Governing collective heat in Amsterdam

LESSONS LEARNED FROM A CASE STUDY COMPARISON OF 5TH GENERATION DISTRICT HEATING AND COOLING

MSc. Thesis

Marieke Buisman

Governing collective heat in Amsterdam

LESSONS LEARNED FROM A CASE STUDY COMPARISON OF 5TH GENERATION DISTRICT HEATING AND COOLING

Thesis submitted in partial fulfilment of the requirements for the

Master of Science

In

Metropolitan Analysis, Design and Engineering (MADE)

Author:	Marieke Buisman
Student ID:	1279505 (WUR) & 5895340 (TU Delft)
Supervisor 1:	Dr. Aad Correljé – TU Delft, Faculty of Technology, Policy and Management
Supervisor 2:	Dr. Aksel Ersoy – TU Delft, Faculty of Architecture
Additional coaches municipality of Amsterdam:	Katelien van den Berge & Britt Bourguignon

Cover image adapted from: Amsterdam by Liene Ratniece

Executive Summary

Introduction

To reach the goal of becoming a natural gas-free city, the municipality of Amsterdam has to move towards more sustainable heat sources. A relatively new sustainable alternative for gas is 5th generation district heating and cooling (5GDHC).

Unlike the electricity- and gas market, there are no European guidelines for heat. There are two new Dutch laws on their way: the new Dutch Heat Act (WCW) and the Municipal Heat Transition Instruments Act (WGIW). The shift in the heat regime raises the question of how to govern sustainable, collective heat.

This master's thesis explores how the municipality of Amsterdam currently governs her heat grids, how the upcoming legislations might affect this, and what lessons could be learned from the way two case studies governed their 5GDHC grids.

Theoretical Background

Theoretical research has been done to define the outlines of 3 concepts; (how did we get to) 5GDHC, governance of heat and the quadruple helix model.

5GDHC is based on the principle exchanging heating and cooling between different types of buildings, making use of low temperatures. This makes it a sustainable alternative for gas. In this research, two cases have been studied and compared that have implemented 5GDHC successfully.

Governance of heat is defined as the local / regional / national / European governments' processes taken for the implementation of collective heat. This research looks at the governance of heat in a multi-level and multi-actor way. To operationalize the governance of collective heat, the quadruple helix model has been used.

The quadruple helix is a model that looks into the interactions (bi-directional and multidimensional) between four spheres: the government, society, academic research and business. Figure 1 visualizes the phases of the research and how, in each phase, the interactions between the different spheres of the quadruple helix are studied.

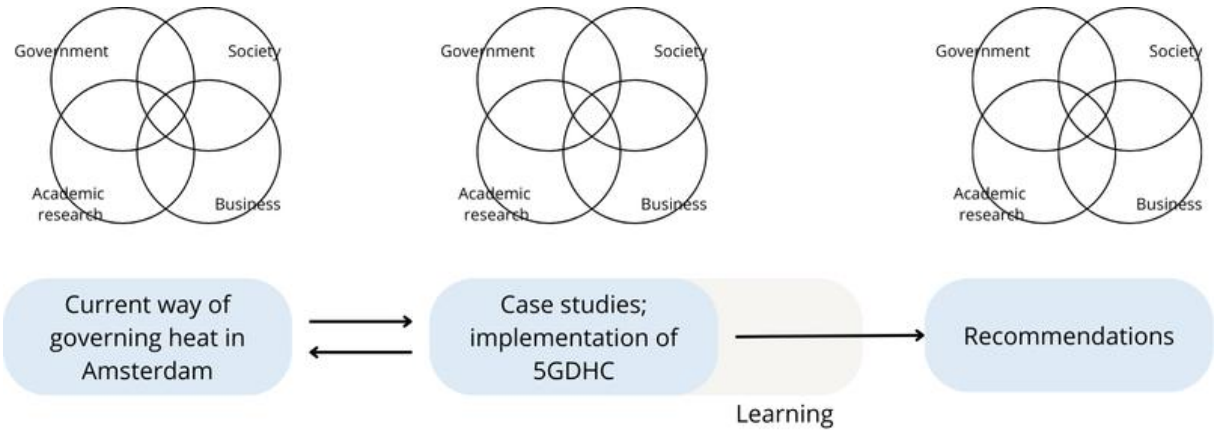

Figure 1: Drawing lessons in governing heat from case studies; a conceptual model. Adapted from (Jansen, 2024)

Research Methods

This qualitative research is done through a document analysis, and a case comparison through interviews. The emphasis is on learning from the governance of cases that have implemented 5GDHC. The synthesis brings together the findings of the case study comparison, and the current situation of governing collective heat in Amsterdam. The methods used are shown in the framework in figure 2.

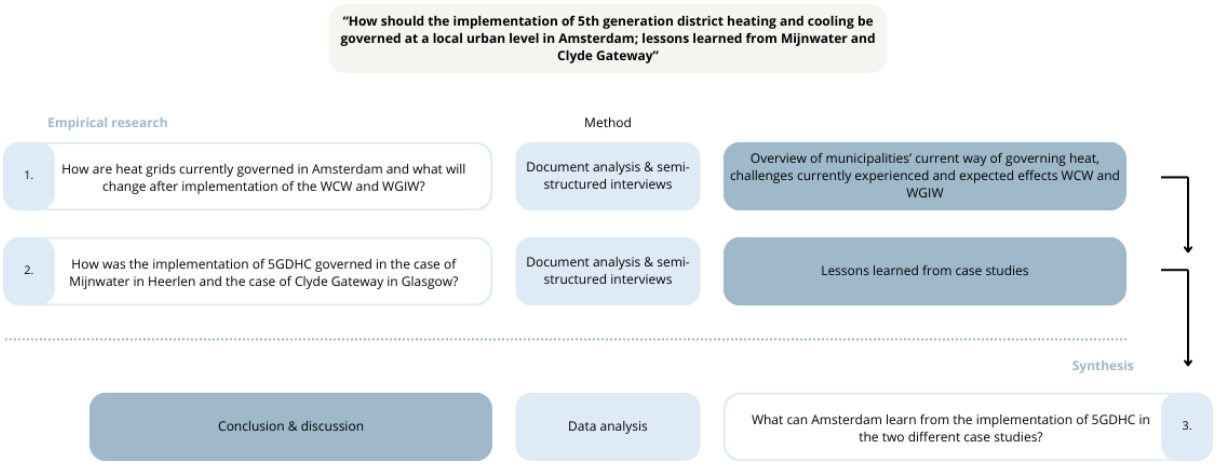

Figure 2: Framework for finding lessons learned regarding the governance of 5GDHC. Adapted from (Jansen, 2024)

The selected cases are Mijnwater in Heerlen and Clyde Gateway in Glasgow. Both cases are part of the D2GRIDS project from Interreg, which are European pilot projects.

Results

The results of the document analysis show that both the WCW and WGIW aim to give municipalities more power in their directive role in the heat transition. The municipality of Amsterdam will take the lead by publishing a new heat source strategy in 2027, together with looking at the potential of a municipal heat company and looking at insurance of affordability and participation.

The interviews insights showed that the municipality of Amsterdam currently struggles with creating a feasible business case, a lack of trust from stakeholders (mainly residents, and weak management tools. The WCW and WGIW will most likely not change anything about this.

The cases of Mijnwater and Clyde Gateway showed how there is still a knowledge imbalance regarding 5th generation district heating and cooling. These cases proved there's a need for strong leadership, clear communication, and a need to start looking at heat differently (as a service instead of a commodity).

Conclusion

The research results in a synthesis with the following recommendations for the municipality of Amsterdam on how to govern collective heat:

1. There is a need for strong leadership and a clear initiator.
2. If the municipality is to move towards low temperature collective heat like 5GDHC, there is a need for knowledge sharing regarding these systems and stakeholder collaboration / education.
3. Research should be conducted on how to manage challenges related to the business case.

4. Research should be done on how to align regulatory frameworks.
5. Residents should be included and well-informed

Recommendations

The following directions can be explored in future research:

Implemented cases in other countries: Countries like Sweden have successfully implemented multiple cases of 5GDHC. It would be interesting to look at countries / cities that are more experienced with 5GDHC, to learn from their way of governing.

New pilots**:** To address the knowledge deficit regarding the governance of collective heat systems like 5GDHC, there should be more pilot projects like the ones from Interreg. Different countries that implement 5GDHC should collaborate by sharing knowledge on the governance of the systems and the challenges experienced.

Alignment of legislation: This research confirms that the upcoming legislation is not yet tailored to the newest (and more sustainable) generations of heat grids. More research should be done on how these kind of systems could be included in the legislation. Since feasibility is still an issue without subsidies, different types of pricing models / business cases should also be a topic in these studies.

Content

Executive Summary 3
Acronyms 8
Acknowledgements 9
1. Introduction 10
1.1. Context 10
1.2. Problem definition 11
1.3. Research objective 12
1.4. Research questions 13
1.4.1. Sub question 1 13
1.4.2. Sub question 2 13
1.4.3. Sub question 3 13
1.4.4. Relationship between the sub-questions 14
1.5. Scope 14
1.6. Reading guide 15
2. Literature Review 16
2.1. How did we get to 5GDHC? 16
2.2. Governance of heat 18
2.3. Quadruple Helix model 19
3. Methodology 21
3.1. Research design 21
3.1.1. Document review 22
3.1.2. Case comparison 22
3.1.3. Semi-structured interviews 23
3.1.4. Stakeholder analysis 25
3.1.5. Quadruple Helix model 25
3.1.6. Ethics 26
3.1.7. Use of Chat-GPT 26
3.2. Description of cases 26
3.2.1. Mijnwater in Heerlen 26
3.2.2. Clyde Gateway in Glasgow 27
3.3. Data analysis method 28
4. Governance and Legislative Landscape 30
4.1. Intended goals of WCW and WGIW 30

4.2. Municipal heat strategy 31
4.3. Governance of 5GDHC in Limburg 32
4.4. Governance of 5GDHC in Glasgow 32
5. Interview Insights 33
5.1. Governing collective heat in Amsterdam and its challenges 33
5.2. Lessons learned from Mijnwater and Clyde Gateway 36
5.2.1. Mijnwater 36
5.2.2. Clyde Gateway 38
6. Discussion 40
6.1. Key findings 40
6.2. Interpretation 41
6.3. Implications 43
6.4. Limitations 44
7. Conclusion 45
8. Recommendations 47
Bibliography 48
Appendices 52
Appendix 1: Interview questions 52
Interviews with case studies (Focused on the organizational challenges) 52
Interviews with organisations 52
Interviews with municipality of Amsterdam 53

Acronyms

4GDH – 4th Generation District Heating
5GDHC – 5th Generation District Heating and Cooling
ACM – Autoriteit Consument & Markt
CHP – Combined Heat and Power
IPCC – Intergovernmental Panel on Climate Change
LEF – Limburgse Energie Fonds
LTH – Low Temperature Heat
WCW – Wet Collectieve Warmtevoorziening
WGIW- Wet Gemeentelijke Instrumenten Warmtetransitie

Acknowledgements

In front of you lies my thesis, marking the end of my MSc. MADE journey. I am very proud to wrap up my academic journey with this thesis as my final product.

The rollercoaster of writing this thesis was both enjoyable, interesting and sometimes very stressful. I loved diving deeper into the topic of collective heat and 5th generation district heating and cooling (which was such a new concept to me), and really enjoyed meeting the pioneers who worked on implementing 5GDHC.

I want to thank everyone who participated and contributed to this project. First and foremost, my supervisors Aad and Aksel, for offering me useful feedback. Their patience with me while I struggled with writing really helped me out. I also want to thank Katelien and Britt for generously offering me a place to work on my thesis at the municipality. Their support extended far beyond a workspace, as they helped me connect with most of the interviewees!

Speaking of interviewees, I want to thank everyone who took the time to speak with me to share their experiences. I talked to a lot of inspiring people and really enjoyed hearing about all the different cases.

Finally, to my MSc. MADE peers, friends and family who listened, asking about my progress… Thank you for your moral support!

Marieke Buisman
Amsterdam, 7-7-2025

1. Introduction

1.1. Context

Climate change is a fact we cannot ignore. Approximately 80% of the world's energy production is accounted for by fossil fuels. This is affecting both the environment and our health (National Academy of Engineering & National Research Council, 2007). The Intergovernmental Panel on Climate Change (IPCC), established in 1988, completed 4 assessments on impacts of climate change and possibilities for adaptation and mitigation (MacCracken, 2008). In 2015, 196 parties signed the Paris Agreement, with the goal to maintain the increase in global temperature to below 2°C compared to preindustrial temperatures (Delbeke et al., 2019). At the same time, the global demand for energy is significantly increasing. Thus, to reach the goals of the Paris Climate agreement and the objective of the municipality of Amsterdam, using renewable energy sources like wind, solar, hydropower and geothermal is essential to avoid energy crisis (Qazi et al., 2019).

In 2020, the municipality of Amsterdam came with the objective to be a natural gas-free city in 2040, aligning with the IPCC and the Paris Agreement. New neighbourhoods no longer get connected to the gas grid. Instead the municipality is moving towards sustainable heat sources like geothermal energy, waste heat (from datacentres) or aquathermal energy. In the future, it is expected that heating can be done at lower temperatures. (Programmateam Amsterdam Energieneutraal et al., 2020)

5th Generation District Heating and Cooling (5GDHC) is introduced as a sustainable way of addressing the growing demand for energy. The CO_2 reduction in traditional heat grids ranges from 50-75% (compared to a natural gas heating boiler), while 5GDHC systems can be completely CO_2-free when the electricity used by heat pumps is sustainably sourced (Setzpfand, 2020). Additionally, 5GDHC makes efficient use of energy sources, by using ultra-low temperature and using sustainable heat sources like waste heat (Gudmundsson et al., 2021). Waste heat would otherwise be discharged, resulting in an increase in the urban heat island effect.

The implementation and governance of heating grids are likely affected by upcoming Dutch legislation. The new Dutch Heat Act (Wet Collectieve Warmte) and the Municipal Heat Transition Instruments Act (Wet Gemeentelijke Instrumenten Warmtetransititie) will redefine heating tariffs, focus on growing collective heat systems, ensure sustainability and give municipalities the opportunity to obligate grid-operators to stop supplying gas to certain neighbourhoods after a certain date (Van Der Staak et al., 2022). This thesis explores the governance of 5GDHC in two case studies, and how the municipality of Amsterdam could learn from these approaches in the implementation of collective heat systems.

1.2. Problem definition

There aren't many cases in the Netherlands where 5GDHC is implemented; currently there's only one in Heerlen-Brunssum (Nationaal Programma Lokale Warmtetransitie, 2025). 5GDHC-systems are technically complex systems, but as seen in 40 cases throughout Europe, achievable (Buffa et al., 2019). However, in the Netherlands the implementation is challenging as there is a lack of regulation for collective low-temperature heat-systems (LTH) like 5GDHC, specifically in the current Dutch Heat Act. In the new Dutch Heat Act (Wet Collectieve Warmtevoorziening) which will likely take effect in 2025, there is no mentioning of regulation of 5GDHC either (Schepers et al., 2022). This results in uncertainty of who should do the initial investments, or who gains from the profits (van den Berge, 2024).

There are currently no European guidelines for the heat market, unlike the electricity and gas markets. The current Dutch Heat Act is based on 3rd generation heat grids. This means that heat transport is assumed to be over short distances, and there is no open network access and no regulation for network access for third parties. Maximum prices are set by the Autoriteit Consument & Markt (ACM) based on *Niet Meer dan Anders* principle (price for supply of heat cannot be more than supply for gas).

There are two new Dutch laws on their way: the new Dutch Heat Act and the Municipal Heat Transition Instruments Act (Wet Gemeentelijke Instrumenten Warmtetransitie or WGIW). Both aim to focus on how municipalities are to be given direction in rolling out heat supply, and a new tariff method that will be more cost-based and should protect consumers from heat companies' monopoly. Both are still not tailored to the governance needs of 5GDHC. (Lavrijssen, 2020)

The new Dutch Heat Act (in Dutch Wetsvoorstel Collectieve Warmte or WCW) was presented to the House of Representatives in June 2024. One of the principles of the WCW is that municipalities will get the directing role in the heat transition by appointing heat companies for heat plots (also defined by municipalities). Heat companies will have to be at least 50% owned by public parties. (Nationaal Programma Lokale Warmtetransitie, n.d.-a)

The new Dutch Heat Act distinguishes four different organizational models:

1. Public heat company; with a public majority interest where more than 50% of the shares are owned by a public organization like the municipality or state)
2. Joint venture; between a heat grid company and a heat supply company (again, 50% of the shares should be publicly owned)
3. Heat community; a community that aims to offer climate-, economic-, or social benefits to its members. It operates on a non-profit basis.
4. Private heat company (by exception); for small collective heat systems with less than 1500 consumers, the public majority interest requirement does not apply to heat systems with less than 1500 consumers.

(TNO, 2024)

There will also be a new way of regulating heating tariffs; instead of a tariff based on gas prices, we will move to a cost-based tariff (Nationaal Programma Lokale Warmtetransitie, n.d.-a)

The proposition for the Municipal Heat Transition Instruments Act (in Dutch Wet Gemeentelijke Instrumenten Warmtetransitie of WGIW) aims to give municipalities the power to organise the

district- or area-based approach of the heat transition. This law is scheduled to take effect on July 1st, 2025. (Nationaal Programma Lokale Warmtetransitie, n.d.)

Over the past five years, municipalities have published a heat transition vision where they mark areas to be renewed in a sustainable way or made gas-free and when. When the WGIW is implemented, these transition visions are to be actualised every five years. The WGIW will also give municipalities power of designation, which enables municipalities to appoint areas to transition to sustainable heat sources instead of gas. (Nationaal Programma Lokale Warmtetransitie, n.d.)

Both the WCW and the WGIW do not address LTH-systems yet. The challenge of the unclear guidelines for the heat market with the upcoming legislation raises the question of how we should govern collective heat like 5GDHC-systems. This research specifically focuses on how Amsterdam can learn from existing European case studies that have implemented 5GDHC systems. In what way did they govern the implementation of the system? What are potential roles and responsibilities for the municipality of Amsterdam and how do these align with the upcoming legislation?

Through the interviews conducted for this research, it became clear that the implementation of 5th Generation District Heating and Cooling is not (yet) feasible in the current context of Amsterdam. As a result, this study focuses on recommendations for the municipality of Amsterdam regarding the governance of collective heat, based on lessons learned from two cases that have successfully implemented 5GDHC.

1.3. Research objective

Previous research done by the municipality of Amsterdam (van den Berge, 2024), has shown that 5GDHC is technically possible, but that the biggest challenge is organizational. At the same time, the heating regime in the Netherlands is changing with the development of the WCW and the WGIW. The goal of this research is to find out how Amsterdam could learn from approaches of cases that successfully have implemented 5GDHC. The outcome of this research focuses on lessons for the municipality; how to govern the integration of collective heat systems (like 5GDHC) in urban infrastructure planning in Amsterdam, within the new heating regime.

1.4. Research questions

This research focuses on drawing lessons learned from two case studies that implemented 5GDHC. These lessons learned result in recommendations on the governance of collective heat for the municipality of Amsterdam. This is done through the lens of the quadruple helix model (see chapter 2.3). Figure 3 visualises how, in each phase of the research, the interactions between the spheres are analysed.

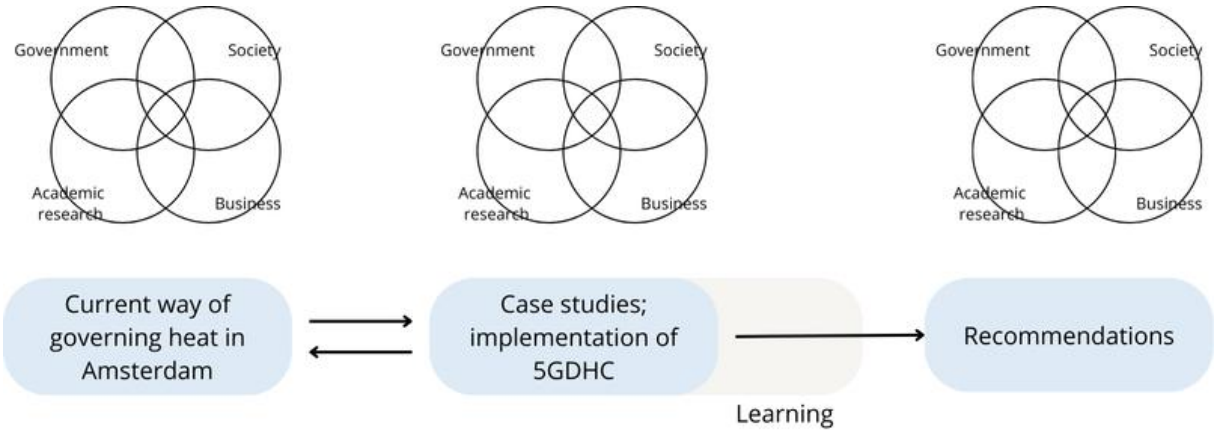

Figure 3: Drawing lessons in governing heat from case studies; a conceptual model. Adapted from (Jansen, 2024)

The main research question is as follows:

"How should the implementation of collective heat be governed at a local urban level in Amsterdam; lessons learned from Mijnwater and Clyde Gateway"

1.4.1. Sub question 1

How are heat grids currently governed in Amsterdam and what will change after implementation of the WCW and WGIW?

This question aims to gain a better understanding of the current way the municipality of Amsterdam governs her heat grids and what organizational challenges are currently being faced. It also explores the expected effects of the upcoming legislations.

1.4.2. Sub question 2

How was the implementation of 5GDHC governed in the case of Mijnwater in Heerlen and the case of Clyde Gateway in Glasgow?

This question focuses on the two case studies, and how they governed the implementation of 5GDHC. What did the interaction between the spheres of the quadruple helix look like in both cases? What is the difference in approach between the cases and why did they approach things differently?

1.4.3. Sub question 3

What can Amsterdam learn from the implementation of 5GDHC in the two different case studies?

This sub question applies the lessons learned from the two case studies on the way Amsterdam governs her heat grids. It looks into the spheres of the quadruple helix and how they usually interact in collective heat projects in Amsterdam, and how this is different from the two case studies. In what

way can we learn from them; should actors from these spheres take on different roles, should there be a change in interaction?

1.4.4. Relationship between the sub-questions

Figure 4 shows the relationship between the sub-questions. To answer the main research question, the following steps are taken:

First, examination of the context of Amsterdam; how does the municipality govern heat grids currently and how will this change after the implementation of the new legislation? Step 2 involves a case comparison to identify what challenges are experienced in the case studies and the lessons learned. Step 3 is a synthesis of sub-question 1 and 2.

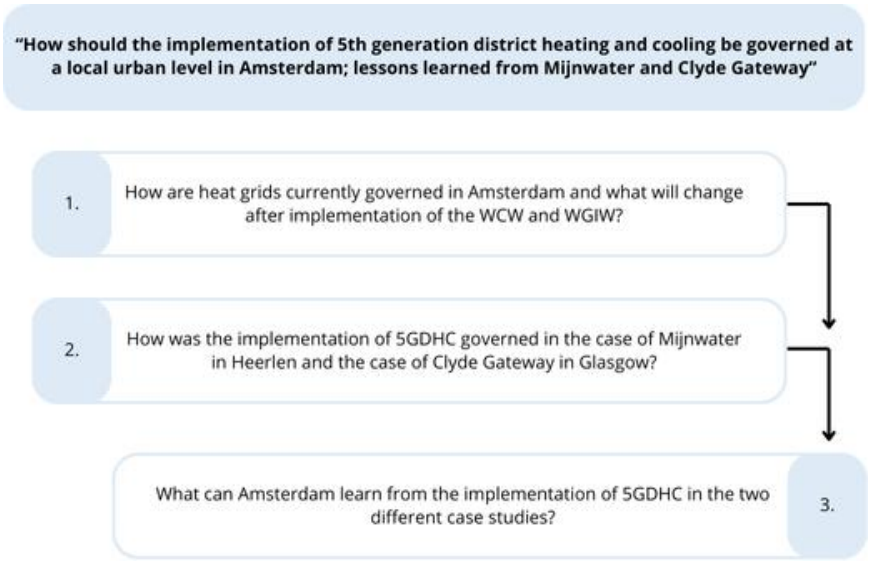

Figure 4: Relationship between sub-questions. Adapted from (Jansen, 2024)

1.5. Scope

This research focuses explicitly on the governance of collective heat. This includes regulatory- and policy barriers, financial barriers (a feasible business case) and stakeholder interactions. The research is conducted through interviews with two D2GRIDS-cases that have implemented 5GDHC, to learn from their key takeaways. Through interviews with other experts, the governance of collective heat grids in Amsterdam and effects of the current and upcoming laws are investigated .

The lessons learned result in recommendations for the municipality of Amsterdam; how the municipality generally governs collective heat grids and how she could learn from the way this is done in the case studies. To analyse how the municipality generally govern heat grids, three interviews have been conducted with the municipality focusing on the implementation of three different, recent collective heat systems (WAD-kwartier, Centrumeiland and Strandeiland). The current situation in Amsterdam is based on / focused on traditional heat grids, however the municipality is moving towards implementing more collective, lower-temperature, heat grids.

1.6. Reading guide

This thesis consists of eight chapters, of which you can see the outline in table 1.

Table 1: Chapter overview

Chapter	Content
1. Introduction	Introduction to the context, problem definition, research objective, research questions and scope
2. Literature Review	Analytical approaches based on academic research to conceptualise 5GDHC, the governance of heat and the quadruple helix model
3. Methodology	Research design. Methodological framework with a description of the steps taken in the data collection and data analysis, and a description of the case studies.
4. Governance & Legislative Landscape	Document review of the upcoming legislation, the heat strategy of the municipality of Amsterdam, and the governance of heat in the case studies
5. Interview Insights	Results arising from the interviews
6. Discussion	Description of the key findings, the interpretation of the results, the academic / societal contribution of this research and the limitations
7. Conclusion	The synthesis resulting in recommendations for the municipality of Amsterdam in governing collective heat based on the lessons learned from the case studies
8. Recommendations	Recommendations for future research

2. Literature Review

The literature review consists of the definition of 5th generation district heating and cooling and how we got there, defining governance of heat, and lastly, the quadruple helix model and how it's used in this research.

2.1. How did we get to 5GDHC?

The first district heating systems were introduced in the United States, and used steam as a heat carrier. These systems used very high temperatures, and had a low efficiency. The second- and third generation of district heating are alike, using hot water as a heat carrier. They are distinguished by their operating temperatures and fabrication methods; 2GDH functions with temperatures over 100°C, while 3GDH operates with temperatures below 100°C and uses pre-fabricated pipes. 4GDH functions on low-temperature water from 30-70°C, making it possible to distribute heat very efficiently with low grid losses. By using these low temperatures, it became possible to integrate renewable heat sources and waste heat. The system can also be integrated with smart energy systems. (Lund et al., 2014)

Figure 5 gives an overview of all 5 generations of district heating through time.

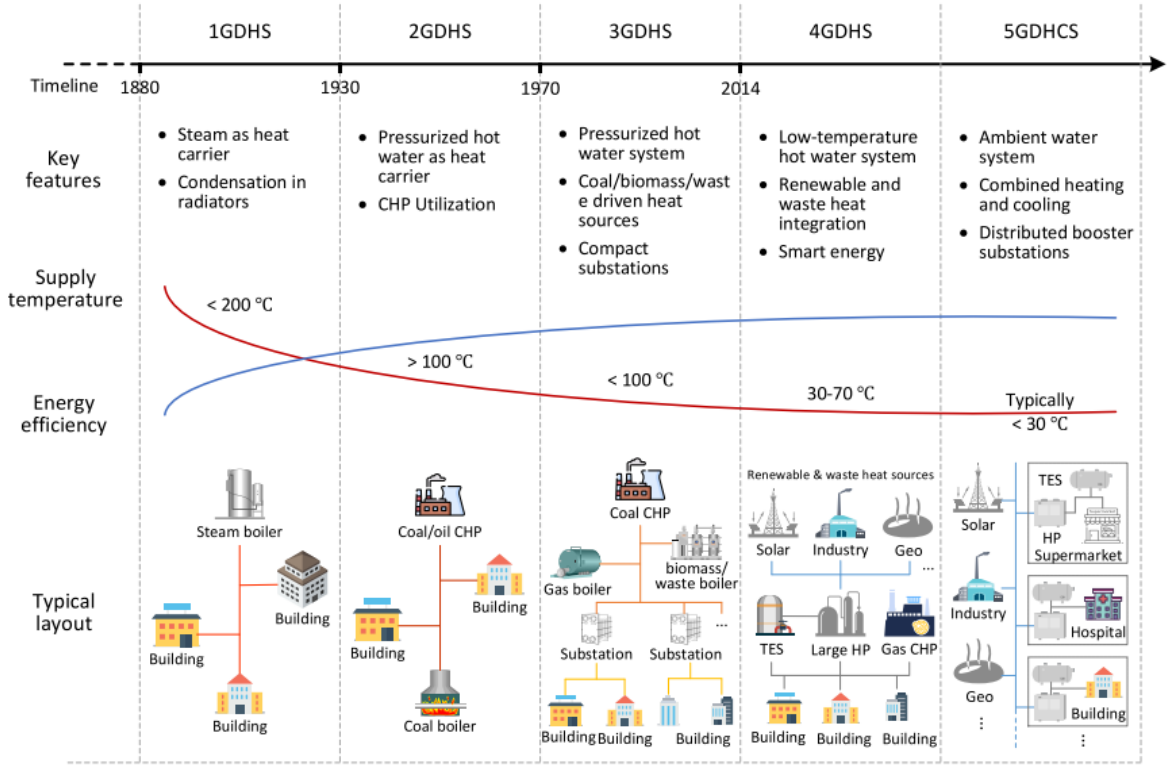

Figure 5: Overview of generations of district heating (Yao et al., 2024)

4GDH and 5GDHC are very much alike. Where 4GDH mainly aims to meet the future needs for heat supply by using renewable energy sources as part of a sustainable energy system (Lund et al., 2021), 5GDHC is based on the principle of exchange between heating and cooling demands of different types of buildings (also called "closing the loop") (Boesten et al., 2019).

5GDHC consists of multiple decentralized heat sources while staying open to new ones. The system operates on ultra-low temperatures; between 0°C and 30°C (close to ground temperature), where the water circulates. Heat pumps deliver the required thermal energy for the water to be used in buildings. What distinguishes 5GDHC from the previous generations, is how the energy flows in the system are bidirectional, making it able to provide both heating and cooling while exchanging heat between users (this can be seen in figure 6). This means users are prosumers (both consumer and producer). (Gjoka et al., 2023)

A 5th generation network meets 5 principles (Dang et al., 2024). The two cases of Mijnwater and Clyde Gateway are chosen as projects where 5GDHC is successfully implemented, since they both meet these 5 principles:

1. Closing the energy loop
2. Using low-grade sources for low-grade demand
3. Decentralized & demand-driven energy supply
4. An integrated approach of energy flows
5. Prioritizing local sources

In literature, 5GDHC can be referred to by other terms, like LTDHC (low-temperature district heating and cooling), LTN (low-temperature network), Flexynets, CDH (cold district heating) and Anergy (Lindhe et al., 2022). In this research, the term 5GDHC will be used.

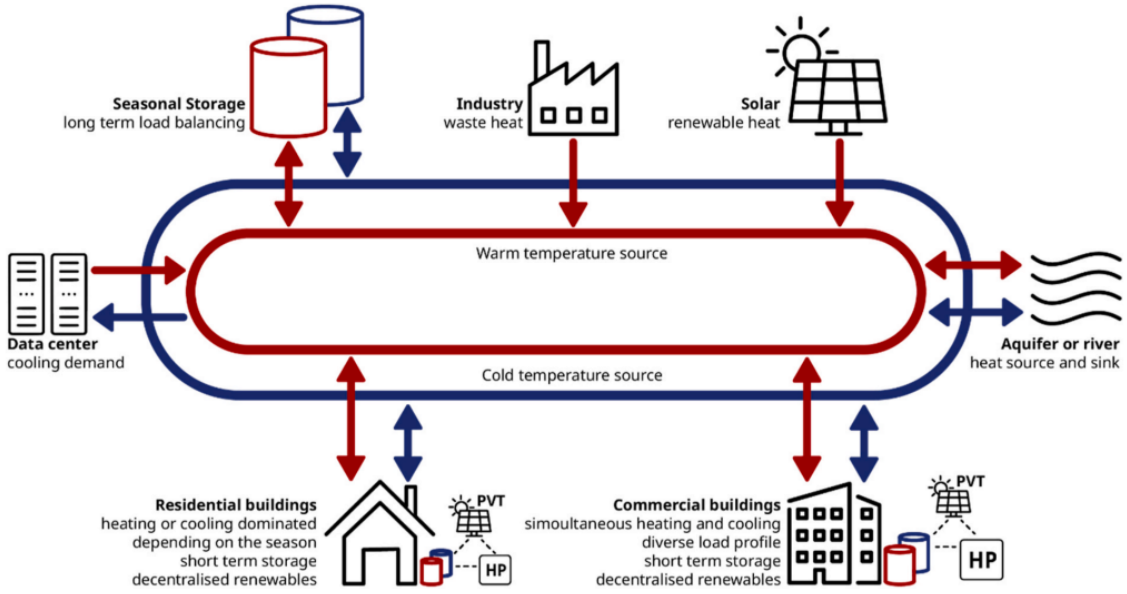

Figure 6: Representation of a 5GDHC system (Gjoka et al., 2023)

As 5GDHC is still a relatively new concept, it raises the question of how to govern these sustainable collective heat systems. The following subchapter describes the main concepts in this research regarding the governance of collective heat.

2.2. Governance of heat

Fukuyama (2013) defined governance as “a government’s ability to make and enforce rules, and to deliver services”. In this research, the governance of heat is defined as the local / regional / national / European governments’ processes taken for the implementation of collective heat. This could be in the planning, regulation, decision-making, coordination, and implementation of (collective) heat systems. This includes legislations and the interactions with other stakeholders in the enforcement of legislation. In the context of heat in the Netherlands, the Dutch Heat Act is an important governmental document.

Multi-level governance refers to “continuous negotiation among nested governments at several territorial tiers” (Bache, Bartle, & Flinders, 2016, p. 487). These levels could be local (like municipalities), regional (provinces), national or international (like the European Union). Another perspective to look at governance is multi-actor governance. Multi-actor governance looks at more actors than just governmental bodies and how they interact together to deal with complex societal problems (Craps et al., 2019).

Research (Yao et al., 2024) describes that typical stakeholders in the governance of 5GDHC are system operators (potentially being responsible for both heat production and distribution), prosumers, regulatory bodies, and external investors. It is challenging to balance the different interests of these stakeholders; especially with the lack of regulations, supportive policies, and economic frameworks for the implementation and development of 5GDHC. (Yao et al., 2024)

The current Dutch Heat Act predates the energy transition. As a result, changes driven by the energy transition are generally not reflected in existing laws and regulations. This also complicates implementation of the newer generations (4th and 5th) of heating grids. (Lavrijssen & Vitéz, 2021)

This thesis examines governance from both a multi-level as a multi-actor perspective, with a main focus on the municipality of Amsterdam. The operationalization of governance is done by looking at the interactions of the municipality with other governmental actors and other spheres from the quadruple helix (see chapter 2.3.). The four spheres all have their own roles and actions in the governance of heat. The research is done by looking at the process of implementing heat grids; how are decisions made and how are interactions between actors / spheres within this process. It will also look ahead to the implementation of the WCW and WGIW, and whether these new laws will make implementation of collective heat grids easier.

2.3. Quadruple Helix model

Research (Schütz et al,. 2019) has shown the importance of including citizens preferences in projects, to end up with accepted and more sustainable innovations. Where the triple helix model focuses on the relationship between academia, industry and governance, the quadruple helix focuses on democracy by adding citizens as a fourth sphere into the mix. The quadruple helix model was introduced by Carayannis and Campbell in 2009. Figure 7 shows the bi-directional and multidimensional interactions between the four spheres. (Schütz et al,. 2019)

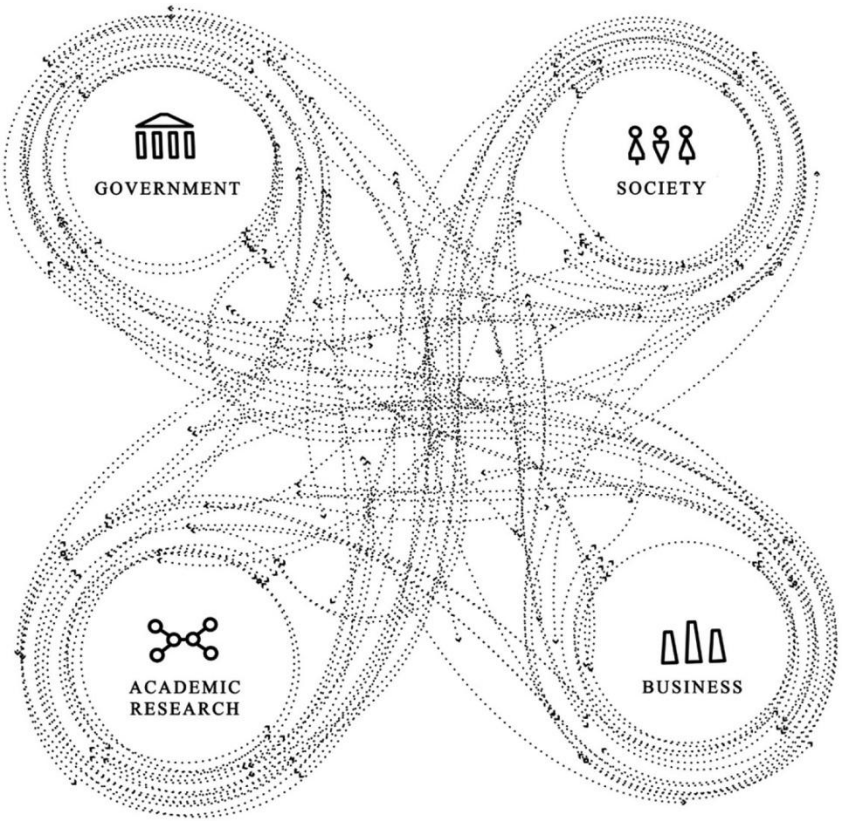

Figure 7: The Quadruple Helix model (Schütz et al,. 2019)

In this research, the quadruple helix model was used as a way to categorize the different stakeholders within those four spheres (to operationalize the governance of heat). This was done to get an understanding of the way the stakeholders interact in both case studies and to gain insights in the decision making process. The forms that the interactions between the four spheres might take, are yet to be determined (Schütz et al,. 2019). This research investigated those interactions with regards to the implementation of collective heat systems.

In this research, the four spheres are defined as:

- Government. Includes municipalities, provinces, national government and any other governmental bodies that decide on the regulation / policies regarding to- or plan / organise the implementation of heat grids. This also includes the ACM.
- Society. Includes (potential) consumers and end-users of a heat grid; any citizens or businesses / organisations that are located in an area where the heat grid is (to be) implemented. Also includes housing associations and developers (who in newly developed areas represent the future residents).

- Academic research. Institutes like universities or other research institutions doing research on collective heat / 5GDHC.
- Business. Includes heat companies (producer / supplier), heat grid operator and ESCO's (Energy Service Companies).

In this research, the quadruple helix model is used as a guideline for the interviews. This is done by making use of dimensions related to the spheres of the quadruple helix, like law & regulation and policy for the governance sphere (see chapter 3.3. Data analysis method, for an overview of all the dimensions). These dimensions are based on the activities / roles linked to the spheres in the implementation of collective heat grids. The interview questions for both the context of Amsterdam as the case studies, are aimed to understand the interactions between the spheres described above. In the synthesis of the results, the quadruple helix is used as a framework to give recommendations to the municipality of Amsterdam.

3. Methodology

The first subchapter of the methodology describes the research design, after which the methods used have been further described. Sub-chapter 3.2 describes the context of the case studies that have been done to perform a case comparison. The last sub-chapter shows how the data has been analysed.

3.1. Research design

This thesis consists of empirical research and a synthesis. Figure 8 illustrates the relationship between the sub questions and the methods used.

Sub question 1 aims to get a better understanding of the current way of governing heat in Amsterdam, by looking at the interactions in between / within the spheres of the quadruple helix model. This question also covers the legislation that impacts the way of governing heat in Amsterdam, and looks forward to the new legislation and how this might change the way of governing heat. Sub question 2 looks into 2 case studies with a comparable legislative framework to Amsterdam, to find out what lessons they learned (again by using the quadruple helix model). The final sub question is the synthesis of the other 2 sub questions, which results in an advice for the municipality of Amsterdam (what they could learn from the case studies, taking the upcoming legislations into account).

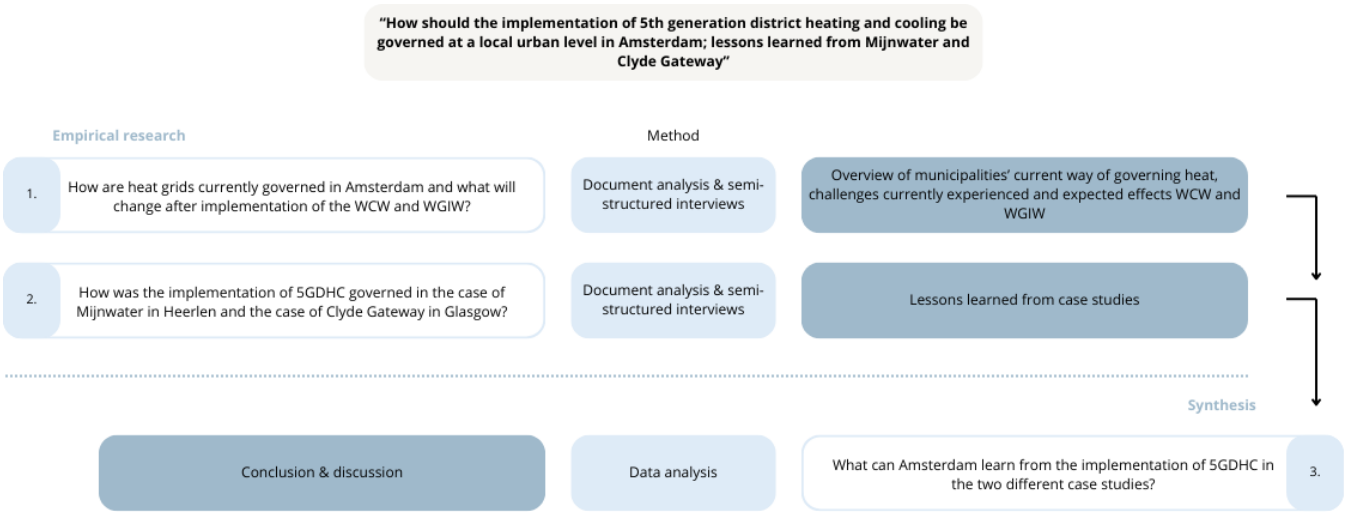

Figure 8: Framework for finding lessons learned regarding the governance of 5GDHC. Adapted from (Jansen, 2024)

Figure 9 illustrates the methods, goals and expected outputs of the empirical research and the synthesis. The empirical research focuses on the first and second sub questions. A document analysis has been done to look into the upcoming legislation, the heat strategy of Amsterdam and the governance of 5GDHC in the case studies. Interviews have been conducted to get an understanding of the governance of heat grids in Amsterdam and to look into the expected impact of the upcoming legislation. Lastly, more interviews have been held with experts of the case studies. In the synthesis, the knowledge gathered in the empirical research gets combined to implement lessons learned about the governance of 5GDHC to the context of Amsterdam.

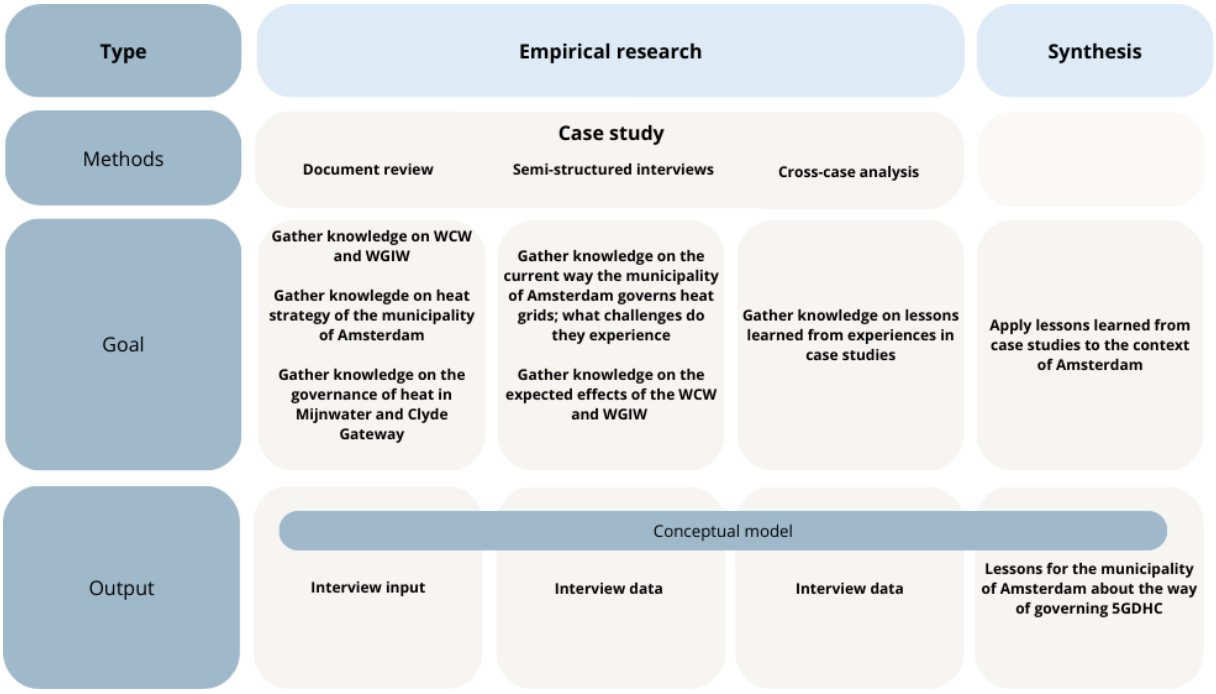

Figure 9: Methods used. Adapted from (Jansen, 2024)

3.1.1. Document review

To answer sub question 1, a document review has been done. This document review started with the exploration of the goals / expected outcomes of the WCW and WGIW. The current heat strategy (and future heat programme) of the municipality of Amsterdam has been looked at as well, to see how these connect to the intended goals of the upcoming legislations and to later connect to the outcomes of the interviews with the municipality. The final part of the document review consists of an analysis of documents regarding the way of governing the case studies, to get a better understanding of sub question 2.

3.1.2. Case comparison

To answer sub question 2, a comparative case study has been done. The cases of Mijnwater in Heerlen-Brunssum and Clyde Gateway in Glasgow have been taken as an example where 5GDHC was successfully implemented. Both Mijnwater in Heerlen and Clyde Gateway in Glasgow are D2GRIDS projects from Interreg North-West Europe (Schepers et al., 2022), and have been chosen due to accessibility of data. These D2GRIDS projects aimed to implement 5GDHC through promoting its standards towards the industry and share knowledge (About Us | 5GDHC, n.d.). This means that data was available online. The main input for the case comparison comes from the interviews with experts.

The lessons learned from understanding how these cases governed their projects, what organizational challenges they faced in the implementation and how they dealt with those challenges, resulted in recommendations for the municipality of Amsterdam in governing collective heat grids. This comparative case study has been done through interviews. Taking into account the

context of the new laws regarding heat, the final recommendations for the city of Amsterdam were developed.

3.1.3. Semi-structured interviews

Interviews have been used both as preliminary research and as empirical research. The interviews with both case studies were relevant to the preliminary research, as they showed the difference between the approach of the two cases and the organizational challenges they encountered. With this knowledge, the focus of the research was to investigate the different approaches and how the municipality of Amsterdam can learn from them.

Using semi-structured interviews gave the opportunity to ask follow-up questions to the interviewees. The interview questions are guided by the quadruple helix model and the interactions between the spheres (see Appendix 1 for the interview questions). This way, with asking follow-up questions, it was possible to dive deeper in the interactions that occur in the process of governing collective heat (and specifically 5GDHC in the case studies). Interviewees have been asked to explain the stakeholder interactions / collaborations, laws- and regulations that obstructed the implementation, other challenges they experienced and the expected impact of the upcoming legislations.

The following table shows an overview of people that have been interviewed:

Table 2: Overview of interviews

	Interviewee Mijnwater Case	**Organization**	**Regarding**	**Date**
1.	Benno Schepers	CE Delft	Mijnwater-case (Sub question 2	29-4-2024
2.	Louis Hiddes	2RC	Mijnwater-case (Sub question 2)	17-6-2024
	Interviewee Clyde Gateway case	**Organization**	**Regarding**	**Date**
3.	Martin McKay	Clyde Gateway	Clyde Gateway-case (Sub question 2)	25-7-2024
4.	Hugh Moore	Clyde Gateway	Clyde Gateway case (Sub question 2)	26-7-2024
	Interviewee Amsterdam case	**Organization**	**Regarding**	**Date**
5.	Nick Smit	Municipality of Amsterdam	Business-case of heat grids and WCW	25-6-2024

			(Sub question 1)	
6.	Julia Eijkens	Autoriteit Consument & Markt (ACM)	Current laws & Regulations and WCW (Sub question 1)	18-7-2024
7.	Expert	Industry Association Energie Nederland	Organisational challenges experienced by heating companies (Sub question 1)	2-8-2024
8.	Steven Roerink	Municipality of Amsterdam	Governance of heat grid in WAD kwartier and challenges experienced (Sub question 1)	25-9-2024
9.	Researcher	AMS Institute	Amsterdam's way of governing heat grids and the organizational challenges experienced (Sub question 1)	27-9-2024
10.	Katelien van den Berge	Municipality of Amsterdam	Governance of heat grid in Centrumeiland and challenges experienced. What changed in Amsterdam's strategy of governing heat grids over time? (Sub question 1)	30-9-2024
11.	Policy officer	-	Governance of heat grid in Strandeiland and	11-10-2024

			challenges experienced (Sub question 1)	

Interviewees have been contacted by email and / or phone. Some of these interviewees have been referred to / recommended by others. Most of the interviewees from the two case studies (Mijnwater and Clyde Gateway) fall within the business-sphere of the quadruple helix model, apart from Benno Schepers, who represented the academic research-sphere. For the case of Amsterdam, most interviewees were policy officers, falling within the governance-sphere. The representative of the ACM also falls within this sphere. Other interviewees for the case of Amsterdam were a researcher, falling within the academic research-sphere, and someone from the industry association Energie Nederland, representing heat companies and thus the business-sphere. No representatives from the society-sphere have been interviewed, but the interviewees have been asked about the interactions with residents / end-users of the heat grids.

The first interviews were held with two experts for each of the case studies. After the interviews with the case studies, experts from the ACM, Energie Nederland, the municipality of Amsterdam and AMS Institute have been interviewed to get a better understanding of the organizational challenges in the Dutch heat market, the current way of governing heat grids in Amsterdam and organizational challenges experienced here and the expectations of how the new heat laws will affect the current way of governing.

3.1.4. Stakeholder analysis

The operationalization of the quadruple helix is done through a stakeholder analysis. It is important to get an understanding of the relevant stakeholders and their roles and interactions. This has been done through interviews with the case studies and the municipality of Amsterdam, by using the framework of the quadruple helix model. The stakeholder analysis is used to understand the interaction and collaboration between the four spheres of the quadruple helix and where in the 5GDHC system these stakeholders play a role.

3.1.5. Quadruple Helix model

The quadruple helix model (see chapter 2.3. Quadruple Helix model) has been used to gain insight in the interactions between actors in the decision making process (and how experts expect this to change after the implementation of the WCW and the WGIW). The quadruple helix was used as a guideline for the interview questions. The model is used in the empirical research to understand the interaction in the governance of heat in Amsterdam, and the interactions in the governance of 5GDHC in the case studies. The synthesis looks at the quadruple helix and results in recommendations based on these interactions.

3.1.6. Ethics

To ensure the privacy of the interviewees, each interviewee signed a consent form. In the form they indicated whether or not they wish to have their name and / or organisation mentioned in this thesis.

Each interviewee also received the transcript of the meeting through e-mail. They were asked to respond this mail, with things they may not want shared, or to add onto the transcript. All recordings and complete transcripts of the interviews will not be shared.

3.1.7. Use of Chat-GPT

Chat-GPT (OpenAI) has been used as a supportive tool for a spelling check and tips for improved phrasing. No content was generated by AI.

3.2. Description of cases

Two different case studies have been taken as an example for implementing 5GDHC. The aim of the case-comparison, was for the municipality of Amsterdam to learn from the way these two cases governed the implementation of 5GDHC. Both case studies are D2Grids pilots. D2Grids is an project from Interreg Noth West Europe, with the goal to increase renewable energy sources for heating and cooling. They do this by implementing 5GDHC in five pilots (Interreg North-West Europe, n.d.). The case of Mijnwater is relevant, because they have to deal with the same legislations as Amsterdam would. Clyde Gateway is also dealing with similar legislations (and the Scottish government also proposed a new Heat in Buildings Bill) (Energy and Climate Change Directorate, n.d.).

3.2.1. Mijnwater in Heerlen

The municipality of Heerlen starting doing research on using the water in mines for heating buildings in 2003. This first concept was based on 4th generation district heating, but it turned out that this concept was depleting the mines, by using them as a heat source. (Müller et al., 2020)

A new concept (Mijnwater 2.0) used the mines as a storage system, making use of aquifers. This turned into a 5GDHC network, by exchanging heat and cold (this can be seen in figure 10). The thermal storage provided by the aquifers (storing heat in underground water layers), doesn't guarantee all peak demand and regeneration of the heat source. For this reason, air-source heat pumps have been installed. (Lieugard, 2022-a)

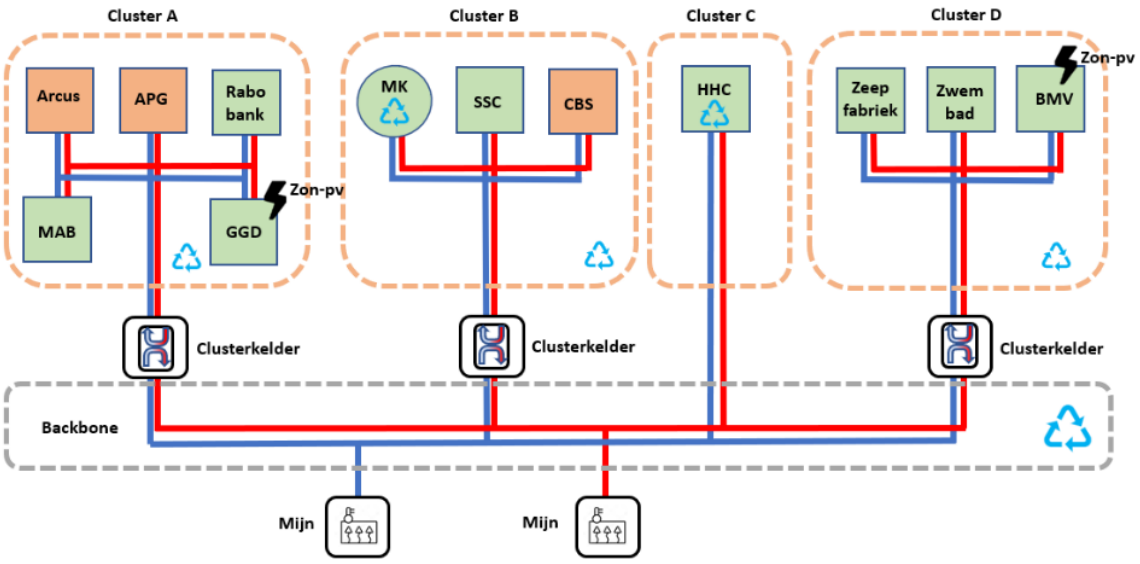

Figure 10: Energy exchange between buildings (rectangles), sectors (circles) and 4 clusters (green = energy plant owned by Mijnwater; orange = energy plant owned by a third party) (Müller et al., 2020)

The annual heating demand of the buildings connected to the district heating network is 1.130 MWh, while the annual cooling demand is 187 MWh (Lieugard, 2022-a).

Mijnwater is owned by the Limburg Energie Fonds which took over the company in 2019 from the municipality (Müller et al., 2020). The municipality of Heerlen is still (partially) funding the Mijnwater project, and they facilitate the necessary construction activities (Brummer et al., 2019).

3.2.2. Clyde Gateway in Glasgow

Clyde Gateway is a partnership between the Glasgow City Council, South Lanarkshire Council and Scottish Enterprise. It's funded by the Scottish government, SSE Sustainability Fund and Scottish Water Horizons and located in the east of Glasgow. The area is transformed into a place with mixed functions (retail, residential, leisure, commercial and educational). (Lieugard, n.d.-b)

The goal of the project is to provide low carbon energy while having attractive technologies for customers and future resident. There are three buildings located in the area; two office buildings (one with multiple tenants) and a building containing both office and workshop spaces. (D2Grids Project, 2023)

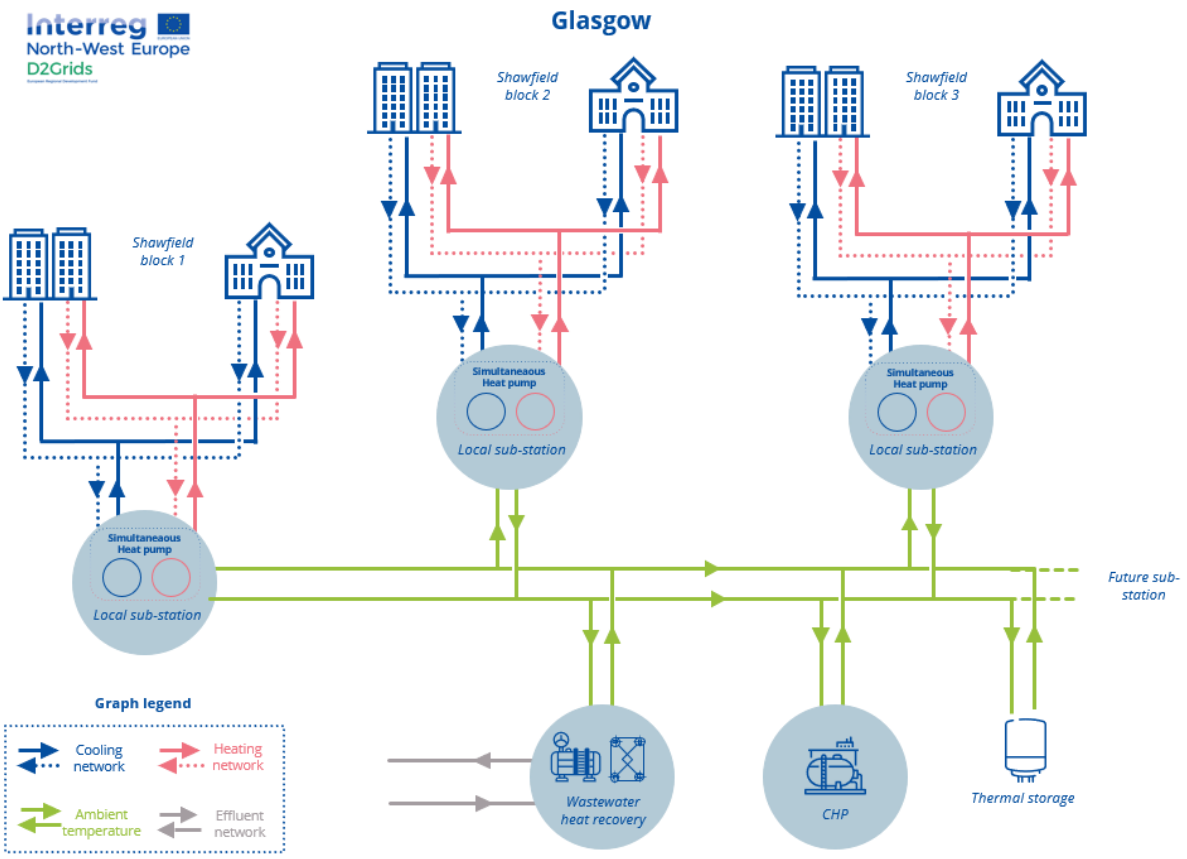

Figure 11: Overview of 5GDHC-grid in Clyde Gateway (Lieugard, n.d.-b)

The annual heating demand of the buildings is 598.926 MWh, while the annual cooling demand is 108.920 MWh. Heat is recovered from waste water as the main energy balancing source. The network contains a gas-fired CHP (combined Heat and Power) that provides heat to the waste water treatment work, as shown in figure 11. (Lieugard, 2022-b)

3.3. Data analysis method

To analyse the data from the interviews, an inductive approach has been taken. This means qualitative results have been generalised by analysing patterns (Thomas, 2003). In this research, the dimensions are based on the four spheres of the quadruple helix (linked to the activities of the sphere in the implementation of collective heat grids). These dimensions were also used in the phrasing of the interview questions. The themes following the dimensions are based on the results of the interviews; these were the themes mentioned by the interviewees when asked questions related to the dimensions. The interviews have been coded in Excel, to find patterns, which resulted in the themes following the dimensions in table 3.

The research focused on the governance of implementing 5GDHC by looking at the interactions between the different spheres of the quadruple helix. Thus, the concept that have been focused on are the four spheres of the helix. To operationalize the four spheres, the analysis of the data focused on the different dimensions related to these actors, stated in the following table:

Table 3: Dimensions and themes used for analysis

Quadruple helix sphere	Dimension	Themes
Government	Law and regulation	Current heating laws
		Upcoming heating laws (WGIW / WCW)
	Policy	Municipal strategies
Society	Citizen-involvement	Stakeholder interactions with citizens
		Other additional values for citizens
Academic research	Complexity of 5GDHC	Knowledge gap issues
		Research done on 5GDHC
Business	Business case	Supply chain
		Financing
		Subsidies
	Decision making process	Stakeholder interactions / collaborations
		Organisation of the heat grid

By focusing on these dimensions in all interviews, the way the municipality of Amsterdam governs her heat grids and the challenges she experiences could be compared to the take-aways from the case-studies.

Beside using the spheres of the quadruple helix for the analysis, it was also used to apply the lessons learned on Amsterdam; to give recommendations on the way of governing heat grids and how they should be interacting with the different actors within the spheres.

4. Governance and Legislative Landscape

This chapter consists of the document analysis of the upcoming heat legislations, the municipal heat strategy of Amsterdam and a short introduction of the governance of 5GDHC in the case studies.

4.1. Intended goals of WCW and WGIW

WCW (new Dutch Heat Act)

The WCW has been drafted with the intention of giving municipalities more management tools to fulfil their directive role in the sustainability of the built environment, setting standards for greenhouse gas emissions, consumer protection, security of supply (and the alignment with other regulations) and replacing the current tariff regulations by cost-based tariff regulations (Ministerie van Economische Zaken en Klimaat, 2024-a). The new law also aims to increase the support of heat as a product, trust in the market, and willingness to invest in sustainable, collective heat systems (Ministerie van Economische Zaken, 2020).

The WCW has different objectives (Ministerie van Economische Zaken en Klimaat, 2024-b):

1. Increase public steering of (realization and exploitation of) collective heat, where that is the desired sustainability strategy for the built environment.
2. Develop collective heat that no longer causes greenhouse gas emissions in 2050.
3. Tighten consumer protection and better guarantee of security of supply of collective heat.
4. Introduce transparent and cost-based tariff regulation for consumers of collective heat tied by contract.

The main proposals of the WCW are local management where municipalities appoint heat plots and heat companies, an integral responsibility for heat companies, heat companies need to have a public-majority interest (with more than 50% of the shares of a heat company owned by a public organization like the municipality, province etc.), a sustainability-norm, security of supply, protection of consumers, transparent and cost-based tariffs. (Ministerie van Economische Zaken en Klimaat, 2024-b)

WGIW (Municipal Heat Transition Instruments Act)

The WGIW aims to give municipalities the authority to establish rules to carry out the transition in the built environment from gas to sustainable alternatives. The municipality will be able to appoint neighbourhoods to make this transition (power of designation). The WGIW also secures that building owners / homeowners have freedom of choice to decide on their own sustainable alternative. (Raad van State, 2022)

Municipalities will have to define a heat programme, including a form of organisation for residents and companies. When a neighbourhood has to transition to a sustainable alternative for gas, building owners and companies will have to adapt their building to this alternative (of a (more) sustainable alternative of their own choice). (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties & Ministerie van Economische Zaken, 2022)

4.2. Municipal heat strategy

The municipality of Amsterdam drafted her heat transition vision in 2020. This document sketches a route map for neighbourhoods; when they should be gas-free and what alternative heat solutions there are. The heat transition vision alternatives are tested on the main principle of affordability; the lowest social costs. Other principles tested on are decreasing CO_2-emissions on short term and the possibilities to become more sustainable on long term. (Gemeente Amsterdam, 2020)

The last years, the municipality took on a directing role in the collaboration with stakeholders to plan this transition by having discussions with building owners, residents and companies about what this transition would look like (for them). This includes a substantiation for the financial- and technical feasibility and the collaboration with the neighbourhood. (Gemeente Amsterdam, 2020)

Currently, the municipality is working on a new heat programme, which is to be finalized before the end of 2026 (Gemeente Amsterdam, n.d.). In the Funding plan for the Energy Transition and Climate- and Energy Policy, the municipality describes the activities they will initiate to properly carry out her new role after the legislative changes. The municipality will establish the new authority role in policy, research the possibility of creating a municipal heat company, review the municipal approach to heat transition (and its collaborations), draft a heat source strategy and development of heat sources, and lastly, they will work on the support of the heat transition (by looking at affordability and participation). (Gemeente Amsterdam , 2024)

Figure 12 shows the process of the different steps the municipality takes around the WCW and the omgevingswet (the law for any environmental changes, like redevelopments of a building or event organisation (Ministerie van Infrastructuur en Waterstaat, 2025)). Throughout the process, the municipality is participating with different stakeholders.

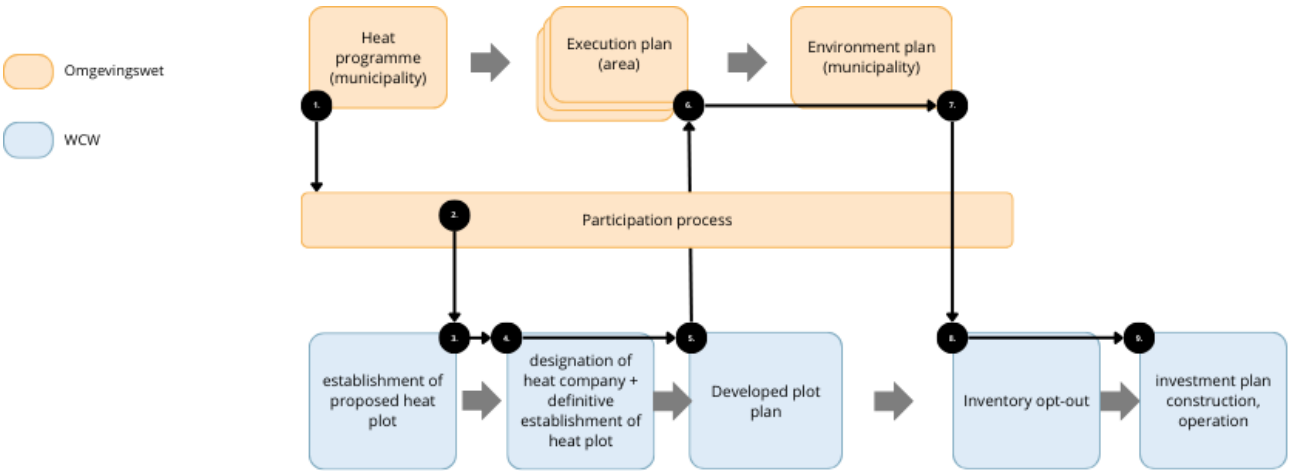

Figure 12: Plan process of the municipality regarding the WCW and omgevingswet. Adapted and translated from Congres Regionale Energie en Lokale Warmte (Engelberts & Vermeulen, 2024)

4.3. Governance of 5GDHC in Limburg

CE Delft has come up with a regional vision for Parkstad Limburg, together with Interreg. For this regional vision, they did a SWOT-analysis for the implementation of 5GDHC. Strengths resulting from this analysis, are having experience with the technology because of Mijnwater, having the existing infrastructure and a growth in cooling demand. A weakness is bureaucracy, due to the complexity of the process and dealing with multiple stakeholders. Another weakness is participation, due to the lack of initiative from residents. A threat identified is the financial feasibility and the initial investment costs. New building projects are mentioned as opportunities for 5GDHC, having a more balanced cooling- and heating demand. (Schepers et al., 2022)

4.4. Governance of 5GDHC in Glasgow

An engineering and consultancy company analysed the advantages and disadvantages of 5GDHC in comparison to 4GDH in Scotland. One of the disadvantages is the lack of understanding of 5GDHC networks in Scotland, which makes including them in local heat strategies hard. An advantage is how uninsulated pipework for 5GDHC requires less training for installers (there's a lack of qualified installers in Scotland). (Ramboll, 2021)

Scotland is still lacking in the management of thermal storage (there are no networks yet using large ambient thermal storage). However, there are large mines that could be used. They also have no sound business model for 5GDHC heat production yet (the risk is still too uncertain for investors). (Ramboll, 2021)

5. Interview Insights

In this chapter, the insight of the interviews for the case of Amsterdam and the two case studies have been presented. This is done by describing the governance process of the implementation of the heat grids.

5.1. Governing collective heat in Amsterdam and its challenges

The results of this chapter came from interviews with experts of the municipality of Amsterdam, AMS institute, the ACM and Energie Nederland. Three interviews with the municipality of Amsterdam focused on WAD-kwartier, Centrumeiland, and Strandeiland (all recent collective heat networks). These cases illustrate the way Amsterdam governs her heat, and what challenges they experienced.

Initial research and planning (pre-tender)

Nowadays, the municipality is usually the one who takes initiative for projects and takes the leadership-role (especially for redevelopments). In the case of Strandeiland, there was a team with project managers, but this was project was not their main work task. Technicians really took the lead as the continuous factor.

With new heat development projects, the municipality of Amsterdam starts with preliminary research on types of systems, storage, environmental reports and soil testing. They will make a zoning plan, which gets confirmed by the college and council. During this process there are continuous consultations with stakeholders in the area. After the zoning plan, the municipality starts issuing land. With developers, different designs will be made, which are needed for the environmental permit.

Tender process and implementation

In tenders for cases like WAD-kwartier, Centrumeiland and Strandeiland, the municipality defined requirements like having the technical space in a public area. Recently, they started being more careful with regard to supra-legal requirements, as a result of lawsuits related to setting stricter requirements than the BENG requirements. Now, the municipality will leave more open to heat companies.

The municipality would also specify sustainability requirements, which they did for WAD-kwartier for example. In 2024, there was a change in legislation (from NEN8058 to NTA8800). Previously, heat companies could include remote sustainable energy sources like solar panels in the equation of how sustainable the heat grid was. With the NTA8800 this is no longer allowed, which made the sustainability requirement unachievable.

Concessions by the municipality nowadays get outsourced system-free (to give heat companies more freedom). The municipality plans a phase during the tender process to come up with the best system (and business case) together with the heat company.

A big challenge is dealing with the full-load risk. Heat companies need at least 70% agreement to connect to be able to implement. Residents get the option to connect to the heat grid, but they don’t have to; residents or corporations can also come up with an alternative, as long as it’s just as sustainable (or more) as the proposed heat grid.

"You don't have to connect if you have an equally sustainable or more sustainable alternative to heat and cool your house. You have to be able to prove that in your building permit." (Katelien van den Berge, Municipality of Amsterdam)

Another challenge currently is dealing with / planning of underground space. The underground space is already quite "full" in some places, so there might not be enough space to install a new heat grid. There is a need for the management of these spaces by the municipality.

A big difference between redevelopments of the built environment and new developments is that in new developments you can't really take the end-user into account, which makes coming to decisions easier. With redevelopments, you have to manage more stakeholders and you have to take these into account with your planning (for digging up the street for example).

The municipality can make use of management tools, like a heat plan, interference plan, soil energy plan etc. They found that these management tools are quite weak; they can be restrictive and there is always an "unless-factor" (for example corporations need to connect unless they come up with an individual systems 5% more sustainable than the BENG score).

"But we also very much encountered that, we found out that the heat plan was weaker than expected, so that actually what was supposed to be the connection requirement, actually wasn't such a strong requirement at all." (Steven Roerink, Municipality of Amsterdam)

Creating a feasible business case

Getting a sound business case for heat grids is hard. Especially in redevelopments there is a need for subsidies to get a cost-effective heat project. The municipality also gives a compensation to heat companies for each project, which is 10% of the total investment. During the concession, they decide on what this compensation will be used for.

Stakeholder collaboration

The municipality of Amsterdam mainly works with private heat companies; on one side of the city Vattenfall is active, on the other side Westpoort Warmte (owned for 50% by Vattenfall and for 50% by the municipality). Amsterdam's heat grid is based on high temperatures, and buildings are designed for these temperatures

The municipality of Amsterdam is committed to collaborate with residents. In new developments, they will collaborate with developers representing the future residents (they did this for example in WAD-kwartier) or the heat company. In redevelopments of existing buildings, they have to work with the housing corporations, private parties / individuals, renters and utility companies as well. In this case, there will be a team from the municipality collaborating with the neighbourhood. Communication with residents usually happens by heat companies.

Nowadays, the municipality will collaborate with the heat company that won the tender to decide on the best heating system and business case. After the concession, it's usually just the developer and the heat company and the municipality is no longer (actively) involved.

Stakeholder motivations

Heat companies are struggling to have feasible heat projects. There are uncertainties in the tariffs, and for LTH grids (where they deliver heat to consumers that still needs to be upgraded) they can only ask a fixed fee.

With the profit margin monitored by the ACM, the heat companies have very low returns (on average 1%). The price cap makes investment risky.

Generally, *residents* don't have much faith in heat grids, because the news regarding these grids is usually not positive. Municipalities have to work hard to gain residents' support.

There aren't many heat grids of which residents have ownership, as it is quite hard to get a bank loan as a residential collective. Therefore, most heat grids in Amsterdam are owned by heat companies.

Residents / corporations have multiple reasons not to opt for heat:
The heating regime is a monopoly, they can't move to a different supplier. Gas is still cheaper, so if possible, consumers will most likely still go for a central heating boiler as the cheapest option (the ACM found that affordability is the consumers main driver). And lasty, , as described above, there is a lack of trust.

The municipality of Amsterdam usually takes initiative in heat projects. They will organize / manage the tender process and decide on a heat company to work with.

The Authority Consumer and Market supervises the legislations; they oversee heat suppliers and check whether they comply with the law. The ACM's main goal is to protect consumers, which they do by tariff and profit margin regulation.

Looking forward

Currently, the municipality of Amsterdam is discussing the option of creating a municipal heat company. Initiating collective heat grids usually happens through public organizations.

The *WCW* is still very much aimed at the traditional heat grid (operating on high temperatures). Because of this, the new legislation will likely have little to no effect on the implementation of 5th generation district heating and cooling. The municipality asked during the consultation to include more experimental heat grids. 5GDHC is mainly interesting on a small scale and in the WCW, there is an exemption for heat grids with 1500 connections or less.

It remains to be seen whether heat grids will become less expensive when the WCW takes effect. With the change to cost based tariffs, all costs can be charged to consumers, which might make it more expensive for residents. If this is the case, residents are more likely to choose individual heat solutions. With the new tariff structure, overseeing the profit margin will be let go of, which is positive for heat companies.

After implementation of the WCW, heat grids have to be owned for more than 50% by public parties. Because of this, private parties like Vattenfall or Eneco are reluctant to create and invest in heat grids, because they might get disowned in a couple of years.

There are still some uncertainties in the WCW. The ACM recommended more clarity in the new tariff structure (and how investment security should be included in here), ownership of the heat grid and who gets to install heat grids.

> "Well, what we did say is that we think it's very important to have clarity soon. Because then everybody will know where they stand. What the tariff regulation looks like. Who can own the heat network in the future. Who can build the heat grid…" (Julia Eijkens, ACM)

With the *WGIW* taking effect, the municipality gets to appoint neighbourhoods that have to move away from using gas. The WGIW will most likely have more effect in existing neighbourhoods. New developments already cannot use gas. This doesn't necessarily mean more connections to the heat grid, as in newly developed areas new residents / corporations can still decide to go for other heat solutions.

Since residents lost faith in heat grids and are done with the government making decisions for them, the municipality will have to be careful with the deployment of the WGIW. It might be challenging to make use of it while not losing support.

5.2. Lessons learned from Mijnwater and Clyde Gateway

Taking the upcoming legislations into account, lessons from case studies provide valuable insight into challenges and opportunities of implementing 5th generation district heating and cooling that have been experienced in practice. The following subchapters illustrate those lessons from the case studies Mijnwater and Clyde Gateway.

5.2.1. Mijnwater

The results in this chapter came from interviews with Benno Schepers from CE Delft and Louis Hiddes (the first director of Mijnwater) from 2RC.

Initiation

Within the municipality of Heerlen, there was a municipal officer who got enthusiastic about the potential of using the mines which were full of water for energy extraction. He took the initiative and the municipality became the first owner of the Mijnwater project. However, since it is a semi-commercial activity, and risk-bearing, the Limburgse Energie Fonds (LEF) took over the ownership of Mijnwater BV.

Formation and organizational changes

Mijnwater BV. started as a small company, but as they started expanding number of heat connections, they needed more money. Beside expanding, they also appointed a new director. This director was very strong organizationally, but the technical development started lacking and they didn't know how to sell the concept to corporations.

The corporations connected to Mijnwater also got new directors. The collaboration started to become more data-driven, which doesn't work very well for systems as complex as 5GDHC (the concept should be explained well).

Stakeholders and roles

The municipality of Heerlen is an important stakeholder of Mijnwater. First as the owner, but now for the development of new projects and housing in the area. Other important stakeholders are housing corporations, installation companies, Parkstad Limburg who provides support, neighbouring municipalities (under which the mines also run, and utility companies. However, the most important stakeholders are the province and LEF as owners and the municipality.

Both Benno Schepers (CE Delft) and Louis Hiddes (2RC, first director of Mijnwater BV.) mentioned the importance of someone taking a lead in complex systems like these. Not all companies have the management-qualities it takes, and not everyone is willing to take the responsibility and carry the risks. There should be one director to take this responsibility, and also to have the persistence to get it done; this was what Louis Hiddes did for Mijnwater.

Collaboration between stakeholders

Benno Schepers mentioned that there was a lot of knowledge exchange / exchange of ideas between the different stakeholders of the Mijnwater project. It took a lot of networking to get it implemented. This asked for some effort from directors of the organizations involved, and Louis Hiddes was very good at convincing and enthusing the other directors.

Louis Hiddes also mentioned the importance of negotiating and talking to residents. He did this himself, and explained that when you send others to do this, it often goes wrong. He explained the concept to the residents and answered their questions.

Complexity

The main challenge ran into during the process of implementing the Mijnwater heating network, was the complexity of 5GDHC and the concept of Mijnwater. The stakeholders involved, like municipalities, didn't always understand how the system worked, which required a lot of explanation (something Louis Hiddes was very good at)

> "Overcoming that knowledge barrier, was really huge. I feel like that still hasn't… for fifth generation heat grid in general, still hasn't been overcome yet" (Benno Schepers, CE Delft)

Business case

Mijnwater had to deal with the current Heat Act, which regulates the price of heat based on gas prices. However, cold is not regulated and Mijnwater wanted to offer its consumers a performance-based revenue model instead. The system was hard to place within the existing legislative regulatory framework due to the lack of regulation of cold.

Mijnwater also found other smart ways to reduce costs; they used one big electricity connection for multiple smaller installations, which resulted in lower energy taxes.

Mijnwater was able to get state subsidies for innovation, exploitation and research. There were also subsidies available through European funds (D2Grids). Beside subsidies, LEF and the province of Limburg, were the most important funders of the project.

"And without new revenue models on top of that as well, because that's the part of it for us as well. That you think about heat, no longer as a gigajoule product, but just as a service." (Benno Schepers, CE Delft)

5.2.2. Clyde Gateway

The results of this chapter came from interviews with Martin McKay and Hugh Moore, both from Clyde Gateway.

Initiation

Scotland does not have many cases of 5GDHC yet, which brings challenges regarding getting funding.

The initiative for Clyde Gateway came from their partnership with Mijnwater BV. Mijnwater approached them to participate in the D2Grids project.

Clyde Gateway started the project with an energy strategy, including an energy and carbon master plan. Initially, they looked at a heating system across the whole Clyde Gateway area, but due to limitations in funding and delivering, they started focusing on smaller scale networks. This lowered cost and area and they could still scale up later.

Organizational changes

The initial plan was to connect three buildings to the heating grid, but funding for two of the buildings didn't materialize. Because of this, the Clyde Gateway company decided to build in capacity, including the deployment of the heat pumps, to future proof for connections in the future.

Stakeholders and roles

Scottish Water Horizons is the main stakeholder of Clyde Gateway, as the owner and operator of the heating system they provided the heat source (the wastewater treatment). Another big party was Mijnwater BV., as the lead partner for the D2Grids project. Other stakeholders were local authorities (for grid connections), Scottish Power, for planning consents. And a range of the potential customer connexions; businesses, residential developers.

The UK government is currently working on a new heat network bill; as for now, heat networks are essentially unregulated in Scotland. The company Ofgem will be the regulator for district heating.

Clyde Gateway found that most residents mainly care about getting a good service delivered at a reasonable price, and to a good standard.

Collaboration between stakeholders

Clyde Gateway partnered with Scottish Water Horizons, who is the heat provider.

Clyde Gateway owing the land (parts of Kilmarnock and Shawfield), and the one building connected to the heat grid made realising these connections easier. However, they still had to engage with third parties to make connections available across the Clyde Gateway area.

Clyde Gateway typically engages with residents on projects, but this was not the case (or not as intense) for the district heating proposal in this project. However, there is a community committee for

consultation and a community team that engages with local schools where Clyde Gateway brings in industry partners.

Clyde Gateway also partnered up with British Geological Survey, to do research around geothermal energy.

Complexity

It took Clyde Gateway some effort to present the proposal and align it with the wider European part (of D2Grids). It was challenging to promote the project; what it would mean, how it would work, the risks involved and getting senior management to buy-in on the project. It took a lot of explaining to all key parties involved (local authorities, funding organisations etc.). Getting everyone to understand what 5GDHC is was quite a bit of work, as it is still quite specialised.

Martin McKay mentioned that in Scotland, there is a knowledge imbalance in terms of these kinds of networks. The Clyde Gateway project is also a pilot project, to gain and share more knowledge of 5GDHC.

Another issue is deciding on which technologies should be preferred ad how these should be applied.

Business case

Getting funding for heating projects is one of the key challenges in Scotland. For the Clyde Gateway project, 60% of funding came from Horizon2020 (European funding through the European Development Fund, ERDF). They also received some other funding sources (local Scottish government) and made their own investments.

Martin McKay emphasised that there was a need to have deeper engagement with the broader supply chain, and to understand how those elements come together (the technical and the economic). There's a limited supply chain in the Scottish context, which needs to be considered. They had to ensure heat pumps, connections etc. were available when the project required them (making sure they had buy-in from all the organisations).

"But also how you then get the broader elements of the supply chain to come together. So ensuring that your larger scale heat pumps are available when the project requires them. Also the grid connexions, so when you need connexions to the electricity grid, and to other utilities, making sure those are required then as well. Organisationally, then it's about buy-in and making sure that you've got buy-in from all of the organisations that you're working with across the project". (Martin McKay, Clyde Gateway)

6. Discussion

This study aimed to advice the municipality of Amsterdam on how to govern collective heat by learning from the governance approaches of successfully implemented 5th generation district heating and cooling (5GDHC) systems. This was done by identifying key takeaways from relevant case studies. This chapter discusses the main findings of this research and how these contributed to the research objective.

6.1. Key findings

Document review

The WCW and WGIW both aim to give municipalities more power in their directive role in the heat transition. The WCW aims to do so by introducing public majority interest requirements. The tariff structure will also change to a cost-based tariff. The WGIW was developed to give municipalities the power to appoint neighbourhoods for the transition to sustainable heat alternatives. It also aims to protect consumers by ensuring freedom of choice for building owners in choosing their sustainable alternative.

The municipality of Amsterdam published a Heat Transition Vision in 2020 as a starting point to map out the neighbourhoods to become gas-free. In this document, there is a focus on affordability, short-term CO_2- reduction and long term sustainability. The municipality aims to take a lead in stakeholder engagement. The Heat Programme that will be published before 2027 will emphasize the potential of a municipal heat company, a new heat source strategy, and insurance of affordability and participation. It also aims to align the municipal strategy with the new legislation.

The Regional Vision Parkstad highlights the experience of Mijnwater as a strength. Because of Mijnwater there is existing infrastructure for future 5GDHC-projects, which is positive due to the rising cooling demand. One of the weaknesses defined is the bureaucracy, because of the complexity of the process and the involvement of multiple stakeholders. Financial feasibility of 5GDHC is currently still a treat. (Schepers et al., 2022)

A big challenge for implementing 5GDHC in Glasgow is the lack of understanding of the system. Another challenges is a sound business model, which makes investing in these projects risky. However, there is a large potential in mines that could be used. (Ramboll, 2021)

Interview findings case of Amsterdam

Unlike the electricity and gas markets, heat is very much unregulated, resulting in uncertainties. The WCW and WGIW will most likely have no effect on the implementation of low temperature collective heat. There are still uncertainties in the WCW, resulting in parties being more reluctant to implement or invest in heat grids.

Challenges the municipality of Amsterdam currently experiences, are creating a feasible business case, weakness of management tools (meaning that building-owners can decide to go for their own, more sustainable, heat solution instead of the collective heat grid planned by the municipality, which increases the full-load risk), stakeholder trust issues (mainly from residents) and the management of underground space.

Lately, the municipality of Amsterdam shifted to a more small-scale approach, and started leaving tenders more open for heat companies by doing system-free concessions. The municipality is also exploring the idea of creating a public heat company.

Interview findings Mijnwater and Clyde Gateway

Both Mijnwater and Clyde Gateway experienced a knowledge imbalance in 5GDHC. The main difference between the two cases, is how Mijnwater implemented 5GDHC in the built environment and had to deal with more stakeholders, also taking residents into account, while Clyde Gateway implemented the heat grid in a newly developed area, not having to take (future) residents into account.

Mijnwater actively engaged with stakeholders, where the director would explain the project and answer questions. Getting a sound business case was challenging; Mijnwater looked into developing a performance-based revenue model (they emphasize the rethinking of heat as a service, not just a commodity). They also combined electricity connections to reduce taxes. To get a feasible project, they did however still depend on national and European funding.

The main challenge experienced in the Clyde Gateway project, was the securing of buy-in. They found it required a lot of explaining and promoting of the project (also due to a knowledge imbalance in Scotland regarding 5GDHC). Aligning the stakeholders, supply chain actors and regulatory bodies was challenging. Like Mijnwater, Clyde Gateway too was depending on European and local funding.

6.2. Interpretation

After writing the results and drawing conclusions, a final conversation with the municipality of Amsterdam was held to validate the recommendations and reflect on the relevance.

The outcomes of the interviews indicate that uncertainties in future legislation complicate the implementation of heat grids and sometimes even prevent stakeholders from investing. There is a need for clarity; specifically regarding ownership and the new tariff structure as heating companies are currently struggling with these points.

The current strategy of the municipality of Amsterdam is not yet connected to the upcoming legislation, as it doesn't really explain how they will take the lead in this heat transition. However, the municipality is working on a new heat plan, in which they will plan the heat transition per neighbourhood and give alternative heat solutions. The municipality usually takes initiative (as described in their Transition Vision Heat), but struggles throughout heat projects with things like management tools and supra-legal requirements. To be able to implement more collective (low temperature) heat projects, while dealing with the full-load risk, they will need more power. The WGIW aims to give municipalities more power, but only to a certain extent. In the end, consumers are still able to decide on their own sustainable heat system. It is questionable whether municipalities should get the power to "force" residents to connect; there already is very little support from residents.

The municipal heat strategy of Amsterdam describes how the municipality takes on a directing role by having discussions with building owners, residents and companies about what the heat transition

would look like for them. However, from conversations with the municipality, it appeared that the communication with residents is usually done by heat companies.

Amsterdam's heating infrastructure mainly functions on high temperatures, so for a 5th generation heating and cooling network, a new infrastructure would have to be installed, which is not likely to happen soon. The municipality does implement collective heat systems (like WAD kwartier, Centrumeiland and Strandeiland). Currently, the municipal strategy has no connection to the WCW and WGIW yet. The municipality experiences issues with legislation in recent collective heating projects. Since the legislation (both old and new) is based on traditional high temperature heat grids, implementation of LTH will probably be even more complicated.

The municipality is discussing the option of becoming a municipal heat company. Since the initiation of collective heat grids usually happens through public organizations, this might make implementation easier.

It is clear that there is a knowledge deficit regarding 5GDHC. Stakeholders not knowing what 5GDHC entails, makes implementation, convincing and collaboration way harder. The two cases are both part of an Interreg project, D2Grids, which made that they both focused on knowledge sharing.

Both in the case of Mijnwater and in Clyde Gateway, the project required communication and collaboration between stakeholders. However, there is a clear difference in approaches. Whereas Mijnwater took a very personal approach, with an emphasis on strong leadership, Clyde Gateways approach was more institutional, with limited engagement with residents. Both cases also exchanged knowledge with consultancy / knowledge institutes, due to the complexity of 5GDHC. The following table 4 further describes the roles and interactions between the stakeholders in both projects:

Table 4: Quadruple helix interactions and contributions to case studies

Quadruple helix sphere	**Mijnwater**	**Clyde Gateway**
Government	Provided (financial) support, alignment of policies and planning. - The municipality of Heerlen was the initiator and key stakeholder. - The providence and LEF now own and finance Mijnwater - Collaboration with other municipalities due to shared infrastructure - Interreg helped funding	Provided support, challenged by lagging regulation and policy. - Local authorities were involved with planning and grid connections. - Scottish government helped funding. - Interreg helped funding.
Business	Did the main networking / communication with other stakeholders.	Initiator, heat source provider, coordinated the supply chain.

	- Mijnwater BV. was the first owner of the system. Did the main networking with other stakeholders. - Installation companies, utility firms, housing corporations were involved in implementation and scaling.	- Mijnwater BV. took the initiative for Clyde Gateway to become a D2Grids 5GDHC project. - Scottish Water Horizons provides the heat source. - Clyde Gateway is the development organization who did the coordination. - Utility companies and developers were involved in implementation.
Academic research	Role of advisor, knowledge exchange - CE Delft did different assessments (impact, regulatory) and advised Mijwater BV.	Knowledge exchange - British Geological Survey did research around geothermal energy - D2Grids was a source of knowledge with other 5GDHC cases.
Society	Were informed by Mijnwater BV. - Residents were able to be personally informed by Louis Hiddes.	No intense community engagement. - FundSTEM project to engange with local schools.

6.3. Implications

This research contributes to filling the knowledge gap by identifying lessons learned regarding the governance of 5GDHC in a society where heat market regulations are lacking. 5GDHC is a relatively new concept, with not many implemented cases in Europe (Buffa et al., 2019). Because of this, there is a knowledge gap in the governance of these systems. With legislation not yet aligning with collective (LTH) systems, it is important to get a better understanding of how these systems should be governed. The case studies investigated give two examples of how this could be done in a heating regime comparable to that of Amsterdam.

This research is done by using the quadruple helix model to get a better understanding of the multi-level / multi-actor way of governing heat in Amsterdam and how this should change to move towards the implementation of 5GDHC. The research resulted in recommendations for the municipality of Amsterdam on how they should change their way of governing heat to be able to implement these LTH-systems.

6.4. Limitations

Case studies

Initially, the research had a focus on a case study in Sweden since they're quite far in the implementation of LTH-networks. However, it was not possible to get in touch with this case. For this reason, another D2Grids-case was chosen. For future research, it would be interesting to look into cases of countries that are further along in the implementation of 5GDHC.

The case comparison between Mijnwater and Clyde Gateway showed that these two cases had some big differences in approaches and context. This made comparison of these cases harder, with as a result that the recommendations for the municipality of Amsterdam are sometimes not supported by both cases.

Definition 5GDHC

5GDHC is still quite new and unknown; there is not one clear definition for these systems. For this reason, doing a systematic literature study was quite hard.

Validation of interviews

The focus of the research has been on the outcomes of interviews regarding the heating regime in Amsterdam and the two case studies. At the same time, a document review has been done. However, with 5GDHC still being a new concept, finding documentation regarding the governance of these systems was hard (especially for the two cases). Because of this, and time limitations, the interview outcomes haven't been validated through additional document analysis. Future research could look into validating these results by doing more interviews, or doing more case studies to look for similarities.

Initially, this thesis' main research question was about applying the lessons learned of the case studies to a case in Amsterdam; Sluisbuurt-Noord. However, after the interview with the case studies, the approaches of the cases appeared to be so different, that applying it to a case in Amsterdam was not possible. Because of this, the focus shifted to the difference in the cases and more general lessons / take-aways for the municipality of Amsterdam.

7. Conclusion

The municipality of Amsterdam aims to become gas-free by 2040, and thus moves to more sustainable heat alternatives. One sustainable alternative, 5th generation district heating and cooling, is challenging to implement due to lack of regulation and governance challenges. This research aimed to get a better understanding of how two cases (Mijnwater in Heerlen, and Clyde Gateway in Glasgow) approached the implementation of 5GDHC, and to learn from these ways of governing heat by answering the following research question:

"How should the implementation of collective heat be governed at a local urban level in Amsterdam; lessons learned from Mijnwater and Clyde Gateway"

To answer this research question, empirical research has been done resulting in a synthesis by combining the key take-aways from the two case studies and the findings of the governing of collective heat in Amsterdam.

The municipality of Amsterdam currently experiences challenges in the governance of collective heat system; mainly in creating a feasible business case, weakness of management tools, stakeholder trust issues (primarily from residents) and the management of underground space. The implementation of the WCW will most likely not have any effect on implementing collective LTH. The WGIW mainly effects redevelopments. The municipality needs to be aware of its role and responsibility starting with the WGIW, but it is possible to increase support for collective heat networks.

There are some similarities between the cases of Mijnwater and Clyde Gateway: how both experienced a knowledge imbalance and struggled with explaining to- and convincing other stakeholders. However, there was also a big difference in approaches between the cases; in community engagement and business model. Main take-aways from Mijnwater are the need for a strong leadership and the need to start looking at heat as a service instead of just a commodity. Clyde Gateway showed the need for clear communication to secure buy-in from all parties.

To conclude, there are five main takeaways and lessons for the municipality of Amsterdam to take into account when implementing collective heat systems:

1. **There is a need for strong leadership and a clear initiator.**
   Mijnwater pressed the importance of good leadership.
   Given the lack of trust from residents in heat projects, it is even more important to have one project leader as a spokesperson. This person should collaborate with and educate the other stakeholders him- / herself. The municipality usually has a team to lead a project and takes the initiative with resident engagement, but this spokesperson could also be someone from the heat company (like the case of Mijnwater). In this case, the managing and initiative could come from the business sphere instead of the governance sphere.
2. **Clear and personal communication with residents**.
   The municipality is already quite focused on resident participation. Mijnwater experienced clear communication to residents as an important aspect, because of the complexity of 5GDHC. The communication with residents should be personal to gain trust, so instead of having an intermediary explain the project to residents, have a director (or someone else close to the project) do the community engagement. In Amsterdam, communication with

residents is usually done by heating companies (for new developments). Resident participation by the municipality is done through a team of neighbourhood directors / managers. For future projects the communication to / collaboration with residents could be done by either a project leader of the heat company (like Mijnwater did) or a project leader from the municipality (it is important that one person does the communication with residents that is closely connected to the project).

3. **If the municipality is to move towards low temperature collective heat like 5GDHC, there is a need for knowledge sharing regarding these systems and stakeholder collaboration / education.**
   Both Mijnwater and Clyde Gateway experienced a knowledge imbalance regarding 5GDHC. To successfully be able to implement 5GDHC (or other smart LTH systems), there is a need for more pilot projects like D2Grids and knowledge sharing. Knowledge institutes and businesses could contribute here by sharing their knowledge through platforms or conferences (which could be organised by local- or national government).
4. **Research should be done on how to align regulatory frameworks**.
   Both Mijnwater and Clyde Gateway had to deal with unclear regulations. The upcoming WCW doesn't address collective LTH systems yet, so it is important to push for more flexible regulations regarding these systems, especially since the municipality currently does not have enough power to go on with some of these projects. The WGIW aims to give municipalities more authority by having them appoint neighbourhoods, but residents can still go for their own, more sustainable heat solution as opposed to the collective heat system, which makes for a larger full-load risk.
   There could be a large role for research institutes / the academic sphere; even though already a lot of research is and has been done on the governance of collective heat, there are still uncertainties regarding the role of the upcoming legislation. These institutes could research what should be included in the upcoming legislation to make implementation of collective LTH-grids easier.
5. **Research should be conducted on how to manage challenges related to the business case.**
   With 5GDHC, getting a sound business case is still not possible without subsidies. It would be interesting to look into smart ways for financing (like the performance-based pricing model that Mijnwater used), or have a phased implementation like Clyde Gateway. The interviews with the municipality proved that they too, struggle with getting a sound business case and that subsidies are required for redevelopment projects. More research should be done on how to create a successful business case. Insights from businesses that have come up with innovative business cases, like Mijnwater, would be very relevant to learn from.

8. Recommendations

This thesis calls for future research on the governance of collective heat. Based on the research findings, the following recommendations are proposed:

Research on governance of 5GDHC in cities or countries further ahead with the implementation of 5GDHC.

Countries like Sweden have successfully implemented multiple cases of 5GDHC. It would be valuable to look at their way of governing heat and compare this to how this is done in Amsterdam.

More pilot projects on 5GDHC / innovative collective heat systems and knowledge sharing regarding the governance of these projects

To address the knowledge gap regarding the governance of collective heat systems like 5GDHC, there should be more pilot projects (like the ones from Interreg). Different countries that implement 5GDHC should collaborate by sharing knowledge on the governance of the systems and the challenges experienced.

Research on aligning the WCW and WGIW with 4th and 5th generation district heating (and cooling), and research related to business cases; could the performance-based model from Mijnwater work with the WCW?

This research confirms that the upcoming legislation is not yet tailored to the newer (and more sustainable) generations of heat grids. The municipality of Amsterdam already requested more innovative heating grids to be taken into account in the WCW, but this has not been done yet. More research should be done on how these kind of systems could be included in the legislation. Since feasibility is still an issue without subsidies, different types of pricing models / business cases should also be a topic in these studies.

Bibliography

Nationaal Programma Lokale Warmtetransitie. (2025, February 17). Zeerlagetemperatuur warmtenet. Retrieved February 28, 2025, from https://www.nplw.nl/warmtenet/warmtetechnieken/zeerlagetemperatuur-warmtenet

Boesten, S., Ivens, W., Dekker, S. C., & Eijdems, H. (2019). 5th generation district heating and cooling systems as a solution for renewable urban thermal energy supply. *Advances in Geosciences*, *49*, 129–136. https://doi.org/10.5194/adgeo-49-129-2019

Buffa, S., Cozzini, M., D'Antoni, M., Baratieri, M., & Fedrizzi, R. (2019). 5th generation district heating and cooling systems: A review of existing cases in Europe. *Renewable & Sustainable Energy Reviews*, *104*, 504–522. https://doi.org/10.1016/j.rser.2018.12.059

Dang, L. M., Nguyen, L. Q., Nam, J., Nguyen, T. N., Lee, S., Song, H. K., & Moon, H. (2024). Fifth generation district heating and cooling: A comprehensive survey. *Energy Reports*, *11*, 1723–1741. https://doi.org/10.1016/J.EGYR.2024.01.037

Delbeke, J., Runge-Metzger, A., Slingenberg, Y., & Werksman, J. (2019). The Paris Agreement. In *Towards a climate-neutral Europe* (pp. 24–45). https://doi.org/10.4324/9789276082569-2

National Academy of Engineering & National Research Council. (2007). Energy futures and urban air pollution: Challenges for China and the United States. In National Academies Press eBooks. https://doi.org/10.17226/12001

Gjoka, K., Rismanchi, B., & Crawford, R. H. (2023). Fifth-generation district heating and cooling systems: A review of recent advancements and implementation barriers. *Renewable & Sustainable Energy Reviews*, *171*, 112997. https://doi.org/10.1016/j.rser.2022.112997

Gudmundsson, O., Dyrelund, A., & Thorsen, J. E. (2021). Comparison of 4th and 5th generation district heating systems. E3S Web of Conferences, 246. https://doi.org/10.1051/e3sconf/202124609004

Lavrijssen, S. (2020, December 2). V*ijfde Generatie Warmtenetten: Wettelijke mogelijkheden en de Warmtewet 2.0* [Webinar]. Topsector Energie. https://youtu.be/YlbubvXsLnw?si=wn5fbxHTRnv9x9Fx

Lindhe, J., Javed, S., Johansson, D., & Bagge, H. (2022). A review of the current status and development of 5GDHC and characterization of a novel shared energy system. Science and Technology for the Built Environment, 28(5), 595–609. https://doi.org/10.1080/23744731.2022.2057111

Lund, H., Østergaard, P. A., Nielsen, T. B., Werner, S., Thorsen, J. E., Gudmundsson, O., Arabkoohsar, A., & Mathiesen, B. V. (2021). Perspectives on fourth and fifth generation district heating. Energy, 227, 120520. https://doi.org/10.1016/J.ENERGY.2021.120520

Lund, H., Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J. E., Hvelplund, F., & Mathiesen, B. V. (2014). 4th Generation District Heating (4GDH). *Energy*, *68*, 1–11. https://doi.org/10.1016/j.energy.2014.02.089

MacCracken, M. C. (2008). Prospects for Future Climate Change and the Reasons for Early Action. *Journal of the Air & Waste Management Association*, 58(6), 735–786. https://doi.org/10.3155/1047-3289.58.6.735

Programmateam Amsterdam Energieneutraal, Gemeente Amsterdam Ruimte en Duurzaamheid, Liander, Waternet, & Energiecoöperatie Zuiderlicht. (2020). Concept RES Amsterdam. In *Regionale Energiestrategie*. Retrieved March 14, 2024, from https://www.regionale-energiestrategie.nl/documenten/HandlerDownloadFiles.ashx?idnv=1575342

Qazi, A., Fayaz, H., Rahim, N., Hardaker, G., Alghazzawi, D., Shaban, K., & Haruna, K. (2019). Towards Sustainable Energy: A Systematic review of renewable energy sources, technologies, and public opinions. *IEEE Access*, *7*, 63837–63851. https://doi.org/10.1109/access.2019.2906402

Ramboll. (2021). Analysis of potential for Scotland to be a leader in 5th generation heating and cooling networks. In *Scottish Enterprise*. Retrieved May 9, 2024, from https://www.scottish-enterprise.com/media/osopjiib/analysis-of-potential-for-scotland-to-be-leader-in-5th-generation-heating-and-cooling-networks.pdf?utm_source=chatgpt.com

Schütz, F., Heidingsfelder, M. L., & Schraudner, M. (2019). Co-shaping the Future in Quadruple Helix Innovation Systems: Uncovering Public Preferences toward Participatory Research and Innovation. She Ji: The Journal of Design, Economics, and Innovation, 5(2), 128–146. https://doi.org/10.1016/J.SHEJI.2019.04.002

Setzpfand, M. (2020, December 2). V*ijfde Generatie Warmtenetten: Wat is een vijfde generatie warmtenet?* [Webinar]. Topsector Energie. https://www.youtube.com/watch?v=3CsmaUDijkU\

van den Berge, K. (2024). Sturing van tegenstrijdige belangen bij nieuwe warmte,-koudesystemen in gebiedsontwikkeling Hoe worden de thermische energiesystemen van de toekomst, de systemen van vandaag?

Brummer, N., Bongers, J., & Mijnwater. (2019). *Mijnwater Heerlen: Roadmap to 2040*. https://vb.nweurope.eu/media/10451/heatnetnwe_heerlen-transition-roadmap_district-heating.pdf

Müller, S., Elswijk, M., Roossien, B., & Jansen, S. (2020). Proces aanpak Van initiatie tot beheer & organisatievormen Deliverable 3.1. 2024-04-26 https://energygo.blob.core.windows.net/kowanet/D3.1%20Proces%20aanpak/20201221_D3.1_Proces_aanpak_Koele_Warmtenetten.pdf

Lieugard, T. (2022-a). Brunssum | 5GDHC. https://5gdhc.eu/project-cases/brunssum/

Lieugard, T. (2022-b). Glasgow | 5GDHC. https://5gdhc.eu/project-cases/glasgow/

About us | 5GDHC. (n.d.). https://5gdhc.eu/about-us/

D2Grids Project. (2023). The 5th generation heating and cooling grid of Glasgow. In Construction21 [Report]. Retrieved July 23, 2024, from https://www.construction21.org/data/exports/pdf/infrastructure/25606_en.pdf

Interreg North-West Europe. (n.d.). About us. 5gdhc. Retrieved July 24, 2024, from https://5gdhc.eu/about-us/

Nationaal Programma Lokale Warmtetransitie. (n.d.). *Wet Gemeentelijke Instrumenten Warmtetransitie (WGIW)*. Retrieved September 17, 2024, from https://www.nplw.nl/regelgeving/wetgeving+warmtetransitie/wet+gemeentelijke+instrumenten+warmtetransitie/default.aspx

Nationaal Programma Lokale Warmtetransitie. (n.d.-a). *Wet collectieve warmte (WCW)*. Retrieved September 17, 2024, from https://www.nplw.nl/regelgeving/wetgeving+warmtetransitie/wet+collectieve+warmte/default.aspx

TNO. (2024, February 19). *Organisatiemodellen en samenwerkingsvormen onder de Wcw*. Binnenlands Bestuur. Retrieved September 17, 2024, from https://www.binnenlandsbestuur.nl/ruimte-en-milieu/tno/organisatiemodellen-en-samenwerkingsvormen-onder-de-wcw

Van Der Staak, M., Schilder, F., PBL Planbureau voor de Leefomgeving, Nico Hoogervorst, Graciela Luteijn, Folckert van der Molen, Martine Uyterlinde, Femke Verwest, & Rob Weterings. (2022). *Besturen in het begin van de warmtetransitie*. PBL Planbureau voor de Leefomgeving. https://www.klimaatweb.nl/wp-content/uploads/po-assets/773856.pdf

Fukuyama, F. (2013). What is governance? *Governance*, *26*(3), 347–368. https://doi.org/10.1111/gove.12035

Bache, I., Bartle, I., & Flinders, M. (2016). Multi-level governance. In *Edward Elgar Publishing eBooks*. https://doi.org/10.4337/9781782548508.00052

Craps, M., Vermeesch, I., Dewulf, A., Sips, K., Termeer, K., & Bouwen, R. (2019). A Relational Approach to Leadership for Multi-Actor Governance. *Administrative Sciences*, *9*(1), 12. https://doi.org/10.3390/admsci9010012

Ministerie van Economische Zaken en Klimaat. (2024,-a, June 24). *Brief aan de Koning over nader rapport wetsvoorstel Wet collectieve warmte*. Kamerstuk | Rijksoverheid.nl. https://www.rijksoverheid.nl/documenten/kamerstukken/2024/06/14/nader-rapport-wetsvoorstel-wet-collectieve-warmte

Ministerie van Economische Zaken en Klimaat. (2024,-b). *Memorie van toelichting: Wet collectieve warmtevoorziening* (Kamerstuk 36576, nr. 3). Tweede Kamer der Staten-Generaal. https://www.tweedekamer.nl/downloads/document?id=2024D25812

Ministerie van Economische Zaken. (2020). *Integraal Afwegingskader voor Beleid en Regelgeving (IAK)*. Retrieved December 17, 2024, from https://www.internetconsultatie.nl/warmtewet2

Raad van State. (2022, December 5). *Wet gemeentelijke instrumenten warmtetransitie*. Raad Van State. Retrieved December 17, 2024, from https://www.raadvanstate.nl/adviezen/@132132/w04-22-0128/

Ministerie van Binnenlandse Zaken en Koninkrijksrelaties & Ministerie van Economische Zaken. (2022). IAK Wgiw. In *Overheid.nl*. Retrieved December 17, 2024, from https://www.internetconsultatie.nl/wgiw/b1

Gemeente Amsterdam. (2020, August 18). *Transitievisie warmte Amsterdam*. Openresearch.Amsterdam. Retrieved December 17, 2024, from https://openresearch.amsterdam/nl/page/63522/transitievisie-warmte-amsterdam

Gemeente Amsterdam. (n.d.). *Meer over het warmteprogramma*. Retrieved December 18, 2024, from https://denkmee.amsterdam.nl/warmteprogramma/meer-over

Gemeente Amsterdam. (2024). Bestedingsplan Energietransitie en klimaat- en energiebeleid. In *Gemeente Amsterdam*. Retrieved December 20, 2024, from https://amsterdam.raadsinformatie.nl/document/14805481/1/09012f978134831c?connection_type=1&connection_id=8853479

Thomas, D. R. (2003). A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation*, *27*(2), 237–246. https://doi.org/10.1177/1098214005283748

Schepers, B., Teng, M., Meyer, M., & Senel, S. (2022). Regional Vision Parkstad Limburg: Opportunities for 5th generation district heating and cooling. In *CE Delft* (22.220182.162). Retrieved June 3, 2024, from https://ce.nl/wp-content/uploads/2023/04/CE_Delft_220182_Regional_Vision_Parkstad_Limburg_FINAL.pdf

Energy and Climate Change Directorate. (n.d.). *Heat in buildings*. The Scottish Government. Retrieved July 3, 2024, from https://www.gov.scot/policies/energy-efficiency/the-heat-in-buildings-programme/

Ministerie van Infrastructuur en Waterstaat. (2025, February 4). *De Omgevingswet*. Rijksoverheid.nl. Retrieved January 29, 2025, from https://www.rijksoverheid.nl/onderwerpen/omgevingswet

Engelberts, M., & Vermeulen, K. (2024, November 13). *Congres Regionale Energie en Lokale Warmte* [Slide show; Powerpoint].

Jansen, F. A. C. (2024). *From urban experimentation to management transformation:: Applying urban living lab findings to challenge business-as-usual management practices*. Retrieved March 10, 2025, from https://repository.tudelft.nl/record/uuid:ee011853-e416-45bb-8340-901c48b7eb45

Yao, S., Wu, J., & Qadrdan, M. (2024). A state-of-the-art analysis and perspectives on the 4th/5th generation district heating and cooling systems. *Renewable and Sustainable Energy Reviews*, *202*, 114729. https://doi.org/10.1016/J.RSER.2024.114729

Lavrijssen, S., & Vitéz, B. (2021). Good governance and the regulation of the district heating market. *Shaping an Inclusive Energy Transition*, 185–227. https://doi.org/10.1007/978-3-030-74586-8_9/FIGURES/1

Appendices

Appendix 1: Interview questions

The interview questions are quite broad, but still focused on the governance of the heat grids. I found that law and regulation and getting a feasible business case were quite big challenges, so asked questions related to this. I also asked questions regarding the process and the interactions between stakeholders.

Interviews with case studies (Focused on the organizational challenges)

1. General question to introduce themselves and how they worked on / collaborated with the case study.
2. Why was 5GDHC selected as a heating solution and who took the initiative?
3. What other stakeholders were involved in the organization of the project?
4. What did the collaboration between the different stakeholders look like? How did they involve citizens?
5. How did participation / grid connections come about? Was there uncertainty about this before construction of the grid?
6. Did they have any policy support like subsidies or other forms of financial support?
7. What organizational challenges did they run into?
8. How did they approach / solve these challenges?
9. What would you recommend other 5GDHC projects, having learned from those challenges? Is this location-dependent?

Interviews with organisations

Interview with the ACM: aimed to get a better understanding of current heat laws and its barriers to implement 5GDHC and the expected effects of the new Dutch Heat Act.

1. General question to introduce herself and what the ACM does regarding 5GDHC.
2. What current laws- and regulations have effect on the implementation of 5GDHC?
3. What are currently the biggest barriers to implement these systems?
4. Are these projects eligible for subsidies or other forms of funding?
5. What do you expect to change after the implementation of the new Dutch Heat Act? Will implementation become easier?
6. What do you think is necessary to deal with the current barriers?

Interview with Energie Nederland: aimed to get a better understanding of current barriers experienced by heating companies.

1. General question to introduce himself and what Energie Nederland does regarding 5GDHC.
2. What are the biggest barriers in current laws- and regulations to implement 5GDHC?
3. How do heat companies experience the uncertainty in current laws regarding payback period due to tariffs?

4. Does the monitoring of profits by the ACM withhold heat companies to implement 5GDHC heat grids?
5. What are other organizational challenges experienced in implementing 5GDHC?
6. What do you expect to change after implementing the new Dutch Heat Act? Will this make implementation easier?
7. How should the barriers experienced be addressed? Do we need more than the implementation of the WCW and WGIW?

Interview with AMS Institute: aimed to get a better understanding of the governance of heat grids in Amsterdam and current organizational challenges experienced. Also inquires expected effects of the new Dutch Heat Act and the WGIW.

1. General question to introduce himself and what kind of research he did regarding the municipality of Amsterdam and organizational challenges they have experienced in the implementation of heat grids.
2. What does the process of implementing heat grids in Amsterdam currently look like in general?
3. What stakeholders are involved in this process? What does collaboration between those stakeholders look like? How are citizens involved in this process?
4. What are barriers in current law- and regulation?
5. What are other organizational challenges?
6. What do you think will change after implementation of the WCW and WGIW?

Interviews with municipality of Amsterdam

1 short general interview which was more aimed toward getting a better understanding of the current organizational challenges of implementing 5GDHC in Amsterdam (to know what to look for in the case studies and their lessons learned). Also inquiring expected effects of the implementation of the new Dutch Heat Act.

1. General question to introduce himself and what he does in regards to the implementation of heat grids within the municipality of Amsterdam.
2. What are current challenges in law- and regulation to implement heat grids?
3. Would the implementation of 5GDHC be more complicated than implementing the traditional 3rd generation heating grid? In what way?
4. Would the introduction of the WCW make implementing 5GDHC easier?
5. I understood that heat tariffs are dependent on gas prices? How does this effect the implementation of heat grids?
6. What are the roles of different stakeholders? Who generally owns the system?

3 interviews focused on 3 recent developments, (since the approach has changed much the last few years). Aimed on how the most recent cases approached the implementation of a heating grid.

1. General question to introduce themselves and what they did for the specific case.
2. What did the process of the implementation of the heat grid in X case look like?
3. What stakeholders were involved? What did the collaboration between the stakeholders look like? How were citizen involved in the process?

4. (question for Katelien van den Berge) You told me before the approach of implementing heat grids in Amsterdam has changed the last couple of years… how?
5. (question for Steven Roerink) You've talked about management tools the municipality uses before… How does this work and what kind of instruments have you used for the case?
6. What kind of law- and regulations have you ran into?
7. What other organizational challenges did you encounter?
8. Would the implementation of the new Dutch Heat Act affect the process of projects like case X? Specifically the new cost based tariffs model? Would the new law make implementation easier?