy supply costs could be covered with the variable prices for electricity, gas and /or heat supply according to Correljé (2013; p15). In the context of sustainable development it was questioned whether the role distribution in heating networks should be following the same monopoly renounce as the roles in the electricity and gas supply chain (PWC, 2015). In the operation phase of heating networks multiple tasks of corporations that are the owners (and operators) can be distinguished *(Figure 3.2)* based on the heat exchange value chain (EBN, 2018; p26).

Figure 3.2 The tasks in the value chain of heat exchange operations (Source: EBN, 2018; p26, own edit)

The larger heat exchange value chain consists of several tasks are performed. These tasks mentioned are not always performed by the same actor since actors can fulfil multiple roles and roles can be fulfilled by multiple parties (van Vliet, van der Voordt & Den Heijer, 2004; p82). This is confirmed in research of Schepers & Valkengoed (2009, pp. 34-35) in which is shown that the heat production company is not often found in the possession of the distribution network and supplying company thus different companies can have the role as producer, distribution service operator (DSO) and supplier performing the tasks in the value chain of heat exchange. Out of the tasks mentioned in value chain, the roles that comprise one or more tasks that corporations can have are distinguished:

1. Heat producer;
2. Heat transporter and distributor;
3. Heat storage;
4. Heat supplier;

Ad 1 Heat producer

The production of heat is done by the production source owner (EBN, 2018). The main interests for the role as heat producer is avoiding interruption of the primary process, keeping flexibility and financial return on investment. The technical feasibility (within budget), reducing primary process interruption, coverage of transaction cost, financial return on investment are aspects that are of interest of heat producers according to RVO (2014, p8). The organizational aspects of producing heat in terms of tasks and responsibilities are the production and delivery of heat, according to the terms agreed in the heat supply contract with the Distribution Service Operator (DSO). Heat producers have to manage the varying heat demand (e.g. seasonal, current and future) with the heat supply (e.g. baseload, middle load, peak load and back-up) according to Brugman (2019;p8).

Ad 2 Heat storage

The storage of heat that is not directly used is found economically unfeasible by EBN (2018), however this argument is in contrast with the feasible large heat storage facility of NUON (NUON, 2019) which is an important example of an innovation that functions as a thermal energy buffer in order to cover the peak loads.. Lower temperature heat is seasonally stored in shallow geothermal layers in the soil, but for higher temperature buffers in the soil innovation is needed (EBN, 2018). Also the institutional setting heat storage in the soil forms important barriers for the implementation by the actors fulfilling the corporation roles (Bloemendal, 2019; van der Woude, 2019), due to the presence of drinking water reservoirs. Although barriers for heat storage in the soil exist, other high temperature heat storage technologies (e.g. PHES, HES, LAES) are found. The implementation of heat storage could improve the heat sales by the actor that fulfils the role of suppliers (and eventually the whole supply chain).

Ad 3 Heat transporter and distributor
The transport and distribution tasks of heat are often performed by the Distribution Service Operator (DSOs) which is the organizational link between the heat producer and heat supplier. In the research of RVO (2014) is found that the main interest of the DSOs are an attractive financial return on investment and the covering of risks. Hereby it is important that the price that is paid can cover the costs of buying heat, distribution and delivery to the end-users while securing the supply. This means that also DSOs have to manage the varying heat demand with the heat supply as mentioned by Brugman (2019; p8). The main income for DSOs is the heat sale price, while costs of coupling, distribution and delivery are based on the number, type and length of the infrastructure (RVO, 2014; p9). The legal aspects are discussed in contracts with the heat producer and heat supplier in which financial arrangements, tasks and responsibilities are addressed (RVO, 2014; p7).

Ad 4 Heat supplier
Heat suppliers can operate on various scales, ranging from district scale to building block scale. When heat is supplied on district scale, heat suppliers can have a heat delivery agreement made with the DSOs which contains contractual terms (RVO, 2014; p7) and in between the heat supplier and the end-users service contracts are made. The interest for heat suppliers is a reasonable financial return and satisfied customers (PBL 2017; p11). The heat supplier role on residential building scale can be the responsibility of the building owners which means that can be performed by many actors: energy cooperatives, housing associations, institutional investors with residential real estate, and HOAs. Heat suppliers that own real estate, such as housing associations, have interest in a lower financial return than commercially orientated suppliers since lowering housing costs has been pursued according to Hoogervorst (2017; p48). When the heat-generating facility is not positioned in the building energy cooperatives, housing associations, institutional investors and HOAs are considered not responsible for the production and distribution roles. Out of the energy corporation roles, the role as heat supplier is bound to the maximized heat tariffs end-users pay per GJ (ACM, 2019).

Out of empirical research in the second phase, the cases should point out the role and task distribution over the actors.

3.3.3 Civic actors

The civic actors can perform a role as homeowner and tenant instead of from a legal entity (consisting of homeowners and tenants) which is why they differ from a private sector actor. The civic actors involved in heat networks are not only single homeowners and tenants **(3.3.3.a)** but also social enterprises such as Housing associations **(3.3.3.b).**

3.3.3.a Homeowners and tenants

The interest of homeowners and tenants want an acceptable heat tariff, individual billing, good service and reliability according to (PBL, 2017; p11). Important is the affordability of the heat (RVO, p10). Individual homeowners and tenants are often found to be members of an organisation that promotes the interests of a group of homeowners or tenants (Schilling et al. 2018).

On top of the main interests of the homeowners and tenants, unknown technologies can form a barrier for the adoption of innovative heat-generating alternatives compared to existing technologies (e.g. natural gas). This barrier can harm the actors that fulfil the role of developers, investors and corporations who want to have a feasible business case in implementing district heating. The “persistence of fossil fuel-based technological systems” known as ‘lock-ins’ is an important constraint for carbon-saving technology diffusion according to Klitkou, Bolwig, Hansen & Wessberg (2015; p22). In the research on diffusion of Innovations by Rogers (2010), diffusion is defined as “the process by which an innovation is communicated through certain channels over time along members of a social system”. According to Rogers (2010) technological innovations creates uncertainty about its expected outcomes in the mind of the potential adopters and reduces uncertainty from the information available from the technological innovation. In Mlecnik (2013; pp. 32-33) five stages in the innovation-decision process are described as a process in which the individual “passes from initial knowledge of an innovation, to forming an attitude towards the innovation, to a decision to adopt or reject, to the implementation of the new idea and, ultimately, to the confirmation of this decision”. To which extend the innovation is accepted depends on variables. Important variables that influence the persistence of fuel-based-technological systems are an acceptable heat tariff, individual billing, good service and reliability (PBL, 2017). The public and private roles must respond to these variables to create a business case for development, because private actors are dependent on heat sales and the public actors are dependent on the adoption that foster fulfilling their ambitious targets for decarbonisation. In order to fulfil the energy demand, the tenants and homeowners have some organisational and managerial tasks. To receive electricity and heat, contracts have to be agreed on by the energy supplier and household. In the contract the tasks and responsibilities of the actors are discussed together with the rules and (financial) requirements that apply to the contract.

3.3.3.b Housing associations

There can be argued whether the (social) housing associations should be placed under civic actors, since they have private actor means, but the core missions and values of the social housing associations are characterized as 'social enterprise' and 'hybrid organisations' by Czischke, Gruis & Mullins (2012). Housing associations serve the overall goal to provide affordable and adequate dwellings, contribute to the quality of life in neighbourhoods and invest in the construction of new dwellings and sustainability (Aedes, 2016; Schilling et al. pp. 37-38). On top of this the national Association of Housing Associations Aedes agreed in the Climate Agreement on having the heat provision of the current social housing stock carbon neutral by 2050 (Aedes, 2018). The roles and interest of housing associations in heat networks is determined by the affordability of utility costs, administrative responsibilities, responsibilities for investment costs for adjustments and infrastructure, investment return and the willingness of tenants to adopt according to schilling et al. (2018; pp37-38). The maximum heat tariffs set by the ACM in the Dutch Heat Act increase the affordability per GJ heat, but the utility costs could increase due to a greater heat demand caused by inefficient isolation of the dwelling portfolio according to Schilling et al. (2018) the housing associations often choose for additional improvement of the quality and comfort for dwellings that might result in rent increase. Schilling et al. (2018) found that the willingness of tenants to agree with the costs, adjustments to the dwellings, sustainable benefits and nuisance are important factors that influence the possibility to connect to heat networks by housing associations. The tenants of housing associations that already have a collective heating facility (on natural gas) could have less nuisance since there is often a possibility to use existing radiators. However, when the renovation involves ten or more dwellings in a building complex, >70% of the tenant should consent according to the Dutch Rental Act. A building complex with less than ten dwelling needs approval of all the tenants (Rijksoverheid, 2019b). In the research of Schilling is found that the primary concern for the tenants of social housing associations is affordability, with equal housing costs compared to the former situation due the fact that these tenants often have a low income. Regarding heating networks this type of tenant prefers equal housing costs, reliable heat delivery, little renovation measures (and only when improvements are being made), clarification of plans and participation according to Schilling et al. (2018).

3.3 Actor dependencies

At the end of the actor analysis the position of actors and their dependency relation is clarified according to literature. The actor dependencies is about what means each actor has at their disposal to solve managerial and organisational problems. In between heat exchange projects it differs when or how these means are being used. There is no consistent role division for the actors involved since different projects are elaborated on in the consulted literature, which could result in an incomplete overview of the dependency relations. The dependency relations between actors, indicates how one actor is dependent on other actors in projects. These so called interdependencies can be visualised by looking at the agreements that are generally made between actors in the Netherlands — which often clearly describe the role division in an agency model *(Figure 3.3)*.

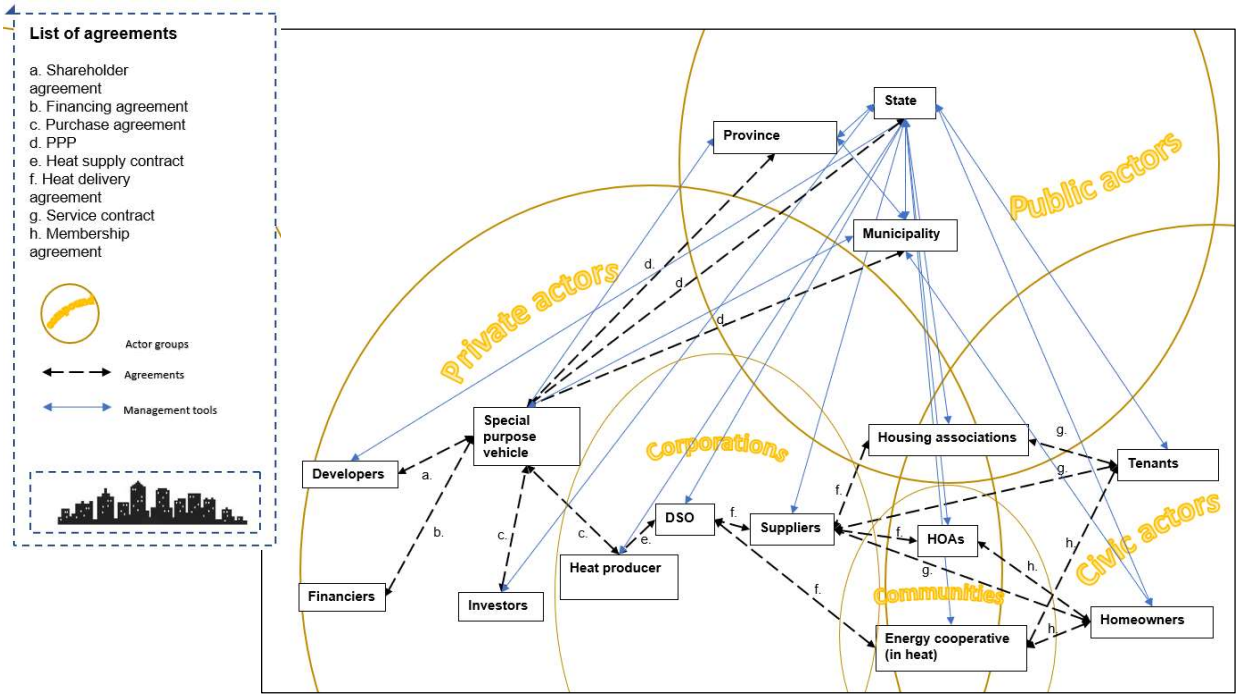


Figure 3.3 An agency model to position the roles of the public, private and civic actors that actors actively involved in, have the means to, have the knowledge of, are expected to be involved or are affected by the management of heat-generating facilities and infrastructure development in the built environment (Source: Own design, based on literature)

The agency model above is the result of a thorough actor role analysis performed in the inventory of actors **(3.2)**. Beyond a doubt there are more actor roles involved in general 'heat exchange' projects, but could vary to a great extend when the actors are explored in practice. The cases elaborated on in the empirical study could show a more consistent role division and therefore there is chosen for general dependencies, with the managerial roles as a base. The blue arrows in the figure indicate the regulatory, shaping, stimulating and capacity building tools that are already elaborated on in **(3.2.1)**. Without a project context these are too broad to be elaborated on, because they indicate all the possible management tools, but aren't case specific.
Written contractual agreements form the base for managerial and organisational tasks and could vary from project to project which makes the viewpoint more suitable for analysing individual projects. The contractual agreements that were found in literature so far are labelled in the agency model:

a. *Shareholder agreement*
A shareholder agreement withholds an agreement between any real estate developer and Special Purpose Vehicle (SPV) in the development of real estate. The developing actors create the SPV where assets are transferred to in order to limit the risk of the individual shareholders during the project. Developers can bring in their financial means (e.g. equity) and receive dividend in return according to Vlek et al. (2016). The shareholder agreement can be made between private actors or between private and public actors.

b. Financing agreement
In a financing agreement the contractual relations between the financer and the SPV are discussed according to Vlek et al. (2016). Often developers prefer interest-bearing dept or loan capital in order to cover (a part of) the development costs. The financing agreement can be made between private actors.

c. Purchase agreement
A purchase agreement is made between the project SPV and the investors or corporations which have an important role in the operation phase. The developed real estate objects are transferred from the SPV to the actors involved on the long-term (RVO, 2014). In these agreements there are writings about the financial arrangements, program, planning and phasing and division of the risks.

d. Public Private Partnership
The arrangements made in Public Private Partnerships (PPP) are the contractual agreements between public and private actors. Within the Dutch PPP models certain public and private roles in the development stages are recognized *(Figure 3.4).*

Development Stage	Sub-stage	Public Realization	Building Rights	Joint Venture	Concession	Private Realization
Initiative	–	Public	Public or Private	Public or Private	Public	Public or Private
Plan & feasibility	Vision and program	Public	Public & Private	Public & Private	Public & Private	Private
	Design plan	Public	Public & Private	Public & Private	Private	Private
Realization	Land development	Public	Public	Public & Private	Private	Private
	Real estate development	Public or Private	Private	Together or Private	Private	Private
	Construction	Private	Private	Private	Private	Private
Operation	Maintenance public space	Public	Public or Private	Public or Private	Public or Private	Public or Private
Land use policy		Active		< >		Passive

Figure 3.4 The public and private roles within Dutch PPP models (Source: Heurkens, 2012;p129)

Arrangements such as private realization or public realization are not considered partnerships but as "an operation agreement between public and private actors" according to Heurkens (2012; p154). Therefore three PPPs are recognized in urban development in the Netherlands by Heurkens (2017c; p22):

1. Building rights model;
2. Joint venture;
3. Concession.

Ad 1 Building rights
In building rights the initiative, planning and feasibility phase is passed with close partnership between public and private actors. Land development is executed by public actors, while the real estate development and construction is performed by private actors. The maintenance of the public space can be operated by public or private actors. According to Heurkens (2012; p150) the building rights models is frequently used in scattered land ownership in an area. While having the land transferred to public actors that are "financially and technically able to buy and prepare land for development", the real estate development risk and revenues are of private actors according to Heurkens (2012, pp. 150-151).

Ad 2 Joint venture
In a joint venture public and private actors found a (land) development company (legal entitity) to which the ownership of the land and/or buildings are transferred to (Heurkens, 2012; p151). By having this partnership model the developers and public parties can give their input, have a voice in the company and shares the risks, revenues and responsibilities. Often a shareholder agreement (3) between actors is included. The joint venture model is characterized as an quasi-firm network form of which an SPV and consortia are other examples of according to Johnston, Peters & Gassenheimer (2016). The network forms differ as in joint ventures "the number of firms collaborate to share profits based upon their agreed contribution in kind or in financial terms" (Gruneberg & Hughes, 2004). In the consortia "each firm contributes an equity stake in the form of risk capital or payment in kind in order to qualify as a member", while an SPV is "a formal accounting and contractual arrangement set up by one or more firms to undertake a project" according to Gruneberg & Hughes (2004). The joint venture model limits the liabilities for the parties involved to the network form.

Ad 3 Concession
A concession is a contract form with clear preconditions in which the risk and responsibility of the development, land preparation and real estate development is shifted to private parties according to Heurkens (2012; p155). Not only the land development (land and building exploitation) but also the real estate development will be done by a private actor in a concession agreement.

e. Heat delivery agreement
The heat delivery agreement is made between the performer of the DSO role or supplier role and the (semi-)private actors that receive heat such as the housing associations, homeowner associations and energy cooperatives in heat (RVO, 2014;).

f. Heat supply contract
The heat supply contract exist when the heat producer role is not executed by the same actor that executes the roles of distribution operator. In the heat supply contract the conditions for the supplied heat as well as the price are discussed between the actors

g. Service contract
The service contract for residential heat in district heating networks is agreed on in between suppliers, homeowners and tenants. The service contract can also be made from indirect suppliers such as the housing associations to tenants. For a service contract, tenants, homeowners, tenants and indirect suppliers will when pursuing affordably prefer lower costs for heat (RVO, 2014). When the option with the lowest price is chosen the contractor admissions for registration and receives the service contract. During operation consumption data is communicated and an utility bill is provided by the heat supplier. By means of periodic payments to the supplier the household is supplied of thermal energy in return. In case of dispute or shortcomings by the heat supplier, the end-user of heat can claim compensation (Geschillencommissie, 2019).

h. Membership agreement
The membership agreement is a typical arrangement that is made between homeowners and their HOAs. When homeowners, in this case apartment owners, purchase apartment rights which withholds that a share in the building is bought with the exclusive right to use the apartment. Together with the other apartment owners, the buyer will become the owner of the entire building (NederlandVVE, 2019). The buyer then automatically becomes a member of the Owners' Association.

The position of actors and their dependency relation extracted from consulted literature shown in the agency model *(Figure 3.4)* can be considered timeless, as if all the agreements are made at the same time. However, urban area development can also be seen as a process consisting of phases. Daamen (2005, p28) defines the initiative, planning, realisation and operation as project management phases. When comparing the involvement of the defined actors in the phases *(Table 3.3)*, the various tasks each phase consists of can come out underexposed. Focussing on tasks that are performed and which actors are involved, followed by the moment in time they occur will prevent underexposure of the management activities of actors in the Empirical study.

Actor group	Actor	Initiative	Planning	Realisation	Operation
Public Actors	State and ministries	x	x	x	x
	Province	x	x	x	
	Municipality	x	x	x	x
Private actors	Developers		x	x	
	Financiers			x	
	Investors	x	x	x	x
	Communities	x	x		
	Corporations	x	x	x	x
Civic actors	Housing associations	x		x	x
	Homeowner associations			x	x
	Tenants and homeowners				x

Table 3.3 The key actors in Dutch projects and their involvement in the project management phases

3.4 Management perspectives

To have an answer to the main research question on how public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands, the definition of management needs to be clear. The roles, interpreted as 'management' activities performed by a certain actor, need some sort of framework to be evaluate on and therefore there is chosen to discuss management perspectives. Management in general is defined by Black & Porter (2000, pp. 19-24) as the process of assembling and using resources in a goal-orientated manner to accomplish tasks in an organisation. To be more specific, management is a process (that involves a series of activities and operations, such as planning, deciding and evaluating), involves assembling and using a variety resource types (means and assets such as finance, material and information) to accomplish tasks in a goal-directed manner within a certain organisational setting (Bruil, Heurkens & Lousberg, 2015, p6). During the process, managers can 'steer' development into desired outcomes.
Management of upscaling towards geothermal district heating instead of single heat-generating facilities on natural gas and thereby scaling up the geothermal sector can be viewed from many management perspectives. There is chosen to view the management of upscaling (geothermal) district heating from two management perspectives: management through levels **(3.4.1)** and management through aspects **(3.4.2)**. The reason why there is chosen for these two perspectives is that at first, management in urban development requires aligning of and steering on different spatial levels **(3.1)** for which managed through levels **(3.4.1)** is required. Second, management is versatile and many and often contradictory perspectives on how urban development projects should be managed exist. By focussing on aspects of management shows how things are managed and why things are managed the way they are in relation to management aspects. The management aspects money, organisation, time, information and quality (MOTIQ) are linked to the activities performed in geothermal district heating development. How the management through levels and management through aspects relate to the topic of the thesis are discussed pointwise in the following paragraphs.

3.4.1 Management through levels

Management in urban development can occur at different levels. Black and Porter (2000) make a distinction between strategic plans, tactical plans and operational plans *(Figure 3.4)*. According to Bose & Pal, (2015; p103) the more plans shift from strategic to tactical to operational, the smaller the planning horizon becomes. Also the number of people that are involved and the detail of plans increases.

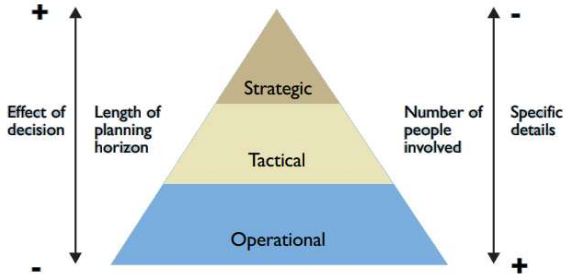


Figure 3.5 The triangle that represents the different levels at which management occurs (Source: Bose & Pal, 2015; p103)

Also Black and Porter (2000) mentioned the decreasing time horizon when strategic plans shift to tactical and operational plans. At first, strategic plans are characterised by their long time horizon (3-5 years), focus on the broad future of the organisation and high interdependence in which the resources and capabilities of the entire organisation are considered according to Black and Porter (2000). The urbanisation of cities demanded for strategic planning for sustainable development (UCLG, 2014). Strategic planning in the context of energy policy is found a base plan for policy to achieve long-term goals (Arababadi, Moslehi, El Asmar, Haavaldsen, & Parrish, 2017). In strategic planning governments can reach consensus with private and social actors about policies and projects (Biffarello, 2014) at an early stage. This reminds us to the definition of real estate by Adams & Tiesdell (2012; P94) as an 'intensely social process' where the interrelation between people determines outcomes as found in literature **(3.1)**. In the Netherlands the public actors are responsible for the creating of long term visions on spatial planning **(3.2.1)**. Public actors have a broad range of management tools to steer on urban development, such as shaping, regulating, stimulating or building capacity. To address the question on how is managed, management through levels is interesting to elaborate on since it addresses tools used for management. Generally these tools are used to induce market behaviour towards desired outcomes to serve a certain goal. In geothermal energy the public authorities are found responsible for the creation of strategic plans for heat **(3.2.1)** for urban areas. These plans are the result of the public actor its ambitions for the future and are implemented in tactical plans. Leal & Azevedo (2016) found that the gap between strategic and tactical plans can be bridged by local authorities by target setting of their sustainability targets. Tactical plans focus on 1-2 years in the future and translate the strategic plans into specific goals for specific parts of the organisation according to Black and Porter (2000). These type of plans relating to urban development are more specific and can commit public actors to achieve their goals within a certain timespan and are developed for the implementation of strategic plans. Operational plans cover 12 months or less and contain tactical plans translated in specific goals influencing a small unit of the organisation. The timespan that plans consist of will be retained to recognise the plan level in the cases.

3.4.2 Management through aspects

How geothermal district heating projects are managed can be viewed from the management aspects money, organisation, time, information and quality (MOTIQ) as mentioned in Bruil et al. (2015, p47). Literature research is performed on these topics in relation to geothermal district heating development. The aspects will serve as support to determine what topics to focus on when analysing the cases on how upscaling to geothermal district heating is managed. The aspects that are discussed are as follows:

Ad 1 Money

The management aspect of money is a broad term that relates to all activities concerning money. This can relate to budget, financial feasibility, investments, sales, stable return on investment etc.. Like other services related to real estate, the feasibility of geothermal projects is dependent of the sales of heat that is determined by the local heat demand and available infrastructure for heat transport (EBN, 2018). In energy transitions the acceptance of alternatives are based on collective (public safety and environment) and individual costs and benefits (money, comfort and time) according to Perlaviciute & Steg (2014). For implementation of innovations there need to be a search for alternatives that are evaluated in which the costs are justified according to (Ling, 2003). Money related management issues concerning end users found in literature **(3.3.3.a)** are the costs of stepping out of 'lock-ins', uncertainties about heat tariffs, service and reliability. Management of costs through the whole development will secure the costs for the end users and therefore a solid business plan is necessary. According to EBN (2018) the main financial risks in developing geothermal projects are the risk for unsuccessful drilling, technical failure during production and responsibility of third parties. For controlling the financial risk, RNES insurances exist from April 1st 2019 on (RVO, 2019). For geothermal projects in the Netherlands important financial instruments in place are the SDE financial incentives for renewable energy (Van Heekeren & Bakema, 2015). The total investment and operational costs should at least be covered with the heat sales (Correljé, 2013;p15) and additional financial incentives to be feasible. Since the maximum heat tariffs are set by law, the minimum amount of heat sales to be feasible can be calculated. A developer of geothermal wells can reduce risks by gaining more certainty about the feasibility: production and sales of heat. Lessons learned from geothermal wells that extract heat from heterogeneous soil layers or 'plays' could indicate similar heat production due to depth and permeability (EBN, 2018). Developing wells that extract heat from known 'plays' (e.g. Jura/Krijt-play, Trias-play and Rotliegend-play) increases the production certainty.

Ad 2 Organisation

Multiple organisation types can be recognized when viewing from the management perspective. Management methods such as line management, project management and process management are found organisation forms for reaching goals according to Bruil et al. (2015). Line management organisations are characterized by a hierarchic top-down structure for repetitive activities, while project management organisations exist temporarily and consist of multidisciplinary and specialised suborganisations (Bruil. Et al., 2015) who manage the project in phases. In van den Bosch, Flipse & Vorage (2013; p20) is shown that geothermal well development organisations are line management organisations. The development of the district heating network and residential adaptations could also exist of line organisations, which together can be controlled by the project manager. The role of the project manager in project management is bringing together the various experts in a divided regime to reach the goal that is in contrast with line management, in which there are more goals under one regime according to Bruil et al. (2015). Different organisation types are found merged in a geothermal district heating organisation, but it is not clear which of the organisation types is most effective for upscaling residential heat. More recent approaches to management found in Bruil et al. (2015) are the integrative approaches, in which a number of different variables are combined in a whole complete system. The most influential theories are the systems theory and contingency theory. Briefly explained, the systems theory refers to the process involved in how inputs (finance, material and human resources) are transformed (processed through actions by organisations) into outputs. Contingency approaches arose from the thought that there was one best way to perform tasks, in which deviation would lead to less desired outcomes. It comprises the choice for a structured approach in stable environments versus a flexible approach in changing and complex environments. Organisations in networks may be autonomous in the legal sense, but they are so dependent on each other that their mutual relationship is not determined by the hierarchy (in the meaning of issuing others) according to de Leeuw (2002). Joint collaborations are characterised by "a large degree of mutual dependency in order to achieve the set objectives" according to Bruil et al. (2015, p29). In Bruil et al. (2015) is found that the non-hierarchical dependency may lead to unpredictability in steering processes and methods. Managing the construction industry organisation is considered highly complex by Lu, Luo, Wang, Le & Shi, (2015), who refer to many who have explored and categorised project complexity (organisational, interaction, tasks, cultural, technological complexity etc.).The more complex the environment, the higher the degree of decision making decentralisation is, in which the choices and decision are spread across the entire organisation according to Bruil et al. (2015; p29). Even more, the organisation in construction innovation is considered sector fragmented (Sandick, 2010) which suggests that scaling up the amount of projects can be difficult. To reduce sector fragmentation, TNO & EBN (2018) recommends that geothermal operators should be the actors to be innovative in reducing risk and costs in order to develop a competitive alternative heat source that can be scaled up. But geothermal operators are not the only decision makers with regard to whether or not connecting district heating to residential real estate. Management related to organisations is about achieving a set of objectives by joint collaborations. Matching supply and demand requires collaboration in organisations.

Ad 3 Time

When speaking of time from a management perspective, time is often associated with planning (Bruil et. al, 2015), but could also relate to project duration, phasing, milestones, deadlines etc.. Planning is defined as guaranteeing the achievement objectives in advance based on estimated future conditions and circumstances according to Bruil et al. (2015). In construction projects for urban development the development is split into the initiative, planning, realisation and operation phase as defined by Daamen (2005, p28). Geothermal energy projects are considered more complex, having more phases for the development. Kennisagenda Aardwarmte en Weisenborn- Linskaill & Associates (2017; p23) defines the exploration, evaluation, development, production and abandonment phases in geothermal projects, which are common in the mining and quarrying industry. The end of a phase implicates a decision point in time in which the progress is assessed and continuation is determined. Management of time in phases through a gateway process in construction is shown by Winch (2010 p. 202). According to Winch (2010) there needs to be a clear set of review points where the progress is reviewed against the project mission. Both the timespan and timing of the activities linked to urban development and geothermal district heating development should be considered. Between urban development management phases and geothermal development phases differences in timing can exist and need to be considered in the case study. In order to lay down geothermal district networks excavation works of streets and sometimes even front gardens are necessary according to Vlerken (2019). The timing would be at its best when replacement of underground pipes is already planned. Also the replacement of individual heat-generating facilities such as boilers could be the best time when these are past due. When, connecting district heating to dwellings the consequences of shutting down the gas pipe and replacing existing appliances that are using it should be considered according to Vlerken (2019). When conducting a geothermal project and associated district heating project, planning is important tool to deliver heat in time. Time overruns are considered important factors for cost overruns due outstanding loans and other financial obligations that are not fulfilled due missed heat sales revenues. According to EBN & TNO (2018) the financial feasibility is among other things (sales and technical risks) influenced by the operational time and production of the heat source. While the production time of a geothermal well is expected to be 20 to 30 years by EBN & TNO (2018; p16). Besides a focus on the management of time, management of quality is necessary to secure a sufficient operating time.

Ad 4 Information

The information in projects can be seen as all the information available that is present in the project in the different phases. Information in innovative construction is dispersed among specialised actors (Nam and Tatum 1997). It is found that innovation is the implementation of new processes (Seaden, 2003, found in Kulatunga, Amaratunga & Haigh 2006) for which learning is necessary. As mentioned by Mlecnik (2018, 20 november, p9) learning is one of the main challenges in niche creation. According to Mlecnik (2018, 20 november) it requires support, actor skills, knowledge and techniques (Kemp, Rip & Schot, 2001) and a multi-player network with the contribution of innovators (Elzen, Geels & Green, 2004). Also Mulder (2019, presentation 2 July) found that education, science and technology is found as important as the involvement of industry, governments and societal organisations. Involvement of education, science and technology institutions can therefore foster upscaling geothermal district heating networks. There is a Geothermal Alliance in the province of South Holland where the branch organisation DAGO (Dutch Association Geothermal Operators), Energiebeheer Nederland (EBN), Eneco, Municipality of Westland, sustainable energy and waste company HVC, geothermal operator Hydreco Geomec and the Province of South Holland are part of (Geothermie Alliantie Zuid-Holland, 2019). They share a vision document in which is agreed on sharing information concerning scaling up and accelerating geothermal well development. The available information about production capacity, covering of risks and potential heat sales are the most uncertain factors that determine the geothermal district heating feasibility. Specific information concerning geothermal well development seems to be shared among specialists, but connecting district heating networks to the built environment with geothermal energy as source also requires the exchange of knowledge between urban development actors. Urban development actors **(3.2.2)** have knowledge of developing a grid and necessary adjustments of the building stock which requires information from geothermal specialists and vica versa. Although, urban area development can have an integrative approach **(3.1)**, little knowledge about geothermal district heating aspects (e.g. technique, efficiency, actors, feasibility in UAD, innovation) is shared among urban developers (Heurkens, personal communication, June 13, 2019). By accident the policy makers and energy advisors of the Municipality of The Hague learned about geothermal energy while looking for ways to making the built environment more sustainable (AgentschapNL, 2011a).

While information is exchanged on the supply side, the demand side of heat should also be considered since urban development is becoming more demand-driven and less supply driven (Heurkens, 2017; p32). A demand is not there if there is a lack of information about unknown technologies which can form a barrier for the adoption of innovative heat-generating alternatives by homeowners and tenants compared to existing technologies **(3.3.3.a)**. Housing associations need to be informed as well since the development of geothermal district heating is in line with the Ambitions of the National Association of Housing associations Aedes, which agreed on having the heat provision of the current social housing stock carbon neutral by 2050 **(3.3.3.b)**. Information can be provided by public actors through capacity building tools **(3.2.1.c)**. The aim of capacity building is seeking collaboration from local residents and communicate well in order to increase public support. According to literature, arenas, pop-ups and consultancy centre for interaction and networking are set up for urban developments and whether these are set up in the development of geothermal district heating is further investigated.

Ad 5 Quality

The various public, private and civic actors define their own qualities **(3.2)** which makes it a paradigm. In urban development, spatial quality is defined by Janssen-Jansen, Klijn & Opdam (2009) as the desired direction of area development or as a management standard from the central government. Spatial quality is also found part of the larger comprehensive term environmental quality. According to de Zeeuw (2018) environmental quality can be divided in three categories:

1. Environmental, health and safety quality: values that are quantative legally established standards;
2. Spatial quality: utility value, experience and future value;
3. Social values that are accepted: social cohesion and economic vitality.

At first, environmental, health and safety quality is considered to be laid down in law: in Environmental Law the Spatial Planning Act, Order in Council, The Building Decree and Crisis and Recovery act are important regulations adopted at the level of The State **(3.2.1.a)**. Lower level Environmental, health and safety quality can additionally be adopted through regionally **(3.2.1.b)** or locally **(3.2.1.c)** binding structure visions and safety assessments **(3.2.1.b)**. The State supervision on the Mines (SSM) also has a saying about the quality and location of the geothermal well: it is an important consideration to foster safety (SODM, 2019). Therefore the SSM adopts regulatory management tools **(3.2.1.a)** to influence market behaviour towards safety in the sector. According to TNO & EBN (2018; p18) there is a concern about the environmental and safety risks from the State Supervision on the mines. By regulating the sector the State can secure quality. On the other hand, the technical regulations that are imposed could restrict the opportunities to be innovative according to Blayse and Manley (2004). Schut (2019) emphasises the risks of corrosion that is the result of insufficient quality of the geothermal well piping that can jeopardize the production time of the geothermal well. In that case steering on quality is not only necessary for public actors, but also for private actors that seek financial security and exploitation continuity for their investments. Second, the spatial quality is defined as the extent to which an area development adds value (utility, experience and future) for actors (public, private and civic) and can be measured with variables *(table 3.4.3)* according to Heurkens (2017c, p18).

Utility value	**Experience value**	**Future value**
Approachability	Clarity	Adjustability
Accessibility	Visibility	Compatibility
Proximity	Recognisability	Sustainability
Safety	Aesthetics	
	Diversity	
	Density	

Table 3.4.1 The variables of spatial quality (Source: Heurkens, 2017c, p18, own edit)

Assessing the spatial quality variables of geothermal district heating development shows the non-appearance of certain variables. For instance the utility value approachability and accessibility) is low considering that the majority of the installation is put away underground and not accessible by all actors due to safety issues. Secondly, the future value of geothermal wells can be enlarged if actors are informed about the sustainability. The development is characterized by a notable industrial look similar to the oil and gas extraction, which is why the credibility of sustainability can be questioned for those who are not acquainted with the actual GHG emission savings. Thirdly the experience value of GDHD can be influenced by the variables visibility, clarity, recognisability and aesthetics and is worth investigating in the cases. However, a potential experience value to add is comfort, which is only experienced by the end user, since it concerns heat.

Lastly, the social values that are accepted also determine the environmental quality. Since there is a trend towards decarbonisation **(1.1)**, the inexhaustible and fossil fuel free geothermal energy source **(2.3)** is thought to be one solution to the GHG emission problem that causes adverse climate change effects **(1.1)**.

Besides the perception of quality by the various public, private and civic actors, steering on quality is an important management assignment. Analysing how is steered on quality in the cases leads to clarifications.

An overview of relevant topics out of the management aspects are extracted from the literature *(Table 3.4.2)*. This overview is provided to support the cross-case analysis on the cases.

Management aspect	**Relevant topics**
Money	lock-in costs, development costs, end-user affordability, heat sale opportunity, competitiveness of alternatives, financial risks, subsidies.
Organisation	Organisation types: line management (top-down hierarchy, with repetitive activities), project management (multidisciplinary and temporary organisation), organisation complexity, organisation fragmentation, degree of actor dependency (joint collaboration).
Time	Project duration, project planning, timing of activities between geothermal district heating development and urban development management, operating time of the geothermal well, time overruns.
Information	Dispersion of specialized information, techniques used to foster learning, information provision to tenants and homeowners, involvement of education, science and technology.
Quality	Geothermal well and location; environmental, health and safety quality; Spatial quality (utility, experience, future value); social values; steering on quality.

Table 3.4.2 Relevant topics extracted from the MOTIQ management aspects (Source: own design, based on literature findings)

The definition of relevant topics is necessary because there is a large ambiguity and interpretation possibility on the management aspects. More specification on relevant topics within an aspect prevents speculation.

3.5 Conclusion

The managerial roles and dependencies of public, private and civic actors in implementing energy policies, heat-generating facilities and infrastructure in urban development in the built environment in the Netherlands have been widely investigated in this chapter. Urban area development is characterised by the public-private actor involvement, where consensus with civic actors is required. To come to a direct answer to the first sub question in the research it is worth mentioning that the implementation of energy policies can come from different spatial levels (supra-national, national, regional, local) and that the implementation of heat-generating facilities and infrastructure requires joint efforts from all the three actor groups (public, private and civic). In order to define the dependencies between the actor groups there is chosen to do deeper research on underlying roles of actors to understand their dependencies. The overview of the various actors show the means that actors have at their disposal to steer and manage implementation of energy policies, district scale heat-generating facilities and infrastructure in urban development. Often is spoken about district scale heat exchange projects, but these refer to the same principle: district scale heat-generating facilities and infrastructure.

The managerial roles of public actors are viewed from the governmental levels of the State and Ministries, the Province and the Municipality. Categorisation of the governmental levels is necessary to understand how management is performed, as well as there is a necessity to categorise the type of management that is performed by public actors. On the management tools used by public actors can be concluded that The State and Ministries profoundly use regulatory (e.g. Spatial Planning Act, Order in Council, The Building Decree and Crisis and Recovery act, Heat Act, licence granting etc.), shaping (e.g. climate agreement) and stimulus (e.g. direct state grants, subsidies) instruments. The Province uses regulating (e.g. Provincial-Bye law, environmental permit licencing), shaping (e.g. structure plans) and stimulus tools (e.g. subsidies and guarantees). The Municipality uses regulatory (e.g. environmental permit assessment), shaping (e.g. land use plans, heat plans), stimulus (e.g. development grants, loans) and capacity building (e.g. setup of popups & interaction arenas for communication) tools. The mentioned management tools is a summation of all the possible tools, which does not necessarily mean that these management tools are used in a project.
For the managerial roles of private actors a distinction was made between developers, financiers, communities, investors and corporations. The main conclusion on the roles is that there are certain activities accompanied to the role, which can be fulfilled by various actors. This can be very confusing when all the possible role-actor formations are treated. Important to mention is that a certain combination of private actors is capable of managing the implementation of district scale heat-generating facilities and infrastructure in the built environment. These private actors are dependent on the several management tools by the public actors. For each development an environmental permit need to be acquired in which the public actor in place assesses the alignment with their shaped plans for an area often translated in land use plans or heat plans. This is a general dependence between private and civic actors.
The managerial roles of civic actors are more of a participatory base when speaking of homeowners and tenants, considering that their true managerial role is performed from the community private actor. However, some administrative obligations need to be performed from the homeowner and tenant role regarding the heat contract.
Housing associations on the other hand do not really belong in the categorisation of civic actors, but are more characterised as hybrid having a combination of public, private and civic actor roles. Private actors are dependent on the civic actors, because these generate future cashflow to cover the development costs.

Since no role distribution over the actors can be elaborated on due the lack of specific project data there is an agency model made for the dependency analysis limits the conclusion on dependencies contracts that are agreed on. To conclude on the agreements between the roles it is found from the majority of the agreements is based on an exchange of resources (finance, material and human resources).
The emphasis of the research lies on the analysis of revelatory cases, which means that there is a gap in literature regarding the management of GDHD. Reflecting on how the management aspects influence the actor roles and actor dependencies found in literature does not lead to an answer to the research question demarcation on geothermal energy, but can provide important characteristics of the roles that actors perform in the cases.

3.6 Research model and conceptual model

Here, at the end of the literature phase an overview of the research phases, parts and chapters is provided. It shows the instruments for data collection, processing tools, literature input and output result that is utilised in each phase, part and chapter *(Figure 3.6)*. In the figures the arrows indicates data that acquired, processed and evaluated in order to find answer to the research sub questions. At the end of each part there is a result. The results of part II until part IV represent the answers to the research sub questions.

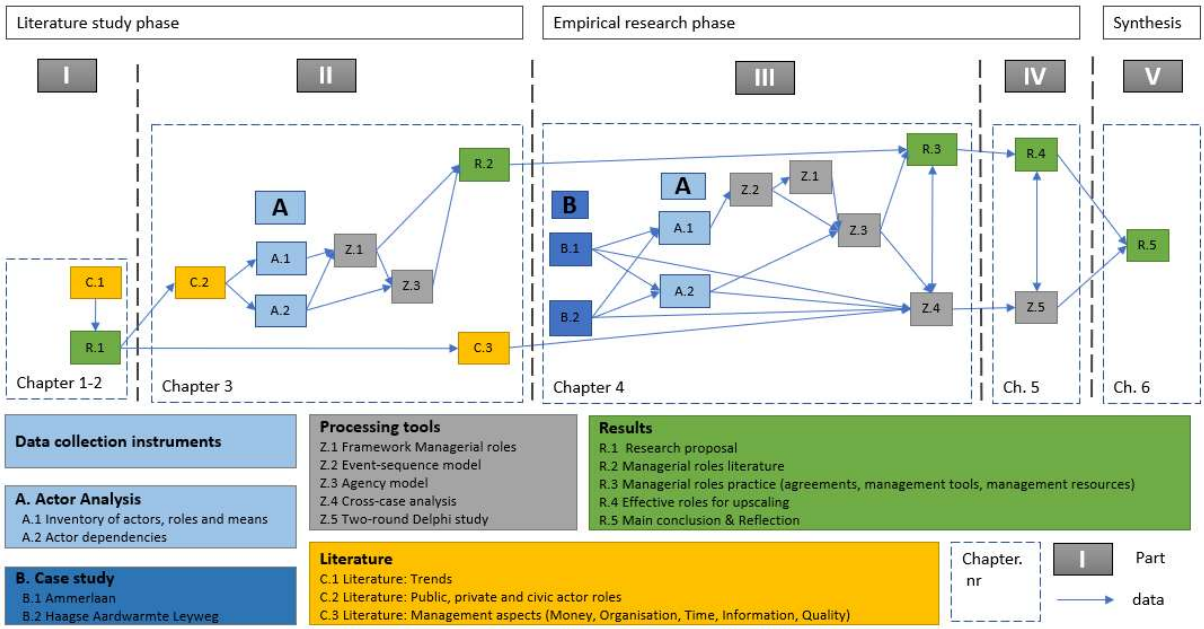


Figure 3.6 Research model (own design)

Now let's first return to the main question of the research: how the public, private and civic actors manage upscaling residential heat-generating facilities to the district scale. A conceptual model can be produced *(Figure 3.7)* showing variables that are used to elaborate on GDHD management. At first actor roles are defined from literature and later evaluated on within the GDHD cases of Ammerlaan and HAL. Further there is determined to what extend various managerial roles and aspects are present among the roles GDHD actors perform. Eventually the results are assessed by experts before conclusions are made on effective managerial roles for upscaling GDHD.

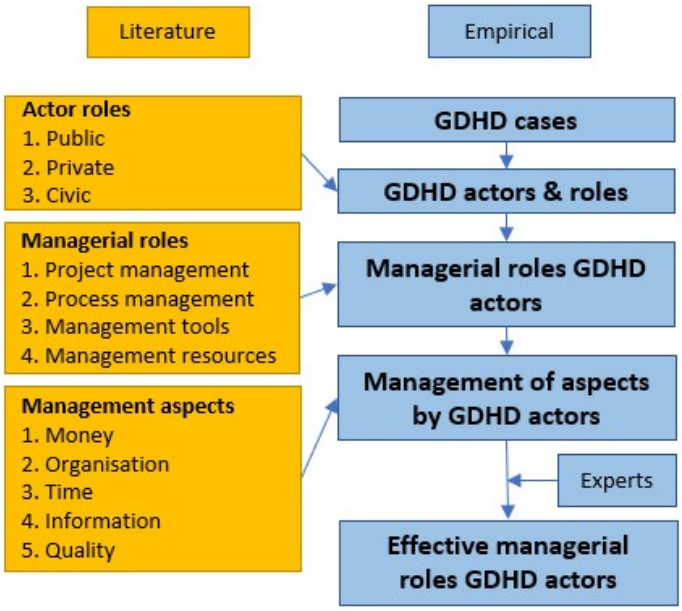


Figure 3.7 Conceptual model (own design)

4. Case study

The object of the study is deep geothermal district heating for residential buildings. Deep geothermal district heating is delivered from agreements of various interdependent private, public and civic actors. The empirical study aims to find an answer to the question on how public, private and civic actors manage the development of district-scale heat-generating facilities and infrastructure for the residential sector in the built environment in the Netherlands. The empirical study focusses on public, private and civic actors and the roles they perform in practice. The aforementioned actor groups are elaborated on by analysing two cases: Ammerlaan **(4.1)** and Haagse Aardwarmte Leyweg **(4.2)**. After there is elaborated on the actors and actor dependencies in the cases, a cross-case analysis **(4.3)** is performed to clarify the managerial activities in both cases from the perspective of management aspects. The findings **(4.4)** from the cross-case analysis are made up where the most important differences and similarities, management aspects and levels are brought to light. Conclusions of the case study are formed **(4.5)**.

4.1 Ammerlaan

Ammerlaan The Green Innovator (TGI) is a greenhouse horticulture company from Pijnacker-Nootdorp that implemented the construction of a geothermal well as heat source to provide its own company (and surrounding environment) of renewable heat, resulting in a major reduction of fossil fuel emission. From the conversations with L. Ammerlaan of Ammerlaan-TGI (personal communication, march 26, 2019), A. Swank from housing association Rondom Wonen (personal communication, march 26, 2019) and K.H., Wolf from Delft University of Technology (personal communication, April 25, 2019) project information is gathered about the development of the Ammerlaan project. Also background information on the project such as ministerial development reports and council meeting reports are used in the empirical study. In order to have an understanding of the actors involved in the development, the case study starts with an inventory **(4.1.1)** of actors through consecutive performed tasks supported by a table showing the involved actors and their means per task. After the inventory, an analysis of the dependency **(4.1.2)** relations between the actors is analysed based on the managerial and organisational variables **(2.3)**.

4.1.1 Inventory

In 2008, researchers from Delft University of Technology made plans to acquire an exploration licence for geothermal heat in the Delft area along other organisations. Because there were many licence requests a concession agreement together with policy plans **(1)** for a heat transition were made in 2009 for a justified development of geothermal heat in the Pijnacker-Nootdorp-Delft region (Gemeente Pijnacker-Nootdorp, 2009a).
Before the actual development started there had to be a closed business case **(2)**. For closing the business case a feasibility study was made based on technical and financial variables. The business case had an estimated production of 200.000 GJ, but requested a minimum production of 100.000 GJ to be feasible (L. Ammerlaan, personal communication, march 26, 2019). Intention agreements were made with the Rabobank for the co-financing of the project and a subsidy was requested **(3)**. The intended geothermal heat project was expected to deliver a heat output that was more than the heat demand of Ammerlaan TGI solely, so plans were already made for the expansion of the heat network *(Figure 4.1)* according to L. Ammerlaan (personal communication, march 26, 2019).

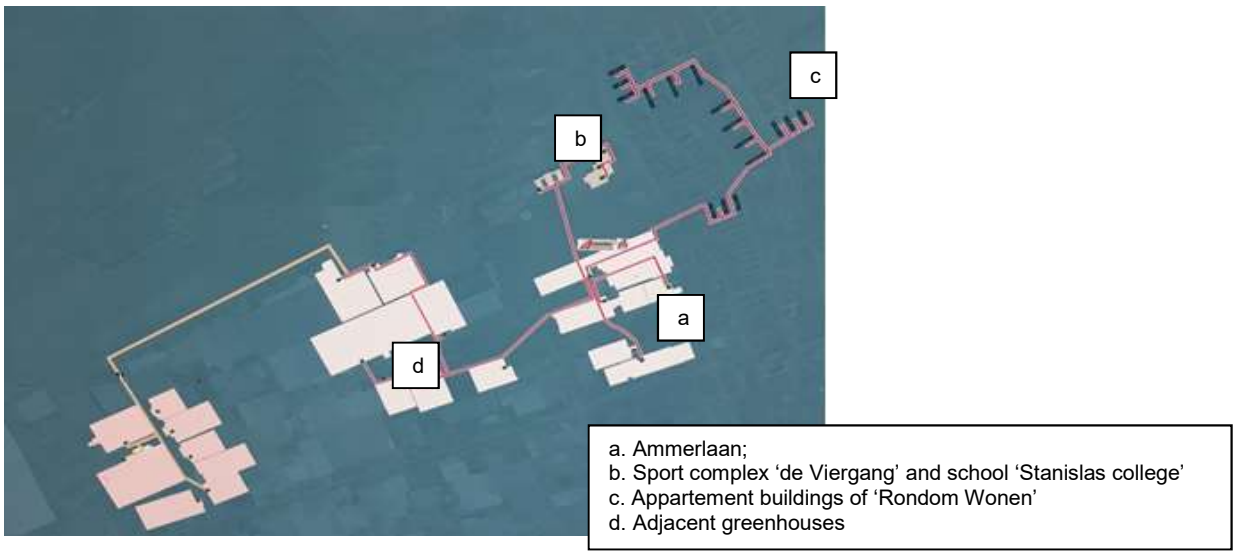


Figure 4.1 A map of the surrounding area of Ammerlaan (a) with the heat consumers in 2016. In the first phase the sportcomplex 'de Viergang' and school 'Stanislas college' (b) were connected to the heat network. In the second phase the apartment buildings of 'Rondom Wonen' (c) and adjacent greenhouses (d) were connected. (Source: Ammerlaan, personal communication, march 26, 2019; own edit).

Before drilling the wells, Ammerlaan TGI was in need of certain licences (L. Ammerlaan, personal communication, march 26, 2019) and had to arrange actors that were able to drill the well. According to L. Ammerlaan (personal communication, march 26, 2019), The Energy market agency is the executive department of the Ministry of Economic Affairs that processes the application and assesses the exploration application with the advice of the State Supervision on the Mines (SSM). The SSM is responsible for the supervision and monitoring on the abidance of laws and regulations of the Mining Act. The SSM also has the task to provide the Ministry of Economic Affairs advice concerning the application for the exploration licence on mining activities below 500m.The exploration licences **(4)** for the production (PNA-GT-01) and injection well (PNA-GT-02) were granted in 2010 (NLOG, 2019).
The drilling company Daldrup & Sönhe AG was chosen to deliver the geothermal well in a turn-key agreement **(6)**, so company was bearing the development risks (L. Ammerlaan, personal communication, march 26, 2019) and acquisition of environmental licenses **(5)**. At the same time of the well development planning, conversations were held between Ammerlaan and potential heat costumers in the future. The first heat costumers were the sportcomplex 'de Viergang' and the school 'Stanislascollege' in Pijnacker, which are owned by the Municipally of Pijnacker-Nootdorp. The operator 'Stedin' was asked to lay down the heat infrastructure to the costumers since they often perform the role of a DSO in the area. Due to insufficient return on investment and high uncertainty the infrastructure development seemed unfeasible for them (L. Ammerlaan, personal communication, march 26, 2019). Eventually, Ammerlaan insisted on taking the responsibility of the infrastructure construction and approached a company for heat network excavation **(7)**. From the personal communication with L. Ammerlaan (march 26, 2019) was told that the Environmental license was assessed by the licensing department of the Municipality of Pijnacker-Nootdorp and The Province is the actor that assesses the compliance of the same environmental license application for the development activities on the surface until a depth of 500m with the provincial rules. According to Ammerlaan, the infrastructure development was only allowed in a given period of time due to management regulation of the Waterboard: in the fall and winter no heat infrastructure development was allowed. The first infrastructure was laid down before the geothermal well was delivered, so the heat was first supplied from the present cogeneration plant in October 2010.
When the geothermal well and heat exchange facility were constructed in 2010 (Daldrup, 2010), an extraction plan was formed to request an extraction licence. The extraction licence **(8)** was granted by the Ministry of Economic Affairs, with the recommendations of the State Supervision of Mines (SSM) and in December 2010 the first heat was supplied **(10)** from the geothermal source according to L. Ammerlaan (personal communication, march 26, 2019). However, in April 2011 the extraction license was withdrawn until the extraction plan was amplified **(9)** due to discovery of gas and oil in the formation water. Multiple adjustment of the environment and system were necessary (Ministerie van EL&I, 2015), which resulted in the repositioning and engagement of additional actors for the extraction plan amplification. The oil and gas industry 'Well Engineering Partners (WEP)' firm was called in and consulted for the renewal of the extraction licence **(10)**. After the extraction license was renewed the geothermal heat was delivered from the beginning of 2012 **(11)** where after a SDE subsidy was requested. An overview of the tasks in the first phase is described and analysed *(Table 4.1.A)*.

Task	Name	Main tasks	Time	Involved actors
1	Publication of plans	Plans for a heat transition in the region	2009	Delft University of Technology, Municipality, Province of South-Holland
2	Business case	Feasibility study: Estimating the production and financial result	Before 2010	Ammerlaan
3	Financing and investment	Acquiring project funds for the well and infrastructure development	Before 2010	Ammerlaan, Rabobank, State
4	Application for exploration license	Requesting exclusive investigation on the presence of geothermal heat.	Before 2010, estimated average 7-10 months before start of drilling	Ammerlaan, Municipality, Delft Aardwarmte Project (DAP), TU Delft, Ministry of Economic Affairs, Dutch State Supervision of Mines (SSM).
5	Application for Environmental licence	Requesting licence for the construction of the geothermal well and heat exchange facility.	Before 2010, usually the normal procedure takes 8 weeks and extensive procedure 26 weeks.	Ammerlaan, Municipality, Province, Water authority
6	Geothermal well and facility construction	Drilling geothermal doublet (PNA-GT-01 & PNA-GT-02) and construction of heat exchange facility	Feb 2010 – nov 2010	Daldrup & Sönhe AG, Ammerlaan, component suppliers and contractors
7	Infrastructure	Construction of heat infrastructure to the costumers of the first phase	unknown-Okt 2010	Ammerlaan and installer, municipality, authority
8	Extraction licence	Requesting license for heat production	December 2010	Ammerlaan, Ministry of Economic Affairs, Dutch State Supervision of Mines (SSM).
9	Extraction plan amplification	Redesigning and replacing wellheads and location adaptation	April 2011 – Start of 2012	Ammerlaan, SSM, consultant Well Engineering Partners (WEP), Deep Drill.
10	Renewed Extraction licence	The acquisition of the extraction license	Start of 2012	Ammerlaan, Ministry of Economic Affairs, Dutch State Supervision of Mines (SSM).
11	Operation	Heat supply of sport complex and school	Okt 2010 – now	Ammerlaan, Sportcomplex 'de Viersprong', school 'Stanislas college'

Table 4.1.A An overview of the steps that were taken in the development of the geothermal well from the moment the business case was made until the moment the renewed extraction licence was granted (Sources: L. Ammerlaan, personal communication, march 26, 2019; van den Bosch, Flipse & Vorage, 2013; Daldrup,2010, p24; AgentschapNL, 2011b).

During production there was a surplus of heat that was produced which offered opportunities for further expansion to the apartment buildings of the housing association and adjacent greenhouses according to L. Ammerlaan (personal communication, march 26, 2019). Negotiations between Ammerlaan, the Housing association 'Rondom Wonen' and the Municipality followed and took a couple of years in which the financial and technical possibilities were determined **(12a)**. Plans were made to connect a couple of the apartment buildings of Rondom Wonen (A. Swank, personal communication, march 26, 2019).This resulted in the intention to connect apartment buildings, consisting of 470 dwellings that already had a collective building scale heat-generating facility and network to each of the dwellings according to A. Swank (personal communication, march 26, 2019). In order to make the project technically feasible and heating comfortable for the tenants, replacement of the two-plate radiators by three-plated radiators and single glazing by insulated glazing was necessary and adjustments of the boiler rooms of the buildings had to be executed (L. Ammerlaan, personal communication, march 26, 2019). Rondom Wonen selected the Energiewacht who made an attractive offer for the renovation. According to A. Swank (personal communication, march 26, 2019) there was no budget available for the renovation, but together with the Municipality of Pijnacker-Nootdorp the project could be 100% financed with subsidies in April 2015. Before granting permission for the realisation of the heat network infrastructure and adaptations to the apartment building, licenses were needed **(12b)**.

The expansion of the network was realised at the end of 2015 **(13)** at which time Ammerlaan and the housing association Rondom Wonen signed **(14)** a ten year heat delivery agreement (A. Swank, personal communication, march 26, 2019) and a heat delivery agreement with the adjacent greenhouses **(15)**. During operation **(16)** of the heat production facility between 2012 and 2017, the system was in need of monitoring and maintenance (L. Ammerlaan, personal communication, march 26, 2019). An overview of the tasks in the expansion phase are provided *(Table 4.1.B)*.

Task	Name	Main tasks	Time	Involved actors
12	Planning	Determination of technical and financial feasibility (12a) and application for environmental licence for renovation and infrastructure (12b)	2012-2015	Ammerlaan, Housing association 'Rondom Wonen', municipality, adjacent greenhouses
13	Realisation	The realisation of the renovation of the apartment buildings and infrastructure	Juli 2015 – December 2015	Housing association 'Rondom Wonen', adjacent greenhouses, Municipality, Ammerlaan & partners (VB-projects, energiewacht, montera techniek, welvreugd)
14	Heat delivery	The production, distribution and supply of heat to housing association	Dec 2015	Ammerlaan, Housing association
15	Heat delivery	production, distribution and supply of heat to adjacent greenhouses	Dec 2015 - now	Ammerlaan, Adjacent greenhouses
16	Operation	The maintenance and operation of the heat exchange system	2012- okt 2017	Ammerlaan, maintenance partners and suppliers

Table 4.1.B An overview of the steps that were taken in the development of the infrastructure expansion and renovation of apartment buildings from the feasibility study until the operation of the geothermal system (Sources: L. Ammerlaan, personal communication, march 26, 2019; A. Swank, personal communication, march 26, 2019)

After many years of operation a technical failure occurred in October 2017 *(Table 4.C)*. At a depth of approximately 1000m the production well broke resulting in the shutdown of the geothermal well (L. Ammerlaan, personal communication, march 26, 2019). The cogeneration plant present needed to be used again to provide heat for the consumers. After the production well broke down, Ammerlaan sat on the table with the Rabobank and Municipality of Pijnacker-Nootdorp to discuss the financing **(17)** for a new doublet (PNA-GT-05 & PNA-GT-06) and future heat infrastructure. When there was a financing agreement, Ammerlaan was in need of the necessary Environmental license and selected construction partners for the development of the second doublet **(17)**. During the realisation of the doublet there were setbacks and the construction came to stop. The project for the second doublet was halted until there was additional funds **(19)**, which happened to come by at the moment of personal communication on the 26th of March. Due the potential negative effects of energy facilities on the environment, an Environmental Impact Assessment (EIA) is found obligatory by councils decision (Ruimtelijkeplannen, 2018) from July 2018 onwards **(20)**. Now that additional funds for the project are acquired, the execution of the new expansion plan for 2019 could be continued.

Task	Name	Main tasks	Time	Involved actors
17	Financing and investment	Acquiring project funds for drilling a new production well and future infrastructure	Oktober 2017 – Februari 2018	Ammerlaan, Rabobank, Province of South Holland, Municipality of Pijnacker-Nootdorp
18	Planning	Determination of technical (engineering) and financial feasibility and application for environmental licence for second doublet (PNA-GT-05 & PNA-gt_06) and future regional infrastructure	Oktober 2017 – Oktober 2018	Ammerlaan and partners (WEP, Innodrill, etc.), Rabobank, Province of South Holland, Municipality of Pijnacker-Nootdorp
19	Realisation	Realisation of the second doublet	April 2018 — now	Ammerlaan and construction partners (WEP, Innodrill)
20	Financing	Acquiring additional project finance	Unknown — now	Ammerlaan, unknown
21	Environmental Impact	Assessing the environmental impact of the development	Sep 2018 — now	Ammerlaan, Munipality

Table 4.1.C An overview of the steps that were taken after the shutdown of the first doublet (Sources: L. Ammerlaan, personal communication, march 26, 2019;; van den Bosch, Flipse & Vorage, 2013; Gemeente Pijnacker-Nootdorp, 2018; WEP, 2018).

4.1.2 Dependency analysis

Many actors were involved in the development of the geothermal well and infrastructure but there can be concluded that Ammerlaan was at the heart of the development. In order to determine the dependencies and cooperation between the actors an agency model of each of the three earlier found (expansion) phases is made. For each phase the aspects and corresponding variables of the managerial and organisational variables **(2.3)** are deeper analysed following the sequentially executed tasks of the actors involved. Each agency model name corresponds with the eponymous table to avoid confusion. The first phase, called phase A from here *(Figure 4.1.A_1 & Figure 4.1.A_2),* comprises the timespan from publishing of municipal plans before 2010 until the moment the SDE subsidy was granted in 2012. The figure forms the basis of the organisation in the project in which the dependencies between actors is shown with an arrow. The single arrow can indicate an exchange of multiple dependencies: exchange of money, information and knowledge and mutual agreements (*Figure 4.1.A_1)*.

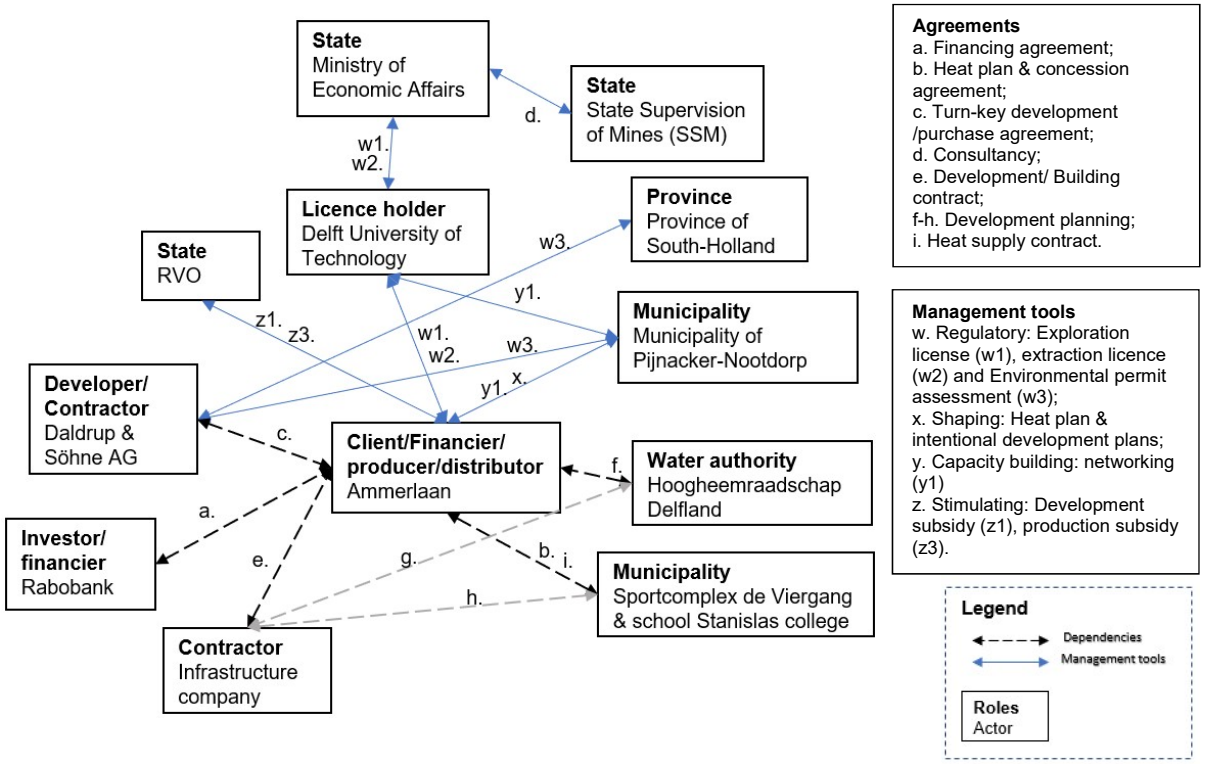


Figure 4.1.A_1 An agency model of phase A_1 from the moment the business case was made until the moment the first geothermal heat was delivered. (Source: own design, based on empirical findings).

One of the first steps found in the development is the publishing of plans for a heat transition by the Gemeente Pijnacker-Noordorp **(x)**, which were accompanied by a budget allocation reserve called 'warmtetransitiefonds' for the implementation of the project plan. Publication of plans by municipal governments as shaping instrument found in literature **(3.2.1.c)** is recognised in the initiative of the Ammerlaan project. The shaping instrument influences the development plans of organisations, because they are legally binding. The publication of the heat transition plan followed after Delft University of Technology as exploration licence holder was asked to cooperate with local organisations in a heat transition since The Ministry of Economic Affairs received multiple exploration requests in the region (Gemeente Pijnacker, 2009). Instead of competing actors and organisations the actor relationships were improved by the in literature described capacity building tools **(3.2.1.c)** as networking **(y1)** facilitated by the Municipality.

Before physical implementation a closed business case needed to be created in which the company of Ammerlaan was responsible for gathering the correct technical and financial variables according to L. Ammerlaan (personal communication, march 26, 2019). Developers of heat-generating facilities such as Ammerlaan are found to be interested in covering the development risks and sale opportunity according to literature **(3.2.2.a & 3.4.1)**. The internal actors within the company of Ammerlaan had the task to determine the risks and revenues for the feasibility of the project using the financial and technical variables in a financial calculation model. The financial calculation model could assume certain investment costs, production of the facility, sales of heat and operational costs. In the first phase Ammerlaan intended to use the heat for its own greenhouses with expansion potential, so a benchmark for heating the Ammerlaan portfolio must have been made to come to the decision for alternative heating sources. Looking at the management resources, the land the well was placed on was already in the possession of Ammerlaan, which would lead to less discord among property owners.

In order to acquire additional capital for the construction of the geothermal well Ammerlaan approached the investment bank Rabobank **(a)** to come to a financing agreement for the co-financing of the project. Investments in energy facilities are characterised by returns on the long term through periodical payments, so the project financing could be considered a long-term investment. In between Ammerlaan and Rabobank an exchange of money would follow, based on contractual agreements made. At first a request for a loan is made, accompanied by a an estimated business case for the development. There was a high certainty on the sales of heat since Ammerlaan expected to use the heat itself and the development risks were covered. Ammerlaan would receive a preferred amount of money for development against an agreed rent which will be periodically paid back. As found in literature **(3.2.2.b)** financers play an essential part in the development as they provide capital for investment, whereas the development of a geothermal plant is characterised with high up-front investments and long-term investment returns.
The state department RVO, who is responsible for the assessment of requests for and grants of subsidies, was approached **(z1)** for a MEI-subsidy, in order to ensure financial feasibility. Subsidy is an example of the stimulating management tool that public actors use to induce market behaviour. The MEI-subsidy stand for Market introduction for energy innovation and is an investment subsidy that exists to financially support horticultural companies who would like to invest in sustainable energy systems (RVO, 2019c). In order to receive a subsidy the applicant must meet the predetermined conditions and there is limited budget available to which the applicant can apply according to RVO (2019c).

At the time the development of the sport complex and school was executed, Ammerlaan communicated and negotiated with the actors responsible where after both decided on having a potential connection for the heat infrastructure **(b)**. These plans were panned out in the Municipal spring memorandum of 2010 (Gemeente Pijnacker-Nootdorp, 2010), which is a shaping instrument used by public actors The development of land and real estate were performed by private actors which means that a concession agreement is made for the infrastructure according to the initiative of the Municipality. For ensuring the technical feasibility of the geothermal well development, Ammerlaan involved the contractor Daldrup & Söhne AG, who had the knowledge and capital at their disposal **(c)**. After communication and negotiation between Ammerlaan and Daldrup there was decided to intentionally agree on a turn-key development. In the turn-key agreement the rules and requirements of the actors concerning the development and transfer of real estate in return for money were recorded. Ammerlaan insisted on transferring the development risks and responsibilities to the contractor as well as the licensing activities, on behalf of Ammerlaan.

After the tentative agreements were made **(a-c)**, the Ammerlaan project was dependent on the various management tools executed by the different government layers **(w-z)**. An analysis shows that the regulatory management tools are frequently used here, were the emphasis lies on laws and regulations from the Spatial Planning Act (SPA) and Mining Act (MA). At first an exploration license has to be requested **(w1)** from the Ministry of Economic Affairs for which a geological survey, exploration plan, safety and health measures and technical and financial capabilities has to be submitted in accordance with the Mining Act. Whether the exploration licence is approved depends on the prevailing preconditions for Mining for which the State Supervision on Mines (SSM) is consulted **(d)**.
The approval of an Environmental license was dependent of the licensing department of the Municipality of Pijnacker-Nootdorp **(w3)** who was involved as the actor that assesses whether the submitted geological survey, construction plan for the intended development activities on the surface comply with the municipal rules (e.g. land use plan), while the Province assesses **(w3)** the compliance with the Provincial rule until a depth of 500m. Literature **(3.2.1.b & 3.2.1.c)** confirms that this role of the Municipality and Province is a general task for all Municipalities and Provinces when an environmental license is requested.

For the development of the heat infrastructure to the school and sport complex, Ammerlaan had contracted **(e)** an infrastructure developer to complete the heat network within budget in a predetermined timespan. The heat network was passing through municipal land and since it could have consequences for the soil structure, it concerns the operation field of the Municipality of Pijnacker-Nootdorp and the water authority Hoogheemraadsschap Delfland **(f)**. The regulatory management tools were predominant for determining the project planning. The moment the excavation works had to take place was determined by management regulation, so arrangements had to be made between the Ammerlaan, the contractor, Hoogheemraadschap Delfland **(g)** and Municipality Pijnacker-Nootdorp **(h).** Planning the delivery of the heat requires time management of the realisation of the geothermal well, facilities and infrastructure, while also considering the licensing procedures. When the geothermal well and heat exchange facility were constructed, necessary information for the extraction license **(w2)** was acquired through monitoring the composition of the formation water from the subsurface. The results from the tests determine how an extraction plan is formed and the outcome of the results influence the decision for further development. The extraction plan forms the basis for the extraction request for which the preconditions are set by the State Supervision on Mines (SSM) in the Mining Act. The Ministry of Economic Affairs assesses the extraction plan for the extraction licence request, with the recommendations of the SSM. The granting an extraction licence to the applicant is dependent on the rules set on that moment in time. So far, the extraction plan was in accordance with the former Mining Act for geothermal heat so in December 2010 the first heat was supplied from the geothermal source.
A part of the development costs were covered by allocation of cost by replacing natural gas by geothermal heat for Ammerlaan and for another part by the heat sales to the Sport complex and school. For the latter Ammerlaan and the school and sport complex agreed on a heat delivery contract **(i)** consisting of the heat price that is paid for the delivery of heat in GJ and other tasks, responsibilities, rules and requirements that apply to the actors. Ammerlaan was also eligible for renewable heat production subsidy **(z3)**.

The heat supply from the geothermal source lasted for a couple of months before the production had to be shut down due the little amounts of gas and oil that were found in the formation water. At this point the dependency of Ammerlaan in relation to the different governmental layers became more visible. The regulations in the Mining Act, regulations were tightened where after the same standards as in the gas and oil industry were required. As a result of the former event, the extraction license was withdrawn and led to role repositioning and involvement of additional actors that had the means to run the redevelopment of the geothermal well *(Figure 4.1.A_2)*.

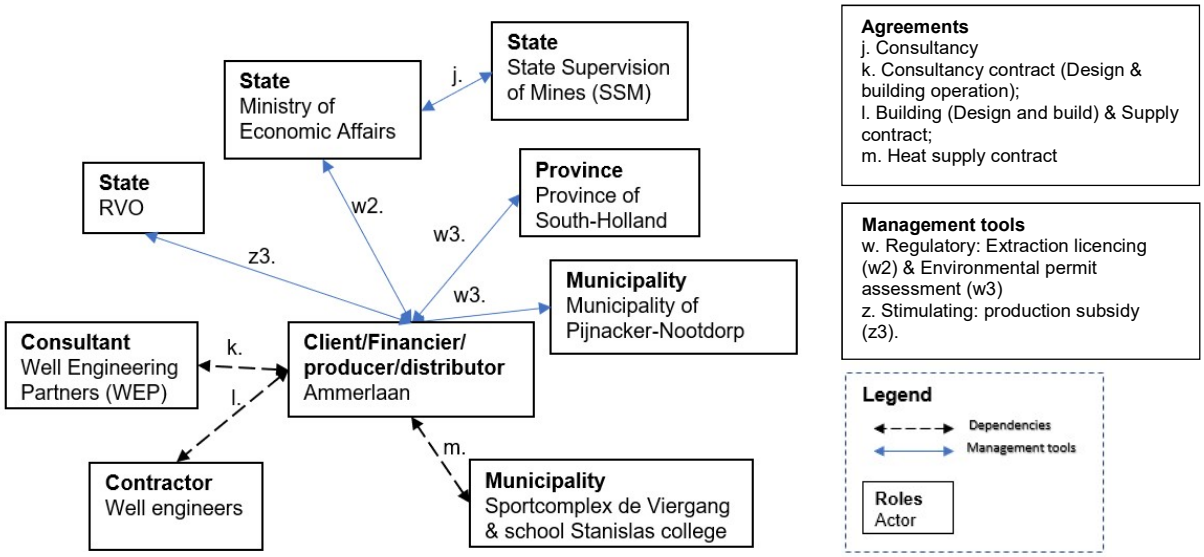


Figure 4.1.A_2 An agency model of phase A_2 that indicates the dependencies between the actors as a consequence of the extraction plan amplification (Source: own design, based on empirical findings).

In this phase the process management tools communicating, negotiating and decision-making are predominantly recognised when deeper analysing the extraction plan amplification. The wellheads needed to be redesigned and in order to separate the small amounts of oil and gas from the formation water, an oil tank and degassing installation needed to be installed **(w2, j.)** as well as also environmental adjustments to prevent soil contamination were mandatory **(w3)** as reported by Ministerie van EL&I (2015). Because of the lack of specific knowledge the consultancy firm from the oil and gas industry 'Well Engineering Partners (WEP)' was called in together with well engineers **(k, l)**. The role of WEP concerns well engineering and the supervision during rig site operations. Together with the wellhead supplier of Daldrup & Söhne AG, 'Deep drill', multiple wellhead were designed and tested against the standards defined by the SSM, which led to a final design for the renewed extraction licence **(w2)**. Environmental adjustment were realised to prevent soil contamination and an ATEX-zoning plan was drawn up for health protection and safety purposes according to Ministerie van EL&I (2015).

The setbacks resulted in a delay of the heat supply from the geothermal well **(m)** until the beginning of 2012. From the moment the geothermal well was producing heat from a renewable source, Ammerlaan was authorised to request a SDE subsidy for producing renewable heat **(z3)**, which is recognised as stimulus instrument for the project which was granted in 2012 for a period of 15 year (RVO, 2019). An SDE subsidy is a state subsidy that can be requested for renewable energy production.

The surplus of heat during production offered opportunities for further expansion which led to a larger actor involvement *(Figure 4.1.B)*. At this time shaping instruments executed by the Municipality of Pijnacker-Nootdorp are recognized in the environmental structure vision in which the Municipality has plans to realise, stimulate and facilitate developments concerning the heat transition and does this in cooperation with Ammerlaan **(x)** and affects all the real estate in the Municipality, among which housing associations. The municipality facilitated the execution of an energy transition by thinking along and creating value for the heat project of the housing association. It was told that the communication occurred at the moment the Municipality and Ammerlaan approached the housing association, which can be considered as capacity building management tools facilitated **(y2)** by the Municipality. As found in literature **(3.3.3.b)** housing associations have the intention to have a carbon neutral solution for the heat provision for its portfolio and this is confirmed in the case where 'Rondom Wonen' was interested in the proposal for geothermal heat from Ammerlaan. Communication and negotiation between Ammerlaan, the Municipality, the Housing association 'Rondom Wonen' followed and resulted in the decision for intended renovation of 470 apartment buildings that already had a collective building scale heat-generating facility and network to each of the dwellings. Although the housing association had end-user data concerning heat demand, they were dependent on Energiewacht **(a)** for the technical calculations because of a changing heat source for the residents. The changing heat source is of a lower temperature than heat from natural gas combustion and required replacement of the two-plate radiators by three-plated radiators and single glazing replaced by insulated glazing was to keep thermal comfort. Also the collective boiler room needed to be adapted. There could be a risk of tenants not accepting the changes and therefore a juridical assessment was performed and there was concluded that the tenants had no influence on the decision making concerning the renovation because the elements being replaced are part of the maintenance responsibilities of the housing association as building owner. This is in contrast with the results that are found in literature **(3.3.3.b)** in which is found that at least 70% of the tenants should consent with the renovation in general.

Before the actual renovation decision was made, internal negotiations took place in the meeting of Council of the Municipality of Pijnacker-Nootdorp regarding arguments, conditions, policy alignment, further municipal tasks and costs. On behalf of Rondom Wonen, the Municipal Council acquired two subsidies that covered the costs for 100%: the allocation of the Stadsgewest Haaglanden subsidy and an EFRO-subsidy (European Funds for Regional Development) **(z1)**, which are both considered stimulus instruments. The former subsidy is a specific stimulus for developments that promote decarbonisation and the latter is a specific European subsidy for innovation and decarbonisation for European regions. Both require certain preconditions of the applicant to be granted. Agreements for the heat delivery to the corporation were signed in May 2015 with Ammerlaan **(b)**.

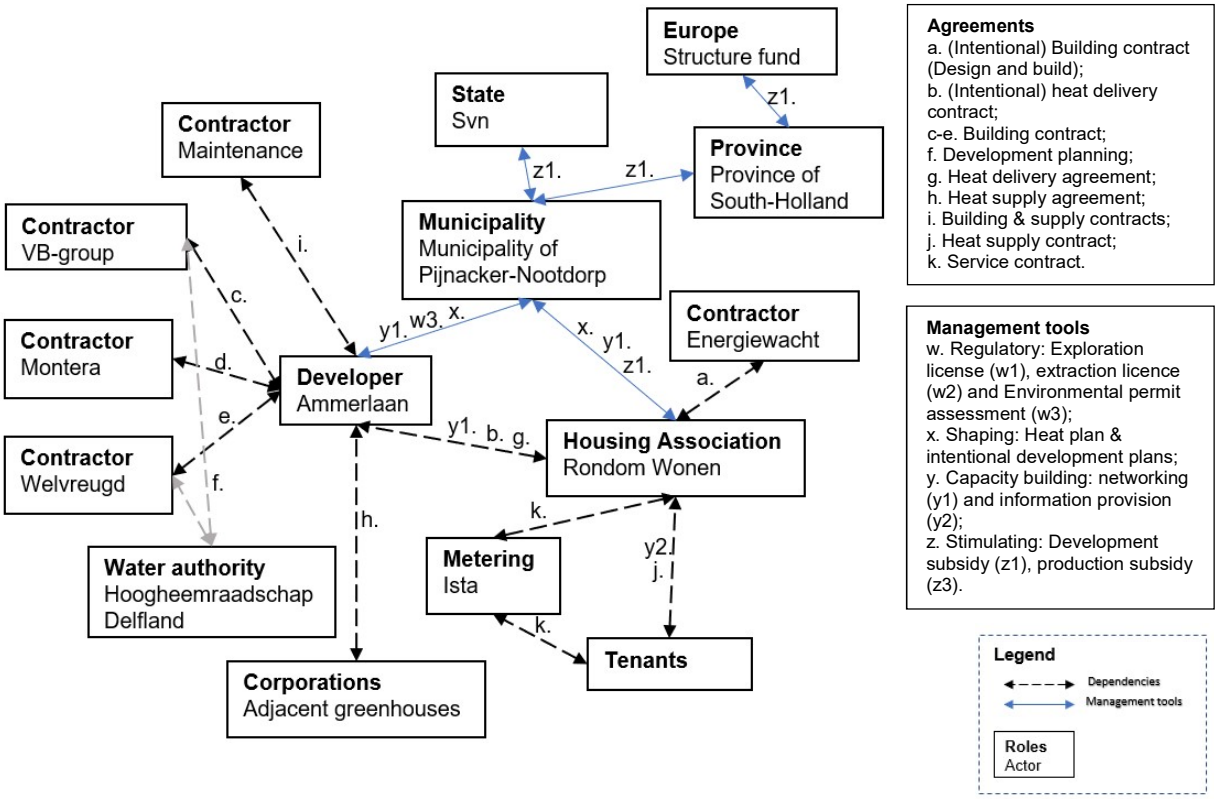


Figure 4.1.B An agency model that indicates the dependencies between the actors in the expansion phase (Source: own design, based on empirical findings).

After the EFRO-subsidy was acquired, the residents were informed **(y2)** about the planned residential adjustments by the housing association, which led to surprised reactions of the tenants. A legal test was performed beforehand to determine to what extend the tenants had voice in the decision making. The outcome enacted that for the replacement of radiators the service component nor the heat cost did not change so there was no legal issue for reaching consensus for the adaptations. The replacement of glass is a rental component, which means that as a corporation you may ask additional rent from tenants because of the limited financing capacity. The tenant acceptance of insulated glass was measured from surveys in order to make an inventory of the residents who wanted to participate, where after quite a few people participated in this. The lock-in of the depreciation period of the existing boilers of the apartment buildings was taken into consideration and the divestitures were deducted from the margins of Ammerlaan. Ammerlaan had the tasks to involve partners that were able to realise the system for expansion, from the heat exchange facility at the geothermal well until the heat exchange facilities at the housing association and adjacent greenhouses. VB-group was responsible for the realisation of 2,8 km heating infrastructure to the apartment and delivery systems **(c)**. Other involved contractors **(d, e)** were Montera (specialist in electrical and water engineering for greenhouse horticulture) and Welvreugd (specialist in earthwork design and engineering). To acquire permission for the realisation of the heat network infrastructure and adaptations to the apartment building an Environmental license **(w3)** had to be granted beforehand by the municipality of Pijnacker-Nootdorp and for the earthworks coordination with the water authority Hoogheemraadschap Delfland was necessary **(f)**.

The expansion of the network was realised at the end of 2015 at which time Ammerlaan and Rondom wonen signed a ten year heat delivery agreement with the housing association **(g)** and a heat delivery agreement with the adjacent greenhouses **(h)**. During the operation of the heat production facility, the system was in need of monitoring and maintenance **(i)**. In the operation period of the geothermal well between 2012 and 2017 several components were in need of replacement. The pump and heat exchangers required annual maintenance, while the filter system required weekly maintenance. The pump had to be pulled many times for several causes: casing, seals, cables, logging and engine (re)placement. In the operation Ammerlaan is responsible for multiple roles in the heat supply chain: producer and distribution. As a producer Ammerlaan manages the varying heat demand (e.g. seasonal, current and future) with the heat supply (e.g. baseload, middle load, peak load and back-up), from a combination of the geothermal well (baseload and middle load) and cogeneration plant (peak load and back up). As distribution service operator Ammerlaan controls the heat balance to match the supply and demand. At the end of the supply chain the housing association is responsible for the heat sales **(j)** to the individual apartments. The means used for the settlement of costs **(k)** is a distribution key metering from the company Ista. According to Rondom Wonen the tenants cooperated fine although they had to be home during renovation. Their largest concerns were the costs of heat and comfort that could change after renovation according to Rondom Wonen.

Now that the geothermal well is not operational plans are made to build a new geothermal well that has a larger capacity than its predecessor so there is expansion potential. The Municipality of Pijnacker-Nootdorp and Province of South-Holland would benefit from the expansion of the current heat infrastructure network since they pursue the execution of sustainable policy (Gemeente Pijnacker-Nootdorp, 2018). However, the development of the new well and further expansion is considered a repetitive process of the previous steps and ongoing and therefore is not included in the report.

4.2 Haagse Aardwarmte Leyweg

Haagse Aardwarmte Leyweg (HAL) is an initiative consisting of three actors: Hydreco Geomec, Perpetuum Energy Partners (PEP) and Energiefonds Den Haag (ED) who have taken over the existing geothermal well of the former organisation. The rollout of a new heating network is considered the management of upscaling individual heating to heating by one heat-generating facility. The aim of this project is to produce geothermal heat for a more sustainable inner-city environment for the district The Hague Southwest. From the conversations with B. van Dun from Hydreco Geomec (personal communication, march 26, 2019), N. van Est from ED (personal communication, April 24, 2019) and Eneco (personal communication, April 25th, 2019) extracts were made to clarify how the development of the HAL project is managed. Also background information on the project such as presentations at the DAP symposium, council meeting reports and Municipal documents are used in the empirical study. In order to have an understanding of the actors involved in the development, the case study starts with an inventory **(4.2.1)** of actors through a chronological time-sequence of tasks supported by a table showing the involved actors. After the inventory, an analysis of the dependency **(4.2.2)** relations between the actors is analysed based on the managerial and organisational variables **(2.3)** where it becomes clear which means are used by which actor and how and why these means are being used.

4.2.1 Inventory

The Hague was third Dutch city that decided to lay down a district heating network in 1975 as a result of the oil crisis according to Den Haag (2014; p16). In 2014 the total amount of connections is 16.277 of large and small costumers (Den Haag, 2014). The existing heat infrastructure (HT network 90-70 C) in The Hague is shown *(Figure 4.2.1)* with the red lines and are connected to the black dots which represent heat plants. The green lines show the geothermal heating network (LT network 70-50 C) but due to the bankruptcy of ADH supplied by the HT network until the geothermal wells are completed and is connected. The geothermal plant is shown with a red circle.

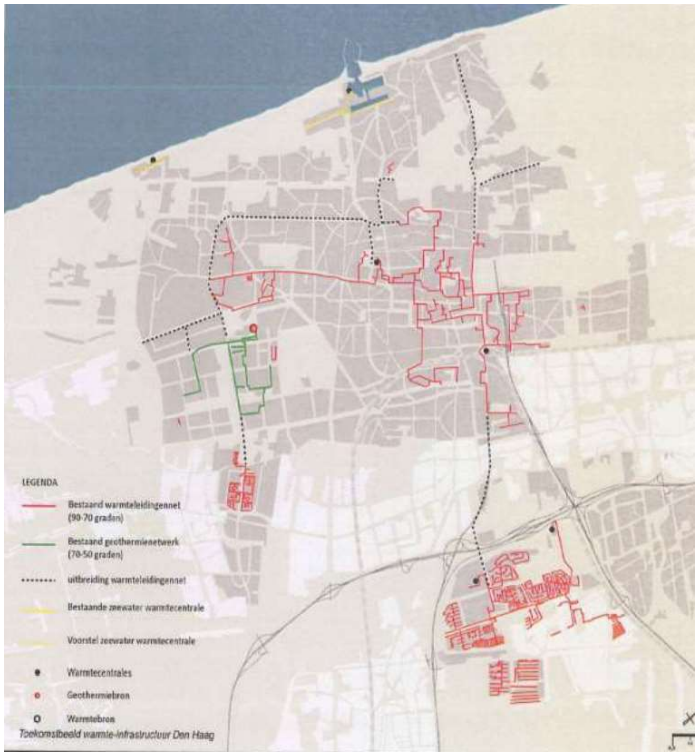


Figure 4.2.1 The existing heat infrastructure in The Hague (Source: Den Haag, 2014, p18)

Before the Haagse Aardwarmte Leyweg (HAL) organisation was established, Aardwarmte Den Haag (ADH) was the organisation that initiated the project in 2007 **(1)** according to Gemeente Den Haag (2016a). ADH was a joint venture of the Municipality of the Hague, the housing associations Vestia, Haagwonen, Staedion and the energy companies Eneco and Uniper Benelux (former E.on) according to van Dun (personal communication, march 26th, 2019). The organisation of ADH planned to provide 3.812 dwellings and 20.000m2 of offices in the The Hague Zuidwest district, which is an urban area within the city in The Hague. The Hague Zuidwest is a district that is entitled as 'krachtwijk', which means it is a problem area that qualifies for restructuring (Den Haag, 2007). The sustainable ambitions of the Hague led to a heat plan (Gemeente Den Haag, 2014) in which this district would be connected to a heating network with geothermal energy as a source. The ADH organisation of heat and expected to lay down the necessary infrastructure **(2)** between the period 2009-2015 according to Aardwarmte Den Haag (2011).

The geothermal well was drilled in 2010 by ADH and development partners **(2)** according to Schoof (2011). ADH was declared bankrupt in 2013 after the geothermal well was drilled **(3)** due to setbacks in the sales of heat due unfinished residential development caused by the credit crunch (Gemeente Den Haag, 2016a). Since the geothermal well was closed down, Eneco acquired the distribution net in order to deliver heat **(5)** to the already connected dwellings. The heat of Eneco is purchased from Uniper produced by a Combined-Cycle Gas Turbine (Gemeente Den Haag, 2016b). Since the conditions have changed, the Municipality of The Hague decided that the relaunch **(6)** of the project is an attractive option from Municipal perspective (Gemeente Den Haag, 2016a). In 2016 the geothermal well was taken over by the special purpose vehicle HAL **(7)** in which Hydreco Geomec is contracted as operator that carries out the planning **(8)**, realisation **(9)** and operation of the geothermal well. In the new situation HAL will be the heat producer, while Eneco is purchasing the heat and executes the heat transport and distribution to the end-users. At the moment the heat is being delivered from Uniper until the geothermal well is operational **(10)** according to B. van Dun (personal communication, march 26, 2019).

Task	Name	Main tasks	Time	Involved actors
1	Start-up of ADH	Development of the ADH organisation	2007	Municipality of the Hague, the housing associations Vestia, Haagwonen, Staedion and the energy corporations Eneco and E.on Benelux
2	Development of infrastructure	Development of heat infrastructure for 4000 dwellings	2009-2015	ADH and partners (Eneco: infrastructure, consultants)
3	Development of the well and infrastructure	Drilling the geothermal well, development of buildings and geothermal system components.	March – Nov 2010	ADH and development partners WPMI: well construction, Stebru Bouw: civil works heat plant, Cofely: installation components, consultants)
4	Bankruptcy	Bankruptcy declaration	August 27th, 2013	Municipality of the Hague, the housing associations Vestia, Haagwonen, Staedion and the energy corporations Eneco and E.on Benelux (ADH)
5	Delivery of heat	Heat delivery from the gas turbine	2012-now	Eneco, Uniper, end-users
6	Project relaunch	Redevelopment of the ADH project	September 2015	Municipality of The Hague, Energiefonds Den Haag (ED).
7	Takeover	Well acquisition	2016	Official receiver (curator) of ADH, HAL
8	Planning	Licencing, engineering and cleaning wells	December 2018 – August 2019	HAL, PEP, Hydreco Geomec
9	Realisation	Construction to connect to the grid, supervision and monitoring	August 2018 – January 2020	Hydreco Geomec
10	Operation	Start up and operation of the geothermal well	Feb 2020 (Planned)	Hydreco Geomec, Eneco

Table 4.2 An overview of the steps that were taken in HAL project (Sources: B. van Dun, personal communication, march 26, 2019; Gemeente Den Haag, 2016a&2016b; Aardwarmte Den Haag, 2011; Schoof, 2011).

4.2.2 Dependency analysis

In the last step of the actor analysis the dependency relations between the involved actors in the project are determined. The actors involved are gathered from the actor inventory **(4.2.1)** and their interdependencies are viewed by looking at the types of resources actors have at their disposal to perform their role. Similar as in the case study of Ammerlaan **(4.1)**, a diagrammatic representation of the actors (*Figure 4.2.2)* forms the structure of the organisation of the project. The dependencies between actors are shown with an arrow. The single arrow can indicate an exchange of multiple dependencies: exchange of money, information and knowledge and mutual agreements. The arrows are labelled **(a-y)** and are discussed in the following paragraphs.

Before the HAL project was initiated, ADH and partners were declared bankrupt **(4.2.1).** The prospect of connecting a large residential area to the geothermal well formed a feasible business plan for the actors involved (Municipality of the Hague, the housing associations Vestia, Haagwonen, Staedion and the energy corporations Eneco and E.on Benelux) but unfortunately led to bankruptcy. The restart after bankruptcy in 2016 under the name Haagse Aardwarmte Leyweg (HAL) is an initiative consisting of three actors: Hydreco Geomec, Perpetuum Energy Partners (PEP) and Energiefonds Den Haag (ED) who have taken over the existing geothermal well from the curator.

In the restart, the Municipality of The Hague still had the ambition to pursue heat delivery from the geothermal well. Plans **(x)** such as the energy transition plan of the Municipality of The Hague is a recognized shaping instrument used. Another management tool recognised is the capacity building that is used for the provision of information and interaction concerning development by the Municipality and HAL organisation with housing associations, tenants and homeowners. To execute that plan a restart with a Special Purpose Vehicle (SPV) under the name of HAL was put into operation for the development. In 2013 the Municipality of The Hague started a revolving energy fund 'Energiefonds Den Haag (ED)' that deploys financial instruments that makes use of the European Funds for Regional Development (EFRO). According to the correspondent from ED, N. van Est (personal communication, April 24, 2019), ED meets the capital demand that was lacking in the project due market failure. Findings in literature **(3.2.1)** show that management tools by public actors such as development grants and loan guarantees are common public law instruments, but the provision of capital for investment was only possible through private law instruments: the involvement in a legal entity. ED now has an important capital-providing or -raising **(z2)** role in HAL as shareholder **(a)** in the SPV. The means of ED are providing capital for development at which interest and amortisation is due and provided by future cashflows of HAL.

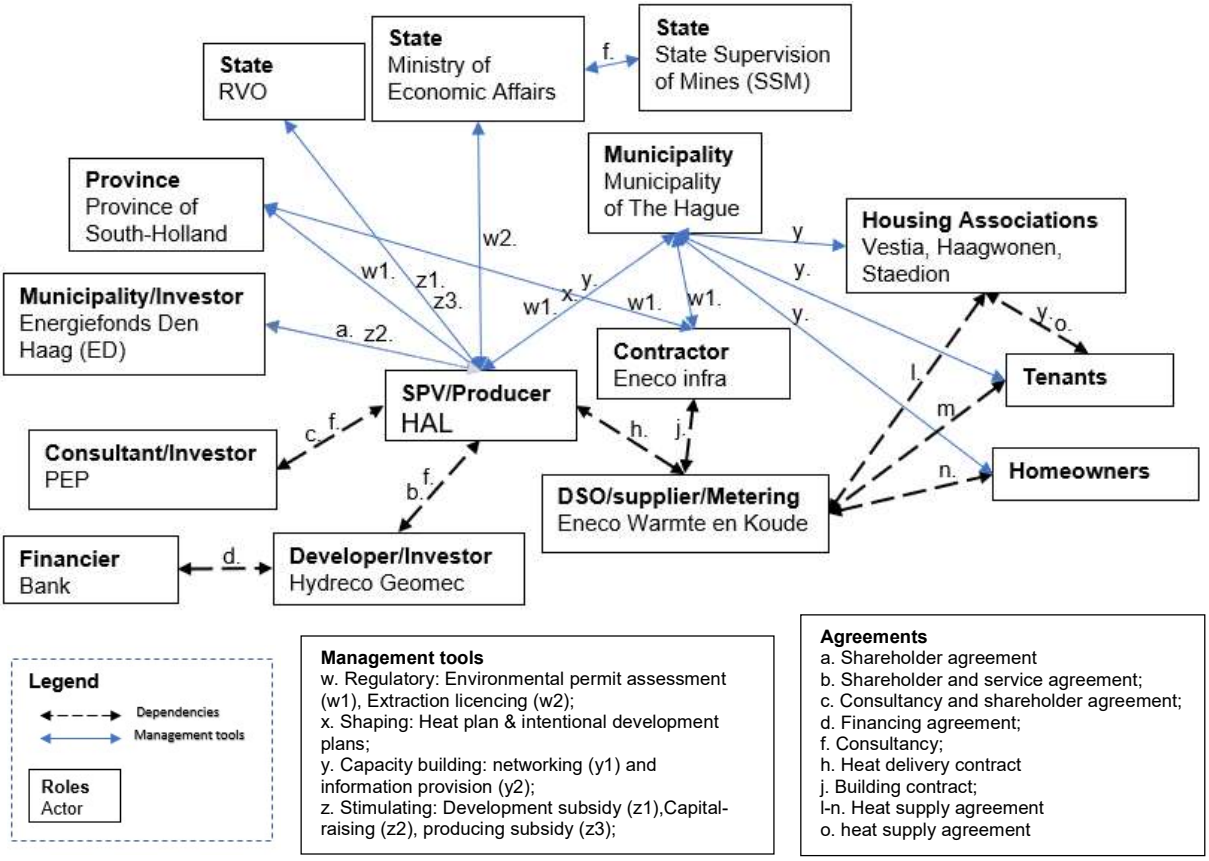


Figure 4.2.2 An agency model that indicates the dependencies between the roles of actors in the HAL project (Source: own design, based on empirical findings).

Not only Energiefonds Den Haag (ED) is involved as shareholder in the HAL project, so also are PEP and the developer Hydreco Geomec. According to B. van Dun (Personal communication, march 26, 2019), the HAL SPV is an empty legal entity so Hydreco Geomec is a contracted actor that delivers managerial and organisational services belonging to the HAL project **(b)**. On behalf of HAL the developer Hydreco Geomec is responsible for gathering the necessary licenses, planning, realisation and operation of the geothermal well. Besides being operator and manager of the realisation and operation of the geothermal well Hydreco Geomec fulfils a role as investor **(3.2.2.d)**. Hydreco Geomec also invested in HAL and holds shares in order to gain interest out of the future revenues. This is in accordance with the findings in the literature study: investors provide capital for investment and costs, which in this case is transferred to an SPV which holds the risks, cash flows etc. that are disconnected from Hydreco Geomec its own activities. B. van Dun (personal communication, march 26, 2019) mentioned that HAL is one of many projects Hydreco Geomec manages and for the other projects they cooperate with partners in SPV's who will arrange loan at capital banks to provide a part of the capital to finance the projects. Perpetuum Energy Partners (PEP) is involved **(c)** in the project as consultant for the engineering of the geothermal well. The continuity of HAL as SPV is dependent on the means of private equity investors such as Hydreco Geomec and PEP who are having dividend in return, while Hydreco Geomec on the other hand is dependent on loan capital financiers such as banks **(d)** that receive interest in return for capital provision **(3.2.2)**.
From the HAL organisation development activities for the geothermal well are performed. The Province of South Holland and the Municipality of The Hague are responsible for the publication of plans for heating networks **(x)** that affect HAL as also found in literature **(3.2.1)**, but are also responsible for the licence assessment for Environmental modifications such as construction of the geothermal plant and necessary infrastructure. At the time HAL took over the organisation from the curator, the installation was not completed. ADH acquired certain licences for the geothermal well and in that time they were dependent on the decision of the Municipality and Province concerning the construction plans. However, B. van Dun (personal communication, march 26, 2019) mentioned that these licenses were not fully correct and needed to be acquired again. With the engineering plans an extraction licence was requested directly from the Ministry of Economic Affairs **(w2)** who is advised by the SSM for the license assessment **(f).** Environmental licences were acquired from the Municipality **(w1)**. An analysis on the presentation on the HAL project by de Ruiter (2019) of Well Engineering Partners (WEP) shows the importance of and dependence on various aspects during the construction in populated areas, which is assessed during the environmental license assessment. The inner-city geothermal development environmental aspects found important in de Ruiter (2019) are limited space, well design, noise, logistics and noise emission are projects and are considered in the license assessment.

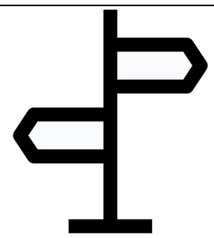
As found in literature developers **(3.2.2.a)** in urban development practice are traditional real estate industry agencies and can be financial-organisationally linked to banks, investors, construction companies and is positioned in the heart of different disciplines. The by B. van Dun (Personal communication , march 26, 2019) determined position of Hydreco Geomec in the agency model confirms that the developer is linked to the bank, Distribution Service Operator (DSO), state and linked to the public actors and consultant PEP through the SPV. The specialised field of expertise of Hydreco Geomec, namely managing the planning, realisation and operation geothermal wells, leads to a sector-division of real estate whereas other disciplines such as DSOs are necessary for the transport of heat to residential areas in the operation phase. In the interview with B. van Dun (Personal communication, march 26, 2019), it was told that the delivery of heat Hydreco Geomec is business to Business in which the risks of claims by end-users are transferred to intermediary companies such as DSOs. B. van Dun (Personal communication, march 26, 2019) confirms that Hydreco Geomec is the contracting actor for many suppliers for the redevelopment of the geothermal well.

An analysis on the developer **(3.2.2.a)** role Hydreco Geomec has, shows that they take the risks of redeveloping the geothermal well for heat production and need to cover the redevelopment cost by a future cashflow (e.g. heat sales) which is also found in the literature study. According to B. van Dun (Personal communication, march 26, 2019), this is managed through a gate-structure that consist of exploration, feasibility studies, licencing and intentional contracts, subsidy test, financial investment decision and financial close (contracts and bank finance). The gate-structure follows consecutive steps where each activity ends with a decision to continue or not. The reason for following the gate-structure in the project are the large development risks and uncertainty of future cash flows.
In literature **(3.4.1)** is found that there are financial risks to development, production and sales. The future cashflows to cover the development costs are twofold: sales of heat and subsidy.
In order to receive approval for loan capital **(d)**, Hydreco Geomec is dependent on the DSO/supplier Eneco warmte en Koude that agrees on the intentional contract **(h)** for heat sales. At the financial close the final heat delivery contract is agreed on between HAL and Eneco warmte en koude. In this setting both HAL and Eneco warmte and Koude can be considered as heat corporations **(3.2.2.e)** since their core business here is not real estate. They have a long-term project involvement **(3.2.2)** but in contrast to urban area development corporations Hydreco Geomec as geothermal operator fulfils the role as developer, investor and corporation and therefore can be seen as institutional investor in geothermal real estate.
The by B. van Dun mentioned presence of subsidies from the state body RVO **(z1)** as also found in literature **(3.2.1.a)** ensures additional revenues that benefit the project feasibility. The SDE++ subsidy on energy from geothermal energy is there to stimulate the production of energy from sustainable sources and seems indispensable in geothermal projects. Executing the subsidy test beforehand gives more certainty of future cashflows.

Looking at the heat exchange value chain from the literature study, Eneco is responsible for the heat transport and distribution. As confirmed in literature, some large energy corporations have affiliate legal entities to fulfil the roles in the heat supply chain: so is Eneco infra the contracted actor **(j)** who is responsible for managing and constructing the district heating infrastructure and acquiring. Eneco infra is dependent on the Environmental permit assessment by The Municipality **(w1)** and Province that is requested for the construction of heating networks. When the heating network is laid down, Eneco acts as DSO and transports the produced heat. The heat is bought business to business and sold to end users who are connected to the district heating network in The Hague such as housing associations **(l)**, tenants **(m)** and homeowners **(n)** according to Eneco (Personal communication, April 25th, 2019). Eneco as distribution service operator controls the heat balance to match the supply and demand. For tenants of housing associations, the housing association is responsible for the heat sales to the individual apartments **(o)**. The means used for the settlement of costs is a distribution key metering.

4.3 Cross-case analysis

After analysing both cases with an actor inventory and actors dependency analysis, the way how upscaling geothermal district networks is managed is analysed in a cross-case setting *(Table 4.3)*. On the top row of the table the two projects, similarities and differences are placed. On the left column the management aspects money, organisation, time, information and quality (MOTIQ) are located. In the boxes where the top row and left columns cross, the relevant topics *(Table 3.4.2)* from the management aspects **(3.4.2)** are elaborated on. These relevant topics will be written in *italic* for clarification purposes.

Project	 Ammerlaan-TGI	 Haagse Aardwarmte Leyweg (HAL)	 Similarities	 Differences
Money	- The *development costs* of the geothermal well came out higher due to unexpected cost for extraction plan amplification demanded by the State Supervision on the Mines (SSM). - There was a high certainty about the *heat sale opportunity* since Ammerlaan would use the it for its own greenhouses. A benchmark showed that the development costs outweighed the costs for natural gas for heating. - The expansion to the apartment buildings of Rondom wonen, school, sport complex and adjacent greenhouses meant more *heat sales and subsidies* for Ammerlaan. Although the *development costs* for the development of the geothermal well were sunk, Ammerlaan had to consider the extra investment costs belonging to laying down heating infrastructure. - The State body RVO introduced the SDE subsidy for sustainable energy production in 2008 (Beterduurzaam, 2019) and introduced the Market introduction for energy innovations subsidy in 2011 (RVO, 2011). Both were used by Ammerlaan for the development of the geothermal well. - The *development costs* for the housing association were too high and would not fit in the budget of the housing association. The budget allocation of the of the Stadsgewest Haaglanden subsidy and an EFRO-subsidy was made possible by the Municipal Council of Pijnacker-Nootdorp **(4.1.2)**. If the two *subsidies* did not cover 100% of the *development costs*, the apartments of the housing association would not have been not connected to the geothermal district heating. - The *financial risk* of the development was spread over the involved actors. The developer of the geothermal well **(4.1.1)** was bearing the development risks as stated in the turn-key agreement. The *financial risk* that was accompanied with infrastructure development for the expansion were for Ammerlaan, who had to ascertain that the development costs could be covered with future cashflow. - In order to keep *end-user affordability* the State has decided to set maximum heat tariffs which also applied to the Ammerlaan project. However no connection costs were charged by Ammerlaan to keep the heat offer attractive. - The heat that was offered by Ammerlaan is from a source where zero CO2 is emitted. Ammerlaan as user, the Municipality and the housing association found geothermal energy a *competitive alternative* to the collective heat-generating facility.	- The *development costs* of the geothermal well and infrastructure were expected to be € 45 Mln.with a long payback period (Schoof, 2011), but the organisation of ADH prospected insufficient future cashflow. - The *heat sale opportunity* was jeopardized due the credit crunch that resulted in an insufficient heat demand to cover the development costs, which led to the bankruptcy of ADH. The redevelopment of the well took place when there were there was more certainty about the connected households. - The *redevelopment costs* of the geothermal well could be covered when HAL took over the organisation. There was a sufficient *heat sale opportunity* for the organisation of HAL since Eneco was willing to buy the heat business to business. - In the HAL organisation the Municipality used private law instruments **(4.2.2)**: Energy fund The Hague (ED) became shareholder in the organisation. In this way ED could provide interest-bearing capital for development through a revolving energy fund, which is considered a stimulus tool. - The Ministry of the Interior covers the unprofitable top margin of the residential adjustments in the area of Bouwlust-Vrederust by a state grant that is made possible through the budget allocation for the pilot project 'natural gas-free neighbourhoods' (Gemeente Den Haag, 2019; p5) - State body RVO introduced the SDE *subsidy* for sustainable energy production in 2008 (Beterduurzaam, 2019). The *SDE+* subsidy that the project of HAL was eligible for created more financial certainty of future cashflows. - The *financial risks* are spread across the HAL organisation, where multiple shareholders such as PEP, ED and Hydreco Geomec invested money. In comparison with the ADH project the *financial risk* is expected to be smaller since there is a larger sale opportunity to dwellings that were connected in the time between and more existing dwellings that are being connected to the district heating network in the near future. - In order to keep *end-user affordability* the State has decided to set maximum heat tariffs which also applied to the Eneco in the HAL project. HAL itself sells b2b and therefore the sale price should be competitive with the prices that other heat producers offer. - ADH had built a bad reputation for geothermal energy because of its bankruptcy. Therefore it was hard to be *competitive* in terms of reliability. In terms of CO2 emission, the geothermal well is preferred over the gas turbines (Den Haag, 2018). - Due to the bankruptcy of ADH the dwellings that were connected to the grid receive heat from the Uniper gas turbine until the geothermal well is operational. Because geothermal energy without a heat buffer is only capable of fulfilling the base load **(3.2.2.e)**, the gas turbine stays operational to cover the peak load. Therefore the *lock-in costs* and revenue losses for Uniper for the shift to geothermal energy are mitigated.	- The development costs of the geothermal well are considered high and there is a long payback period. - State body RVO subsidised the production of geothermal energy in both developments with the SDE and later developed SDE+ subsidy. - The local governments in both cases are involved in covering development costs with stimulus instruments, although the origin, type and utility of the tools are different. - In terms of GHG emission, geothermal energy as source in district heating is a *competitive alternative* in comparison with natural gas. - The *end-user affordability* is equal due to the maximum heat tariffs that are set by the State, however the connection costs variate.	- Ammerlaan had a high certainty about heat use and future heat sale opportunity due to the expected capacity of the geothermal well. The ADH organisation failed to secure the heat sale opportunity due to the dwelling development variable, while the organisation of HAL stepped in when there was a prospect of sufficient heat sale opportunity. - In the development of HAL capital is transferred to an SPV which holds the risks, cash flows etc. that are disconnected from the financiers' own activities in contrast to the development of Ammerlaan in which all the risks were connected to the horticultural company as developer/investor. - The stimulus tool used by the Municipality of the Hague is a revolving energy fund, that could only be used through private law instruments: becoming shareholder in the SPV and provide interest-bearing capital. - The stimulus tool used by the Municipality of Pijnacker-Nootdorp concerned budget allocation of two former subsidies that where not utilised. - Since Ammerlaan is a horticultural company, the organisation was eligible for a Market introduction for energy innovations subsidy, while HAL received state grants from the pilot 'natural gas-free neighbourhoods'.
Organisation	- Negotiations for expansion of the geothermal grid took place between housing association Rondom Wonen, the Municipality and Ammerlaan. - In geothermal district heating development of Ammerlaan, the public actor organisation is arranged such that there are *repetitive activities* concerning licencing safety, construction and environmental issues **(3.2.1)**. The first developer the geothermal well is also recognised as a *line organisation* since its core business is constructing geothermal wells, for which repetitive activities are executed. - Generally there is a strong *top-down hierarchy* were the Province and Municipalities carry out many tasks in commission and according to the rules of the higher government. However, when it concerns geothermal district heating development by the horticultural sector, the Municipality of Pijnacker-Nootdorp chose to carry out a facilitating role, while a director role is applied for residential, commercial and Municipal real estate (Pijnacker-Nootdorp, 2016a). Private actor *top-down hierarchy* is recognised due to the private secotr realisation where the local public actor was only involved the initiative phase: the development was in accordance with the Municipal environmental structure vision for heat **(4.1.2)**. Although the availability of the supply that matched the demand of the housing association, the development is considered less demand-driven by locally rooted civic actors because Ammerlaan had an oversupply of heat that was generated by the geothermal well. - The Ammerlaan project organisation of the expansion to the dwellings as presented in the actor dependency analysis **(4.1.2)** can be considered a project management organisation: the organisation involved (specialised) actors from multiple disciplines (engineering, real estate, planning, environmental law etc.) and exists temporary. - The organisational environment of the Ammerlaan development can be considered sector *fragmented* where multidisciplinary actors decide about the project outcome. Ammerlaan fulfilled multiple roles (e.g. developer, operator and distributor) that are normally divided among other actors, so chain integration management is recognised were Ammerlaan was less *dependent* on intermediate actors. The decision to connect to the geothermal grid was up to the housing association and not *dependent* on the tenants **(4.1.2)**, which made it easier due to the involvement of less decision makers that could influence the development.	- Also in the geothermal district heating development of HAL, the public actor organisation is arranged such that there are *repetitive activities* concerning licencing safety, construction and environmental issues **(3.2.1)**. In the HAL development project, Hydreco Geomec was contracted to perform management activities **(4.2.2)**. As a geothermal operator that operates multiple geothermal wells, Hydreco Geomec can be considered a line management organisation that performs *repetitive activities*. - Generally there is a strong *top-down hierarchy* were the Province and Municipalities carry out many tasks in commission and according to the rules of the higher government. The Municipal council of the Hague takes a leading role in developing district heating since 1975 (Den Haag, 2013; p16). The development by the former ADH organisation and the current HAL organisation is a typical example of public-private partnership where the municipality is actively involved in the realisation **(3.3)**. - Due to the involvement of the Municipality, an area-based approach is followed to match the prospected supply with the demand is determined by the Municipality (Gemeente Den Haag, 2019). The development can be considered supply-driven by public and private actors, because the heat demand of civic actors was already fulfilled with other means before the alternative geothermal was proposed **(4.2.2)**. - For the development project management activities in the planning and realisation phase are performed in a *temporary* setting (e.g. engineering, installation realisation). In the operational phase repetitive maintenance activities (e.g. ESP replacement) and heat production are carried out from the HAL organisation **(4.2.2)** and can be considered process management activities. - The organisational environment of the HAL development project is considered *complex* since there is a large role fragmentation, chain segregation and decision making decentralisation **(3.4.2)** among the actors in the heat supply: the producer, distributor, supplier and multiple end-users are separate actors. - Stakeholders in the neighbourhoods and building blocks are gathered and involved to execute plans neighbourhoods in the district Bouwlust/Vrederust (Gemeente Den Haag, 2019). Involved stakeholder group consist of Haag Wonen, Vestia, Staedion (housing associations), Stedin (gas and electricity grid), Eneco (geothermal grid), HAL and also Homeowner associations (Gemeente Den Haag, 2019).	- In both cases the regime is partly similar: The state and ministries and Province of South Holland. Therefore the regional plans of both development organisations are on the same page. - The line in the organisation are the actors that have a specialisation to perform a role in the organisation. - The development organisations have a top-down hierarchy that is supply-driven where in Ammerlaan the development is a private realisation. - Also in the HAL organisation a *top-down hierarchy* is recognised: from the initiative phase until the operation phase the local government is involved.	- An important difference in regime is the Municipal ambition: Pijnacker-Nootdorp wants to be energy neutral in 2050 (Pijnacker-Nootdorp, 2016b) and The Hague wants to be energy neutral in 2030 (Den Haag, 2019). - The Municipality of Pijnacker-Nootdorp carried out a facilitating role while the Municipality of The Hague carried out a directory role. - Although the organisation of geothermal district heating development is considered *fragmented*, the organisation of Ammerlaan is considered less fragmented due to integration management of Ammerlaan and less decision makers that influence development on the demand side. On the supply side Ammerlaan also fulfilled multiple roles, while in the HAL project there was a larger role fragmentation and decision making decentralisation in the heat supply chain. In the HAL organisation there were relatively more varying ownership types recognised.

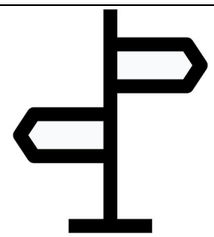
Project	 **Ammerlaan-TGI**	 **Haagse Aardwarmte Leyweg (HAL)**	 **Similarities**	 **Differences**
Time	- The Ammerlaan project started in 2009 so the *project duration* approximately 10 years. The initiative and planning the development of the first phase took one year, the realisation took two years (due amplification) and *well operation time* 7 years. Planning the expansion to the housing association took 3 years (2012-2015), realisation of infrastructure half a year and the housing association received geothermal heat for 3 out of 7 years if the well operating time. - In 2009 the Municipality of Pijnacker-Nootdorp made policy plans for a heat transition (Gemeente Pijnacker-Nootdorp, 2009a). - Plans of Ammerlaan to become a climate neutral horticultural company: there was a target set to change the 2,5mln. m³ gas use per year for geothermal energy (Ammerlaan, 2010). Also plans were made by Ammerlaan together with the Municipality to connect the Municipal real estate (school and sportcomplex) in 2010 **(4.1.2)**. - Students of Delft University create a planning for the realisation of geothermal well in 2007 (TU Delft, 2007) - Regarding *timing* the housing association planned to improve the insulation of the dwellings and combined the redevelopment with the connection to the geothermal district network. - So far no information is found on planned maintenance or soil excavation works by the Municipality of Pijnacker-Nootdorp that coincided with the soil excavation works Ammerlaan. Tough the Water Authority in place determined in which time frame excavation work could take place, taking into account the soil conditions over the year. - The only *time overrun* found is the amplification that was necessary for safety reasons. Time overrun is well managed because the risks of time overrun is covered by Ammerlaan by providing heat through a backup heat-generating facility.	- Before HAL started the redevelopment of the geothermal well, ADH initiated the project in 2007 so the *project duration* is 13 years. The planning phase took two years and in 2009 the first infrastructure was developed. In 2010 the geothermal well was realised in 8 months. In 2013 insufficient infrastructure was realised to provide future cashflow and the geothermal well was closed. In 2015 the project was relaunched and in 2016 the geothermal well organisation was taken over by HAL. - The first initiative started with backcasting studies in 2013 of The Municipality which led to plans to become climate neutral by 2040 (Den Haag, 2013; p2; Den Haag, 2018). Until august 2017 different strategic and binding plans for the city are drafted (Energy vision, Sustainability vision, Housing vision, council proposal sustainable heat). - In the coalition period 2018-2020 a concrete decision was made to make 25000-30000 dwellings more sustainable (by shutting down gas connections) in ten districts in The Hague, where the district Den Haag Zuidwest is part of (Gemeente Den Haag, 2018). - A district specific inventory for preferred alternatives for heat is made and visualised through an Energy map (Den Haag, 2018). In the district Bouwlust/Vrederust it showed which dwellings to connect to geothermal grid (Gemeente Den Haag, 2019). After mapping, an execution plan with a planning for dwelling and building block adjustments in the different neighbourhoods in the district Bouwlust/Vrederust were made to connect to geothermal grid of the HAL project (Gemeente Den haag, 2019). - The timing of the district heating development is aligned such that the outdated gas piping could be replaced during the same soil excavation works (Gemeente Den Haag, 2018). - For the redevelopment of the geothermal well Hydreco Geomec presents their operational planning (HAL, 2019). In the HAL organisation the planning (engineering, licencing, cleaning wells) phase lasted approximately 9 months until august 2019. After that the realisation of the installation and connection to the grid will take 7 months and the geothermal well is expected to be operational from January 2020.	- The planning and realisation of a geothermal well takes less time (11–36 months) in comparison with the possible planning and realisation time of district heating networks (6- 72 months). Also the time spend on the planning and realisation of the dwelling adjustments (from 36 months) is considered long. - The infrastructure development and geothermal well development was executed at the same time in the projects. - The housing associations in both cases were looking for ways to make their building portfolio more sustainable. Since the area of Den Haag Zuidwest was already qualified for urban restructuring the geothermal district heating development could coincide with the sustainability aims. - In both projects a backup system was in place to generate heat while the geothermal well was not operational. This is also needed for fulfilling the peak demand.	- In the Ammerlaan case there were no urban area developments such as excavation works etc. planned by the municipality at the time infrastructure was going to be laid down, while in the HAL case the realisation of the geothermal district heating network is aligned with the planned Municipal urban area developments and infrastructure works (e.g. outdated gas piping). - Due to the bankruptcy of ADH, the already connected dwelling had no other heat source so there was decided to feed the grid with a backup system, while in the Ammerlaan case the geothermal well was already operating when a connection to dwellings was made. - Time overrun of the infrastructure development and insufficient sales of heat in the ADH organisation led to cost overrun and bankruptcy of the organisation.
Information	- The Ammerlaan project was one of the first geothermal projects in the Netherlands and the *specialised information* regarding engineering was dispersed among the well developer and students of TU Delft. There were assumptions about the subsurface conditions, production capacity **(4.1.2)**. At the time amplification was needed well engineering consultants were called in because knowledge was not present at that time - The tenants were *informed* late about the plans of geothermal district heating and it came as a surprise. This was done when it was certain that the geothermal well could be developed. Although no consensus with tenants was obliged, the residential adjustments require tenant cooperation. Lessons learned are the early involvement of tenants (A. Swank, personal communication, march 26, 2019) - The *information provision* to residents was managed by the housing association and Ammerlaan. Through residential information evenings, information letters, press reports, Q&A forms and folders the residents were informed about Ammerlaan, the geothermal technique, safety, sustainability ambitions, grid route, residential adjustments, comfort, uncertainties, costs, planning, progress and project delivery (Rondom wonen, 2015). These documents are publicly accessible on the website of the housing association and residents (tenants and homeowners) were provided with contact information for additional (technical) information, complaints or damages concerning the geothermal district heating development.	- The specialised information is shared among the experts in geothermal well development in order to have certainty about the subsurface conditions, production capacity and techniques used **(4.2.2)**. - During the development of ADH, information concerning geothermal energy and the project was shared during residential meeting evenings (Schoof, 2011). - When HAL restarted the development in 2016, they had the intentional plans to involve local residents, other stakeholders, companies and the neighbourhood council for cooperation (HAL, 2016). - The *information provision* to residents was managed by the different involved housing associations, Municipality of The Hague and HAL. Through residential information evenings, information letters, press reports, Q&A forms on the website the residents were informed about the organisations behind HAL, the geothermal technique, safety, sustainability ambitions, residential adjustments, uncertainties, planning, progress and project delivery (HAL, 2019). These documents are publicly accessible on the website of the housing association and residents (tenants and homeowners) were provided with contact information for additional (technical) information, complaints or damages concerning the geothermal district heating development. In 2017 there also was a visit to the geothermal well plant (HAL, 2017) - The directory role that the Municipality of the Hague is performing, a lot of *information* concerning costs, planning etc. is shared in Municipal Documents that are publicly available. The Municipality of The Hague has been directory in making their building stock more sustainable since there	- In both cases much effort is made to provide information to the neighbourhood and residents that are going to be connected. - The geothermal well of Ammerlaan and the geothermal well of ADH were drilled in the same year. - In the time the well was drilled the available information about production capacity was uncertain and formed a risk for the geothermal district heating feasibility.	- The residents in the Ammerlaan case were informed late by the housing association: when there was a certainty that the realisation of the dwelling adjustments could be financed. - In the ADH organisation the residents were already involved in the planning phase of the development.
Quality	- The geothermal well of Ammerlaan is *located* in an agricultural/horticultural area that is not in the vicinity of sensitive functions (e.g. dwellings). - The public actors, predominantly the State Supervision on the Mines (SSM), were actively involved in the *environmental quality* assessment concerning the health and safety of the geothermal well **(4.1.2)**. - Ammerlaan and the housing association steered on the *spatial quality aspects*: there was thought about end-user comfort and factors that can be experienced as disturbing (e.g. soil excavation) were mitigated by information provision beforehand and financial compensation for the dwelling adjustment was awarded to residents (Rondom wonen, 2015). - Although future value and sustainability are part of *spatial quality*, these are also *social values* that were present at the time of development. The replacement of the collective natural gas fed heat-generating facility by geothermal district heating was an alternative that met the social values of decarbonisation caused by the various trends **(1.1)**.	- The geothermal well of Haagse Aardwarmte Leyweg is *located* in an urban area with sensitive functions (e.g. dwellings, hospital). - In the geothermal district heating development of ADH, a document concerning the desired installation quality (Eneco, 2011) is shared among the stakeholders of ADH. - The plant where the geothermal installations are in is located in an urban area so certain *spatial qualities* are steered on. An architect was contracted to shape the appearance of the building (Visser, 2013) to steer on the experience value variables (e.g. clarity, visibility, recognisability, aesthetics). However, some may find the building ugly and strange (Hoogland, 2018), which indicates that *spatial quality* is subjective. - Concerning the *spatial quality,* the area of The Hague Zuidwest district is pointed as district for restructuring (Den Haag, 2007), which indicates that the spatial quality is below the desired level. - The Hague as public actor, considered district heating to be an important solution for CO2 emission from the 90's (Den Haag, 2013; p17), which is an indication for certain social values. - The large willingness of multiple stakeholder types to cooperate in the project shows that the development is in line with the *social values*.	- The decarbonisation trend is witnessed by and happening to the same society. Therefore the social values are in line, although some actors could find alternative solutions to gas (e.g. all electric) more fit than geothermal district heating.	- Due to the directory role of the Municipality of The Hague they are much involved in working to the desired quality, although the Ministry also had an important role in the qualification for restructuring. - In the Ammerlaan project, Ammerlaan and the housing association worked hard to foster *spatial quality*, while the Municipality of Pijnacker-Nootdorp held a facilitating role. - The location type of the geothermal well is different, which may demand for different *spatial qualities*.

Table 4.3 A cross-case analysis of the Ammerlaan project and the Haagse Aardwarmte Leyweg project in relation to the management aspects money, organisation, time, information and quality (Own design, sources are included in the boxes).

4.4 Findings

The actor inventory and dependency analysis performed showed the actors involved in the geothermal projects of Ammerlaan and Haagse Aardwarmte Leyweg and what means were used by actors to develop such projects. Also it showed how the dependency between actors is determined, why the dependencies and actions occur as they are and are the reasons for this. An inventory of actors involved based on the tasks that are recognized in practice in the cases resulted in an overview of different phases that were passed in the course of time. Some actors appear in each phase, but seem to fulfil distinct roles in each phase. Many actors were involved in the development of the geothermal well and infrastructure but there can be concluded that Ammerlaan was at the heart of the development in the first case. In the case of HAL the SPV is in the centre of the organisation but can be concluded that Hydreco Geomec was managing all the activities on behalf of HAL.

The main similarities in the geothermal district heating development are that the actors involved in geothermal energy come from multiple government scales. There are several management tools **(3.2.1)** used by different government scales such as shaping tools, stimulating tools, capacity building tools and regulatory tools *(Table 4.4.1)*, which are key for steering on development.

	Shaping	Stimulating tools	Regulatory	Capacity building
The State	x	x	x	
RVO (state)		x		
State Supervision on the Mines			x	
Ministry of Economic Affairs	x		x	
Ministry of the Interior		x		
Province	x	x	x	x
Municipality	x	x	x	x

Table 4.4.1 Management tools used by public actors that are involved in geothermal district heating development (Source: Own design, based on the framework of Adams & Tiesdell, 2012 and input from empirical findings).

From the table can be concluded that the lower the governmental level is, the more management tools are used. Also are capacity building tools only found applied on the level of the Province and Municipality. An important finding is the capacity building tools used by the Province in the cases, which was not found in literature before **(3.2.1)**. The reason for this is that the Province of South Holland is leading in geothermal energy, where they have an overarching role in building capacity between GDHD projects in the Province. This role is assumed to be an unique role of the Province. However, the general findings of actor involvement are insufficient to assess the management perspectives of geothermal well development. By performing a cross-case analysis the management aspects of money, organisation, time, information and quality (MOTIQ) are elaborated on **(4.4.1)**. There is chosen not to elaborate on the strategic, tactical and operational (TSO) management levels during the cross-case analysis, but afterwards **(4.4.2)** because management through levels requires a combination of management aspects.

4.4.1 Management aspects

In the cross-case analysis **(4.3)** the table shows the cases of Ammerlaan and Haagse Aardwarmte Leyweg in relation to the relevant topics **(3.4.2)** of the management aspects (MOTIQ). The conclusions on these are discussed in the following paragraphs and will be placed against findings in theory to recognise differences and similarities and clarify why this is. The findings on each of management aspects end with a statement that are used for verification by experts. In the form of statements experts are able to respond to the findings. The sub-paragraphs follow the order of the management aspects money, organisation, time, information and quality.

Ad 1 Money

Deep geothermal district heating development (GDHD) is characterised by high investment costs and long payback periods **(4.1.1)**. When there is a high uncertainty about heat sales opportunities, the feasibility of geothermal well development is jeopardized **(4.3)**. This is in accordance to the findings by EBN (2018), which stated that GDHD is dependent of the sales of heat that is determined by the local heat demand and available infrastructure for heat transport. Needless to say there needs to be infrastructure to transport heat. In the Ammerlaan case is found that there was a high certainty about the use potential of heat, since the greenhouses of Ammerlaan were about to use geothermal energy for heating **(4.1.2)**. Before the development of HAL, the certainty of heat sale by ADH was determined by another variable: the development of dwellings **(4.2.1)**. After the bankruptcy of ADH, HAL managed to restart the development. The factor that led to 'acceptance' of GDHD by end-users in the cases was the elimination of that what was found uncertain in literature. Perlaviciute & Steg (2014) mention individual costs that had to be justified (Ling, 2003), which is under the supervision of ACM. Also 'lock-ins' and uncertainties about heat tariffs, service and reliability were eliminated by the actors on the supply side of GDHD **(4.3)**. Additional investments were necessary on both the supply and demand side to make the transition, in which the public actors were strongly involved. In both cases the production of geothermal energy is subsidised by the state body RVO **(4.3)**. Also is found that in both cases, the local government is providing development grants, direct or by a revolving energy fund **(4.3)**. Therefore it seems that geothermal district heating development is infeasible without stimulating tools from public actors **(3.2.1)**, although no cases where these stimulus were absent are investigated. An assessment of the need for stimulus can be confirmed or denied by experts, therefore the statement is as follows:

The sales of heat to private and civic actors is insufficient to cover the development costs: without the availability of subsidies and grants, the development of geothermal district heating will not happen.

Ad 2 Organisation
The large actor involvement and actor dependencies in developing geothermal district heating projects shows multiple organisation types and complexity in actor collaboration over the various actor groups (public, private and civic). Where in the Ammerlaan project, Ammerlaan predominantly led the development, the Municipality had a facilitating role between the housing association Rondom Wonen and Ammerlaan **(4.3)**. In contrast to the Ammerlaan case, the Municipality of The Hague in the HAL case is taking a directory role in executing plans to involve public and civic actors **(4.3)**. While both cases show that there was a private and a public initiative, the role of civic actors seemed minor. In literature locally-rooted civic actors that engage in urban development are described and found often operating on the building scale. These civic actors join community organisations **(3.2.2.c)** that have a legal entity from which management is performed. In literature two community organisations are frequently found: homeowner associations and energy cooperatives. The involved civic organisations in HAL in the Bouwlust / vrederust district consists of multiple stakeholder types ranging from housing associations, tenants and homeowners through a homeowner association **(4.2.2)**. In the Ammerlaan case the involved organisations are adjacent greenhouses, a sportcomplex, school and 470 apartments belonging to the housing association Rondom Wonen. According to literature important barriers for energy cooperatives are found to be high up-front investments, administrative responsibilities and low degree of professionalism (Bakker, 2016; Boon, 2012). Although homeowner associations have a reserve fund for expenses **(3.2.2.c)** they might experience equal barriers as civic actors. Therefore it is assumed that, despite the community organisations are willing to develop low carbon heating alternatives, barriers harm the effectivity of such initiatives. With effectivity is meant: achievement of intended actor's objectives and resolved problems. The statement is as follows:

An area-based approach that is steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor (homeowners & tenants) initiatives (bottom-up).

Ad 3 Time
Management of time in geothermal district heating projects requires aligning subprojects that run side by side such as well development, infrastructure development and residential adjustments, but could also coincide with urban area management such as soil excavation works, public infrastructure maintenance etc.. The timing of developments is worth considering according to Vlerken (2019). In the HAL case is found that the gas infrastructure was outdated and needed to be replaced anyway, which showed opportunities to coincide further infrastructure development **(4.3)**. In the Ammerlaan case the first buildings were connected to the grid before the geothermal well was finished, which was made possible due to back up heat-generating facilities from Ammerlaan **(4.2.2)**. IN the Management of time is proven in the cases, but when time is not managed well this can lead to an unnecessary increase in costs . Therefore two timing statements are formed:

The connection of dwellings to geothermal district heating can only happen before the end user's current heat-generating facilities are past due and municipal soil excavation works are planned.

Before the start of geothermal well and infrastructure development legally binding agreements with the end-users regarding dwelling adjustments and grid connections are necessary.

Ad 4 Information
In urban development literature is found that urban development is becoming more demand-driven and less supply-driven **(1.1)**. On the demand side of heat are the end-users, who might be unfamiliar with the innovative geothermal energy. In literature concerning diffusion of innovation is found that lack of information about unknown technologies can form a barrier for the adoption of the innovative heat-generating alternatives by homeowners and tenants compared to existing technologies. According to Rogers (2010) uncertainties influence the expected outcomes from an adopters perspective but is reduces when more information becomes available. Capacity building tools are frequently used by public actors. These include network arenas, pop-ups and consultancy centres for interaction and networking with the aim to seek collaboration from local residents and communicate well in order to increase public support (RVO, 2012, p12; Heurkens, 2012, p207; Meijer et al., 2018). Public support can be created by fulfilling the demands and expectations. In the Ammerlaan case the tenants of the housing association were informed late: after certainty about feasibility was obtained **(4.3)**. Information letters to the tenants by the housing association Rondom Wonen and visits to the geothermal well were facilitated by Ammerlaan and led to acceptance and cooperation. In the HAL project resident meetings are frequently held to evaluate the progress of the geothermal well development. Also visits to the geothermal installation building were facilitated **(4.3)**. Therefore the following statement is formed.

The provision of development information (planned and ongoing) and civic participation through capacity building tools leads to more acceptance, cooperation and fosters adoption by civic actors.

Ad 5 Quality
In literature quality is often found a paradigm in which the various public, private and civic actors define their own qualities **(3.2)**. Regarding urban area development environmental quality is a comprehensive term referred to by scholars. According to de Zeeuw (2018) environmental quality can be divided in (1) environmental quality (health, safety: legally established standards), (2) spatial quality (utility value, experience and future value) and (3) social values that are accepted. In the first, the different governmental layers (State, Province and Municipality) lay down legislation to steer on quality **(3.4.2)**. In the second, it is the extent to which the development adds value to the stakeholders in the urban area, who can have a subjective opinion about the utility value, experience value or future value. In the third, the social values determine quality. In both the geothermal development projects in the cases the environmental quality opposed by public actors was predominantly present and it is thought that those are minimal requirements for geothermal district heating developments. The spatial quality and social values are thought to be desirable quality requirements by the stakeholders. It is assumed that steering on only the first is insufficient to come to upscaling geothermal district heating development and that the spatial quality and social values need to be honoured. Although the environmental quality standards can be met, geothermal well development can conflict with certain social values that prefer other alternatives for heating. To clarify what quality needs to be steered ono the following statement is formed:

Meeting the environmental quality standards will only lead to geothermal district heating development if the desired spatial quality and social values are met.

4.4.2 Management levels

Management of urban area development is happening on strategic, tactical and operational level. It is found that Management through levels concerns the development and execution of plans, which means that this is related to the management aspect of time. However, it is assumed that the management aspects money, organisation, information and quality are also linked to strategic, tactical and operational planning. Therefore it is hard to indicate from which management aspect in the cross-case **(4.3)** table management from a certain level is performed. For this reason there is chosen to reflect on the management levels from plans that are made in each case in another cross-case table *(Table 4.4.2)*. Since it is assumed that management through levels requires multiple management aspects (MOTIQ), these are attached to the plans in the cross-case table.

Project	Ammerlaan-TGI	Haagse Aardwarmte Leyweg (HAL)
Strategic	- In 2009 **(T)** the Municipality of Pijnacker-Nootdorp **(O)** made policy plans **(I)** for a heat transition **(Q)** (Gemeente Pijnacker-Nootdorp, 2009a) - State body RVO introduces the SDE subsidy **(M)** for sustainable energy production **(Q)** in 2008 **(T)** (Beterduurzaam, 2019) and introduced the Market introduction for energy innovations subsidy **(M)** in 2011 **(T)** (RVO, 2011) - Plans of Ammerlaan to become a climate neutral **(Q)** horticultural company instead of using 2,5mln. M^3 gas per year, (Ammerlaan, 2010) - Plans **(I)** were made by Ammerlaan together with the Municipality **(O)** to connect the Municipal real estate (school and sportcomplex)	- The Municipal council of the Hague **(O)** takes a leading role in developing district heating since 1975 (Den Haag, 2013; p16) and from the 90s district heating is considered an important solution for CO2 emissions **(Q)** for the future (Den Haag, 2013; p17); - The Hague Zuidwest district is pointed **(I)** as district for restructuring **(Q)** (Den Haag, 2007) - State body RVO introduces the SDE subsidy **(M)** for sustainable energy production **(Q)** in 2008 **(T)** (Beterduurzaam, 2019) and introduced the Market introduction for energy innovations subsidy **(M)** in 2011 **(T)** (RVO, 2011) - Backcasting studies **(I)** in 2013 of The Municipality **(O)** lead to plans **(I)** to become climate neutral by 2040 **(T)** (Den Haag, 2013; p2) - Until august 2017 different strategic and binding plans **(I)** for the city are drafted (Energy vision, Sustainability vision, Housing vision, council proposal sustainable heat**, all MOTIQ**). - Concrete decision to make 25000-30000 dwellings in ten districts, of which also Zuidwest district, more sustainable by shutting down the natural gas connection **(Q)** in the coalition period of 2018-2022 **(T)** (Gemeente Den Haag, 2018).
Tactical	- Students of Delft University **(O)** create a planning **(T)** for the realisation of geothermal well in 2007 (TU Delft, 2007)	- Implementation of strategy by forming an Energy map **(I)** that visualises preferred alternatives for heat **(Q)** (Den Haag, 2018); - Target set to become climate neutral **(Q)** by 2040 **(T)** (Den Haag, 2018); - An execution plan **(I)** for the different neighbourhoods **(O)** in the district Bouwlust/Vrederust was made to connect to geothermal grid of the HAL project (Gemeente Den haag, 2019)
Operational	- Negotiations for expansion of the geothermal grid **(Q)** took place between housing association Rondom Wonen, the Municipality and Ammerlaan **(O)**.	- For the redevelopment of the geothermal well Hydreco Geomec **(O)** presents their operational planning **(T)** (HAL, 2019). - Stakeholders in the neighbourhoods and building blocks are gathered **(O)** and involved to execute plans **(I)** in the district Bouwlust/Vrederust (Gemeente Den haag, 2019)

Table 4.4.2 The assessment of the strategic, tactical and operational management levels in the cases. In each case a mixture of the management aspects is indicated (Source: Own design, based on empirical findings).

The table shows that there is a great mixture of the management aspects used on the management levels. In Bose & Pal (2015; p103) is found that the number of people that are involved increases during the shift from strategic to operational plans, which can be proved by looking at the role the Municipal council performs by shaping plans. An important conclusion on the table is that strategic plans for GDHD are made by public actors through shaping instruments in case of top-down developments and that during the shift to tactical and operational plans private and civic actors are involved through capacity building.

4.5 Conclusion

The case study performed in this chapter answers the research sub question on what the managerial roles & dependencies of public, private and civic actors are in implementing energy policies, district scale heat-generating facilities and infrastructure in the practice of urban development in the built environment in the Netherlands. A combination of data-collection instruments and processing tools with literature support led to the thorough analysis of the Ammerlaan and Haagse Aardwarmte Leyweg (HAL) cases.

Comparing the findings between literature and the empirical study reveals actors found in the empirical study that were not described in literature. In the HAL case, ED providing the revolving energy fund is found fulfilling a financiers role, providing interest-bearing dept or loan capital, while in literature was found that only private actors could make such financing agreements. Other additional involved actors are the involvement of the Ministry and State Supervision on the Mines. While additional actors were noticed, actors that were not or less present in the cases where bottom-up initiatives: energy cooperatives and homeowner associations.

The limitation of the previous chapter was that there was no specific project data that was needed to conclude on the managerial roles & dependencies of public, private and civic actors. After performing a case study with an actor analysis, analysis on dependencies and cross-case comparison important conclusions are made on the managerial roles that public, private and civic actors have.

In both cases there was a large public actor involvement noticed, where in each governmental level certain management tools are considered. The Ammerlaan project in the case study shows that with a faciliatory role of the Municipality capacity building tools are used to bring several private actors to the table to communicate, negotiate and decide on the heat supply by geothermal district heating. In the HAL project is shown that the directory role of the Municipality was using an area-based approach where for different neighbourhoods simultaneously tactical plans were formed with the actors in order to match the varying demand with the geothermal supply. Hereby the private actors such as developers, investors, corporations and housing associations were involved to plan, realise and operate the geothermal well, district heating infrastructure and dwelling adjustments.

There is a large role segregation among the actors, pointing out that there is no GDHD agency that has all the in-house capabilities of developing a geothermal well, district heating infrastructure and residential adjustments together. Ammerlaan as actor managed to fulfil many private roles to plan, realise and operate the geothermal well and infrastructure such as the role as developer, corporation (producer, distributor) and investor. In the HAL project there was a special purpose vehicle created in which private and public actors invested for the redevelopment of the geothermal well. Public actor involvement by a revolving energy fund was needed as stimulus to get the project going. There was a larger role segregation noticed in the case of HAL compared to that of Ammerlaan.

Although the development resembles a concession development were public plans are formed and the private and civic actors implement, the reality shows the opposite. In the Ammerlaan case there was a private realisation of Ammerlaan as horticultural company on the first place, to reduce carbon emission and natural gas dependence. Later on residential buildings were incorporated for which important stimulus from local government was needed to cover the development costs for the realisation of dwelling adjustment. The HAL organisation is a joint venture were public and private actors closely cooperate.

Regarding the management of money relevant topics for GDHD were high investments, long payback periods and uncertainty of heat sales that private actors are dependent of. Although civic actors are dependent on justified individual costs and lock-in, for all the adjustments to dwellings and development additional public actor stimulus seemed necessary.

Conclusions on the organisational context of GDHD are on the multiple organisation types and actor dependencies. Not all the actors found in the literature study seem actively involved in the development of the cases. The civic actors such as homeowners or tenants often seem less involved in the planning and realisation, but can be involved from a community role from a homeowner organisation or energy cooperative.

Time management can reduce the costs of the development by preventing delay or by coinciding processes needed for GDHD development. Important moments in time to reach legal consensus between the supply and demand side can reduce the risks in GDHD.

The provision of information from the supply side of GDHD to the demand side is important to foster the adoption. Through capacity building tools public support can be acquired, but informing tenants and homeowners by informational letters and frequent meetings could increase the civic actor support as well.

For GDHD development a minimal environmental quality standard are opposed from the different governmental layers and are considered minimal requirements. The spatial value is considered subjective as this is perceived differently for each actor. Lastly the social value is a determent of spatial quality. Variations on these influence the acceptance of plans for GDHD.

Although conclusions are found based on empirical and literature study, there might be circumstances in which these conclusions might not be valid. Therefore a Delphi study is performed in the next chapter to make experts assess whether the findings are correct.

5. Delphi study

A two-round Delphi study is organised to hear from experts how is thought about statements that are the result of the literature **(3)** and empirical research **(4)**. At first a list of ten experts is made to have an overview of the participants **(5.1)**. The experts were asked to fill in a statement document **(Appendix I)**. The responses of the results of the Delphi study and the statement documents are merged and elaborated on **(5.2)**.

5.1 Expert list

The parties involved in assessing the statements are policy advisors from the Municipality and Province, geothermal developers and operators, housing associations, researchers from TU Delft and area development managers. An overview of the experts that are contacted for participating in the Delphi study are as follows *(Table 5.1)*:

Name	Institution	Role	Name and institution in statement	Actor group
Lennart van der Linde	Duurzaam Den Haag	Project coordinator climate & energy	L. van der Linde, project coordinator climate & energy, Duurzaam Den Haag	Public/ Civic
Sander Snelleman	TU Delft	Teamleader Energy TU Delft	S. Snelleman, Teamleader Energy TU Delft	TU Delft
Johan Noordhoek	[..]	Expert	Expert	Public
Koen Gommers	[..]	Expert district heating	K. Gommers, Expert district heating.	Private
Karel Mulder	TU Delft	Associate professor Faculty of TPM	K. Mulder, Associate professor Faculty of TPM, TU Delft	TU Delft
Mark Boerée	Interim-manager	Urban development manager	M, Boerée, Interim Manager Urban Area Development	Private
Joris Stouten	Heijmans/ Dura Vermeer/Stevast	Manager Real Estate Development	J.Stouten, Manager Real Estate Development	Private
Arne Swank	Rondom Wonen	Housing Association	A. Swank, housing association Rondom Wonen	Public/Civic/ private
Bas van Dun	Hydreco Geomec	Geothermal project manager / Operator	B. van Dun, geothermal project manager, Hydreco Geomec	Private
Gerdien Priester	Province of South Holland	Senior heat policy officer	G. Priester, Senior Heat policy Officer, Province of South Holland	Public

Table 5.1 A list of experts that are contacted for the two-round Delphi study.

For the two-round Delphi study a document for the attendants is prepared as a statement document **(Appendix I)**. The ten experts that were consulted responded to the statements by e-mail. Therefore the responses is combined in the statement forms document **(Appendix II)**.

5.2 Results

The results on the statements that are assessed by experts are discussed. There is chosen to arrange this in separate subchapters, whereby in each subchapter is evaluated on the management aspects money **(5.2.1)**, organisation **(5.2.2)**, time **(5.2.3)**, information **(5.2.4)** and quality **(5.2.5)**. In each sub chapter the statement and the for or against section of the table with the statements are inserted as they were presented in the statement document **(Appendix II)**. The responses of the experts are filled in the correct box followed in which the experts are numbered in order to keep anonymity according to the Delphi method.

5.2.1 Money

From the management aspect money there was context presented which was the result of literature and empirical research. The results are filled in the statement box ***(Appendix II.1)***. The first statement is repeated:

The sales of heat to private and civic actors is insufficient to cover the development costs: without the availability of subsidies and grants, the development of geothermal district heating will not happen.

Important findings on the assessment by experts on the management aspect money is that the statement can be misleading and partly incorrect and paints a misleading picture because:

1. The need for subsidies is not only determined by the sales of heat or heat potential, it is the sum of uncertainties related to geothermal development, but heat sales remains an important factor (Expert 4).
2. Competition is not possible without subsidy: the alternative of geothermal heat (natural gas) is subsidised as well since the costs and risks of maintenance and installation of natural gas networks by regulated companies are embedded in the social system (Expert 3).

For now it seems that the development of geothermal district heating is not feasible without subsidies and grants, which is caused by many reasons:

1. First of all there is a competition with other alternatives (for heat). The most important competitor found is natural gas (Expert 1; Expert 9), which is also the case in geothermal well development: the extraction of geothermal heat is only sold on the local market while extraction of natural gas can be sold on a worldwide market. Another example for competition variables are that individual heat-generating alternatives suit the demand better (Expert 5), have less risk and upfront investments that are included in the purchase price of a dwelling (Expert 7). There is no fossil free alternative for large scale winter heating except for storage (Expert 5).
2. The financial crisis resulted in a more cautious approach of developers and loan capital provides/banks (Expert 6, Expert 9): meaning large risks, high upfront investment with uncertainty of heat sale potential and uncertain growth potential. Risk are partly covered by local funds such as ED (Expert 9).
3. The failure of local governments to translate views and planning to concessions (Expert 4)
4. The geothermal heating market is in the initiative phase, immature, insufficiently developed and that there is no best practice yet (Expert 6; Expert 4; Expert 2), which is made harder due to different local subsurface conditions.
5. Not only the geothermal well and infrastructure development needs to be subsidised: the severe adjustments to dwellings are accompanied with an unprofitable margin that are covered with subsidies and grants (Expert 8).

Subsidising geothermal developments common and practical way to bridge the uncertainties (Expert 4). An important argument is that subsidising leads to more research in a short period of time, resulting in better techniques and materials being developed and occurrence of scaling up (Expert 6). In the future there might be solutions that can make GDHD feasible without grants and subsidies:

1. A competitive advantage arises when there is a CO2 tax (Expert 1; Expert 3;)
2. The adoption of appropriate legislation and regulation (Expert 1, Expert 4)
3. The development of a firm view (and planning) on the heat transition to create growth potential could cover the uncertainties of heat sales (Expert 4);
4. The underlying factors of heat demand should be considered: although cities densify and the demand per grid investment increases, heat-insulation decreases the heat demand (Expert 5);
5. Development of the sector towards maturity: techniques and organisation, becoming a 'regular business' with cost reductions (Expert 10; Expert 6).

5.2.2 Organisation

From the management aspect organisation there was context presented which was the result of literature and empirical research. The results are filled in the statement box ***(Appendix II.2)***. The second statement is repeated:

An area-based approach that is steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor (homeowners & tenants) initiatives (bottom-up).

The assessment on the management aspect organisation by the experts led to a tendency to be for the statement, which suggests that an approach steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor initiatives (bottom-up). The arguments against the statement imply that the effectivity depends on the policy-based market context (Expert 1) resistance against public plans and the access to expertise by civic actors (Expert 5). Bottom-up initiatives are driven by the reduction of money (savings of natural gas) and carbon reduction and are more common in the greenhouse area (Expert 9), considering that horticultural companies are developing for themselves as end-user.
Arguments for the statement suggest that the scale of geothermal development is too large to by led bottom up (Expert 3; Expert 5) and therefore public actor engagement can lead to better coordination of plans in neighbourhoods to achieve the scale needed in a shorter time (Expert 8; Expert 4). A top-down approach leads to sharing experiences, knowledge and the preservation of quality and organisational processes (Expert 10). Also, the interest of civic actors are lower costs for heating, cooling and comfort for which the management role is expected to be taken care of by private and public actors (Expert 7; Expert 3). As suggested by (Expert 6) the Municipal positive-critical attitude towards such sustainable developments reflects the opinion of the municipal community. Although top-down approaches are found more effective, the combination of bottom-up and top-down approaches are found necessary for receiving support and reaching the scale needed for a successful business case (Expert 10; Expert 2; Expert 4; Expert 3).

5.2.3 Time

From the management aspect time there was context presented which was the result of literature and empirical research. The results are filled in the statement box **(Appendix II.3)**. In the aspect management of time, two time management statements are formed based on literature and empirical findings. On these statements will be elaborated on separately. The first statement of the third time management aspect is as follows:

The connection of dwellings to geothermal district heating can only happen before the end user's current heat-generating facilities are past due and municipal soil excavation works are planned.

The statement probably suggests the most desired situation or extra opportunity in the development of geothermal district heating (Expert 4; Expert 9). From the perspective of the urban area development manager this situation is necessary for a step by step controlled development approach to reduce uncertainty: risk and interest surcharge (Expert 6). The past due time of heat-generating facilitates and planned municipal excavation works are found factors for the GDHD business case optimisation (Expert 3), such as prioritising the neighbourhoods as first areas where natural gas will be replaced (Expert 10). Unfortunately, the exploitation period of the heat-generating facility is different for each homeowner or tenant in practice (Expert 3; Expert 4; Expert 8; Expert 10). Due to the CO2 targets and concept climate agreement there might be a need to replace the heat-generating facilities in place prior to the due date (Expert 10). However, heat-generating facilities can also pass their due date. Solutions to deal with this problem are the existing service of temporary lease of a heat-generating facility in case of breakdown of the current before planned switch to a district heating network (Expert 3; Expert 5).
The second statement regarding time management is as follows:

Before the start of geothermal well and infrastructure development legally binding agreements with the end-users regarding dwelling adjustments and grid connections are necessary.

The statement shapes the image that a legally binding agreements with the end-users are a precondition for GDHD. There seems to be a difference in opinion for who and what the precondition applies to. From the arguments against the statement is found that gathering the necessary contracts is not possible due the large number of costumers and unfamiliarity with the development (Expert 7; Expert 8) and that a serious expression of interest or potential for development provides enough incentive for an investor (Expert 3). This is in contrast with the findings of the experts that are for the statement: the investments are usually that high that developers can not afford having no legal certainty (Expert 6). It is of importance to make clear agreements about responsibilities: who does what and when (Expert 10). Long-term planning, development of infringement locations with many stakeholders, long lead times harm the return and becomes less manageable without certainty (Expert 6).
The moment of legally binding agreements are found necessary are at the financial investment decision (Expert 4), which is the moment that all permits and financial arrangements and construction works contracts are ready. Even more, it is found that no bank loan will be provided without completed permits, granted subsidies and given guarantees on heat sales (Expert 9). Important solutions to this problem are given: business to business (B2B) contracts where the risks of heat sales is transferred to the heat supplier, contractors or other developers who pass through agreements to the end-users (Expert 9; Expert 7). But that does not cover all the risks: it seems that only a B2B contract is insufficient to secure future cashflow because the SDE+ subsidy is based on the real heat supply, which means that production of heat is not subsidised when there is no heat delivered.

5.2.4 Information

From the management aspect information there was context presented which was the result of literature and empirical research. The results are filled in the statement box ***(Appendix II.4)***. In this section the fourth statement is repeated:

The provision of development information (planned and ongoing) and civic participation through capacity building tools leads to more acceptance, cooperation and fosters adoption by civic actors.

The majority of the experts have indicated to be for the statements. GDHD is characterised by mining activities in the neighbourhood causing nuisance (Expert 4)., which relates the most to the HAL case compared to the case of Ammerlaan. IN the HAL case HAL and the and Eneco wanted to inform the neighbourhood on the plans (Expert 9). Important reasons for the provision of development information is reducing resistance against plans, increasing acceptance and cooperation, but does not necessarily lead to acceptance (Expert 1; Expert; Expert 10). Civic actor behaviour is an important consideration. Sustainability is a hot topic people have interest in, people like to be heard, want to be included in the process and might even act as a 'representative' of your project when a the right approach is executed (Expert 7; Expert 6; Expert 8). A certain quality level of the information provided is needed. The information must be completely transparent, honest, reliable, has to be factual and must promote trust, what can be done by using capacity building tools (Expert 5; Expert 10; Expert 4). However, it is thought that the provision of development information can be perceived wrongly, is lacking or can be 'biased', resulting in uncertainty, suspicion, resistance and speculation about risks that are not applicable (Expert 3; Expert 5; Expert 6). It is therefore necessary the respond adequately with appropriate information.

5.2.5 Quality

From the management aspect quality there was context presented which was the result of literature and empirical research. The results are filled in the statement box ***(Appendix II.5)***. In this section the fifth statement is repeated:

Meeting the environmental quality standards will only lead to geothermal district heating development if the desired spatial quality and social values are met.

The statement described a precondition that expects that the spatial quality and social values have to be met to come to GDHD. It is thought that it would be more interesting to see if there are opportunities for GDHD if the desired spatial quality and social values are not met (Expert 6). According to literature the spatial quality is reached if the development adds value to the environment. Although spatial quality is subjective, there can be a difference in perception of how spatial quality is perceived considering that GDHD consist of multiple elements in a system: infrastructure, building installations and the geothermal well. Some elements are perceived as adding value while others harm the spatial quality. For instance the piping and installations are not visible after realisation and only cause temporary nuisance (Expert 8) and provide future sustainability. For the geothermal well, the space loss and impact on spatial quality is significant, given that about 10.000m² has to be reserved for at least 30 years (Expert 4). In certain cases the spatial quality is declined, due to green areas has been replaced by parking lots (Expert 3). Therefore, the location of the geothermal well development could influence the resistance: urban areas might experience a larger loss of space compared to developments outside the urban area. Existing neighbourhoods are much more organised for resistance and the opposition against GDHD becomes stronger if it is associated with loss of space (Expert 5; Expert 3). This is also referred to as the NIMBY-phenomenon, in which people do want a more sustainable solution, but do not prefer this to be placed in their vicinity (Expert 2). The resistance arises if the spatial and social values are insufficiently met, resulting in objection procedures which makes the development politically and legally impossible (Expert 1). It is found that the renewable objective as social value is the focal point (Expert 4), but could that outweigh the loss of spatial quality? It is found that the choice for and an acceptance of a solution is based on quality (proper functioning) and price first (Expert 7; Expert 2), after which the environmental impact follows. Having a higher quality than is needed for the environmental quality standards (e.g. GRE-lined casings), improves the spatial quality on the topics of durability and continuity (Expert 9) and might balance the loss on other aspects of spatial quality. It is important that there is at least support on all the environmental quality aspects regardless if they outweigh each other and therefore there is frequently communicated to the surroundings of the project (Expert 10; Expert 9).

5.3 Conclusion

From the panel with experts there is concluded on what managerial roles are effective for upscaling heat-generated facilities and infrastructure to a district scale in the Netherlands to give an answer on the third sub question in this research. The conclusion section consists of five paragraphs that each discuss one of the management aspects.

Concerning the aspect of money, effective roles in upscaling geothermal district heating development are those of the public and private actors. As long as there are subsidies and development grants the uncertainties of the private sector can partially be covered. From the cases is shown that also the unprofitable top margin of the residential adjustments is covered by public actors, resulting in no additional costs for the civic actors. While stimulus tools are used by public actors, the geothermal sector is able to become more mature and develop a best practice. When the techniques are sufficiently developed the operational period can be extended, what would mean that there is a larger future cashflow to cover the development costs. The regulatory tools that public actors can use to steer on development are also considered effective for upscaling: when the State and ministries decide to introduce a CO2 tax or other legislation and regulation a competitive advantage arises.

The roles that are effective for upscaling are found public, private and civic actors. In GDHD civic actors are dependent on civic and private actors, who have the means (e.g. knowledge, experience, capital) to develop while reducing costs and carbon emissions. The public actors, particular the local government can increase the success of upscaling by facilitating such developments. Considering the large number of households that are needed the local governments can match the heat demand of various organisations, housing associations and individual homeowners and tenants by coordinating and planning the involvement of these actors. By doing so, private actors in the GDHD are more certain of their future cashflow. Not only the municipality can gather civic actors, but also the private actor communities, who have the means to operate on behalf of a larger number of households who have decarbonising ambitions. The same applies for housing associations, who as ‘hybrid’ organisations can decide for a large number of households. According to literature the complexity in organisations decreases when the decision makers are less spread over the organisation (Bruil et al., 2015), but joint collaborations arise if there is a large mutual dependency of actors, which is the case in GDHD in the existing built environment.

For effective upscaling concerning the management aspect timing various actor roles are of importance. From the responses on the first statement can be concluded that the urban area developer is in need of certainty. The is a major role for local governments in optimising the GDHD: aligning the excavation works and mapping the current heat-generating facilities and their due date. Hereby the local government is dependent on civic cooperation for the assessment of heat-facility and building properties. Their next step is the planning the development together with private actors: involve installers, developers, etc. and making available temporary heat-generating facilities in case the exploitation period is exceeded before planned date. In case of acceleration of the development, it can be questioned if there is a financial compensation in place.
Where there is an important role for the local government in acquiring a serious expression of interest or potential for development, drafting legally binding documents is the role for private actors. These documents offer development security but are hard to gather from a large number individual end-users at the same time. The involvement of private actors that operate between the producer and end-users (e.g. distribution service operators, heat suppliers, homeowner associations, housing associations) are found effective roles for upscaling GDHD.

Important roles are the management of providing ‘correct’ information before, during and after the development so the change of resistance reduction, acceptance and cooperation is enlarged. The implementation of capacity building roles by private actors offers opportunities for transparency, reliability and trust. The actors that fulfil the roles on information provision need to be considered wisely to promote trust. Therefore discipline specific information towards end-users has to come from the specialist in that field to be reliable. Capacity building is frequently used by public actors, but the involvement of private actors in capacity building is not often performed, but is proven necessary for GDHD to be adopted.

Again there is an important role of providing information to the people regarding the environmental quality, in which improved spatial quality aspects and social value can outweigh the decrease of other spatial quality aspect. Support can be acquired through consensus with all the actors involved in such developments. There is an important role of the public, private and civic actors to frequently communicate, negotiate and decide on the (desired) environmental quality. Since the spatial quality is subjective, joint collaboration between the three actor groups can lead to satisfactory alignment of the desired environmental quality.
Not only providing information, but also maintaining quality is of great importance. Constant improvement of the materials and techniques used in GDHD can increase the perceived quality. There lies not only an important role for public actors that use regulatory tools for maintaining the environmental quality standards, but also for private actors that implement better quality then is obliged by law.

6. Synthesis

The synthesis of the research consists of the conclusion **(6.1)** were answer is given to the research questions. In the discussion and recommendation section the limitations of the research are discussed and recommendations for further research are made **(6.3)**.The reflection on the research discusses the process of the thesis, position in relation to , relevance of the research, methods used and ethical dilemma's encountered **(6.2)**.

6.1 Main conclusion

Public, private and civic actors manage upscaling residential heat-generating facilities to district scale in the built environment in the Netherlands by forming a strategic plans, making deliberate decisions and executing several processes. Public actors use management tools to induce marker behaviour towards desired outcomes. Regulatory instruments from different governmental layers foster the safety and feasibility of such developments through multidisciplinary assessments. Strategic plans for GDHD are recognised as shaping instruments in the form of heat plans. Local authorities can build capacity, performing a facilitating or directory role in the implementation of these plans as shown in the case study on Ammerlaan and HAL. The role they perform eventually determines which stimulus tools are used by them: in the facilitating role performed in the Ammerlaan case local subsidies are granted while in the directory role in the HAL case a revolving energy fund was in place. Stimulus for the production of geothermal heat was subsidised as well from the State body RVO and for the adjustment of the dwellings stimulus instruments were in place to cover the unprofitable margin, since GDHD links up with the sustainable public actor ambitions (for which budgets are allocated). In between public, private and civic actors there is communicated, negotiated and decided on desired outcomes of the project, settled in (intentional) agreements, which provide certainty for feasible development.

- In both cases there is a large public actor integration noticed in the cases, indicating that steering from several governmental levels is necessary to induce the market behaviour towards desired outcomes, for safety but also to meet binding climate commitments. While public actors 'steer' on the development, the private actor roles performed such as developers, investors, corporations and housing associations plan, realise and operate the geothermal well, district heating infrastructure and dwelling adjustments.
- There is a large role segregation among the actors, pointing out that there is no GDHD agency that has all the in-house capabilities of developing a geothermal well, district heating infrastructure and residential adjustments together. However, in the Ammerlaan case there was a larger role integration by the development actor Ammerlaan, compared to the developer in the HAL case: Ammerlaan managed to fulfil the role as developer, corporation (producer, distributor) and investor.

On the management aspects of money, organisation, time, information and quality conclusions are made:

- Although the private and civic actors are making deliberate decisions and start several processes to implement the GDHD, the sector is dependent on stimulus by public actors because of competition, immaturity of the sector, reticence of loan capital providers, failed concessions and unprofitable margins.
- In the organisation of GDHD a combination of bottom-up (were end-users are gathered) and top-down initiatives (were important knowledge is shared and process are coordinated from) is considered the most effective setting. Optimising timing or coinciding development activities are necessary to acquire certainty. Without certainty GDHD becomes less manageable.
- Solutions for timing the replacement of existing heat-generating facilities are lease or replacing them before due date. The moment legal agreements with end-users are made is at the moment of financial investment decision, but might be hard to accomplish due the large number of individual end-users. Intermediaries that accommodate (intentional) heat contracts (B2B) bridge sale uncertainties and make it possible to acquire certainty on a bank loan, but does not cover all the risks, since subsidies compromises the majority of the future cashflow and is only paid over the real heat supply.
- Information provision to civic actors and neighbourhood is key for GDHD in order reduce public resistance against plans, increasing acceptance and cooperation, but does not necessarily lead to acceptance. An appropriate approach is necessary to prevent biased information and to convey a certain quality level of information to steer on civic actor behaviour.
- The management of quality of GDHD should be taken into consideration by looking at the several aspects of environmental quality, that can outweigh each other. Consensus on desired quality is needed.

Effective roles for upscaling are found on the public, private and civic actor side. The public actors need to continue using stimulus tools and develop regulatory tools to foster maturation of the sector and evoke competitive advantage. Also their capacity building tools should be used to their full extent to match the heat supply and demand. Planning the timing of development is something that can be strategically planned by public actors but involvement of private actors in this increases the reliability. Intentional agreements on GDHD by civic actors can be arranged by public actors, while private actors draw up legally binding contracts, with or without intermediate, to secure the development. Probably the most effective solution for upscaling GDHD is consensus between public, private and civic actors, where through intensive communication, negotiation and decision making is agreed on the desired environmental quality for the built environment, our built environment.

6.2 Discussion and recommendation

The discussion and recommendation section follows after the main conclusions of the findings. At first the discussion **(6.2.1)** on the limitations of the research is discussed which form the input for the recommendations. In this chapter the recommendation for the GDHD practice is presented **(6.2.2)** followed by the recommendations for further research **(6.2.3)**.

6.2.1 Discussion

The research on actor roles and dependencies of GDHD has its limitations:

1. The research is limited to two cases with certain actors involved in the Province of South Holland. Cities in other Provinces, for instance Utrecht or Amsterdam focus on to other solutions than geothermal energy. These cities see biomass and waste heat as an important source for renewable district heating and in this research it did not came forward very clear why this is.
2. The research is limited to Dutch practices, which shows private actors implementing GDHD. International cases could show a different role dispersion, where public actors are developing actors, since heating dwellings is expected to be a social responsibility of the public actors.
3. Both the cases are development projects that were initiated ten years ago. These projects had some (technical) setbacks from which is learnt: new techniques applied such as composite casings will prevent corrosion and enhance the continuity of production. Also techniques that simplify the drilling process such as plasma drilling enables faster and deeper drilling (UDG), opening opportunities to reach higher formation water temperatures that could not only be used for direct heating, but also for electricity production. The aforementioned technical innovations could change the organisation structure drastically.

6.2.2 Recommendations for practice

For the GDHD practice recommendations are made relating to actors roles, exploration, anticipation to CO_2, and acceleration of processes.

1. From the research effective roles for upscaling GDHD are found on the public, private and civic actor side. The public actors need to continue using stimulus tools and develop regulatory tools to foster maturation of the sector and evoke competitive advantage. Also their capacity building tools should be used to their full extent to match the heat supply and demand. Planning the timing of development is something that can be strategically planned by public actors but involvement of private actors in this increases the reliability. Intentional agreements on GDHD by civic actors can be arranged by public actors, while private actors draw up legally binding contracts, with or without intermediate, to secure the development.
2. In the very beginning of each GDHD there needs to be a certainty about the production capacity from the geothermal well. In the Netherlands most GDHD are in the Province of South-Holland because for this region subsurface data is available, but unknown for other parts of the country. Subsurface surveys and exploration near dense urban areas need to be conducted in an early phase to see whether GDHD is feasible in specific regions (with a desired amount of connections per km^2).
3. In the research is shown that there are plans for a CO_2 tax which could negatively influence the financial results of private actors that emit CO_2. Not only the owners of residential real estate but also the owners other types of real estate could anticipate to the CO_2 tax by looking for geothermal development.
4. Technological innovations could change the organisation structure drastically, which is on one side made possible through stimulus from public actors to help to make the sector more mature. GDHD actors should question themselves if the shorter procedures and enhanced production period leads to a higher financial feasibility.

6.2.3 Recommendations for further research

Research is conducted on the management of geothermal district heating development in the built environment as a solution to reduce the greenhouse gas that is emitted by suppling the heat for residential real estate. The research shows the managerial roles performed by public, private and civic actors in the cases of Ammerlaan and Haagse Aardwarmte Leyweg. The actor and role composition is case specific and dependent on a range of variables An important variable is the low maturity of the sector, resulting in large public actor integration in GDHD. Further research is recommended on:

1. The actor organisation and GDHD of (international) cases, that can indicate the existence of less or more public actor integration and role dispersion among actors and explain what the reason for this is. On one side the risks and revenues are spread among the actors for feasibility purposes but leads to more decision makers, with possible divergent goals that can form obstacles.
2. Comparable studies on countries that have a mature geothermal sector (e.g. USA, Germany, Iceland) could have important and relevant lessons to learn from. Further research could be conducted on the transferability of international practices.
3. The research has shown an overall picture of all the public, private and civic actors in the organisation with their dependencies. From each actor, several departments within the actor organisation are also worth investigating. For instance: in the research the environmental license is discussed to a certain extent, but in reality this covers over 40 different licenses that might require a certain discipline within the organisation.

6.3 Reflection

In the reflection section of the synthesis there is reflected on various aspects which is in accordance with the graduation manual. At first there is reflected on the process **(6.3.1)**. After the reflection on the process a reflection on the position of the research is made **(6.3.2)**. The reflection on the societal and professional relevance of this thesis is included **(6.3.3)**. In order to review the methodology a reflection on the methods and processing tools is made **(6.3.4)**. At last, the ethical dilemmas that were encountered during the research are discussed **(6.3.5)**.

6.3.1 Reflection on process

As a student management in the built environment I have always been eager to learn more about how complex problems in the built environment are managed. The built environment has always been an area where everyone has a strong opinion about its design and only few manage to bring together conflicting interests. In the reflection on the process the own process **(6.3.1.a)** is reflected on. There is also reflected on the guidance of both the first and second mentor in the reflection on internal accompaniment **(6.3.1.b)**. Lastly, there is reflected on the external accompaniment **(6.3.1.b)**

6.3.1.a Own process

There is chosen not only reflect on the milestones in the process but also reflect critically on the moments that were perceived as hard to endure. The structure of the reflection on the own process follows the structure of the assessment moments. In each assessment moment there is reflected on the approach, feedback given by mentors and the way I translated this into my work. At the P5 there is described on how the final part of the graduation period will be filled in.

From the beginning of the graduation period it was very clear that the student was expected to choose a mentor from the preferred graduation domains. The first approach was to find a research topic that could solve the energy issue on a large scale, by looking at the various technical and financial methods available. Therefore Erwin Heurkens was selected from the domain of Urban Development Management, because of his expertise on sustainable urban development projects and public-private partnerships. A preliminary literature study on the topic showed that there was a challenge to transform the residential stock since this is one of the dominant end-users of energy. Therefore Erwin Mlecnik of the housing domain was selected, because of his research experience in market development of sustainable building concepts and process innovation. These mentors were not only chosen because of their expertise but also due to their reputation in guidance. Erwin Heurkens is in favour of a lot of students because of his convincing, inspiring and insightful attitude during guidance and presentations. Erwin Mlecnik is frequently chosen as mentor because he is critical, resourceful, strict and accurate in his guidance and presentations. There were immediately dates scheduled for the first four meetings with the first mentor Erwin Heurkens. These meetings took place in group context for two reasons. Erwin Heurkens was extremely busy and working in groups fosters the process and expands the feedback of the graduation work.

At the P1 I delivered a document containing three research questions where bottom-up initiatives regarding energy solutions were shown. The feedback on this was that there needed to be more attention on the innovativeness, methods and questions. The topic of energy cooperatives showed up on the national news and became more interesting. On top of the research, Erwin Mlecnik invited me to attend the EUKN conference, in which interesting presentations were held by various guest speakers.

In the road towards the p2 the topic and focus of the thesis changed multiple times. Frequent meetings every two weeks were held with Erwin Mlecnik to critically reflect on the topic. First it was on the creation on energy initiatives and shifted to the focus on their barriers on upscaling the local energy collectives to the district scale. At first there was thought that there was little research done on these collectives, but then it seemed that already a lot of research was performed on the barriers of these bottom-up initiatives that could not be neglected. The research gap melted like snow in the sun and I tried to find a way to investigate something within the topic that was not yet investigated before. As a result of the P2 a conclusion was drawn: there was insufficient progress on the focus on type of bottom-up initiatives, the conceptual model was lacking, there were no selection criteria for the cases and potential list of cases was lacking. This resulted in the retake of the P2. The most important comment in my opinion was that I had to stop widen my research on all the energy types, but focus on either wind, solar or thermal energy.

Due to the retake I became very uncertain on the topic and perspective, considering the urban development domain I was graduating in. Why would I be interested in social sciences such as bottom-up, while I am studying on a technical University with a management track. I had to rethink the topic drastically. In the study on energy alternatives came forward that there were little bottom-up initiatives for heating. On top of that it was found that 93% of the residential sector is dependent on natural gas for heating. This was a major opportunity to grasp because research on management of a transition this big would relate to the domain and laboratory topic of sustainable area development. The focal point had to be on the management of actors involved in a transition on this scale. At first a selection was made on potential solutions for making a transition on a district scale happen, two cases were chosen and actor groups for the empirical research were chosen.

The major change of topic succeeded in a go for the P2. Unfortunately, a vacation planned in the past threw a spanner in the works. Hesitation of the first and second mentor were present already since I was behind and the project was delayed for two weeks already because of the P2 retake. I decided to continue working during my holiday but the progress was insufficient. At first a literature study was started that was supposed to clarify what actors where involved in managing upscaling the residential heat provision to the district scale. It was intended to form a basis on understanding what the roles of actors are in managing district scale 'heat exchange projects' that were expected to be similar to GDHD in my opinion. The approach resulted in a literature study on all the actors that could have a potential influence or role in the development. Although the steps of an actor analysis were performed, this led to a real time-consuming activity were mostly generic activities of each actor were discussed, that had no direct added value to the research. The second disappointment that is experienced during the literature study is the difference between actors and roles. The main question is on the actors, while the sub questions is on the roles they perform, which arose from the thought that the existing actors should perform other roles in order to come to GDHD. When actor roles in management are defined as managerial activities performed by actors, this leads to difficulties in the interpretation of both. Was I describing the actors performing certain roles, thus activities or was I describing roles, that were performed by certain actors? The third problem was the overlap between the actor groups and roles performed, such as a public actor that can perform private actor roles. In my opinion the approach did not work. The reason for this is that there was a lack of information on 'who' does 'what' in a specific context. There are a numerous combinations possible on actors who perform certain roles when there is not a specific project. While I made a selection and demarcation for the research in the methodology chapter, this was ignored in the literature chapter. Although I continued making the actor dependency analysis I felt again providing an incomplete image of what can be found in literature. This progressed insight led to the choice to continue the research to empirical studies, which was the urgent request of the first mentor Erwin Heurkens. Although I consider the literature study as unsatisfactory in answer the research sub question completely, it helped to become familiar with the instruments for data collection and processing tools, that were going to be used again in the empirical phase. At the moment of P3 I was halfway the empirical study and made some early conclusions about the methods and results. I was already foreseeing a lot of work that had to be finished and both Erwin Heurkens and Erwin Mlecnik advices me on extending the research. I neglected their advice for two reasons: the first reason is that I have always been optimistic in achieving targets. The master is the fourth degree I try to conquer at the age of 30. The second reason is that the risk of extension is a relaxed attitude. When the grades from electives would arrive later than the obliged date and the amount of work was considered too much, I withdrawn from the P4.

After the P4 withdrawal I continued the research but ran into the problem that the topic of study was not operating on the district level. Later when the actor analysis and case study was finished this conclusion was reconsidered: an area-based approach for geothermal district heating development was in place, meaning that different neighbourhoods where consequently redeveloped, so there was a district scale reached. The basic understanding on the roles that can be performed in urban area development was now established but missed a perspective on management according to Erwin Heurkens. At the P3 I was advised to specify on certain management aspects and how to use this in the cross-case analysis by Erwin Heurkens. This really worked out for me because now I was finally retrieving interesting results concerning management from the cases. When I was just a kid I learned during running competition that I was accelerating in the last kilometre. The plot of this short story indicates one of my personal motivators: becoming extra motivated when seeing the finish line and being prepared to make more effort to finalise the product. After an additional sub chapter was added to support the view on how management is performed in GDHD I came up with five management aspects. In the last meeting before the summer holidays there was agreed on aiming for the p4 presentation in the end of September. From the management topics the cases would be elaborated on and the findings were planned to be presented as statements to experts in an expert panel. The expert panel was planned for the end of August, but due to a large amount of cancelling there were too little participants in the panel meeting to be interesting. I think I had to send multiple reminders to the experts, so they would not forget the meeting. The participants however did want to cooperate by responding to e-mail so I changed the method to a Delphi study. When the responses came in I was very pleased with the wide-ranging answers, which would never be so complete as when an expert panel was performed in which respondents talk over each other.

6.3.1.b Internal accompaniment

With the internal accompaniment is meant the mentors Erwin Heurkens and Erwin Mlecnik. There is chosen to reflect on the internal accompaniment by looking at how the variables *feedback*, *reachability, availability and motivation*. Both mentors have always supported me during the process. The *feedback* of both was really accurate but sometimes I had trouble with understanding what was meant. What I found disturbing in the feedback is that there were critical comments of something that needed to be elaborated on, while this was done later, if reading was continued. Erwin Heurkens usually adjusted the comment in such that it was clear that he did read this further in the research and that the comment could be forgotten. However, in some of the feedback of Erwin Mlecnik this was not done and led to misunderstanding and questioning whether the piece was actually read or not.
Although both mentors have a very busy schedule, their *reachability* by e-mail was excellent. I always received quick answer to my questions. It surprised me when the second mentor was on the other side of the world, told there was no internet, and het still managed to reach out to me.

The *availability* of both mentors was acceptable. I had the feeling that I could always find them in the Faculty building, although we mailed most of the time when there were urgent questions. Although Erwin Heurkens had a papa-day I think he, and also Erwin Mlecnik managed to schedule al their appointments well in the time available. The last aspect to evaluate on is *motivation*. There can be said that motivation should come from the student itself and not from their mentors, but this is a major point of attention. During the graduation period I noticed a difference in the way criticism was handed over. From Erwin Heurkens I always felt motivated, heard and supported by the way guidance was given. Erwin Heurkens has always been reasonable and fair, in particular when it seemed impossible to plan the P4 before the summer. Although, the comments of Erwin Mlecnik were very accurate, precise and honest, I always felt coming short in my delivered work. In the very start I discussed this with Erwin as, you may also give compliments as well. During the summer holidays I worked very hard on the thesis and it shocked me that my progress was found insufficient. By returning a long mail, I told that I perceived his criticism as destructing. Apologies followed, Erwin earned his keep and the comments on the pieces improved such (with a motivational twist) that I could work with them and feel motivated again. The feedback so far has always been exceptional where there was constant aimed at steering towards high quality, coherence and accuracy. I think this has also something to do with how I deal with criticism. I am just that person that prefers to be served a hamburger, were the bread are the compliments and the meat is criticism. To conclude, the tutoring periods are characterised by serene and eventful moments where criticism, suggestions, tips, compliments and motivation alternated. Within this unique setting I was able to find my way to achieve a higher quality level, which would not have been possible without the guidance of Erwin Heurkens and Erwin Mlecnik.

6.3.1.c External accompaniment

There was no specific external accompaniment appointed during the thesis. However I am very pleased with al the external help from professionals and experts who conducted int his research. Most important are the people I conducted interviews with to gather information from the cases. At first, I think that Bas van Dun the geothermal project manager at Hydreco Geomec (also developer of the future TU Delft geothermal well!) had a great role in bringing these thesis to a higher level. Arne Swank from the Housing Association Rondom Wonen provided important insights concerning the civic actors and management performed from the role of housing association. Also Leon Ammerlaan qualifies for credits for welcoming me to his geothermal well and massive greenhouses, providing important case specific information and most important, credits for being a pioneer in the sector and a great example for others.

6.3.2 Reflection on position

In the reflection on the position of the research there is elaborated on the relationship between the graduation topic, domain/studio topic **(6.3.2.a)**, master track **(6.3.2.b)** and master program **(6.3.2.c)**.

6.3.2.a Domain and studio topic: Urban Development management (UDM) and Sustainable Area Transformation (SAT) laboratory

The domain Urban Development management looks at the development of larger urban projects and accompanied processes. All the UDM research is meant to contribute to real urban problems. UDM research is there to help local authorities, developers and other actors solving key urban challenges such as climate adaptation, economic transformation and energy transition. Within the sustainable area transformation laboratory the focus is on the existing built environment.

The research emphasised on the transformation of the residential heat-generating facilities in the existing built environment. The management that is required for sustainable area transformations were investigated with the goal to clarify how developments where public, private and civic actors together foster climate adaptation and lead to an energy transition taking place. The various managerial tools used by public actors such as regulations, shaping plans, stimulus and capacity building tools and the way these influence the behaviour of private and civic actors has been shown and seem decisive in implementing sustainable change in the heat provision on the district scale.

6.3.2.b Master track: Management in the Built Environment (MBE)

In the Management in the Built environment track the student is engaged with the managerial dimension and processes in the built environment and construction industry. Management of these processes were many stakeholders are involved in guide urban development projects towards qualitative and valuable developments.

In relation to the master track, the research on managing geothermal district heating development in the build environment seems to touch upon the various elements, such as the managerial dimension, processes, the built environment and construction industry. The actor analysis performed on geothermal energy development demonstrates the multi-actor involvement in such urban development processes. The development that are the topic of the research are considered qualitative and valuable since it seeks for solutions to the contemporary energy issues concerning heat: decarbonisation and (effective) managerial roles to achieve this at district level.

Recommendations for the management track is to shift the focus towards the decarbonisation trend. For geothermal energy this could mean that for instance Fred Hobma and Pieter Jong could be challenged to continue their work on *Planning and Development Law in the Netherlands.* Prospected geothermal district heating development rates for residential heat provision purposes demands for know-how on the Mining Act. It seems that contemporary geothermal energy systems provide solutions for sustainable heat for the built environment. Worth reading in Mining Act regards licence assessment procedures for exploration and extraction of geothermal heat. However, decarbonisation is looking at a broad horizon of solutions, of which geothermal energy development is one for dense urban areas. I believe that each student should be free in choosing their own specialisation.

6.3.2.c Master program (Msc Architecture, Urbanism and Building Sciences)

The core of the master programme Architecture, urbanism and building sciences is the traditional Dutch approach of working in a multi-disciplinary way and coming to integrated solutions for the built environment.

The built environment is characterised by a multi-disciplinary actor involvement which also came forward during the research. It is not only the project manager who comes to integrated solutions, but also the engineering (design), governance, economic, financial and user (!) are important to consider. The master program is designed to be multi-disciplinary such that there tends to be a focus on generic urban development managers but underappreciates the actors involved in energy management, while these have an important role in the dynamic patterns of cities.

6.3.3 Reflection on relevance

In the reflection on relevance the relationship between the graduation project and the wider social **(6.2.3.a)**, professional **(6.2.3.b)** and scientific **(6.2.3.c)** relevance is elaborated on.

6.3.3.a Social relevance

The decarbonisation trend demands for managerial view on the achievement of sustainable targets. The research on how public, private and civic actors manage upscaling heat-generating facilities to the district scale could lead to more understanding on how to accelerate the pace in which decarbonisation takes place. However, the transferability of the methods can be limited due to the political and environmental circumstances: in the subsurface of the Province of South Holland there is a large geothermal potential, while this might not be the case in other provinces in the Netherlands. The public actors in other areas in the Netherlands might pursue plans for other solutions that suit the environmental circumstances.

6.3.3.b Professional relevance

For the professional field on geothermal district heating development sharing knowledge on ‘how to’ can be of added value. There was literature and empirical research performed with regard to management aspects. How these are performed in the cases is concluded on and assessed in a Delphi study. From the findings on the Delphi study it was noticed that there was a large difference in how much the actors involved in GDHD knew of the topic. By conducting the Delphi study it was not only possible to draw conclusions on the validity of the results but also sharing knowledge in between the actors involved. This knowledge could be used by the various experts to fulfil their roles in a more effective way, considering the management aspects.

6.3.3.c Scientific relevance

The graduation project aimed to broaden the understanding of what public, private and civic actors are involved, what their roles and dependencies are in upscaling residential heat to a district level in the existing built environment. Since there is little literature on the managerial roles performed in GDHD the study is considered revelatory and of scientific value. The scientific value is that there is a clarification on the roles and dependencies of all the actors involved in GDHD. This is done by modelling the actors involved in an agency model, from which the positions of actors could be placed in where labelled arrows indicate dependencies.

6.3.4 Reflection on methods and processing tools

During the research several data-collection instruments and processing tools were used, some simultaneously and therefore is briefly reflected on these. At first the data collection instrument actor analysis is reflected on **(6.3.4.a)** followed by the reflection on the case study method **(6.3.4.b)**. The data processing tools used in the thesis are the framework of managerial and organisational variables **(6.3.2.c)**, event-sequence model **(6.3.2.d)**, agency model **(6.3.2.e)**, cross-case analysis **(6.3.2.f)** and the Delphi study **(6.3.2.g)**.

6.3.4.a Actor analysis

The actor analysis is based on Koppenjan & Klijn (2004) and is used as a data-collection instrument to analyse actors involved in upscaling residential heat-generating facilities to the district scale. The limitation on the actor analysis is that some actors are ‘compounds’ revealing inner-actor networks having ‘persons’ or ‘departments’ responsible for certain tasks. The actor analysis was however suited for the inventory in which an event-sequence model was used. In the dependency analysis part the framework of managerial and organizational variables was added to foster a management approach and agency model was added for modelling and clarification purposes. It was not recommended to do it this way but can be of great value when there is little known about actors in projects.

6.3.4.b Case study
The execution of a case study with less cases leads to a deeper analysis while a case study with more cases could lead to shallow findings. Since the revelatory background of the topic, namely GDHD for the built environment on district scale, there were little other cases found. The case study is used as a method to order collect data from cases and could therefore be seen as a data processing tool. I think that performing case studies is suited for comparable studies on projects were certain similarities and different are sought.

6.3.4.c Framework of managerial and organisational variables
The use of managerial and organisational variables lead to a thorough analysis of the versatile means actors have at their disposal that define their dependencies. However, it might be hard to order all the managerial and organisational variables from projects in the way they are presented in the table, because there is a combination of these performed and it is often unclear and less separated.

6.3.4.d Event-sequence model
The use of an event- sequence model gives the author the ability to process project data to a desired consequent follow-up of events occurred. By doing this the I could analyse the projects in the way they occurred and link the activities that happened in a particular time to certain actors.

6.3.4.e Agency model
The agency model was used to visualise the actor positions and their dependencies. The benefit of modelling the dependencies in an agency model increases the clarity. The agency model is however timeless, meaning that the dependencies and actions on the labelled arrows are not occurring on the same time. An improvement would be an interactive agency model, summarising al the dependencies of all the actors in the past 10 years of development. This however tends to a game-analysis, in which is looked at actor interaction.

6.3.4.f Cross case analysis
The cross-case analysis leads to a strong comparison of two or more cases in which similarities and differences are analysed based on aspects. The cross-case analysis was very helpful in processing and ordering the case data. I would recommend informing students at an early stage on how the cross-case analysis works and how the composition of the table should be shaped in order to achieve the desired results.

6.3.4.g Delphi study
The Delphi study was conducted for the validity of the results. It turned out that the Delphi study was multifunctional: more information could be gathered and the response group was educated at the same time. In comparison with the planned panel meeting this was a relief. The limitation of the Delphi study is the duration, that's why a two-round Delphy study was conducted, risking that no consensus about the topics is reached.

6.3.5 Ethical dilemmas
In this research case studies were performed on real cases were interviews were conducted with experts that were involved in the cases. In Yin (2012; p73) is found that research should always be conducted with the highest ethical standards and therefore the researcher should consider gaining *informed consent* from all persons, protection against *harm and deception*, protecting the *privacy and confidentiality* and taking special precautions for *vulnerable groups*.

Before participation to the research the research aims and goals were made clear to the participants. Also it is told that the results of the research would be publicly available from the repository of Delft University of Technology. From the persons taking part in the research as interviewee, consent was asked by mail, in which was asked if their name could be used as a reference in the thesis. Also there is chosen not to include transcripts in the report because they could possibly harm. For the actors that were repetitively mentioned in the report, consent is acquired by sending the document. By doing so the actors were able to verify project specific information in order to prevent *harm and deception*. When these documents were verified their needed to be consensus for the use of personal information for the respondents in the Delphi panel. At first it was not known that complete anonymity was required for the Delphi panel so with each of the ten actors involved was agreed on the use of their personal information such as name, role and institution. All the ten actors agreed on having their name in the report under contacted experts, but some requested to have their institution removed from the list, because the were participating from their personal view and not on behalf of their institution. Having the aforementioned measures the *privacy and confidentiality* is preserved. There were no *vulnerable groups* such as children involved in the research.

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Figure list

For the list of figures, their name and references a tabular format is used as shown below.

Figure number	Name	Source
1.1	A photograph of the eastern Scheldt storm surge barrier in Zeeland that protects the land from sea level rises and floods. The hydrological construction shown in the picture is part of the Delta Works in the Netherlands	Rijkswaterstaat (2007) Stormvloedkering Oosterschelde Oosterscheldekering Noordzee. ID313550.Retrieved at 21-1-2019 from: https://beeldbank.rws.nl/MediaObject/Details/313550
1.2	The Gas bubble found in Slochteren, Groningen, led to an emergency construction rate of natural gas pipe networks throughout the Netherlands. From left to right: (1) Picture of the construction of the drilling rig at Slochteren in 1959, (Source: Historisch Archief Midden-Groningen, 2018), (2) Photograph taken of the gas pipelines being laid down in the Dutch soil in 1963 (Source: NOS, 2016), (3) The preparation of gas boilers and gas cooking appliances by the Municipal Energy Company (GEB) in 1963 (Source: Vernieuwbouwd, 2018)	NOS (2016). In de Jaren 60 werden door heel Nederland gasleidingen geplaatst. Retrieved at 21-1-2019 from:https://nos.nl/video/2139599-in-de-jaren-60-werden-door-heel-nederland-gasleidingen-geplaatst.html (2) Historisch Archief Midden-Groningen (2018) Gas in Groningen! Retrieved at 21-1-2019 from:https://historischarchief.midden-groningen.nl/ontdekken/verhalen-van-midden-groningen/gebeurtenissen/gas-in-groningen (3) Vernieuwbouwd (2018). Overschakeling op aardgas in 1963. Retrieved at 22-1-2019 from: https://www.vernieuwbouwd.nl/blog/overschakeling-op-aardgas-in-1963/
1.3	A diagram that shows the working temperature range of available heating technologies	Sayegh, M. A., Jadwiszczak, P., Axcell, B. P., Niemierka, E., Bryś, K., & Jouhara, H. (2018, p126). Heat pump placement, connection and operational modes in European district heating. Energy and Buildings, 166, 122-144.
1.4	The interaction between the State, the market and civic society.	Heurkens, E.W.T.M. (2012, p140). Private Sector-led Urban Development Projects: Management, partnerships and effects in the Netherlands and the UK (Vol. 4). TU Delft.
1.5	Conceptual framework	Own design
2.1	Steps of an empirical research process	Kumar, J., 2011 p. 22, own edit
2.2	Research design	own illustration, inspired by Heurkens, 2012; Veenhof, 2018
2.3	An image of a geothermal drilling rig during the construction. To reach the 70 C water well at depth of 2.1 km extensive drilling is required	Energieoverheid, 2016
2.4	Geothermal plant Ammerlaan	Energievastgoed (2016). Duurzaam warmtenet verwarmt woningen. Retrieved at 27-1-2019 from: http://www.energievastgoed.nl/2016/02/10/duurzaam-warmtenet-geothermie-verwarmt-470-woningen/?doing_wp_cron=1548635962.2321639060974121093750
2.5	Geothermal plant HAL	Energienieuws (2017). Haagse Aardwarmte Leyweg levert vanaf 2018 warmte aan woningen. Retrieved at 27-1-2019 from:http://www.energienieuws.info/2017/11/haagse-aardwarmte-leyweg-levert-vanaf.html
3.1	Degree of Actor involvement and development strategy	Heurkens, 2017b; p2
3.2	The tasks in the value chain of heat exchange operations	EBN, 2018; p26, own edit
3.3	An agency model to position the roles of the public, private and civic actors that actors actively involved in, have the means to, have the knowledge of, are expected to be involved or are affected by the integration of heat-generating facilities and infrastructure in the built environment	Own design, based on literature
3.4	The public and private roles within Dutch PPP models	Heurkens, 2012; p129
3.5	The triangle that represents the different levels at which management occurs	Bose & Pal, 2015; p103
3.6	Research model	Own design
3.7	Conceptual design	Own design
4.1	A map of the surrounding area of Ammerlaan (a) with the heat consumers in 2016. In the first phase the sportcomplex ‘de Viergang’ and school ‘Stanislas college’ (b) were connected to the heat network. In the second phase the apartment buildings of ‘Rondom Wonen’ (c) and adjacent greenhouses (d) were connected.	Ammerlaan, personal communication, march 26, 2019; own edit
4.2.1	The existing heat infrastructure in The Hague	Den Haag, 2014, p18
4.2.2	An agency model that indicates the dependencies between the actors in the HAL project	own design, based on empirical findings

Table list

For the list of tables, their name and references a tabular format is used as shown below.

Appendix I

Statement document

Dear experts,

First of all, thank you for cooperating in my research. Unfortunately you were not able to attend the expert meeting on 03th of September at the Architecture and Built Environment faculty. With this email I aim to provide information regarding my graduation research on geothermal district heating development.

Plan
The document starts with the introduction of the research background and findings. After the introduction the statements are presented one by one, after which the experts can respond and give their opinion and foundation.

Introduction
In the Dutch cities there is a decarbonisation trend for 2050. Households in the Netherlands are one of the dominant final end users of energy and a transition within this group could contribute to reducing GHG emissions. While measures to reduce the GHG emission for electricity seem decisive, the vast majority of the Dutch households retain a carbon lock-in for heating. Alternatives for residential heat are determined by the available technologies and applicability considering the energy efficiency discord among residential areas. The decarbonisation trend for 2050 requires an area-based approach in which deep geothermal district heating networks is found a suitable alternative for residential heating.

As a student from the Delft University of Technology in Management of the build environment, urban development management track, I was interested in how public, private and civic actors manage upscaling these geothermal district heating networks. Empirical research on actor roles and their dependencies is performed on the development project of Ammerlaan-TGI and Haagse Aardwarmte Leyweg (HAL). After the actor analysis is performed the management activities of the various actors is shown whereby management levels and management aspects from literature are used for evaluation. Both cases show successful management of upscaling to the district scale, that is characterised by different building types and varying heat demand. Although the rollout of geothermal energy solutions over the existing built environment seems successful, the amount of geothermal wells that are connected to residential real estate is yet limited.

This statement document aims to clarify the limitations of and seeks answers for effective upscaling of geothermal district heating in the upcoming decennia.

Statements
There is chosen to form six statements from research findings that relate to the MOTIQ (Money, Organisation, Time, Information and Quality) management aspects. Before each statement a sort of context is attached to clarify the origin of the statement. I would like to ask you to take position for or against the statement and explain why that is. You are also free to give your opinion on the discussed topic. Since you are the expert here your judgement is of great value. There are multiple text fields in the supported table that can be filled in. The statements can be found in the tables after the next paragraph.

Additional
I would like to ask you how you want me to handle your personal information such as name, occupation and role, since this research can be found on the TU Delft repository after the graduation work is finished. I hope you will be able to fill in the form and deliver the results to my e-mail before the 10th of September. Could you inform me if that is not possible? Thanks in advance and good luck with the statements!

Cheers,

Daniël Brandon
Msc. student Management in the Built Environment, urban area development track, faculty of Architecture and the Built Environment, Delft University of Technology.

Appendix II

Statement forms

The statement forms were empty before they were send to the experts. To prevent unnecessary repetition of the context and statement there is chosen to combine the empty statement forms with the expert assessments.

1. **Management aspect**: Money

Context

Deep geothermal district heating development is characterised by high investment costs and long payback periods. When there is a high uncertainty about heat sale opportunities the feasibility of geothermal well development is jeopardized. In the Ammerlaan case is found that there was a high certainty about the use potential of heat, since the greenhouses of Ammerlaan were trading the large amounts of natural gas for geothermal energy. Before the development of HAL, the certainty of heat sale by ADH was determined by another variable: the development of dwellings. Due to the credit crunch the residential development stopped and led to the bankruptcy of ADH. After the bankruptcy of ADH, HAL managed to restart the development. In both cases the production of geothermal energy is subsidised by the state body RVO. Also is found that in both cases, the local government is providing development grants, direct or via a revolving energy fund. Therefore it seems that geothermal district heating development is unfeasible without stimulating tools from public actors, although no cases where these stimulus were absent are investigated. An assessment of the need for stimulus can be confirmed or denied by experts.

Statement

The sales of heat to private and civic actors is insufficient to cover the development costs: without the availability of subsidies and grants, the development of geothermal district heating will not happen.

Against

- A future change in legislation (nieuwe warmtewet) or taxation (additional tax on natural gas) could easily swing the answer to this question towards no, geothermal energy can run without subsidies (Expert 3).
- The hypothesis on which the statement is based is not entirely correct. It is not necessarily only the insufficient sales, or lack of perspective on growth of sales, that implies the need of subsidies. More important, especially when geothermal heat is aimed at district heating, is the sum of the uncertainties related to development and realisation of a geothermal. The fact that geothermal energy is new in the Netherlands is the most important cause: there certainly still is no best practice, the maturity of the development process is low. From a viewpoint of the geothermal source developer, the uncertainties in potential heat sales will be an important uncertainty factor. Development of the source will have to go hand in hand with development of heat sales / growth of district heating grid. Subsidies are a common and practical way to bridge these type of uncertainties. However, if municipalities develop a firm view (and planning) on the heat transition, and if and when they are serviced with appropriate legislation, the growth perspective should and could be such, that no subsidies should be required to cover the specific uncertainties related to the off take of geothermal heat (Expert 4).
- Urban areas densify and so there is more heat demand per grid investment. Although heat-insulation diminishes the demand for heat, it also diminishes the seasonality of heat demand which implies that the load factor of the system will become more attractive. Especially when there is (non-seasonal) heat demand and there are storage facilities, geothermal might be attractive. There is still a lot to learned in geothermal heating, so costs will probably go down. Except for heat storage, there is no real fossil free alternative for large scale winter heating (Expert 5)
- As the context explains, it's all about risks and forward funding. But in the end the business case of de exploitation period has to feasible, the risks has to be manageable. Because otherwise why would you spend money on a solution like this and at the same time there are other solutions who are feasible and have less risks. Like heatingpumpsystems with air or with a heatingwell. There is no forward funding and it is one-piece-flow, so it the investment is only been done when a dwelling is sold. It's dependent on the time. Now that the amount of realisation of dwellings is big, there is an amount that maybe there is no need for subsidies. I can imagine that it this moment feasibility is a lesser issue? I think that it is better to use a construction of revolving fund and with a good loan rate. Without these type of interventions I think that a project is not feasible (Expert 7).

For

- Subsidies and grants will be necessary as long as the geothermal heating market remains insufficiently developed and has to compete with the current natural gas heating market. If natural gas becomes less competitive through CO2-taxation and/or regulation, then the geothermal heating market will need less subsidies and grants to develop and become more efficient. (Expert 1);
- This is true under the current market conditions. However, a statement like this paints a misleading picture. Geothermal heat cannot compete without subsidies, because the alternative (natural gas) is subsidized as well. For instance natural gas networks are installed and maintained by regulated companies. Costs, including risks are socialized. Income for the regulated companies is guaranteed (Expert 3).
- However, if municipalities fail to translate their view and planning to concessions, and the government fails to implement legislation accelerating the heat transition, subsidies could be required (Expert 4).
- Heat demand declines as better insulation and more solar heat will cut demand. Small scale heating is the way to go: individual solar heating with individual heat storage (Expert 5);
- Agree! For various reasons. Since the crisis, developers (and vv providers / banks) have been more cautious in their approach, which is increasingly an "organic" development. This usually means that a large investment is needed at the start of a relatively small number of homes / offices, whereby it is not certain upfront whether and if so, at what speed the rest of the area can be developed. So there is a lot of uncertainty in relation to a financially major challenge / investment. Considering the fact that more parties have a position and are each other's competitors at the same time, this does not simplify a joint financial effort (Expert 6).
- Subsidies remain necessary. Not only for the company who invest in the well and realizes the installation on his property, but also for the homeowners, who have to make severe adjustments to their home. After all, it is no longer a free choice whether you participate or not. The houses have to get rid of the gas because of the climate agreements set by the Dutch government (Expert 8).
- Without SDE+ no geothermal project will be feasible due to the relative low prices of fossil sources for heat production, mainly natural gas. This can change by the introduction of a CO2 tax. The high development risk are partly covered by local funds as Energiefonds Den Haag. This "seed" money is very welcome because senior loans (bank loans) will not provide before all permits are completed (onherroepelijk) If local loans are not available the risk for the developer is too high to continue the development and for small portfolio developers the capital is not sufficient to develop more than one project on the same time (Expert 9).
- Although I am not myself involved in the business cases. Form what I know Currently Yes, if SDE+ subsidie wouldn't be inplace , no projects would have developed. Hopefully the business becomes a more "regular" business with cost reduction, that the market can function without SDE+ (Expert 10).

Opinion on or additions to the management topics (optional).
- Also individual alternatives provides cooling, which is a hot item at this moment. On the other hand these systems do get a subsidy of the government, but in a few years this will end (Expert 7);
- Every new technology and development needs a subsidy to get started. The approach is of course to be able to run Geothermal Energy in the future without extra incentive. That depends on many things and we cannot say anything about that now. A lot still needs to be learned! Geothermal energy will become cheaper if more is known and more is learned, less risk. You must also have a sufficient decrease and if you then fully utilize Geothermal energy and you look over a period of 30 years, then I think that in the future Geothermal Energy can certainly be done without a subsidy. Apart from that, what do other low-CO2 solutions cost compared to gas? You have to compare them with each other and not just draw the comparison with gas. We have to go to fossil free (Expert 2).
- This is unfortunately the case in this initial phase. But the good news is: subsidising leads — and that is sometimes difficult for a liberal thinking person — to more research taking place in a short period of time, better techniques and materials being developed and occurrence of scaling up ……. Which leads to more profitability (Expert 6).

2. **Management aspect**: Organisation

Context

The large actor involvement and actor dependencies in developing geothermal district heating projects shows multiple organisation types and complexity in actor collaboration over the various actor groups (public, private and civic). Where in the Ammerlaan project, Ammerlaan predominantly led the development, the Municipality had a facilitating role between the housing association Rondom Wonen and Ammerlaan. In contrast to the Ammerlaan case, the Municipality of The Hague in the HAL project is taking a directory role in executing plans to involve public and civic actors in geothermal district heating development. While the cases show that there was a private and a public initiative, the role of civic actors seemed minor. In literature locally-rooted civic actors that engage in urban development are described and found often operating on the building scale. These civic actors join community organisations that have a legal entity from which management is performed. In literature two community organisations are frequently found: homeowner associations and energy cooperatives. The involved organisations in HAL in the Bouwlust / vrederust district consists of multiple stakeholder types ranging from housing associations, tenants and homeowners through a homeowner association. In the Ammerlaan case the involved organisations are adjacent greenhouses, a sportcomplex, school and 470 apartments belonging to the housing association Rondom Wonen. According to literature important barriers for energy cooperatives are found to be high up-front investments, administrative responsibilities and low degree of professionalism. Although homeowner associations have a reserve fund for expenses they might experience equal barriers as energy cooperatives. Therefore it is assumed that, despite the community organisations are willing to develop low carbon heating alternatives, barriers harm the effectivity of such initiatives. With effectivity is meant: achievement of intended actor's objectives and resolved problems. Therefore the following statement is drawn.

Statement

An area-based approach that is steered by public actors (top-down) is more effective in upscaling geothermal district heating than civic actor (homeowners & tenants) initiatives (bottom-up).

Against	**For**
- This probably depends on the policy-based market context: Denmark for example seems to show bottom-up initiatives can be effective if policies have created the right market context. For effective upscaling of geothermal district heating complementary top-down and bottom-up initiatives could be possible and necessary (Expert 1); - Top down initiatives often meet public resistance, as they do not acknowledge other values that stakeholders have. Expertise is more widely available today. Municipalities should perhaps support bottom up access to expertise (Expert 5);	- Homeowner initiatives rarely reach the scale that is needed to generate enough customers for a geothermal well. The numbers needed range from 4000 households to 8000 households. It is possible to combine different initiatives and housing association buildings, so critical mass is reached. This asks for coordination, logically a role for the municipality. However, a local initiative bringing together potential customers for geothermal energy can play an important role (Expert 3). - In residential areas public actor(s) are required in order to achieve the scale needed for a successful business case. Civic actors like housing associations (in their role of tenants) build the corner stone of said business cases (Expert 4). - You need a clear problem owner to get things going. Geothermal energy exploitation requires a considerable scale, and therefore, it is hard to work with bottom initiatives (Expert 5); - A civic actor is not especially interested in how a house is heated. He depends on it that it is. It's like the starting of the heat pumps, a lot of people didn't care. Only arguments like lower costs for heating, cooling, comfort are what they want to hear. So it has to come out of public actors or investors on bigger scale (Expert 7) - Agree! Not only because of the above argument, but also from the signal the statement assumes: the municipality believes and invests in this area and nowhere else and we (municipality) will contribute to the more sustainable development of this area from a positive-critical attitude. Ever tried having ten tenants or owners on one line and also have them all pay on time? No chance! (Expert 6); - I believe in this case in top-down approach. If they are facilitated by the government or housing associations they are more effective and more realizable in a shorter time, then if they were initiated by individual homeowners or tenants. In addition, a municipal government can better coordinate a plan with other activities in the various neighborhoods, so that unnecessary activities take place (Expert 8). - In the urban area the local government will help to facilitate the development but due to the fact that energy production is privatised their role is limited, In the greenhouse area the project are more bottom-up initiatives as it is manly driven by the reduction of money (savings of natural gas) as by carbon reduction (Expert 9). - Although Bottom-up initiatives are very important, and also very important to create support by the general public, upscaling in an efficient and optimum manner will in my opinion be best achieved by a top-down approach; passing on experiences to next projects, ensuring knowledge is used in next projects, quality and processes in organisation is maintained (Expert 10).

Opinion on or additions to the management topics (optional).
- Given the complexity of all the technology and regulations that come with it, I do agree with that. However, support for the decrease in Geothermal Energy is essential for the decrease. Involving homeowners & tenants at the start is very important and what in it for them? (Expert 2)
- With regard to this type of technology, we are still in the initial phase, both organisational and for many, technically. You can only get through this phase by taking the lead as a government (Expert 6);

3 ● **Management aspect**: Time

Context

Management of time in geothermal district heating projects requires aligning subprojects that run side by side such as geothermal well development, infrastructure development and residential adjustments. The subprojects could also coincide with urban area management such as urban restructuring, urban redevelopment, soil excavation works, public infrastructure maintenance etc.. The timing of developments is worth considering. In the HAL case is found that the gas infrastructure was outdated and needed to be replaced anyway, which showed opportunities to coincide further infrastructure development. In the Ammerlaan case the dwellings were connected to the grid before the geothermal well was finished, which was made possible due to back up heat-generating facilities from Ammerlaan. Management of time is proven in the cases, but when time is not managed well this can lead to an unnecessary increase in costs. Therefore two statements regarding timing are formed.

Statement

A. *The connection of dwellings to geothermal district heating can only happen before the end user's current heat-generating facilities are past due and municipal soil excavation works are planned.*

B. *Before the start of geothermal well and infrastructure development legally binding agreements with the end-users regarding dwelling adjustments and grid connections are necessary.*

Statement A

Against	**For**
- Both factors play a role in optimizing the business case for a heat grid and geothermal well. However, there will never be a point in time when all customers are at the end date of their previous heating system simultaneously. In the case of individual gas heaters (cv-ketel) a solution has been suggested. Suppose a moment a fewer years in the future has been chosen at which time a neighbourhood will switch from natural gas to a heat grid. If in the period leading up to the switch a gas heater breaks down, a new one can be rented/leased instead of bought. This service already exists (Expert 3). - The practical situations are often simply too complex for this statement to be valid in all cases. Mentioned criteria are more of an extra opportunity (Expert 4). - During summer, people could be served with a temporary solution for hot water (Expert 5); - Not necessarily, you only need enough houses to make a connection to get the feasibility positive. You can give customers an incentive to change (Expert 7) - I tend to disagree. Every homeowner has a different exploitation period and you will therefore never achieve it (Expert 8). - No it will help but is not a fact (Expert 9). - No, especially now with the concept climate agreement and C02 targets therein, it will be necessary to develop projects prior to wait when facilities are past due. Although these conditions may help to prioritise these neighbourhoods as first areas where natural gas will be replaced (Expert 10). -	- Certainly! Recent developments have shown delays and changes in planning, contractors who cannot (or do not want to) fulfil their obligations: uncertainty leads to risk and interest surcharge and no party wants to pay for it. "Chain integration" (a bit of a buzzword in area development) did not arise from luxury, but from the necessity to take up a (partial) development step by step and in a controlled manner. Time management is crucial here (Expert 6);

Statement B

Against	**For**
- These legally binding contracts are not necessary. A serious expression of interest of a large group of individual home-owners may provide enough incentive for an investor in heat grids as well (expert 3). - This is not possible. For a geothermal well you need a lot of dwellings (1.000?). What can be done is making agreements with contractors and developers, and they give the agreement through to the end-users (Expert 7).	- In case of a solitary project (Source & heating grid both have to be developed) legally binding agreements are required at the moment of FID (Final Investment Decision) (Expert 4) - Agree! Compare the situation with the discussion on cars that are more environmental friendly; electric or gasoline / diesel cars. The frequency with which news and fake news alternately governs the discussion makes people wary and thus increases the uncertainty for the initiators. The investments are usually so high that you as a developer cannot afford having no legal certainty. In addition, developers are generally not the most solvent parties. It is not only related to the search for leverage boundaries, but also to the increasing development of infringement locations with many stakeholders and therefore long-term planning uncertainty and therefore an expected long lead time of the entire area development, which does not benefit returns (Expert 6); - Oops, that's a tricky one. Unknown makes unloved and that is why you will not get there if you first want to have connection contracts. On the other hand, there is a risk for the entrepreneur or agency that wants to make and exploit the geothermal source. In the case of Rondom Wonen the dwelling was already there. I think there must be a certain potential before the source is started. Just to minimise the risk for the entrepreneur (Expert 8). - No bank loan will be provided for realisation of a geothermal well before the permits are completed, subsidy is granted and guarantees on heat sales (Take or Pay contracts) are given. Heat sale contracts can be B2B and then the off taker may take the risk in the Take or Pay contract for the connections of the dwellings. Even with a Take Or Pay contract the geothermal heat supplier will take a large risk because the SDE+ subsidy is based on real heat supply. The SDE+ subsidy is mainly higher than the price of the heat so income is not secured with a Take Or Pay contract (Expert 9). - Dependent on the situation but in general I think it is good to agree on the responsibilities for these matters in a contract. The supplier must of course not receive any complaints about matters "behind the front door" which are the responsibilities of for instance the housing association. So clear agreements about who does what and when (Expert 10).

- If you go back to the costs, you can conclude that you must be able to generate cashflow from heat sales as soon as the source is operational. So yes, all other adjustments, contracts, connections etc. must be ready as soon as the source is operational. (Expert 2);
- Many developments are tackled from a return point of view. Time is the greatest "opponent" of return. As developments become more complex, returns are becoming less and less manageable (Expert 6);.

4. **Management aspect**: Information

Context

In urban development literature is found that urban development is becoming more demand-driven and less supply-driven. On the demand side of heat are the end-users, who might be unfamiliar with the innovative geothermal energy. In literature concerning diffusion of innovation is found that lack of information about unknown technologies can form a barrier for the adoption of the innovative heat-generating alternatives by homeowners and tenants compared to existing technologies. Capacity building tools are frequently used by public actors. These include network arenas, pop-ups and consultancy centres for interaction and networking with the aim to seek collaboration from local residents and communicate well in order to increase public support. Public support can be created by fulfilling the demands and expectations. In the Ammerlaan case the tenants of the housing association were informed late: after certainty about feasibility was obtained. Visits to the geothermal well were facilitated by Ammerlaan and information provision sessions by the housing association were actions that led to acceptance and cooperation. In the HAL project resident meetings are frequently held to evaluate the progress of the geothermal well development. Also visits to the geothermal installation building were facilitated.

Statement

The provision of development information (planned and ongoing) and civic participation through capacity building tools leads to more acceptance, cooperation and fosters adoption by civic actors.

Against

- Information will easily be perceived as 'biased' and so it might trigger (more) suspicion. Especially if relations between project and citizens are not too good, informing citizens will be perceived as marketing water (Expert 5);

For

- Appropriate information, communication and participation indeed seems important for increasing acceptance and cooperation and for reducing potential resistance against the development of geothermal district heating (Expert 1);
- Yes, I agree (Expert 2);
- It is exactly as you describe. Additionally, without good communication, you can be sure that people living around the well will fight against realisation. The perceived risks of geothermal wells can easily grow bigger than the real risks. Internet searches of "geothermal risks" will find many risks that are not or less applicable to province Zuid-Holland (expert 3).
- Geothermal energy sources in residential areas implies the adoption / acceptance of mining activities in the neighbourhood, with al related aspects including nuisance factors.All measures should be taken to involve stakeholders amongst which the civic actors and build trust. Capacity building tools can be used for this purpose (Expert 4).
- Yes, transparency is a key condition for acceptance, information should be completely honest and reliable (Expert 5);
- Now sustainability (duurzaamheid) is more and more a theme that people have interest for. It can also be used for marketing. If you let people understand that this solution is cheaper than a boiler (gasketel). It's a special solution so when you inform people /buyers of it a group of them (no all) will be interested (Expert 7).
- Certainly, and with a good approach they will even act as a representative and representative of "your" project. What I indicated above: uncertainty paralyzes and that uncertainty is fueled by a lack of information and participation (Expert 6);.
- The learning moment of Rondom Wonen was indeed that we should have informed our tenants more in advance about what was about to happen. That it offers chances to make a big leap when it comes to sustainable heat. The residents therefore had the feeling that they could be heard and included in the progress process if they were informed earlier (Expert 8).
- Eneco is the heat supplier and not HAL. HAL together with Eneco (and Uniper) wants to informs the public about the development of the geothermal project (Expert 9).
- Not sure if it directly leads to more acceptance; it will definitely help in generating more information and knowledge with the public regarding this technology and will be able to provide facts to the public. This is very important (Expert 10).

Opinion on or additions to the management topics (optional).

- The paradox is that it has never been easier to spread information over time ... but there is also a lot of wrong, unmanageable information coming to the consumer, so reason to respond adequately, involve people, let them go thinking, etc (Expert 6);

.

5 ● **Management aspect**: Quality

Context

In literature quality is often found a paradigm in which the various public, private and civic actors define their own qualities. Regarding urban area development, the quality of an area is a comprehensive term referred to by scholars. Quality of an area can be divided in (1) environmental quality (health, safety: legally established standards), (2) spatial quality (utility value, experience and future value) and (3) social values that are accepted. In the first, the different governmental layers (State, Province and Municipality) lay down legislation to steer on quality. In the second, it is the extent to which the development adds value to the stakeholders in the urban area, who can have a subjective opinion about the utility value, experience value or future value. In the third, the social values determine quality. In both the geothermal development projects from the cases the environmental quality opposed by public actors was predominantly present and it is thought that those are minimal requirements for geothermal well developments. The spatial quality and social values are thought to be desirable quality requirements by the stakeholders. It is assumed that steering on only the first is insufficient to come to upscaling geothermal district heating development and that the spatial quality and social values need to be honoured. Although the environmental quality standards can be met, geothermal well development can conflict with certain social values that prefer other alternatives for heating.

Statement

Meeting the environmental quality standards will only lead to geothermal district heating development if the desired spatial quality and social values are met.

Against

- Spatial qualities are not necessarily improved in all realised geothermal projects. Green has been replaced by parking lots in a particular project (expert 3).
- Resistance against district heating systems only occurs in existing areas, which have a good organisation, etc. In new areas, citizens do not organise themselves (Expert 5)
- I don't see why that would be the case. The installations are not that large that there would be a lesser living environment or lesser social values. The pipe network is underground. That is now also the case with the gas network (Expert 8).

For

- Yes, if spatial and social values are insufficiently met the development will not be politically/legally possible (Expert 1);
- However if geothermal energy in general becomes associated with loss of spatial quality, opposition will become much stronger (expert 3).
- The impact of geothermal energy sources in residential areas is such, that a marginal test won't suffice. Given that about 10.000m2 have to be reserved for at least 30 years, the spatial quality of this area is a topic of interest. Social values however could be of less importance, if the renewability objective (CO_2 emission free heating) remains the focal point (Expert 4).
- There is a distrust among citizens against the costs of district heating (Expert 5);
- The end-user needs to accept this solution. But I think most of the people will accept as long as it is assured that it works and the quality is good (Expert 7).
- Yes, agree and and almost an "open door" when you put it that way. The question was (for your learning curve and info) the other way around more exciting: do you also see opportunities for gdhd when these conditions are not met? Then you will discover the critical success factors other than those you already know faster and better (Expert 6);
- Yes and therefore we communicate frequently to the surroundings. As example Hydreco Geomec develop their projects on a higher standard. For example we will install GRE lined casings in our new projects. This is not needed for the permit but we will reduce the consumption of inhibitor and install on this way an extra barrier to protect the sub surface to potential leakages.
- For each project it is important that on all aspects there is support (Expert 10).

Opinion on or additions to the management topics (optional).

- I do not know if I fully understand this statement, but I think there is also much room for development here. People will also have to change a lot, everyone wants wind energy, but prefer this the windmill not to be placed their backyard. Risks for the Geothermal environment are extra in the news through Groningen, this also needs time. Ultimately, end users will make a choice for a solution based on a mix, quality, price, certainty and of course also an impact on the environment, but usually this only comes after quality and price (Expert 2);