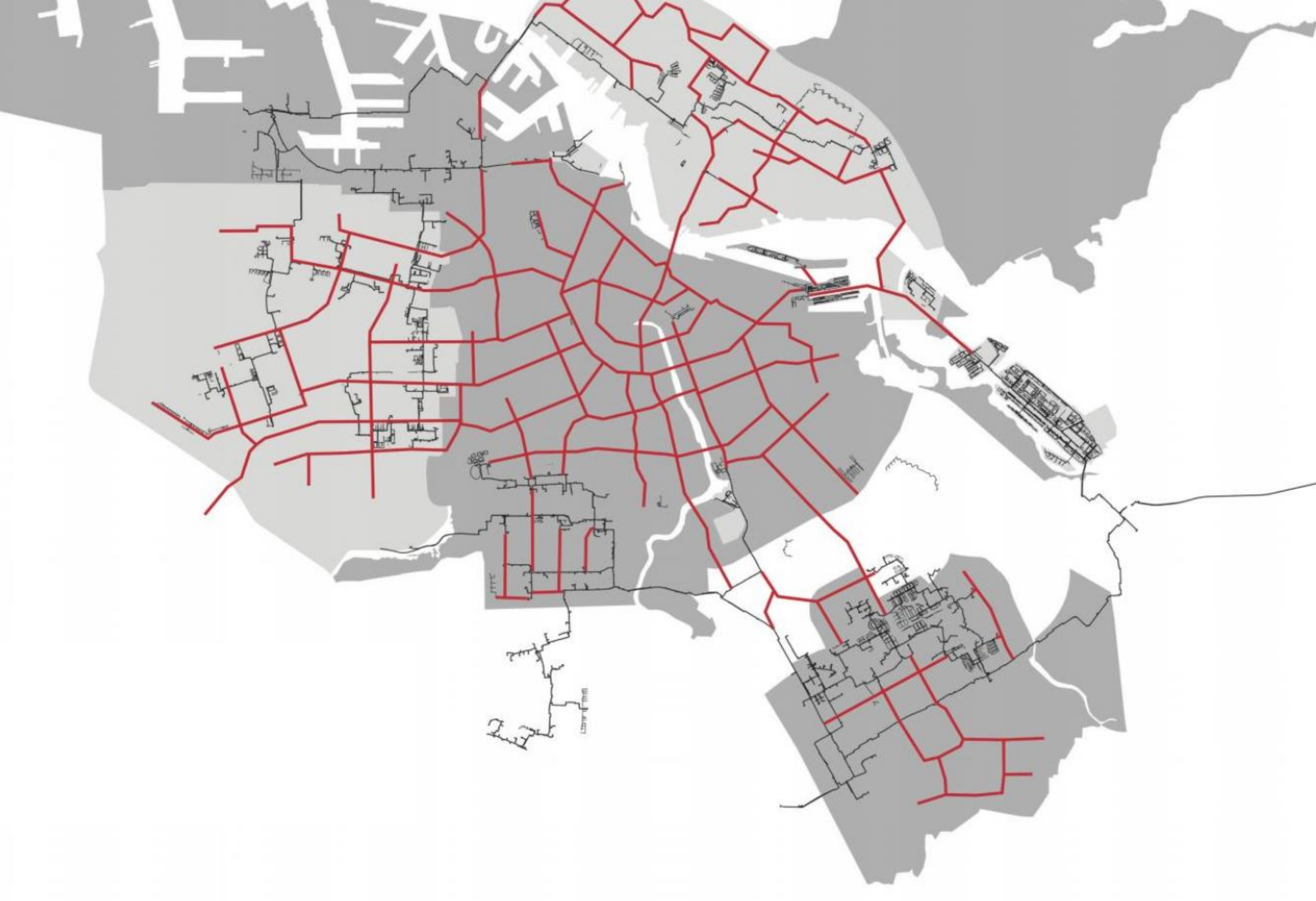

Guiding local and sustainable district heating projects towards policy targets

Exploring the Amsterdam heating transition towards district heating using data centre waste heat

Graduation Thesis

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Guiding local and sustainable district heating projects towards policy targets

Exploring the Amsterdam heating transition towards district heating using data centre waste heat

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Preface

During my masters, I experienced a growing interest in the contribution of construction management to the energy transition. Via a full year of master courses, an internship at a construction firm and a multidisciplinary project in Indonesia, I ended with the City of Amsterdam to write my graduation thesis. The ambitions of the City of Amsterdam to abandon the use of natural gas appealed to me.

And so I came in contact with Jan, who pointed out to me that there is a need for the transition towards sustainable district heating using data centre waste heat. A challenging subject, so I thought: this is going to be the topic of my thesis.

Although it was challenging, with much scientific literature, interviews and qualitative data analysis, I was fortunate to have the supervision of a great committee. Jan, I would like to thank you for your day-to-day support and the many 'bila's' (lucky that I learned that word). You could always push me to 'just do it' on when I was strangling myself with doubt on what my approach would be. I am going to miss our conversations about sustainability. Thomas, thank you for your clear advice and sometimes making the most complex features of organisation in the heating transition sound clear. You really helped me to demarcate my research and in formulating the result. And Daan, thank you for your guidance during the meetings, especially when I was going way ahead of myself and the topic, again. Marian, I want to thank you for always helping me out (and frequently as well). Whenever I was stuck, you could motivate me to follow through. Your ability to provide clear feedback has helped me to structure my process and project. Without you, I probably would still be working on this thesis.

I also want to thank everyone at CTO; I had a wonderful time with lots of good times and table tennis duels. I honestly think that there is no municipal department as fun as CTO.

And to end with a personal note, I want to thank my family and friends.

Christian Alferink
Amsterdam, June 2020

Summary

Driven by the targets set by the Dutch central government to reduce CO_2 emissions (COP21), the City of Amsterdam set a target for not using any natural gas anymore in 2040. One way of achieving this goal is to transform the gas-powered heating system to district heating (DH). For optimal sustainability, these networks should have low-temperature (LT) heating water, use waste heat (WH) from data centres (DC) and should be 'open' for third party inlet and integration possibilities [19].

The City of Amsterdam is attempting to steer this heating transition. However, there seems to be a gap between long-term policy and small local heating transition initiatives in Amsterdam. On the one hand, the municipality is working on setting the framework for the transition by formulating policies and setting targets. On the other hand, there are several DH projects in Amsterdam where many actors work parallel without using clear guidance from policy.

Scientific methods could support the coalescence of multiple actors in the transition towards sustainable heating. There seems to be a need for guidance towards the 'gas-free 2040'target with specific actions to start sustainable DH projects. The preferred solution should be a combination of actions based on how to proceed presently and how to proceed based on a desirable future vision.

The goal of the research is to use transition theories to provide scientific support to the City of Amsterdam in the organisation and guidance of the transition towards an open (LT)DH network using WH from DC's. In order to investigate which and how scientific theories could assist in the heating transition, the central question of this research is:

How can small-scale local heating transition initiatives be guided towards a future way of district heating envisioned in municipal policy?

To answer this question, first, a literature review is done to find suitable scientific theories for creating a common view and provide guidance in DH projects. A conceptual framework has been created by integrating the creation of consensus among actors (based on Constructive Technology Assessment (CTA)) into Backcasting (BC). The BC method focuses on technological and societal shifts towards a normative future. The changes for actor networks cause by societal shifts are anticipated with the use of interactivity, participation and a shared vision. Multiple alternatives that lead to the normative vision are created and divided into short-term transition paths.

Next, following the steps of the conceptual framework, the heating transition in Amsterdam has been explored, together with two case studies of DH projects in Amsterdam by interviewing 11 experts involved. Interests and views of key actors and main barriers have been identified and analysed using ATLAS.ti to code the transcribed interviews. Five trade-offs have been derived from the analysis on which it is aimed to form a consensus. By surveying the five trade-offs (as a substitute for the discussion workshop proposed by scientific the-

ory, that could not take place due to the coronavirus), it has been attempted to formulate a common view on the trade-offs among actors.

Last, based on the survey results, a scenario has been articulated in the form of a transition pathway towards the 'gas-free' target. The pathway has been divided into three short-term strategic episodes: preparation (2020-2025), implementation (2025-2030) and integration (2030-2040). It has been concluded that small-scale local heating transition initiatives can be guided towards a future way of DH envisioned in municipal policy by taking public initiative in top-down planning of decentral DH systems in the first episode. The municipality could prepare for market organisation, tariff regulation and appointment of locations for DH by organising an intra-municipal learning programme. Private parties could adjust and optimise their business case while residents' collectives could start plan and organise themselves.

In the second episode, the planned decentral DH systems could be implemented using a bottom-up approach with an emphasis on participation. The intra-municipal learning programme could be extended to a city-wide programme for all actors to optimise participation, collaboration and flexibility. Market organisation becomes more important to regulate the growing competition. Residents' collectives could be assisted in creating local support by providing financial support in various ways, by the inclusion of the collectives in the learning programme and by forming official partnerships. A municipal representative for each collective could lobby for its interest within the municipality. The municipality could be careful in demanding capacity of the collective to preserve the human energy and commitment of the members of the residents' collectives.

Emphasis could be on the city-wide integration of the decentral DH systems during the last episode to exploit integration benefits for local initiatives. Integration benefits are the possibility to balance supply and demand and reduce peak demand by using smart operating systems, cooling synergy, minimising the dependence on individual heating sources and uniform heating cost. The DH networks are still operated bottom-up, but integration oversight is top-down. Policy and legal frameworks could be further developed through the learning programme to optimise sufficient regulation to achieve integration. Implementation of new DH systems could continue, but with flexibility towards new and more efficient heating technologies and renewable heating sources. Potential landscape events (e.g. impact of global warming, hydrogen potential, an increase of electrification) could then be anticipated adequately.

This thesis describes the research design after the introduction. A literature review is presented, followed by the methodology. Then, the Amsterdam heating transition is explored combined with two cases for more in-depth and practical insights. Last, the transition pathway is articulated after which the research is discussed, and the conclusion and recommendations are given.

Contents

1

Introducing gas-free heating in Amsterdam

The Dutch government signed the Paris Climate Accord (COP21) in 2015, committing to a 49% reduction of CO_2 emissions in 2030 compared to the 1990 levels. This reduction should rise to 95% in 2050. Besides this agreement, the Dutch government should have reduced 25% already in 2020 by their targets [33]. Unfortunately, the Netherlands is part of the five worst-performing countries of the EU regarding CO_2 reduction. In 2018, the CO_2 emissions where 14.5% lower than in 1990 [14], nowhere near the mentioned 25%. So, one could speak of a high urgency in the reduction of CO_2 emissions in the Netherlands.

There is no one all-encompassing solution to CO_2 reduction in the attempt of mitigating climate change. The most feasible solution probably is a combination of utilising all renewable energy sources (RES) with the majority of sustainable innovations to reduce CO_2 emissions. All different (sub)solutions contribute to a reduction in various sectors. One of the five sectors appointed in the Dutch climate agreement is the built environment [33]. In this sector, solutions range from insulation increase and solar panels to large scale smart energy distribution systems. Innovative ways of meeting heat demand can potentially reduce CO_2 emissions more circularly. An example is the use of waste heat (WH).

Nowadays, some (parts of) cities have a district heating (DH) network to warm their buildings. DH is a network of tubes that distributes warm/hot water to provide hot water and heating for houses, commercial and service buildings and sometimes industrial users. There are multiple sources for DH, varying from conventional power plants, renewable energies such as geothermal heat and solar energy, to the use of WH [7].

In the context of 'gas-free living', the City of Amsterdam set a target for not using any natural gas anymore in 2040. The municipality mentions that one way of achieving this goal is using DH networks. These networks should have sustainable sources of heat (e.g. WH or RES) with a focus on low temperature (LT) heating water [19]. Because it is unclear where new residential areas will be built in the future, where new potential energy sources will settle or if multiple smaller networks might be able to integrate, there is need for flexible DH networks. Such so-called 'open' DH networks provide flexibility towards new heating sources and make sure that new neighbourhoods could get connected too.

One form of WH that might be suitable for DH is that of data centres. Servers of data centres produce much heat. Estimated is that all the WH of data centres in the Netherlands (currently 90% of the energy they use) can provide heating for one million households [12, p. 7]. 70% of the commercial data centre capacity in the Netherlands is concentrated around Amsterdam [12, p. 14]. Given the CO_2 reduction targets for the Dutch government, making use of WH of data centres via DH is interesting for the City of Amsterdam.

This research will be written as a graduate intern for the CTO (Chief Technology Office) Innovation team of the City of Amsterdam, an independent department within the municipality, specialised in technology and innovation. One important project is the transition towards LTDH networks. Together with other departments within the municipality, they try to use policy to steer this transition. However, there seems to be a gap between long-term policy and small local initiatives in Amsterdam regarding the heating transition. On the one hand, the municipality is working on setting the framework for the transition. They are formulating policies and envisioning future city demands with the abandonment of gas in 2040 in the back of their heads. These policies should guide new projects. On the other hand, throughout Amsterdam, there are several projects already busy with transitioning towards a sustainable DH system. Many actors are working parallel without being able to reach one another. Even within the municipality, there are a lot of these 'little island' projects. Ingenieurs Bureau (IB), the engineering firm from the municipality, is responsible for (technical) operations of the transition. Today, multiple projects are executed without policymakers from Ruimte & Duurzaamheid (R&D) being fully aware of what is going on. This form of miscommunication might result in a mismatch between policy and experiments. So, the City of Amsterdam is looking for a way to exploit municipal resources (policy, financial resources, procurement) and determine its role in the heating transition.

Scientific methods could support the coalescence of multiple actors within the municipality but also the unification of all actors involved in the transition towards sustainable heating. There seems to be a necessity for specific actions on how to proceed with (ongoing) projects. The current process should be disrupted to omit the incrementality of these projects. Such actions should be specific per actor, on all possible levels, in every dimension present and based on a shared view. Moreover, the necessity for guidance towards a 'greater goal' should not be missing in setting up such actions. The preferred solution should be a combination of actions based on how to proceed presently and how to proceed based on a desirable future vision.

First, the research design is explained in chapter 2 after which a literature review results in a conceptual framework in chapter 3. Then the way of analysis is explained in chapter 4. Results are presented in chapter 5 for the heating transition in Amsterdam and chapter 6 where two DH cases in Amsterdam are more thoroughly elaborated. Chapter 7 presents scenario analysis with an elaborated path for DH in Amsterdam towards the future. Last, chapters 8 and 9 close with the discussion, conclusion and recommendations.

2

Research design

This chapter presents the design of the research. First, the research questions are stated after which an explanation of the research approach is given.

2.1. Research questions

In order to provide a beneficial outcome that guides the transition process now and towards the future goal of 2040, the following research questions should be answered:

How can small-scale local heating transition initiatives be guided towards a future way of district heating envisioned in municipal policy?

1. *What are useful theoretical insights on transition processes and sustainable district heating?*
2. *How can academic transition theories assist in addressing present actions and a future goal together?*
3. *What are the interests and views of (key) actors on a transition towards such system?*
4. *Which present actions organise collaboration between all actors and influence the transition towards such a system?*
5. *How can the transition be guided towards a future way of district heating?*

The goal of the research is to use transition theories to provide scientific support to the City of Amsterdam in the organisation of the transition towards an LTDH system.

The aimed result is a scientific method on how to guide small-scale local initiatives of the transition towards LTDH networks and how to connect these initiatives with municipal policy. The result is envisioned in the form of a scenario with specific actions per actor, dimension and level, guided by a shared future vision. This scenario should have a step-by-step focus and should support the breaking of barriers to stimulate and accelerate the transition process.

2.2. Research approach

Use is made of scientific literature and two different cases of sustainable DH in Amsterdam to answer the research questions. Both cases aim to implement an LTDH network in a part of a city district in Amsterdam, making use of WH from data centres.

First, scientific literature on transition processes and sustainable DH is thoroughly reviewed to find useful theoretical insights. The state of the art of research regarding sustainable transitions, scenario methods and DH is explored by using Google Scholar articles with the highest count of citations. Keywords in searching articles are sustainable transition, sociotechnical transitions, scenario methods, transition scenarios and (innovative) DH (using WH). From this review should become clear which scientific theories can assist in bridging the gap between policy and local initiatives, which answers the first sub-question. The second sub-question is answered by creating a conceptual framework based on the theoretical insights of sub-question one. This framework should scientifically support small-scale heating transition initiatives.

Next, the Amsterdam heating transition is explored, and the cases are further scrutinised. The general heating situation in Amsterdam is explored by interviewing multiple stakeholders. Two cases are scrutinised to assess this situation more in-depth in practice. For the two cases, two different configurations of LTDH local initiatives in Amsterdam are used. One case is an initiative from residents in a part of the eastern city district to transform their existing gas heating supply to DH. This local and decentral initiative has a variety of stakeholders. It is used to assess what role the City of Amsterdam should play in stimulating following citizens' initiatives in LTDH network projects. Scientifically, this case should add to the knowledge of connecting municipal policy and small-scale, local and decentral initiatives. The other case is a small-scale market initiative. The area of a former jail is tendered and awarded to one project developer. They partly won the tender based on sustainability targets. Multiple new areas are being developed by project developers, and the municipality would like to know how they can stimulate small-scale market initiatives. Similar to the first case, the research on this case should add to the scientific knowledge of connecting long-term municipal policy to small-scale and local initiatives. Though in this case there is one initiator with a more business-like interest. So, the interests of the initiators of these cases differ. It is assumed that this difference probably means that a different approach is necessary, which should be proven in this research. Within each case, there are multiple stakeholders. Their interests are also assessed when investigating these cases by performing a stakeholder analysis. First, a general view on which stakeholders are involved is formed. Interviews with each stakeholder then show who are the key actors with their views on and interests in an LTDH network, so combining and analysing the interview data answers sub-question three.

Last, the results of the Amsterdam heating transition analysis and the two case studies are used as a basis for creating a common view among actors on the transition and for the articulation of a scenario for guidance. Question four is answered by taking the beginning of the scenario and combining it with the common view of actors for the articulation of specific actions—the articulation of the scenario for the Amsterdam heating transition answers to question five.

Overview of the deliverable and approach per research question is presented in table 2.1.

Table 2.1: Research approach

RQ	Deliverable	Approach
1	Overview of useful insights on DH, transition theory and scenario methods	Literature review
2	Conceptual framework	Combining transition theory and scenario methods
3	Amsterdam heating situation and case descriptions, stakeholder analysis and current policy and legal framework overview	Interviews with stakeholders for exploration of Amsterdam heating transition, two case studies of DH projects and policy and legal analysis
4	Common view of actors on trade-offs for transition pathway configuration	Expert survey analysis
5	Scenario for the Amsterdam heating transition	Following the steps of the conceptual framework for scenario building

2.3. Scientific relevance

The problem posed in chapter 1 of how to organise the unification of actors and come up with specific actions is also seen as a scientific knowledge gap by other scholars. Markard et al. [29, p. 962] suggest that the understanding of actors and their linkage to management approaches should be further researched and lead to further knowledge on 'innovation management on an organisational level'. More recently, the problem of how to steer towards concrete actions in transition projects is suggested by Köhler et al. [20]. They indicate that the link between transition research and management studies is a topic for further research. Although transition studies often have a more holistic perspective compared to management studies, the link between these fields has considerable potential for research. The use of transition studies for linking long-term policy with small-scale initiatives is investigated so that the aimed outcome of specific actions could form process support for management. This way, the linkages between transition studies and management are explored. The importance of local initiatives is also stressed by Lund et al. [28] as facilitators for mitigating potential barriers in the implementation of an LTDH network. They suggest creating local ownership, empowerment of local actors and a socioeconomic perspective in the planning process as such facilitators, together with providing energy saving incentives and optimising supply efficiency. This research investigates whether such facilitators are present and desirable in the Amsterdam heating transition.

3
Literature review

The state of the art of research regarding sustainable transitions is explored together with literature about sustainable district heating. Literature concerning methods for achieving long-term goals is also reviewed to answer the question of how to guide such transitions. The focus lies on governance and organisational difficulties and how to address such issues.

Literature regarding sustainable DH is reviewed, and theoretical insights from transition studies are explored together with theoretical methods on guiding transitions towards the future. Last, useful insights are summarised, and a conceptual framework is proposed.

3.1. District heating

DH is seen as a potentially viable heating source for warming residential, commercial and even industrial buildings, with growing RES as input [7, 17, 22, 26–28, 47]. According to Frederiksen and Werner [16] cited by Werner [47, p. 618], the idea of DH is 'to use local fuel or heat resources that would otherwise be wasted, in order to satisfy local customer demands for heating, by using a heat distribution network of pipes as a local market place'. Especially low temperature (LT)DH is seen as sustainable. Schmidt [36, p. 595] argues 'that low-temperature district heating is a key enabling technology to increase the integration of renewable energy for heating and cooling. Low-temperature district heating is one of the most cost-efficient technology solutions to achieve 100% renewable and CO_2 emission-free energy systems on community level.' This level of sustainability is also the reason why the City of Amsterdam wishes for low temperature. According to Lund et al. [27] and Werner [47] drivers for LTDH networks are:

- Transition to a sustainable energy system
- The reduction of primary energy supply due to recycling of WH
- Lower heat costs (gas) and less responsibility for boilers for consumers
- Legislative incentives such as high fossil fuel taxes (gas in the Netherlands)
- Synergies between heating and cooling
- Flexibility toward the use of other (renewable) energy sources

3.1.1. Environmental impact

The environmental impact of DH is seen as potentially low. Heat recycling results in low to nil CO_2 emissions. Since 1990 the CO_2 emissions form DH in Europe has decreased 35%. Studies indicate that the CO_2 reduction from increased DH network use will rise further, which is mainly due to the use of WH and RE heat supplies [7, 47]. Other positive environmental impacts are improvement in the health of the population by cleaner breathing air, the synergy of heating and cooling, the potential to store heat in buildings and optimise intermittent energy sources utilisation. Also, demand-side management can be used to engage consumers in the promotion of sustainability and meeting comfort, and heat demands [22]. The positive environmental impact of implementing innovative ways of DH could be used to create broad support. These arguments could function as drivers of the DH project.

3.1.2. Heating market globally

Worldwide, the total amount of DH networks is approximately 80.000. Around 6.000 of these systems are built in Europe. The share of heat delivery is 13% in Europe, with a larger share of heat supplied by electricity. Compared to the share of natural gas (41% in Europe), the share of DH is small. In Europe, most heat is delivered to industry and residential areas and sometimes the service sector [47]. In 2013, Ahlgren [7] stated that the total share of recycled and renewable heat in DH is around 80%. Four years later, Werner [47] found that in the DH market in Europe, the heat supply consists of 72% recycled heat and 27% renewable heat. The percentage for recycled heat is so high because heat from combined heat and power (CHP) plants is seen as recycled heat as well. Nevertheless, these percentages indicate that the share of recycled and RES in DH is growing, which means that the contribution to CO_2 reduction of DH networks is growing. Current systems are of the second and third generation. A new form of DH is the fourth generation which distributes heat with lower temperatures and is integrated with a smart energy system. In Europe, heat meters are used to measure heat delivery per customer for the energy bill [47]. This fourth generation of DH is now the most sustainable form. The City of Amsterdam is aiming for these kinds of DH networks.

3.1.3. Heat source possibilities

As a heat source, waste heat if preferred. The use of WH increases the CO_2 reduction and can reduce the heating fuel costs [7, 22, 47]. However, WH often cannot provide DH solely [22] and the shutdown or supply failure of an industry with excess waste heat constitutes a high risk economically and for supply [22, 47]. Such risk also goes for large electricity users like data centres. Thereby, according to Ahlgren [7], diversification of energy sources strengthens the competitive character of DH by reducing the dependence on imported fossil fuels. A brief overview is provided next to explore potential energy sources for such cogeneration.

The share of fossils fuel in heat supply in Europe is 70% and is mainly due to fossil fuels being the primary energy supply for CHP and boiler plants. Non-fossil heat sources are waste to energy (WtE), excess heat in industrial processes, nuclear reactor heat recovery, solar energy, geothermal heat, biofuels and large electricity users such as data centres [47].

- WtE is used in Amsterdam by AEB. This WtE plant delivers heat for 35.000 houses and is an example of using waste heat. However, since July 2019, the plant has encountered problems with backlog maintenance and safety. Therefore it only runs on a third of its capacity, creating problems for heating during the coming winter [19]. For the City of Amsterdam (the owner of AEB) this is an eyesore. Also, burning waste is not the most sustainable way of using WH. Environmentally, better results are obtained when recycling waste instead of burning it.

- Solar heat requires a lot of square metres in order to provide significant deliveries [47]. In a densely populated area like Amsterdam, this is likely to have many implications. However, the possibilities of utilising roofs could be explored.

- Geothermal heat has a very high potential for being a DH source. 25% of the European population lives in urban areas that can use geothermal heat distributed by DH networks [47]. So geothermal heat is probably the most available source in Amsterdam to combine with WH.

- There are mixed opinions on biofuel as an energy source. The advantage of biofuels is that they are easy to use because they are compatible with the conventional infrastructure used with fossil fuels. However, the level of heating is lower with biofuels, and there is not enough biomass in Europe to replace fossil fuels completely [47]. Although biofuels are considered climate neutral because the CO_2 emissions equal the CO_2 absorbed by the biomass, the CO_2 emitted from biofuels contributes to global warming before being absorbed by new biomass. It is questionable how sustainable this energy source is [11]. Still, multiple municipalities around Amsterdam and the City of Amsterdam signed a covenant together with a large energy company for the development of a biomass plant to bridge the transition towards the use of WH and geothermal sources [44].

- An electricity system with intermittent power generation from solar or wind power can create opportunities for DH networks. The excess electricity can be absorbed in the DH system by electric boilers. Also, the storage of heat is a possible reason to integrate electricity with heat systems because heat storage requires fewer installation costs than electricity storage [47].

3.1.4. Design considerations

The climate is an important design consideration. Heating is required in colder climates. As already mentioned, the synergy between heating and cooling should be explored in every climate. Global warming will play a more significant role in the future, so demand between heating and cooling could shift [7, 22]. Another consideration is the location and size of the DH network. A smaller DH network means higher cost and fewer opportunities for co-generation [22] while an open system creates flexibility in these co-generation opportunities. Most performance and cost-effective is to implement a DH network in densely populated areas with high energy demand due to the minimised heat losses [7, 17, 22, 27, 47]. Because of the planned transportation fluid of low-temperature water, the connected buildings must have sufficient insulation and the right technology for heating [27, 28]. Other technical specifics such as heat exchangers and circulation pumps [22]. However, the technical part of this project is not within the scope of this research.

3.1.5. Organisational challenges

The literature suggests some organisational challenges in the transition to an open LTDH network using WH. This section reviews these challenges.

Legal frameworks
Organisational challenges because of legal frameworks vary from particular DH legal frameworks to ordinary energy laws. This is often different for every country and region. A legislative barrier could be that some countries do not consider DH as an energy-efficient measure. Also, the ability for lowering CO_2 emissions using WH for DH is often underrated in the climate change mitigation assessments. Only the use of renewable energies for DH is then acknowledged as reducing emissions [28, 47]. In the Netherlands however, since January 2019, WH of data centres is classified as a RES [42, p. 3].

Role of energy policy
According to Lake et al. [22], the role of energy policy is to encourage research and financial incentives to increase the availability and quality of DH networks. Policies can change the energy source of DH to renewable and recycled energy. Also, the shift towards a central DH system instead of single user heat consumption requires economic policies. Higher electricity costs and lower initial investment are examples of policy outcomes that stimulate the transition towards DH networks.

Awareness
Awareness of DH benefits is high globally. However, the integration with district cooling is not well known. This synergy between cooling and heating increases sustainability. For the Netherlands, the awareness for DH increased to a high level. Integrated networks between cities are even explored [7, 47]. Also, the use of WH (of data centres) is in the news more often.

Ownership
In Europe, municipal ownership is common due to substantial local business opportunities, especially during the implementation phase. Disadvantages for municipal ownership are poor financial status and absence of energy experience (an example is the AEB crisis), which results in stagnating development and insufficient use of existing infrastructures [28, 47]. The capacity of the City of Amsterdam should be assessed for defining its role in the transition towards an open LTDH network. Then the decision for privatising the network or keeping it public could be made. However, this decision is political.

Economic feasibility
A DH network is economically feasible for high-density buildings and complexes and densely populated urban areas. Generation/production costs, distribution/network costs, connection costs and the costs of heat loss in distribution are four cost factors. Generation and distribution costs are divided in investment, operational and maintenance [7, 22, 47]. Because the potential to utilise WH, geothermal and other renewable heat in combination with a gain in efficiency, LTDH could provide significant energy savings [7, 28]. This might not be the case for large centralised DH networks for these are prone to significant heat losses in heat distribution. Another organisational challenge is pricing, which might be market-based or cost-oriented. For private owners, prices close to that of competitive heat supply alternatives deliver optimal benefits of DH (market-based). Municipal owners often use cost-oriented prices to share DH benefits with the consumer. In countries with a mar-

ket economy, like the Netherlands, pricing is often via invoice based on data from the heat meters at the consumers home/building [47].

Intra-municipal tensions
'The major limiting factor in developing innovative local energy policies is the lack of co-operation between municipal departments when working together on urban projects' [17, p. 196]. A better collective understanding and thus a better connection between local energy and urban planning policy could be helpful. There is a need for a coordinating role for the municipality to achieve this. The capacity for adaption in urban planning policies can be seen as a resource which also could be assessed for the City of Amsterdam.

Collaboration
Other papers suggest that especially the collaboration between actors is a crucial factor in the success of a DH network project. Thollander et al. [40] state that the factor that influences DH collaborations the most is the human factor. Elements of collaboration like risk, imperfect and asymmetric information, credibility and trust, inertia and values have the highest share in failure of collaboration between industry and energy utility. Other elements such as heterogeneity, access to capital and hidden costs have less impact. These topics are explored extensively in the research.

Other challenges
Some challenges are not precisely organisational but worth mentioning. These challenges are meeting peak demand, the modest economic competition in DH market, that there often is a monopoly by energy companies and that the economic competitiveness can decline over time in mild climate areas due to global warming [7]. The urgency of these challenges should be assessed in the research.

These organisational challenges are taken into account during the research. Findings from the case studies are assessed for similarities with the challenges mentioned above.

3.2. Transition studies

Sustainable transitions are 'radical shifts to new kinds of socio-technical systems'. Sustainable transition research focuses on conceptualisation and explaining of how these shifts can take place so that they fulfil societal needs [20, p. 2]. The difference between a sustainable transition and the process of technological innovation is that the latter is more incremental and often the societal embedding knows relatively little change [15, p. 3]. Abandoning gas as heat supply can be seen as a radical shift and the new sustainable district heating system with WH or RES as a new socio-technical system.

The characteristics of sustainability transitions are [20]:

- Multi-dimensionality and co-evolution: transitions consist of multiple elements that evolve parallel. The process is non-linear with various interdependent developments
- Multi-actor process: there are multiple actors with different interests involved in transitions. This variance in interest increases complexity.
- Stability and change: innovative (environmentally friendly) technological development constantly stimulate radical changes, where the regime offers stability and path-dependence. Interaction between the two is a playing field and a characteristic of transition studies.

- Long-term process: it often takes a long time for these innovations to develop from a niche scale to spread out on a large scale. Also, the destabilisation of the current regime and the resistance of incumbent actors is a long term process. Phases in transitions are pre-development, take-off, acceleration, and stabilisation.
- Open-endedness and uncertainty: the future is uncertain and open-ended due to multiple transitions pathways. Also, the non-linearity in innovation, politics and socio-cultural aspects creates uncertainty.
- Values, contestation, and disagreement: there is often much disagreement throughout the innovation which is due to different points of view of actors together with a transition being a potential threat to established systems.
- Normative directionality: sustainability is a public good. Public policy should provide direction, incentive and regulation for private actors to reach sustainability goals.

The four theoretical frameworks that are seen as the foundation of sustainable transition studies are Multi-Level Perspective (MLP), Technological Innovation System approach (TIS), Strategic Niche Management (SNM) and Transition Management (TM). The view of these frameworks is system-wide to assess co-evolutionary complexity and fundamental phenomena like path-dependency, emergence and non-linear dynamics [20, p. 4]. SNM however, descends from the theory of Constructive Technology Assessment (CTA) [37, p. 538]. So CTA is considered as the fourth theoretical framework of sustainable transitions to maintain a broad perspective in this literature study.

3.2.1. Technological Innovation System approach (TIS)

Technological Innovation System approach (TIS): a combination of innovations systems theory and industrial economics. Technologies, actors and institutions are the focus. The development of a innovation should fulfil seven functions:

1. knowledge development and diffusion
2. entrepreneurial experimentation
3. influence on the direction of search
4. market formation
5. legitimation
6. resource mobilisation
7. development of positive externalities

TIS focuses more on the development of innovations than on the stability of regimes [20, p. 4].

3.2.2. Multi-Level Perspective (MLP)

Multi-Level Perspective (MLP): a combination of evolutionary economics, sociology of innovation and institutional theory. They propose three analytical levels with processes wherein transitions occur, namely; niches (a protected environment), socio-technical regimes (existing systems with path-dependence and incremental change) and socio-technical landscape (exogenous development) (figure 3.1). Landscape development pressures the regime to change, leaving space ('window of opportunity') for niche-innovations to develop widespread and potentially change the regime. [18, 20, 34]. 'The systemic dimension of transitions and the tension between stability and change are central to the MLP, represented by the interplay of different degrees of structuration at different levels of analysis' [20, p. 4].

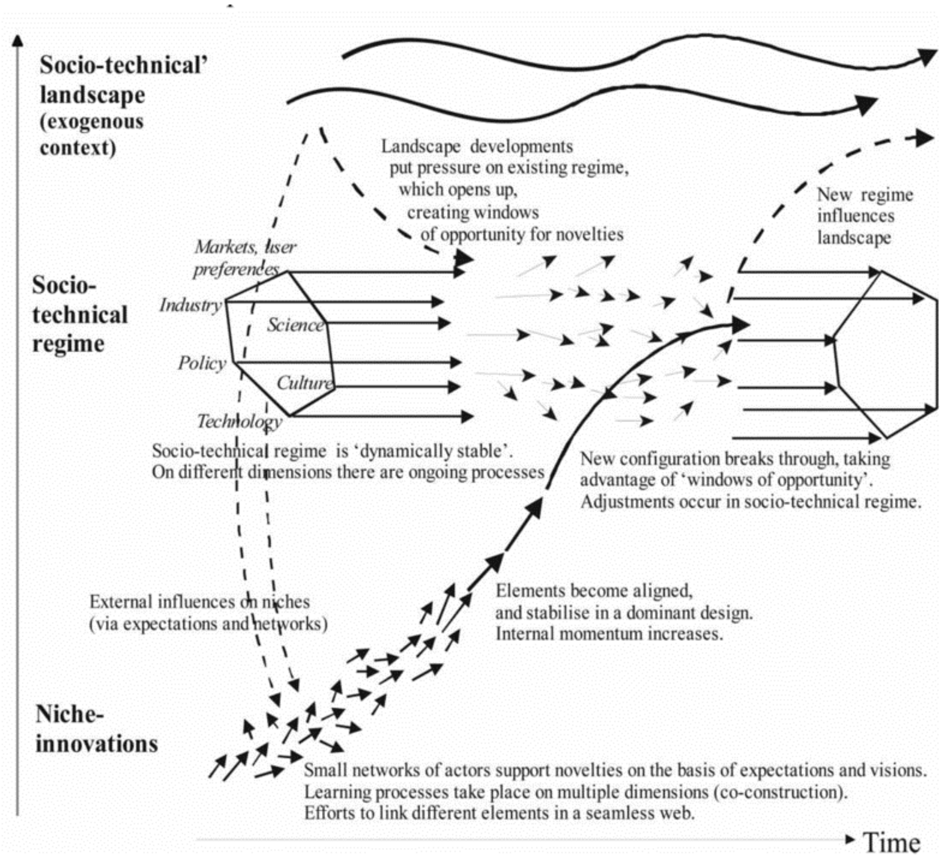

Figure 3.1: Multi-level perspective from Geels and Schot [18]

3.2.3. Constructive Technology Assessment (CTA)

Constructive Technology Assessment (CTA): Schot and Rip [39, p. 255] define CTA as 'a new design practice (which includes tools) in which impacts are anticipated, users and other impacted communities are involved from the start and in an interactive way, and which contains an element of societal learning.' The reason for developing CTA was that governments tend to take responsibility in mitigation of and compensation for impacts of fixed technologies [37, p. 538]. So it can be seen as a form of technology assessment where the focus lies on the early interaction with all actors involved to include them in the design and implementation process to prevent compensation and mitigation by the government. CTA concentrates on creating discussion among actors. This way, social actors such as consumers, residents and corporations are involved in broadening the design and implementation process. Where the overall philosophy of technology assessment is to anticipate potential impacts of new technologies and use these in decision making during design and implementation, CTA extends this by focusing on broadening design and implementation of new technologies by creating a feedback from diverse (social) actors with different interests. This feedback often is the result of strategies and tools such as discussion workshops and social experiments that create space for dialogue and interaction [38, 39].

3.2.4. Transition Management (TM)

Transition Management (TM): combining complexity studies with governance research to a framework that is policy-oriented, which means that it is suggested that policy is able to shape transitions by using four different types of governance activities (figure 3.2) [20, 23–25, 35, 46]:

1. Strategic activities
2. Tactical activities
3. Operational activities
4. Reflexive activities

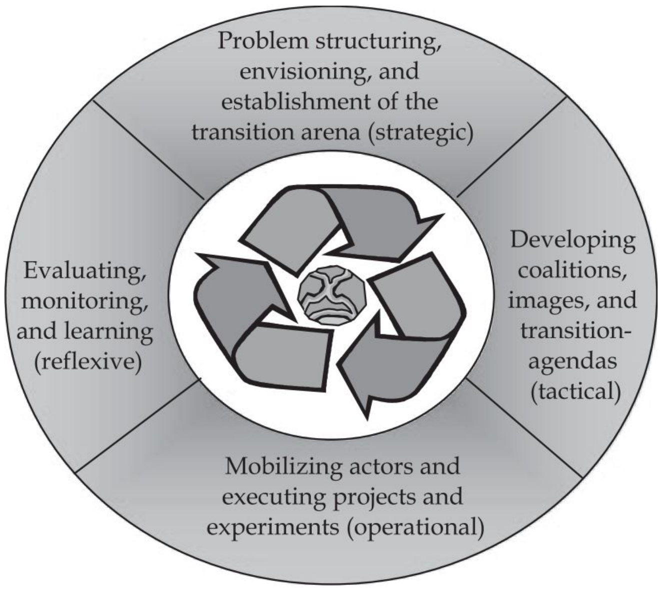

Figure 3.2: Transition Management Cycle from Loorbach [23, p. 173]

Strategic ("culture")
Strategic activities are vision development, strategic discussions, long-term goal formulation, collective goal and norm-setting and long-term anticipation. Future visions, structural reflection and the debate on innovations often contribute implicitly to the desired changes instead of systematically structured. Long-term strategies often are omitted in regular policy-making due to the short political cycles where personal interest and public pressure are significant. TM attempts to integrate long-term governance activities into policy-making as a necessary fundamental element.

Tactical ("sphere")
Tactical activities are interest-driven steering activities regarding the regime. These activities are established patterns and structures like rules and regulations, institutions, organisations and networks, infrastructures and routines. These tactical activities concentrate on the accomplishment of specific goals per actor(group) and are seen as strategic at the actor level. The focus thus is within an actor specific context and not about the overall development of the societal system. Every actor has its strategies based on their interests. All these different strategies might lead to fragmentation in the transition process.

Operation ("innovation")
Operational activities are short-term experiments and actions of innovation (i.e. all practices introducing new societal structures, culture, routine or actors). This innovation process is emergent, random and uncertain and evolves in a niche. The only way innovations solely result in transition is by chance.

Reflexive
Reflexive activities are monitoring, assessing and evaluation of policies and societal change. These activities are institutionalised but also societal embedded (media and internet). Reason for these actions is to prevent lock-in. Noteworthy is the need to be an integrated part of governance processes.

While SNM focuses more on the dynamics of market competition in order to overcome a lock-in and stimulate socio-technical diversity, TM aims for a more strategic and goal-oriented modulation of a transition [37, 542].

3.3. Scenario methods

There are multiple methodologies for scenario planning suggested in literature [8, 15, 21, 45]. Scenario planning is mostly used for social forecasting, decision making and public policy analysis. It helps to minimise uncertainty and stimulates the decision-making process using a holistic way of planning. This holistic manner is consistent with the perspective of transition studies. Besides projecting possible future policy implications and consequences, scenario planning is useful for assessing the roots and timing of these implications [8, p. 24]. The general focus of scenario building is on 'defining the issues, identifying key drivers, stakeholders, trends, constraints and other important issues in a systematic way and ranking of these items by importance and uncertainty' [8, p. 25].

Vergragt and Quist [45] categorise scenario methods into three classes: what will happen, what could happen and what should happen. The first is trend extrapolation of what is happening presently (i.e. business as usual (BAU)). There are no changes relative to the present assumed in these scenario methods. Often these scenarios function as a benchmark to show why change is or is not necessary. The second class consists of forecasting scenarios where the future is anticipated using trends, expectations, shifts and context. The third scenario class asks the question of what could happen and builds scenarios towards a normative future.

Elzen and Hofman [15] suggest five different methods for long-term scenario planning for systemic change (e.g. heating transition) before proposing their method. These are forecasting, foresight, road mapping, breakthrough and backcasting. The first four can be categorised in the 'what could happen' class of Vergragt and Quist [45] and the last in the normative scenario method.

Forecasting focuses on the linear extrapolation of current trends to predict how the future will develop and is often used to compare future trends. It differs from the BAU scenarios because it does take possible changes into account. It has limited attention to the processes of learning and interaction of actors, institutional change and policy. Foresight is more exploratory than the BAU method. It assesses current trends to find out how they may develop into possible futures. The focus lies on understanding threats and opportunities of forces shaping the long-term future. Foresight scenarios are often more diverse and are useful to create a wide variety of alternatives. Because of the broad perspective, the foresight method is more macro-level oriented, so there might be limited attention to interactions on meso and micro level. The road mapping method has a focus on technological aspects and functions to improve technological development. Therefore is the interaction with society and actors limited in this method. Last, the breakthrough method's function is bringing breakthrough developments to the market at which there is a less focus on the broader societal change process. So it operates more on a micro-level and with a relatively short term [15].

The backcasting method concentrates more on technological and societal shifts towards a normative future. Economic and cultural shifts and its changes for actor-networks are anticipated with the use of interactivity, participation and a shared vision. Backcasting methods endorse that systemic societal change often is necessary in order to achieve a normative future vision. It is argued that in this sense, there are similarities between backcasting and transition studies [45, p. 749]. They both take off from a vision about a desirable future that leaves room for flexibility but is evident enough to plan actions to achieve that future. A possible downside of the backcasting method is its limitation in how paths may occur and the lack of learning process specification [15]. Vergragt and Quist [45, p. 749] even argue that backcasting 'is agnostic about strategic niche management'. It is only possible that these preferable futures and the pathways leading to such visions can be developed for transitions, which is in contrast with the assumption of SNM that development of transition technologies happen in socio-technical niches.

The scenario method proposed by Elzen and Hofman [15] is the socio-technical scenarios method (STSc). This method of scenario building is a tool specifically designed to support transition policy. The method has integrated the MLP. It is based on the scientific theory of transitions and has a focus not only on the outcome but especially on the path. STSc provides multiple options with a priority. The strength of the method is that these options can be combined for a more comprehensive scenario purely focused on guiding transitions.

3.4. Combining CTA with BC

This research attempts to find theoretical insights for addressing and to support the problem imposed by the City of Amsterdam. As mentioned before, there is a need for a shared view on how to proceed ongoing and infant sustainable heating projects and a way to guide these projects towards a future overarching goal. A comprehensive yet specific set of actions should be the aimed result.

The theoretical frameworks chosen for this research are the use of a constructive technology assessment (CTA) for creating a common view for present actions (process interventions) and backcasting (BC) to create multiple paths for project guidance towards a normative future vision.

Theoretical transition frameworks
There is much resemblance between the four theoretical transition frameworks, although there is some difference in focus. Therefore, the decision for CTA is made because it is expected to create a common view among actors better. It is aimed that in this process, agreements could be made for specific actions. Thereby, the three general strategies connect well

with the case of Amsterdam. There is technology forcing present by the government and the City of Amsterdam by setting climate targets and the articulation of preferring a sustainable district heating system. The creation of experiments and facilitating certain areas as protected space for development is also possible in Amsterdam. Experiments are already ongoing, which implies that SNM is partly applied, even though it has to be scrutinised if the process of learning is applied during these experiments. Nevertheless, the presence of experiments brings about the opportunity for this graded learning. The third general strategy of CTA, the creation of alignment for reflexivity and feedback, offers the opportunity to have all actors involved and to cope with the uncertainties. The sustainable heating transition cases of Amsterdam are multi-actor processes. In order to create a common view, deep learning and feedback in this process, use can be made of the suggested tools such as discussion workshops or consensus conferences.

TIS approach varies the most from the chosen CTA. It focuses more on the development of the technology of the system rather than the societal impact. Technology for the newest form of district heating (4GDH) is relatively far in development, but there is a lack of deployment [28, 47]. Therefore CTA is chosen over TIS for its focus on organisational challenges instead of challenges regarding technology and market dynamics.

MLP is a less executive framework and focuses more on the systemic dimensions. The levels of dimensions can be used in this research, especially with the societal mapping of the transition dynamics during the first phase of CTA. Also, it is expected that regime barriers emerge when setting up the BC pathways. Though this is questioned by Vergragt and Quist [45, p. 753] for they argue that there is a difference in the conceptual model. Sociotechnical transition studies such as CTA, TM and MLP suggest that sustainable technology arises in a protected experimental environment (niches). However, backcasting assumes a systemic change in society, which might mean that these changes are too complicated to arise in a niche. The expected link of BC with the multi-level character of a transition should be further elaborated based on this research' findings.

The theoretical framework that shows the most resemblance with CTA is TM. However, there might be a slightly different focus. For instance, TM is more strategic and goal- and policy-oriented, which could mean that it is hard to reach an outcome with specific actions. Although policy recommendations cannot lack the outcome of this research, this strategic and goal-oriented modulation of TM should be covered by the combination of CTA with BC, where a strategic path should guide towards a future goal. Using CTA tools, the link between all actors is made so that from an SNM viewpoint, there is more focus on the dynamics of the market.

Scenario methods

For the guidance of the heating transition, various scenario building methods were considered. For the situation in Amsterdam, BC is seen as most optimal to stimulate the transition. With the target of abandoning gas heating in 2040, the municipality set a framework for a normative future way of heating. It also showed their preferred solution; sustainable district heating (using WH or RES). The more specific articulation of the preferred heating system in Amsterdam should be investigated. Because this normative vision is backcasted, the scenarios offer bandwidth in order to keep flexibility and try to reduce uncertainty. There are many different stakeholders and various configurations of sustainable heating projects. So, because of the many stakeholders, societal embeddedness requires a shared vision and sufficient interactivity between all actors. These are seen as cornerstones of BC [15].

Other scenario methods paid either limited attention at the actor level, or are focused on a very small or substantial dimension. Forecasting, for instance, has little focus on the interaction and learning processes of actors. The scenarios are based on an extrapolation of the present, which generates a linear character, limits flexibility and makes it less suitable for the cases in Amsterdam. That is because the present situation is not favourable; there is a need for something different and new. The foresight method focuses more on macro-level and is thus useful to acquire a wide variety of alternatives. The focus is on driving forces and their opposites. Due to the macro-oriented character, this method does suffice less for it could be hard to set up specific actions based scenarios on the macro-level. By contrast, the breakthrough method focuses on the individual project level. The broader sociotechnical process is insufficient addressed because of this micro-level focus. Roadmapping method is very technology-focused and lacks societal interaction, which is an essential factor in the Amsterdam cases [15]. Another method that seems well suited for the Amsterdam cases is the STSc method. However, because of the need for guidance towards 'what-should-be' (normative) future vision, the decision is made for BC. The lack of learning processes of BC compared to STSc might be compensated by specifically integrating such processes into the pathway.

Figure 3.3 shows the combination of the two theories. It is proposed that CTA stimulates a common view on how the process and project should progress. The ideal outcome of performing this assessment is a specific set of actions with collaboration as a foundation. The long-term municipal policy then can be translated to present actions via various pathways by using the backcasting theory. The fusion of these actions based on present and future views should form a comprehensive set of actions that support the City of Amsterdam in utilising and stimulating small-scale local initiatives.

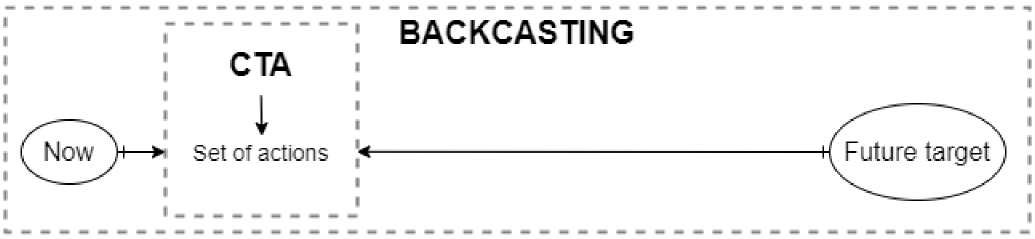

Figure 3.3: Combining CTA and BC (own illustration)

3.5. Conceptual framework

To transform figure 3.3 into a conceptual framework, the actual methods of CTA and BC are further elaborated. Activities and tools are reviewed and converted into a conceptual framework.

CTA starts with societal mapping, which is the mapping of the dynamics of technological developments and can be seen as an extension of a stakeholder analysis. Another method which is an essential achievement of CTA is early and controlled experimentation with new technologies, so-called forceful sociotechnical demonstrators. Together with societal learning, the potential of these methods is seen as high [39, p. 255].

There are three types of actors who are active in providing feedback for technological developments. The CTA framework recognises the technology, societal and meta-level actors.

Technology actors invest in and deliver technological developments (firms, governmental agencies, national laboratories and technology programs). Societal actors provide feedback and anticipate technological developments (governmental agencies, societal groups, also firms and other technology actors). While meta-level actors assign, facilitate and adjust the interaction between technological and societal actors (governments, TA institutions or other institutions). So, responsibility and its nature vary over multiple actors, making all three kinds of actors essential [39, p. 257].

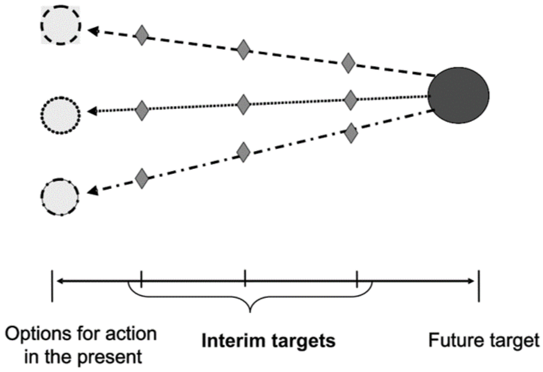

Figure 3.4: Backcasting method [21, p. 82]

Overall there are three criteria for CTA. The first is the anticipation of the broader societal impact of the technology. The second is societal learning, both in first-order (to improve working towards given goals) and second-order (clarifying and relating values to each other). The third is reflexivity, where contrast and conflict between technology and society are avoided and to identify different actor roles for assessment of the presence of all three types of actors.

There are some general CTA strategies. These strategies are referred to as 'the pattern in the actions of actors responding to an evolving situation, which may become reflexive and consciously worked for' [39, p. 258]. They are:

- Technology forcing: inverse anticipation and feedback (demand/societal side)
  - 'The strategy of technology-forcing is to prescribe specifications to be achieved authoritatively. Then, the required technology will somehow be developed' [39, p. 259]. So this is partly the case for the City of Amsterdam. The set targets for 2040, pressured by the targets set by the climate accords can be seen as technology-forcing. Additionally to the accords, the preference for sustainable district heating by the City of Amsterdam could also be seen as a prescribed specification of a heating system.
- Strategic niche management: graded learning and feedback (supply/technology side)
  - The focus of this strategy lies on the emergence of innovations in protected spaces; niches, a shield for experiments from the market selection. Experiments and 'proof-of-concept' projects create innovation trajectories by letting actors learn about the design, user needs and societal acceptability. SNM can thus be seen as a form of reflexive governance for the paths of niches to be modulated into sustainable directions [20, 34, 37, 39].

- Alignment: loci for reflexivity and feedback
  - This strategy aims to create actual spaces and institutionalised linkages between supply and demand. These loci attempt to offer opportunities for the modulation of developments. The use of CTA tools (discussion workshop, consensus conferences) stimulates anticipation, broad and deep learning, and reflexivity. However, often temporary loci that stand distant from the development, making feedback limited. With this strategy, regular connections are created, which means that it is learned how to handle technologies within the network rather than linking supply and demand. It is forceful but might raise barriers for further broadening the development process [39, p. 262].

With CTA, there should be a shared responsibility among all actors for managing the technological change with the common goal of anticipation, learning and reflexivity. On the other hand, differences in interest and potential conflict between actors are required for a sense of urgency to act and learn in the transition. In between a common view and varied interests are the interdependencies among actors. The goal is to let actors accept this dilemma and use it to start co-producing while learning in the process of a transition [39, p. 266].

Step 1: Strategic problem orientation
Setting demands and basic assumptions
System and regime analysis
Stakeholder analysis
Problem and trend analysis
Socio-technical mapping
Step 2: Generating future visions
Idea articulation and elaboration
Generation of multiple perspectives
Creative techniques
Step 3: Backcasting analysis
WHAT-WHO-HOW analysis: technological, cultural-behavioral, organizational, and structural-institutional changes
Stakeholder identification: required stakeholders and actions
Drivers and barriers analysis
Step 4: Elaboration and define follow-up agenda
Scenario elaboration (turning vision into quantified scenario)
Scenario sustainability analysis
Generation of follow-agenda
Transition pathway
Step 5: Embed results and stimulate follow-up
Dissemination of results and policy recommendations
Generation of follow-up proposals
Stakeholder meetings

Figure 3.5: Five steps of backcasting with methods and tools [31, p. 755]

According to [21] there are four phases of backcasting. In the first phase, a future target situation is defined (e.g. abandoning natural gas in 2040). During the second phase, alternative paths are developed and broken down in retrospect from this future target situation into short-term paths. Then, in phase three, the individual steps are defined by asking which actions belong to these short-term paths. Phase four consist of the end product, which are different detailed sets of actions. With these options of action, a concrete strategy can be formulated, or it can just serve as a basis for discussion about bottlenecks. Figure 3.4 is a conceptual representation of the backcasting method with the future target, interim targets and options for actions.

Quist [31, p. 769] has a more detailed explanation of the backcasting method. Actual methods and tools are suggested in five steps (figure 3.5).

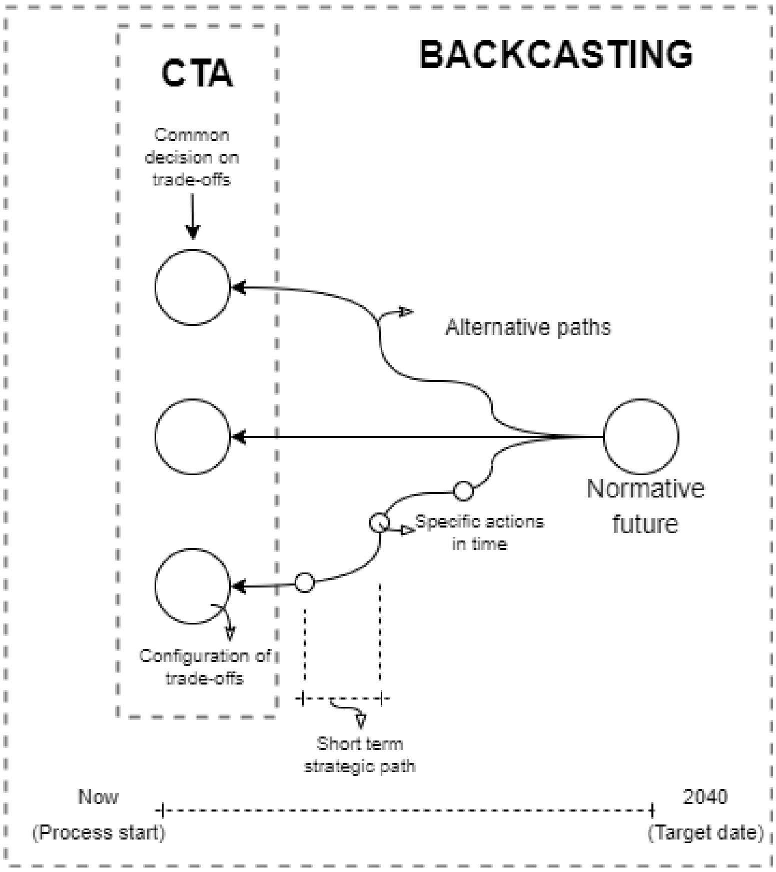

Figure 3.6: Conceptual framework (own illustration)

To combine these two scientific theories into a conceptual framework (figure 3.6), the practical steps of this method are elaborated more thoroughly. For BC, the structure is based on the method suggested by Kosow and Gaßner [21] combined with cherry-picking from the steps suggested by Quist [31]. The idea is that a CTA and the BC method are intertwined and performed simultaneously.

4

Methodology

This chapter explains the research methodology. It is a design based on the conceptual framework (figure 3.5) and consists of six steps with specific actions and deliverables and is presented in table 4.1. Step 1 and 2 are focused on gathering and analysing data from the situation of the Amsterdam heating transition as the basis of the backcasting analysis. Step 3, 4, 5 and 6 are based on the backcasting method. Step 5 is the integration of the CTA method (a survey in this research) in the backcasting method. Next, each step is further elaborated.

4.1. Empirical data gathering

Data is gathered to explore the field of DH using DC WH by interviewing various experts and stakeholders. It is aimed to interview the whole spectrum of stakeholders in the heating transition in Amsterdam where use is made of the network of the municipality. By combining stakeholders mentioned in literature with those known for the situation in Amsterdam (assessed by discussing stakeholders presented in the literature with the supervisor of this thesis from the CTO, City of Amsterdam). Stakeholders of DH networks with DC WH are identified from supply to demand, together with construction and exploitation. On the demand side, there are residents, but also project developers and housing corporations who aim to achieve sustainability targets. On the supply side, there are data centres or other waste heat sources and conventional heat suppliers. Contractors and network operators create an operable system. The municipality is among others responsible for oversight, sustainability target, public interest and area development. Within the municipality are multiple departments (e.g. policy, area development, operational tasks) involved in projects of such scale as DH networks. At least one stakeholder from these groups was interviewed: four market parties (tech scale-up, operator, contractor and data centre association), one residential stakeholder and six municipal officials (with various functions and departments). Appendix A presents the interviewees and their jobs.

Some interviewees are experts on the general heating transition to explore the field of Amsterdam. Others are more specific stakeholders to the two cases but were also asked about the general situation in Amsterdam. A total of 11 interviews with an average duration of one hour were conducted. Use is made of semi-structured interviews for more in-depth data but about the same topics [41], which means that the interviews are bilateral conversations where discussion is simulated. Interview questions are used as an interview guide. In other words, sometimes an interviewee would already answer a question during the conversation, after which it was checked if their answer was valid for that particular question). The interview questions are based on the deliverables of the methodology steps 1, 2 and 3 (table 4.1) and are presented in appendix B. Every interview is transcribed.

Table 4.1: Methodology (based on conceptual framework (figure 3.5))

Action	Deliverable
Step 1. Gather empirical data (chapter 4)	
• Identify stakeholders • Interview experts and stakeholders	Overview of actors with barriers, interests, views on future targets and possible pathways
Step 2. Analyse empirical data (chapter 5 & 6)	
• Identify incumbent regime and system • Analyse current legal frameworks and policy • Stakeholder analysis (barriers and interests) • Perform case studies	Key insights of the Amsterdam heating transition and in-depth insights in practice with case studies
Step 3. Set future target and analyse possible pathways (section 7.1 & 7.2)	
• Set future target based on political decision, policy and actors' normative views • Analyse possible transition pathways based on actors' views	Future target and possible transition pathways
Step 4. Define trade-offs (section 7.2.6)	
• Summarise most important conflicting views from step 2 and 3 • Translate conflicting views into trade-offs	List of trade-offs as basis for configuration of pathways towards future target
Step 5. Create common view for pathway configuration (section 7.3)	
• Survey on trade-offs among representative group of actors • Analyse commonalities and differences • Translate results into implications for transition pathway	Configuration of trade-offs and what it implies for the transition pathway
Step 6. Articulate the transition pathway (section 7.4)	
• Divide the transition pathway into short-term episodes • Describe the socio-technical developments per episode • Describe possible actions for actors per episode	Transition pathway with three episodes containing socio-technical developments and possible actions per actors

The transcripts are analysed using ATLAS.ti. Relevant parts of the empirical data in the transcripts are quoted, and these quotations are linked with one or more codes. The codes are categorised into code groups. Table 4.2 presents what data is required and why (based on what is needed to know to create the deliverables of methodology steps 1, 2 and 3 (table 4.1)), together with the corresponding code group. The ATLAS.ti analysis consists of 11 transcripts with 212 codes in 10 different code groups. The number of quotations differs per transcript from 27 to 52, and the number of codes per code group varies from 7 (learning) to 28 (barriers).

Empirical data in the larger code groups (barriers, interests and transition pathways) could be categorised in organisational challenges found in section 3.1.5. Table 4.3 presents the origin (from organisational challenges from the literature) per code group category.

The ATLAS.ti analysis provides an overview of actors with barriers, interests, views on future targets and possible transition pathways.

Table 4.2: Data planning matrix with related code groups

What do I need to know?	Why do I need to know this?	Code group
General description of Amsterdam heating transition or case project	Creating context	Case descriptions
Which stakeholders are involved and who are the actors	Input for stakeholder analysis	Stakeholders
Current policy, regulations and concessions	Assessing playing field context	Policy and politics
What are the actor interests	Assess common ground and difficulties	Interests
What are the barriers	Assess organisational challenges and opportunities	Barriers
How can policy tools be used	Assess which tools can be used in present actions	Policy tools
How is a learning environment created with experiments	Creating flexibility in the transition	Learning
Actor views on normative future of heat supply	Assess multiple perspectives for future target	Normative view
Actor views on how to achieve that heat supply	Assess multiple perspectives for transition pathways	Transition paths

4.2. Empirical data analysis

In chapter 5, the empirical data is analysed by exploring the general heating transition in Amsterdam. Based on additional desk research, it is explained what the current system and regime look like and which laws and regulation are of effect. The desk research is done by using articles on DH in Amsterdam, Dutch Law and internal (yet unpublished) documents from the City of Amsterdam. Analysis of barriers and stakeholder interest of the Amsterdam heating transition is based on what is found in the ATLAS.ti analysis (appendix C, D and E). Key insights of the exploration are summarised at the end of the chapter to clarify the topics that were mentioned multiple times by different interviewees, which indicates importance. In chapter 6, the two cases are described and analysed. Based on the interview data from the ATLAS.ti analysis, the origin and current status of the projects is explained, together with the project-specific barriers and actor interests (appendix C.8, C.9, E.7 and E.8).

So, chapter 5 provides insights into the socio-technical dynamics of the Amsterdam heating transition on a city-wide level. Chapter 6 investigates in-depth how this relates to practice in two very different projects. By combining these analyses, it is aimed to form a comprehensive overview of the Amsterdam heating transition as the basis of the backcasting analysis and articulation of the transition path.

4.3. Future target setting and pathway analysis

The target situation is based on political preference, actors' views on future heating and existing and required policy. The normative views are analysed based on interview data from the ATLAS.ti analysis (appendix G).

The views of actors on how sustainable district heating is achieved are also analysed based on the ATLAS.ti analysis (appendix F). Together with conflicting ideas, barriers and uncertainties found in the analysis of empirical data, the possible pathways are analysed.

Table 4.3: Organisational challenges with barrier code group

Organisational challenge	Barrier code group
Legal framework	Legal
Role of energy policy	Policy
Awareness	n/a
Ownership	Ownership
Economic feasibility	Financial
Intra-municipal tensions	Municipal
Collaboration	Collaboration
Other challenges	Divided under other groups

4.4. Trade-off definition

From the previously described analysis of barriers, stakeholder interests, normative views and transition pathways, the conflicting views are summarised in section 7.2.6 to define the trade-offs. Conflicting views are topics that return multiple times, in two extreme forms. The two extremes are not the only possible decisions; there is a variety of 'degree of' possible. An example is public versus private ownership (the two extremes). It is possible to have a public-private partnership, which lies in the middle of the scale. Nevertheless, a partnership with public initiative, but private investment and realisation, tends more to the private side. So a trade-off by all actors is necessary to define the configuration of these conflicting views. Next section describes how these trade-offs are configured.

4.5. Survey set-up

Initially, it was intended to use the CTA method to form consent about conflicting views. This way, one alternative pathway is created for the backcasting analysis. It was aimed to do this in a discussion workshop with specific stakeholders and municipal officials. However, due to the crisis around Covid-19, the set-up is changed to a survey.

The survey is created using google forms. The five trade-offs are explained after which the respondent can answer on a scale of one to four. On both ends of the scale are the extremes of the trade-off (e.g. public versus private: answering option 1 means that according to the respondent, ownership could be organised publicly, and answering option 4 means privately. Options 2 and 3 are implemented to apply nuance possibilities). The formulation of the five trade-offs as questions is presented in section 7.3. With every question, the respondents are asked to explain their choice. The seven respondents are aimed to be a representation of the stakeholders (different municipal departments, private party, residents) and presented in section 7.3.

This set-up means that there is a simplification of the scale between the two extremes of the trade-off. As pointed out in 4.4, the 'degree of' has numerous possibilities which means that many hybrid forms are possible (more than only four). Also, the presence of one does not necessarily exclude the other. However, to stay within the scope of this research and be able to analyse the amount of data, the trade-off scale is simplified to four steps.

The analysis is performed by combining the answers into an explanation of the configuration per trade-off. The implications of the survey results for the transition pathway are described and visualised per trade-off throughout the pathway (figure 7.6 to 7.10). These visualisations are based on the researchers' interpretation of the survey answers and used to provide an overview of the survey's implications. There is no quantitative substantiation or validation for the visuals. The levels on the scale between the two extremes of the trade-offs (x-axis) are an approximation and suppose to show the relative differences in 'degree of'. Possible further research could quantify such visualisations using a quantitative survey among a larger group of actors. Then the municipality has a more accurate approximation of trade-off dynamics which could be used as support for policy-making.

4.6. Articulation of the transition pathway

The transition pathway is based on the analyses from the previously explained steps and is divided into three episodes for short-term strategies. Each episode contains an explanation of the expected socio-technical developments and barriers, together with actions for actors. The articulation of the transition pathway is presented as a result of this research in section 7.4.

5

Heating transition in Amsterdam

In this chapter, an explanation of the current situation of the heating transition in Amsterdam is given. Main barriers are highlighted, and an analysis of stakeholder interests is explained. It is aimed to get a comprehensive view of the situation of the heating transition in Amsterdam.

5.1. System and regime

At the moment, there are two major parties with a high temperature (HT) DH network in Amsterdam. The largest is owned by Vattenfall (previously Nuon Warmte) and is heated by a large gas-driven combined heat and power plant (CPH). The other party is Westpoort Warmte (WPW), a joint venture between the Afval Energie Bedrijf Amsterdam (AEB) and Vattenfall (each owning 50%). AEB is 100% owned by the City of Amsterdam. So the source of this network is the waste incineration plant of AEB [32]. For residents with a dwelling connected to DH, there is no choice for heat supplier in Amsterdam other than the one operating in that area (Vattenfall or WPW). So, one could argue that there is a monopoly by Vattenfall in the Amsterdam heating sector and that this could also be the case for future dwellings because currently there are new-built areas where the municipality already made concession agreements with the incumbent parties. Together with the existing monopoly, such concession agreements have to be taken into account while developing transition paths.

5.1.1. Current laws and regulation

Laws and regulation on national level:

- **Heating law (Warmtewet in Dutch):** Heating is classified as a primary utility. Because local DH does not have a national network, most consumers do not have a choice in supplier (contrary to electricity, for instance). Like DH in Amsterdam, this creates a natural monopoly for the heating producer. So the heating law is designed to (financially) protect residents with a dwelling connected to DH. Contents of the law are tariff maximums, contractual requirements, measuring heating use and the consumers' rights (such as compensation) and disconnection [3].

Ministry of Economic Affairs and Climate is currently working on the new heating law: Heating Law 2.0 (HL2.0). This law focuses on market organisation, tariff regulation and sustainability, and provides more responsibilities for municipalities to direct the heating transition. Market organisation is a set of laws and regulations. It describes which private parties can be active, what the boundaries are, and the choices available for the consumer. It has the aim of balancing competition and regulation and is intended to focus on neighbourhoods. Municipalities will be able to appoint areas for collective heating systems. The heating company will also be appointed. This company is then responsible for providing a system that is cost-efficient, sustainable and reliable. New regulation of tariff should provide feasible business cases, with reasonable profits [48]. This approach is similar to the Danish model, where the municipality decides who and where DH systems should be located. The competition also happens before exploitation. The difference is that in Denmark the private parties or residents' collectives can file their plans for new heating systems on which the municipality approves [30]. This approach is more bottom-up than what is likely to happen in the Netherlands (i.e. area and system allocation by the municipality).

- **Environment and Planning law (E&P law)(Omgevingswet in Dutch):** Revision of the E&P law should act as of 2021. The law combines and simplifies laws and regulations. An integral vision of sustainability is the focus. It should accelerate decision making. With its aim to 'make it easier to start up projects', this law provides (policy) tools to integrate the heating transition in area development. Tools are the Environment and Planning vision and plan. This vision should articulate the municipality's vision, ambition and goals to make areas more sustainable in the long term. Residential input is essential. The plan is a legalised and more detailed version of the vision [6].

  This law provides opportunities for the municipality to integrate sustainability more quickly in urban development. So, in 2021 the legal process will be easier for implementing DH.

- **Ban on natural gas for new-built:** According to the bill Progress Energy Transition, all new-built dwellings should be natural gas free as of July 1st, 2018 [13].

Laws and regulation on municipal level:

- **Heating plan (Warmteplan):** Legal document specific development of a DH network. It provides the municipality with the opportunity to oblige connection for dwellings and lasts for at least ten years [9]. This way, it is more attractive for investors.

- **Permits (Vergunningen)**: Various energy systems require permits. The municipality can, for instance, appoint areas where it is forbidden to create new sources for heating pumps.

- **Procurement law (Aanbestedingswet):** System preferences can be specified in tenders.

- **Land issue (Gronduitgifte):** The municipality of Amsterdam owns about 80% of the land. With the land issue, the municipality is responsible for the development process. It can also issue redevelopment of existing areas.

- **Crisis and Recovery law (Crisis- en herstelwet):** This law makes it possible for the municipality to already experiment with parts of the E&P law.

5.1.2. Current policy

Policy on national level:

- **Regional Energy Strategy policy (Regionale Energie Strategie (RES)):** National and long-term approach for integrated energy and climate strategies. These strategies should provide insights into potential renewable energy sources and infrastructures. The final version will be finished before 2021. Together with the local heating transition vision, this strategy should provide a preferable heating system and a timeline [5].
- **SDE++ subsidy:** This subsidy is a national incentive scheme for renewable energy. An exploitation subsidy can cover the financial gap in a business case of renewable energy technologies. In this case, projects using DC WH could claim money to close their business case.

Policy on municipal level:

- **Amsterdam City Deal:** 'Towards a city without natural gas' is a document where the goal of being natural gas-free in 2040 is stated. A regional DH network for 400.000 dwellings should be made in collaboration with regional parties (housing corporations, water department, utility companies) and the municipality. Use of fossil fuel should be phased out by 2040 [4].
- **Motion low-temperature :** In 2017 a motion passed the City Council where it is decided that all new-built dwellings should be connected to LTDH.
- **Coalition agreement participation:** There is a coalition agreement that that one of the first three neighbourhoods in Amsterdam should do the heating transition (implementing LTDH) with the use of extended participation.

Policy tools:

- **The Amsterdam Energy Sourcebook (Het Amsterdamse Bronnenboek):** Overview of available heating (and cooling) sources in Amsterdam. It provides a framework of information to base decisions about the most optimal (combination of) energy source in the area.
- **The Assessment Framework:** Framework that guides decision making on heating systems. Trade-offs should be assessed following the topics affordable, open and sustainable. Other City Council ambitions are flexibility and future proof.

5.2. Barriers

This section presents barriers that are being run into by actors in the heating transition in Amsterdam. Barriers are categorised under the code groups presented in **??**. Appendix C presents the code network and barriers per category. Next, the barriers are further elaborated.

5.2.1. Policy barriers

For the policy barriers, some suggestions on policy changes are made. The overall view is that the current policy is insufficient, or at least lacking a clear municipal vision for the heating transition. Also, it is mentioned that 'policy is often lagging on development in practice' (interview 3, also mentioned in 1, 2, 10 and 11). Some concrete policy barriers mentioned are the lack of market organisation and that there is no tool to oblige consumers to DH. Integrating market organisation in municipal policy should be possible when HL2.0 comes into effect (section 5.1.1). Connection obligation should be a tool to force residents to switch from gas to DH. Such tool reduces loading risk, which might make private investment in DH more attractive. Now, the municipality can force DH connection in new-built areas by using a heating plan (section 5.1.1). However, there is no clear and comprehensive vision or policy on obligating residents to connect to DH.

5.2.2. Ownership barriers

Ownership barriers are regarding the ownership of the heating transition, DH network and DC WH. The main ownership barrier is the ambiguity about the role of the municipality. At the moment, this role officially is undefined. So the municipality acts each project differently, from passive to facilitating to pre-investing in the network. A decision about the municipality's position on a scale with public and private ownership as extremes should solve the issue by providing clarity.

Other ownership barriers are concerning the monopoly of the incumbent energy company. This barrier is also mentioned under other challenges in sub-section 3.1.5 and the situation in Amsterdam is explained in sub-section system and regime 5.1. Multiple difficulties come with a monopoly. One is that market competition often fails to materialise due to higher investment. The transporting infrastructure is already present and owned by the incumbent party, which means new parties face additional investment for a distribution network or should partner up with the incumbent party (interview 8 and 12). Another downside of a monopoly is that it confines the choice of energy producer for the consumer (interview 6). Also, the network in Amsterdam is an HTDH system which makes it challenging to connect with low-temperature. Despite the political preference for LTDH in new-built, it is hard to realise such systems because there often already are underlying concessions with the incumbent energy company for the development area (interview 4 and 8). This monopoly barrier might be surmountable with the new HL2.0 due to new legal possibilities for the municipality to steer the market.

5.2.3. Financial barriers

There are some financial barriers mentioned for the heating transition in Amsterdam, which means that costs are too high or the business case is not feasible. DC WH causes some financial barriers. It is expensive to transfer heat from data centres, while the temperature of waste heat is relatively low. For existing buildings, additional isolation or temperature upgrade is necessary (interview 1, 2, 4 and 10). Additionally, there is a mismatch between the duration of business cases of data centres and DH networks. For DH networks, the lead time for a business case is at least 30 years. However, for data centres, it is uncertain if they are still operating at a specific location in 10/15 years. So data centres are not able to guarantee to be a waste heat source for the entire duration of the DH business case, which is significant uncertainty for investors (interview 2, 5 and 10). Another uncertainty is the loading risk, which is the risk of insufficient dwelling connections to the DH network. This risk could be mitigated with the previously mentioned connection obligation policy tool. The SDE++ subsidy (mentioned in section 5.1.2) could also help close such gaps in business cases.

Currently, a viable DH business case is challenging without public financial support. Next to subsidies like SDE++, pre-investment is an available policy tool (used in case 2, section 6.2). However, subsidy funds are finite, and pre-investing is not feasible for the rest of the heating transition in Amsterdam. Business cases should in-time become more feasible.

5.2.4. Legal barriers

Some barriers to the legal framework are already mentioned in section 5.1.2. Barriers such as market organisation and heating law might disappear or become less when the HL2.0 comes into effect. Hopefully, this law also provides an opportunity to force a DH network to be open (third party inlet). It might be difficult to provide freedom of choice for residents. The intended DH networks have multiple sources, so there is no opportunity to decide who supplies the consumers' heat. A municipal policy, like the assessment framework, should safeguard residents from paying too much.

Another legal barrier is regarding collaboration with residents (public cooperative partnership), and is mentioned explicitly for case 2, but applies to the overall situation in Amsterdam. It is still unclear whether it is legally possible to partner with a residents' collective officially and award them the DH network. Usually, the European procurement law would apply. Legally this is a grey area. It depends on the extent of residential participation, how many legal changes are necessary. This depends, in turn, on the aim of the municipality to provide influence for residents during the heating transition.

5.2.5. Municipal barriers

As mentioned in sub-section 3.1.5, it is possible to encounter intra-municipal tensions. During the interviews, multiple municipal barriers are mentioned. Some barriers concern the political trade-offs about the heating transition, such as the political arena and multi-city councillor decisions. For this research, such political issues are seen as external forces.

Other municipal barriers are regarding the size of the municipality of Amsterdam. Because the municipality is relatively large, it is often unclear who is responsible or whom to contact for external parties, but also internally (interview 2, 6, 7 and 12). Also, tensions have arisen about the administrative process. The focus seems to be too much on risk-averse before addressing City Council (interview 12). This way, it is difficult for policymakers to provide adequate policy.

The most critical municipal barrier is the trade-off that is also related to ownership, the degree of participation. This barrier is addressed under municipal barriers for it is an administrative decision of area development. The trade-off has top-down and bottom-up initiative as extremes. So a decision between the planned marking of transition areas (top-down) versus the use of empowerment of local initiatives (bottom-up). The legal barrier of public cooperative partnership is related to this trade-off.

5.2.6. Collaboration barriers

Difficulties resulting in collaboration barriers are the multi-stakeholder environment of DH projects. In existing neighbourhoods, the municipality also has the aim to integrate the construction of DH network with other projects underground such as sewage system, electricity network and public space (interview 1, 3 and 4). Such activity integration is seen as a barrier to the acceleration of the heating transition.

5.3. Stakeholder interests

This section presents the stakeholder interests in the heating transition in Amsterdam. Interests are also categorised under the code groups presented in **??**, and appendix D presents the code network and interests per category. Appendix E presents interests per stakeholder. These interests are discussed next.

5.3.1. Municipality

The municipality is primarily represented in the number of different interests which is mainly due to its essential role (appendix E.1). No interviewee mentioned interest for the municipality regarding the collaboration category which suggests that either there is sufficient collaboration currently, or that there is a lack of awareness. Most interests are about the municipal organisation and policy, which sounds reasonable, given that these are categories that can be influenced internally. Overall, the interests of the municipality come down to executing the will of politics, serving the public best. However, this causes some contradictions, such as the interest of planned and effective redevelopment and local initiative incentive—the first requiring a top-down approach with little room for participation. By contrast, the bottom-up approach of local initiatives demands time and effort in collaborating and empowering residents. So, the extent of participation is still a question. Another pair of conflicting interests could be a market incentive and control for residents. Transparency in the heating system is vital in the latter, though hard to demand from private parties. It is important to decide in which way the municipality should organise this in the procurement of DH systems.

Organisational interests for the municipality are creating a learning environment around heating transition projects and integrate multiple disciplines in (re)development projects. In the interviews, multiple forms of preferred learning are addressed (figure 5.1). Although it is often mentioned that there is a preference from politics to create a learning environment, inpractice, this often seems not organised yet (interview 1, 4, 11 and 12). With extra focus, this could be a relatively easy implemented long-term benefit. Project integration is further developed and visible in case 2.

It requires additions to the legal framework to fulfil the interests of effective policy and residents freedom of choice. The exploration of the exploitation model is case-specific and will be further elaborated in the description of case 2 (section 6.2).

5.3.2. Contractor

The interview with the contractor was mainly about case 1. However, it was mentioned that these case-specific interest also applies to the general heating transition in Amsterdam. Especially the low-risk investment interest applies to all private parties since investments are financed by banks. The requirement of the banks for these loans are often very similar, with a focus on low risk. Also, interest in meeting sustainability targets for public relations

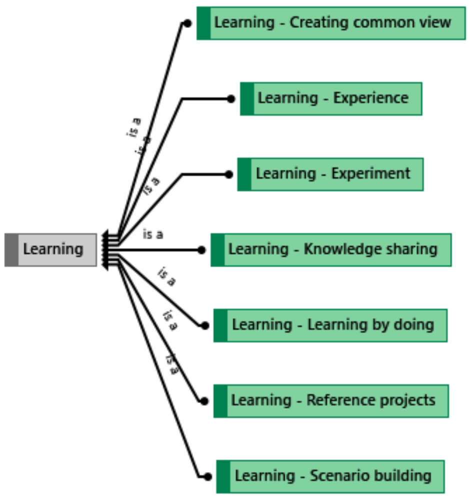

Figure 5.1: Suggested forms of learning environment

purposes is something we see in many companies nowadays. As mentioned in section 1, climate change awareness has grown, which results in increasing societal pressure. This landscape force will be further elaborated during the backcasting analysis (chapter 7). It is assumed that most of the contractor's interests also apply to the project developer because they work closely together in a consortium in this case (because of the scope of the research, there is not a separate interview with a project developer).

5.3.3. Data centres

In 2017, Dutch data centres made a 'popular statement' by saying: 'come get our waste heat, because it a missed opportunity to blow it into the air' (interview 10). This statement returns into the interest of meeting sustainability targets for public relations (same as with other private parties such as contractors, mentioned above). Also, additional interest in meeting sustainability targets is the reduction of energy costs for the data centres. With waste heat delivered to a DH system, the returned cooler water increases cooling efficiency, so less energy is required for air cooling. Such thrive for efficiency is also mentioned as a separate financial interest for data centres. For DH projects that use DC WH, the interest is to have an effective policy and a collaboration with the municipality to achieve an optimal business case for all parties. All in all, similar to the contractor's interest, one could say an overarching interest of optimising business cases is implied.

5.3.4. Network operator

For the network operator, collaboration with the municipality is important. When there is an official collaboration, 'a (semi)public DH network can be achieved, which minimises loading risk. Especially when there is a law for connection obligation, risks for private parties are reduced' (interview 8). Also, it is in the network operator's interest to integrate multiple utility renewal projects into one. In the front-end development phase, this will cause more effort, but in the end, it will be more cost-efficient.

5.3.5. Start-ups

The most significant interest in start-ups in the data centre sector is a practical policy. Because the future is already relatively uncertain, they require a clear vision and policy. Specific for the data centre business, they would like for the municipality to organise an environment where innovation is increased. An example could be an 'innovation lab for data centre efficiency, so that universities, governmental organisations, data centres and tech start-ups can collaborate in making the data centre business more efficient and sustainable' (interview 2).

5.3.6. Residents' collective

The interests of the residents' collective are mostly specific for case 2. These will be more thoroughly explained in the description of case 2 (section 6.2). Nevertheless, again, most interests also apply to the heating transition situation in Amsterdam in general. The interest in affordable heat is assumed to be essential for all residents in Amsterdam. A more profound way of serving that interest is the wish for more residential control in the decision for which parties are involved and which heating system will be constructed. It is mentioned with this interest that transparency (particularly in costs) is critical. The extent of residential control is suggested to be on a scale from voting to being a board member of a collective. Clarity on issues like these should return in effective municipal policy.

It is imaginable that the interest of utility project integration applies to most of the residents. Nuisance will be less if the streets will be broken up only once (though probably for a little longer). Consequently, the residents are dependent on the municipality to facilitate such project integration. Independently of the interest of minimising nuisance, it is mentioned by interviewee 7 (board member residents' collective) that there is an interest of collaboration with the municipality. However, what is experienced is a reticent attitude by the municipality. This could be case-specific (and will be further elaborated in the description of case 2 (section 6.2)), but the reason suggested implies that it has to do with the situation in general for Amsterdam. This interest is also represented in the form of a barrier: Amsterdam having a large municipality. 'I have experienced that it is easier to form a collaboration with smaller municipalities. Officials that are responsible for the heating transition are with few, so they are eager to benefit from private and local initiatives. In Amsterdam, there are many advisers on the heating transition, which results in us being unnecessary' (interview 7). Real collaboration between residents and the municipality could thus be difficult.

5.4. Key insights of exploring the Amsterdam heating transition

Some key insights of the results presented in this chapter are listed next. These are insights into the socio-technical dynamics of the Amsterdam heating transition on a city-wide level. Next, chapter 6 investigates the heating transition more in-depth in practice. Combining the key insights provides a comprehensive understanding of the Amsterdam heating transition as the basis for the transition pathway. Currently, there is an unbalanced market for heating in Amsterdam because of a monopoly by the incumbent party (Vattenfall). However, in 2020 and 2021, HL2.0 and E&P law come into effect. These laws provide the municipality for adequate policy on market organisation (which might solve many policy and legal barriers). The municipality is currently working on multiple policies for the short-term (assessment framework, Amsterdam Energy Sourcebook, motion LTDH). However, there is still a lack of a clear vision and policy for the Amsterdam heating transition by the municipality. Although private parties are driven towards sustainability by societal pressure, it is challenging to create feasible business cases without public finance. So there is need for financially secure business cases for DH with DC WH.

Some trade-offs are found in the exploration of the Amsterdam heating transition. There is a trade-off about ownership. It is still undefined if the heating transition initiative should be public or private. Another trade-off to be made is about the degree of participation. The question is if DH projects should be organised and planned in a top-down or bottom-up manner. The third trade-off is about the degree of collaboration. Because the City of Amsterdam is such a large municipality, difficulties in collaboration are experienced by other actors. Almost every actor mentioned the interest of having a formal collaboration with the municipality in DH projects. What returns is that the municipality could optimise the organisation of a learning environment, both internally and with external actors.

These insights are combined with the results from chapter 6 and chapter 7, to find the preferred path for the heating transition in Amsterdam, including a set of actions. So, together these insights form the basis for the backcasting analysis and the essential elements for the final transition path.

6
Two Amsterdam district heating projects

This chapter describes the two investigated cases more thoroughly based on interview data with the aim of a more in-depth understanding of the practice in the Amsterdam heating transition. Origin of the initiative, current status and case-specific barriers and interest are explained, after which useful insights for the BC analysis are concluded.

The two cases have different characteristics, but both plan a collective DH system with the use of WH form DC. Case 1 (Bajes Kwartier) is a redevelopment project of a former prison area, the Bijlmerbajes, that is awarded after tendering. Case 2 (Middenmeer Noord) is a renewal project of several underground utilities in Middenmeer Noord in the Watergraafsmeer, where residents saw a window of opportunity to take the initiative in the heating transition.

Concerning small-scale local heating transition initiatives, the Bajes Kwartier case is more common than the Middenmeer Noord case. The reason for the Bajes Kwartier case to focus on a sustainable heating system originates from the tender criteria. So the initiative for sustainable DH was stimulated by the municipality via tender criteria. Also, the field of stakeholders often is different because it is a redevelopment project with a change of the function, which means that there are no current users of the area. The Middenmeer Noord case is a renewal project to replace old utility infrastructure in an existing neighbourhood, where the municipality was asked by residents to make a transition to a new heating system. So here the initiative was bottom-up. The field of stakeholders is more diverse and thus more complicated to manage compared to case 1. The Bajes Kwartier case is thus seen as more 'business-as-usual' (BAU) in this research. A project such as a case Middenmeer Noord is new to the municipality and is attractive due to redevelopment of existing infrastructure and participation with a residents' collective.

So, the analysis of the Bajes Kwartier is more concise because The Middenmeer Noord case is more complicated than the Bajes Kwartier case in terms of the organisational process. After all, there are more stakeholders with conflicting interests and barriers. Also, throughout the project, there were many scope changes which shifted interests and increased complexity. The Bajes Kwartier case has fewer parties involved, and the assignment is already contractually defined. The involvement of the municipality is also less than in the Middenmeer Noord case.

6.1. Case 1: Bajes Kwartier

6.1.1. Origin of initiative

Redevelopment of the former prison area Bijlmerbajes is initiated by the City of Amsterdam in the form of a tender. The tender was awarded in September 2017 to a development consortium named Bajes Kwartier, consisting of developer AM (a subsidiary of contractor BAM), asset management firm Cairn and private investment firm AT Capital. The consortium bought the 7.5 acres area from Rijksvastgoedbedrijf (governmental real estate department) for 84 million euros. The area will have an urban look with much green. It will be energy-neutral [43] because part of the tender strategy was focused on sustainability. After all, that was an essential factor of the award criteria. Although, the interpretation of how was entirely up to the market. In collaboration with BAM Energy Systems, the consortium set an Energy Performance Coefficient (EPC) of 0 as a target, which means that the project should become energy neutral. This strategy resulted in the decision to not connect to the existing HTDH network from Vattenfall. It was decided to construct individual heating pumps using a collective source as base heat for dwellings. Because such a collective source declines ground temperature (which is forbidden by permit), a source for regenerating ground temperature is necessary. Use could be made of surface water nearby, or a connection could be made to the adjacent data centre. The latter being most effective, that is why the consortium intends to utilise this waste heat source if the business case is feasible. Two larger connections to the base source are for a school and the commercial area and will be collective systems with back-up from the existing district heating network from Vattenfall for peak demand (interview 5).

The energy will be supplied by Bajes Kwartier Energie B.V., a disguised energy company formed by BAM Energy Systems and a partner. They will deliver heating, cooling and electricity from PV panels. Therefore there is no possibility for future residents of Bajes Kwartier to choose from which party they want to buy heat. Dwellings are connected to the regular electricity grid, however. Because Bajes Kwartier Energie is the owner of the heating pumps, they become supplier and producer. Transferring the heating system and PV panels to owners' association is seen as 'difficult. Therefore the consortium chose for a professional party who owns the system and sells energy to the homeowners' (interview 5).

6.1.2. Current status

Currently, the consortium is awaiting a response from the municipality. In a meeting, the consortium addressed implications of using DC WH and asked the municipality for support. The primary barrier is getting the business case feasible. Adjacent DC is willing to provide produced WH. However, connection to the cooling system and transfer from hot air to water has to be made by the party that wants to use the WH. Also, the DC cannot guarantee WH for more than ten years. So the DC has a positive but passive attitude, which means that the investment for the pipe and the connection to the WH has to be made by Bajes Kwartier Energie. Interviewee 5 claims that 'such investment would only be feasible for their business case if they have a guaranteed period of 30 years of WH. So the business case fails with the heat source guarantee period.'

Now the question for the municipality is: are they willing to support the business case? Bajes Kwartier Energie, together with the consortium Bajes Kwartier, suggested a form of

Figure 6.1: Impression of the Bajes Kwartier [2]

risk division. If the DC disappears within 30 years, the required investment to switch source should be covered by the municipality. Arguments for this strategy are that the area could connect to the DC with an open system. The DC has much more capacity than required for the area. Other systems could connect in the future. It is their view that a public party like the municipality should have a broader, more societal scope and therefore support initialisation of potential project integration such as an open LTDH system using WH from DC (interview 5).

At the time of this research, it is unclear where the municipality stands. From interview 1, it is clear that the municipality thinks that the risk of not having the 30-year heat supply should be borne by the operator (Bajes Kwartier Energie in this case).

6.1.3. Barriers

Main barriers for case Bajes Kwartier to construct DH using DC WH are:

- No 30-year period guaranteed WH source
- Business case with a too high-risk profile
- Alternatives (though less favourable) possible without external parties
- Unclear whom to contact at the municipality
- Unclear process of the municipality

6.1.4. Actor interests

Bajes Kwartier's interests:

- Formal collaboration with municipality
- Risk coverage by municipality
- Societal scope by municipality

The municipality's interests are not apparent for this specific case. By awarding the tender based on high sustainability standards, the municipality stimulated the market to create sustainable heating. Because the municipality is now probably focusing more on areas that do not meet sustainability targets, the potential of stimulating a collective heating system for integration opportunities for a more substantial area might not have occurred to them. For the contractor, it is challenging to create such awareness because it is unclear who best to contact within the municipality.

6.2. Case 2: Middenmeer Noord

6.2.1. Origin of initiative

As mentioned in 2.2, the case Middenmeer Noord can be described as a local, bottom-up initiative to transform the heating system of the neighbourhood to a system which does not use natural gas. It started in 2013 with a local initiative, consisting of a residents' collective (MeerEnergie) and the heating department of a utility company (Alliander), for the construction of a small DH network that is connected to the cooling system of the outdoor ice skate track Jaap Eden Baan. The heat that releases while cooling would be used to warm the DH water, which did not seem very useful, for when it was freezing the cooling system is switched off. However, the idea then arose to lay a pipe to the adjacent DC, connecting the WH source to a future DH network. After pitching the idea to the city district council, the project accelerated.

Figure 6.2: Location Middenmeer Noord in de Watergraafsmeer in Amsterdam [1]

There were already plans for a major underground system renovation, together with the public space, initiated by the urge for the renovation of the sewage system by Waternet, the responsible public authority for drinking water, water management and the sewage system in Amsterdam. At that time, in 2014, the energy transition was not a primary point on the political agenda yet. Initially, the plans were also to renew the gas pipes, the electricity cables and the public space. Nevertheless, in the spirit of transformation to a heating system without using natural gas and for efficiency reasons (the streets would be broken up), at the beginning of 2018, MeerEnergie asked politics to consider constructing a DH network with themselves as the heating operator. This way, it would save money and nuisance. For efficiency and sustainability reasons, the DH network should connect to the adjacent DC (Equinix) as a WH source. According to interviewee 7, the main driver for the residents to form a cooperative is to 'achieve climate targets together with the municipality while keeping a grip on the transition.'

At first, the municipality did not feel much for the idea because they were already working on the plans for four years (since 2014) and they were nearly finished. Nevertheless, in 2018, it went all the way up to City Council who passed a motion to at least investigate the possibility of the construction of a DH network and collaborate with MeerEnergie. Developers of the municipal engineering firm (IB) came up with three different scenarios. The first scenario suggested continuing present plans because constructing an additional system for DH is not feasible. The disadvantage is missing the opportunity for the energy transition. The second scenario suggested starting all over again with MeerEnergie as a heating company who would exploit the DH systems (act as operator). Here the disadvantage was that it would take too long to form a residents' collective with sufficient members and resources, while the sewage system renewal was too urgent. So the officials of the IB came up with a third scenario which consisted of two sub-scenarios. The first being to redesign the plans, taking into account the required space underground for a future DH system. Disadvantageous was that the streets had to be broken up again within ten years, which is more expensive and causes nuisance twice. Second sub-scenario was for the municipality to integrate the construction of a DH network with the integrated renewal plans already present. This way the municipality pre-finances the network and transfers (sell) the network later on (to MeerEnergie or another party). Risks of not selling the network were seen as relatively low because it was unlikely that the policy of abandoning natural gas would be turned around (interview 4). However, the investment made by the municipality is around 12 million euros, a fifth of the total cost (interview 3). Additional construction of, for instance, substations and connections to individual dwellings is still required. So the exploiting partner whom the pipe network is transferred to needs to invest additionally.

A process of political decisions started around the issue. The Alderman of public area development and sustainability stimulated the issue, and it was decided that money had to be made available for the execution of the second sub-scenario (pre-financing and constructing the network of pipes). Agreements had to be made with the MeerEnergie on their development and their feasibility.

6.2.2. Current status

The IB is simultaneously working on two processes in the integrated project in Middenmeer Noord. One for the realisation of construction, currently in the design phase, the other is the process of finding a heating operator to transfer the network of pipes too. For this research and case description, there is a focus on the latter. Currently, the process has stagnated. Municipal officials from the IB and policymakers are now investigating which role the municipality should take. In this investigation, there are two tracks. First, the possibility of collaboration with the residents' collective is investigated, a search into the legal boundaries in privately transferring the network to a party. More important is the assessment of the capacity of MeerEnergie. They are required to provide a detailed plan of action to assure the municipality that they can run a million euro heating operator company. So here the municipality acts passively. At this moment, the MeerEnergie has official partnerships with Firan (a subsidiary of Alliander) and adjacent data centre of Equinix. Second, the IB investigates a way of transferring the network to the most qualified private party, which probably will result in the form of concession or tender (interview 3 and 4).

Because of this approach taken by the municipality, it is uncertain if the transition will be realised with the use of initiative from residents, despite that the idea originated locally. As long as there is uncertainty, the process towards transferring the network (whereafter connection to dwellings should make the system operable) is slowed down. City Council will decide which path to take (interview 3 and 4).

6.2.3. Barriers

From interview data specific for the Middenmeer Noord case (interview 3, 4 and 7), the main barriers are presented in figure C.9. The figure shows which interviewee mentioned the barrier and a brief description of the barrier.

Notable are the barriers addressed by both municipal officer of interview 3 and the board member of the residents' collective. The municipal officer of interview 4 only was involved in the early phases of the project, which might be the reason why there are little commonalities with the other two interviewees of this case. All barriers are input for the backcasting analysis and constructive technology assessment.

6.2.4. Actor interests

Analysis of interests of actors, in this case, is presented in figure E.8. Stakeholders connected to particular interests are seen as actors in this case. There is a common interest in 'control for residents'. Other interests, such as 'sustainability targets' and 'local initiative incentive' are expected to be shared. This assumption is based on the overall vision of the municipality to stimulate the heating transition and on the willingness of the residents' collective to cooperate with the municipality.

Table 6.1 presents the conflicting views of the municipality and MeerEnergie directly summarised from the interviews (3, 4 and 7).

6.3. Key insights of the two case studies

The interest of the private parties and the residents' collective in collaborating with the municipality returns in both cases. The difference is that the private parties in case 1 are not dependent on the help of the municipality. Their interest is a more sustainable DH system with the use of the financial means of the municipality (covering the WH guarantee risk of DC). The residents' collective needs a formal collaboration with the municipality before they can execute their plans. However, the municipality demands a certain level of capacity because the residents' collective wants to act as a private heating operator.

Table 6.1: Conflicting views municipality and MeerEnergie

City of Amsterdam	MeerEnergie
Responsibility to critically assess capacity of potential partners	Incomprehension regarding the lack of embracement of local initiative and collective
Marking transition neighbourhoods where possible, focus on planning	Collaborate with residents, making use of local support and enthusiasm
Detailed plan of action before collaboration	Collaboration before investing spare time, money and resources into plan of action
Bottum-up and top-down is complex	Bottom-up should be leading
Attitude of residents can be bothering because municipality constructs the network	Incomprehension for the effectiveness, who will object to a transfer to residents
No specific 'need' for collaboration with residents but political preference	Residents are 'needed' they should be able to have a say in their energy system
Assurance on capacity and an open attitude from residents towards other forms of local control required	Project lead that is willing to stick his/her neck out for residents' collective within the municipal organisation.
Assess best process for result most optimal within assessment framework 'affordable, open, sustainable, reliable'	Collaboration with municipality and residents' collective as private party operator

There is a dilemma on how to organise collaboration in these DH projects. One the one hand, the municipality is open to collaboration but wants capacity assurance and is used to appoint assignments and take an assessing role. On the other hand, the other actors want a formal collaboration to increase sustainability opportunities and financial resources.

Actors in both case Bajes Kwartier and Middenmeer Noord mentioned difficulties in finding the right person to contact because it is often unclear which department to address, or the contact person was changed.

An apparent trade-off in case Middenmeer Noord is the degree of participation. The municipality wants to plan as much as possible in a top-down manner and participate where possible. The residents' collective would like a more bottom-up approach to the heating transition.

7 Backcasting analysis

Previous chapters 5 and 6 specified system dynamics of the heating transition in Amsterdam. A backcasting analysis will be performed in this chapter to guide the heating transition in Amsterdam towards a future goal. The analysis follows steps 3 to 6 from the methodology (table 4.1) based on the four steps of backcasting suggested by Kosow and Gaßner [21] and the five steps of Quist [31]). However, for the scope of this research, creating short-term individual steps in the transition pathway is switched with the creation of a common view using CTA. This way, only one pathway (instead of all scenarios) has to be elaborated. The backcasting analysis in this chapter consists of:

1. Target situation (normative view of future heating system)
2. Possible alternative pathways (scenarios towards such target situation)
3. Create a common view for pathway configuration decision (CTA workshop/survey for final pathway decision)
4. Individual short-term episodes (transition pathway is split into multiple short-term episodes)
5. Transition path articulation (socio-technical developments and set of actions per actor per episode).

This chapter first presents the results of the analysis of normative views and transition pathways from the interview data (section 7.1 and 7.2). Then, the resulting trade-offs for defining the alternative pathways are given (section 7.2.6). The survey results and implications are elaborated in section 7.3. Last, this chapter concludes with an articulation of the preferred transition pathway with an explanation of individual steps in section 7.4. The result is a roadmap with sets of actions in time for the municipality to address the heating transition in Amsterdam.

7.1. Target situation

As mentioned in chapter 1, the heating system in Amsterdam is aimed to be gas-free by 2040. This is stated in the Amsterdam City Deal [4] and is the target situation and date for this backcasting analysis. According to political preference, the desired heating technology is an open LTDH network using (DC) WH or a renewable energy source. Also, there is a coalition agreement stating that there should be one existing neighbourhood where the transition to gas-free heating is achieved by participating with local groups or initiatives. Ambition is that new-built dwellings should not be connected to the existing HTDH network.

Interviewees also mentioned other ways of heating. So the normative views of the interviewees are analysed first, whereafter the target situation is articulated.

7.1.1. Normative views

In appendix G, normative views from the interviews are presented. These views can be categorised into views on the source, system and organisation. Most striking normative view, mentioned in four interviews (1, 2, 3 and 10), is that interviewees did not believe that it was possible to achieve the target of gas-free heating in 2040. This view implies a necessity for more focus on the path towards the target (to set the transition in motion) than the actual target achievement.

Source
Some interviewees see DC WH as potential because the source is already near the location and provides synergy (increase in DC efficiency)(interview 1,2 and 10). Some were sceptical about this source for the future because it is unclear how long the DC's are located near neighbourhoods and because 'WH should be finite' (interview 3). Others expect hydrogen to be the future source of heating. Its potential is high because it probably can be transported through the existing infrastructure of natural gas in the Netherlands. However, for now, the efficiency of clean production of hydrogen is low, and technology is expensive. Most interviewees see a combination of multiple energy carriers as the future source of heating. They suggest a mix of using WH (from DC's or industry), non-fossil gas (biogas or hydrogen) and electricity.

System
The suggested systems (DH and using existing infrastructure) are in line with mentioned heating sources. DH is mentioned often because it is a relatively simple technology, where there is an experience in implementing. Especially for a transition to gas-free heating, it is useful because the heating source can be switched to a more sustainable (non-fossil) source in the future. Making use of existing infrastructure (e.g. hydrogen in the existing gas network) reduces investment and construction nuisance and could increase speed and circularity. A different way to look at the heating system is upgrading the thermal insulation of the housing stock. Instead of making the input of heat more sustainable, the focus could also be on the efficiency of the system. Currently, the status of thermal insulation of the Dutch housing stock is poor (there was no urgency to insulate properly because natural gas was cheap) so upgrading could make the system more efficient. Of course, this only applies to the existing neighbourhoods. New-built areas nowadays are thermally well-insulated.

Organisation
There are some opposite views about the organisation of the future heating system. Some plea that we should strive for public ownership (interview 8 and 11), while others for local (interview 6 and 7). In the view of public steering, the municipality steers using regulation but leaves ownership to the market (interview 1, 5 and 8). So three conflicting views return here: public versus private, top-down versus bottom-up and decentral versus integrated.

Apart from public, market or local, it is suggested that the supply could be divided from production (like with the Dutch electricity system) to prevent a natural monopoly (as is the case currently).

These normative views might form an incomplete image of the future heating system. Many interviewees found it hard to suggest an optimal heating system because the future is too uncertain. So they focused more on the path towards it. It did not matter which system, only that it should be sustainable and gas-free. So more attention is paid to the suggested transition pathways.

Thus, for the sake of this research, the target situation will be focused on DH with a sustainable source. This situation is to start the transition. Flexibility could play an important role to keep options for other (more efficient and sustainable) heating sources and systems.

7.2. Possible alternative pathways

Insights from exploring the heating transition field in Amsterdam are presented in the next section. Analysis of mentioned transition pathways from the interviews is presented after which articulation of alternative (transition) pathways is concluded.

Transition pathway codes are categorised the same way as barriers and stakeholder interest, with organisational challenges as categories. An overview of all transition pathway codes and more detailed explanation per category is presented in appendix F.

Most transition pathways concern the municipal and ownership challenges. Some transition pathways are contrasting, which creates the necessity for trade-offs. These are articulated into alternative (transition) pathways. There is interconnectedness between categories. Next, these transition pathways are further explained.

7.2.1. Ownership

Most transition pathways (use of existing infrastructure, multiple sources, DC WH and the upgrade of the housing stock thermal insulation) are in line with the normative views mentioned above in section 7.1.

Some interviewees suggest a top-down approach, others a bottom-up. The top-down organisation of heating transition provides opportunities for profit and planning optimisation. By contrast, bottom-up initiatives often are not the most optimal in terms of profit or planning, but human energy and broad support are present. This is a returning trade-off (also mentioned in 5.4). Another returning trade-off is that of public versus private ownership. Both conflicting views are categorised under municipal challenges as well and require further discussion.

The transition pathway to keep in mind is the expected growth of data use, which implies that the difference in duration of business cases of DC's and DH projects could be less of a problem than suggested. So, the risk of 'losing' a DC in 10 or 15 years could be less. That is if the way of processing data stays the same, which could also change according to the transition pathway of disruptive technology. For instance, photon processing could reduce heating of servers to almost nil. However, other technological developments could become a more efficient way of heating.

Such technological developments are the reason that one of the most mentioned transition pathways is flexibility. It is already mentioned that flexibility is necessary because the future is uncertain, and a lot can change. However, flexibility might also mean that there is a lack of speed in the decision making process. Sometimes a transition requires clarity, as suggested in section C as a barrier. Therefore the degree of flexibility could return as a trade-off.

7.2.2. Municipal

Transition pathways in the municipal category are partly similar to those of ownership. Conflicting views on top-down versus bottom-up and public versus private also apply to municipal organisational challenges. The debate about the latter returns in transition pathways such as market incentive and suggested roles for the municipality of steering, risk-sharing with the market and forcing a collective system. These are seen as arguments for the trade-offs.

Other transition pathways are more project-oriented. Interviewees stressed the importance of scaling up and an integrated approach. So, implementing heating transition projects on a larger scale has to be taken into account. Constructing DH networks is not the only underground work. Renewals of the sewage and electricity system are also running behind schedule (interview 4). In order to become more cost- (and eventually time-) efficient, an integrated approach for underground projects is necessary.

7.2.3. Collaboration

There also originates a trade-off collaboration. On the one hand, it is suggested that an official partnership with residential initiatives is the way the transition pathway could be designed. On the other hand, the municipality could steer the market using regulation.

7.2.4. Legal

Creation of heating market competition by regulation is mentioned as a legal aspect for a transition pathway. With HL2.0 coming into effect, it is expected that such legal frameworks provide possibilities for the municipality to steer the heating market. It is still the question of which procurement model is most optimal for creating market competition. The importance of flexibility and learning in the application development of the new laws and forms of collaboration is stressed.

7.2.5. Policy and financial issues

Transition pathways in the categories policy and financial also pertain to categories explained above. The policy is mostly aimed to provide means to regulate the market, and financial issues concern the risks of DC WH use.

7.2.6. Trade-offs for articulating alternative pathways

The most important trade-offs from analysis of barriers, stakeholder interests, normative views and transition pathways are:

- Public vs. private (extent of municipal ownership)
- Collaboration vs. assignment (procurement model)
- Bottom-up vs. top-down (extent of residential participation)
- Small scale decentral vs. large scale integration (extent of integration)
- Flexibility vs. planned (extent of uncertainty)

7.3. Results of survey about trade-offs

In this section, the survey results are analysed. The commonalities and differences of the respondents' trade-offs are explained, after which the implications of the survey are elaborated.

The five trade-offs (questions) as presented in the survey are:

1. Public vs. private (extent of municipal ownership): To what extent has the municipality take the initiative in the heating transition? On the one hand (public) DH networks under public ownership. On the other hand (private) sell out completely to market parties.
2. Collaboration vs. assignment (procurement model): To what extent should the municipality collaborate with market parties? On the one hand (collaboration) together with the market where during the contract duration will be collaborated. On the other hand (assignment) only as of the client in which the municipality acts as an examiner.
3. Bottom-up vs. top-down (extent of residential participation): To what extent should residents get room for participation? On the one hand (bottom-up) in full collaboration with residents, focus on local support and energy. On the other hand (top-down) planned, with a focus on planning and effectiveness.
4. Small scale decentral vs. large scale integration (extent of integration): To what extent should DH networks be integrated? On the one hand (decentral) small scale decentral DH networks, for instance, per (part of a) neighbourhood. On the other hand (integrated) large scale integration of DH networks, for instance, across the whole of Amsterdam.
5. Flexibility vs. planned (extent of uncertainty): To what extent should the heating transition be flexible? On the one hand (flexible) fully flexible, where during projects, decisions are made and with minimal fixed choices. On the other hand (planned) as planned as possible, where a clear and tight schedule and a plan is present.

Respondents are numbered so that differences and commonalities in the results can be related to actors. The numbers return as indication of quotes in the result figures (7.1, 7.2, 7.3, 7.4 and 7.5). The respondents are numbered as follows:

A) Consultant energy transition - Municipal Engineering firm
B) Project manager - Urban development (team 'gas-free')

C) Consultant energy transition - Municipal Engineering firm
D) Member of the board - Residents' collective
E) Participation manager - Urban development (team 'gas-free')
F) Consultant DH exploitation (as external employee hired by the City of Amsterdam) - Engineering firm
G) Policy maker - Urban development

7.3.1. Analysing commonalities and differences

Degree of public ownership
The answers on the degree of public ownership are mostly a combination of public and private and presented in figure 7.1. The board member of the residents' collective (D) suggests that the requirements of the organisation of the DH network should be democratic, transparent, non-profit and without competition. The project manager urban development (B) has a similar opinion, where heating is a utility with a public initiative where costs should be socialised. These views are conflicting with the views of the external DH exploitation consultant for the municipality (F), one municipal energy transition consultant (A) and the urban development participation manager (E). They argue that market innovation is necessary to create an affordable and feasible DH network. According to the urban development policymaker for the municipality (G) and the other municipal energy transition consultant (C), the municipality could take the initiative. Then, clear regulation could organise the market to guarantee public interest requirements such as transparency, affordability, possibility to choose and feasibility.

Way of procurement
Views on the way of procurement seem quite conflicting with again a minor majority for collaboration (figure 7.2). On the one hand, according to the project manager urban development (B), collaboration is essential, and the public organisation could bear the risk. The board member of the residents' collective (D) argues that a tender process opposes proper residential involvement. So both argue for collaboration. On the other hand, the urban development policymaker (G) and two energy transition consultants from the municipal engineering firm (A and C) focus on steering/assessing using regulation. Perhaps this difference originates from the difference in work perspective. In general, the project manager and board member operate at a smaller scale than the policymaker and consultants.

To oppose the view of the participation manager urban development (E) and board member residents' collective (D), using the wisdom of the market does not mean you have to collaborate (assignment relies on market wisdom). Also, a proper residential process can be included in a tender as a requirement. By contrast, in opposition to the argument of external consultant on DH exploitation (F), open innovation could still result in collaboration after a party is chosen in a level playing field. One municipal energy transition consultant (A) argues that the new heating law provides the municipality with the opportunity to appoint areas for collective heating with an assessing role for the municipality. Collaboration could be integrated into that assessing role.

It is suggested by one municipal energy transition consultant (C) that if a DH network is privately owned, the municipality should not collaborate because a conflict of interest might arise. This shows the interconnectedness of the trade-offs on ownership and procurement model. Also, some views are conflicting, but not mentioned under the same topic. It is argued by the project manager urban development (B), as an answer to the procurement question, that public organisations should bear risks because heating is a utility. However, to the ownership question, the policymaker urban development (G) suggested that risks should be borne by private parties. So between different trade-offs and within the same department of the municipality, there are conflicting views. Risk bearing thus could be implemented as a topic of learning during the transition pathway.

If there is no consensus or the topic is too dependent on other decisions, the procurement model can become situation-specific. Then it is also essential to evaluate the process for learning purposes in the transition pathway so that in the future, it is possible to apply what works best.

Degree of residential participation
There seems to be a favour towards a top-down way of initiating DH networks (figure 7.3). However, all respondents stress the importance of local support and the possibility for residents to get involved (participate). According to the two municipal consultants (A and C) and the urban development project manager (B), planning of DH systems could be on a larger scale to ensure scaling benefits. This topic seems interconnected with the next about the degree of integration because differences in scale become clear. On a small scale, according to the residents' collective board member (D), urban development participation manager (E), external DH exploitation consultant (F) and policymaker (G), the municipality should provide residents with a saying in what happens locally. A municipal consultant (C) and policymaker (G) argue that on a large scale, it is vital to ensure scaling benefits, availability, reliability and fairness.

Degree of system integration
As mentioned above, the topics of participation and integration seem to be connected. At first, it seems that opinions are divided, but their answers are quite similar. The answers on the degree of system integration are presented in figure 7.4. Most respondents suggest small scale networks. Either linked together or connected via a sizeable city-wide transport network (C, F, G and B). This way, benefits of utilising local sources and balancing demand and surpluses are exploited which is in line with the view of the board member of the residents' collective (D) who again stresses the need for collaboration and that market competition is insufficient.

For both participation and integration, it seems that there could be a view on two different levels: small scale neighbourhood and large scale city or region.

Degree of flexibility
The majority of the respondents thinks that flexibility during DH projects is important (figure 7.5). Because most situations are unique (in location, residents, resources) and the future is uncertain, the policymaker (G) and urban development project manager (B) argue that flexibility is essential. The external consultant on DH exploitation (F) stresses the importance of flexibility in this phase of the transition. When projects are evaluated, lessons learned can be used to proceed with the development of networks in ways that have been proven to work. Though, the unique character of DH projects still demands a degree of flexibility. Another topic for the learning programme during the transition pathway.

The two energy transition consultants from the municipal engineering firm (A and C) believe that the DH projects could be more planned. One (C) also stresses the importance of flexibility as a prerequisite but thinks that flexibility is already present, and a clear plan and vision is missing. Such plans are necessary for the acceleration of the heating transition. The other (A) mentions that DH projects have a long-term business case, so planned is necessary; otherwise, investments are lost.

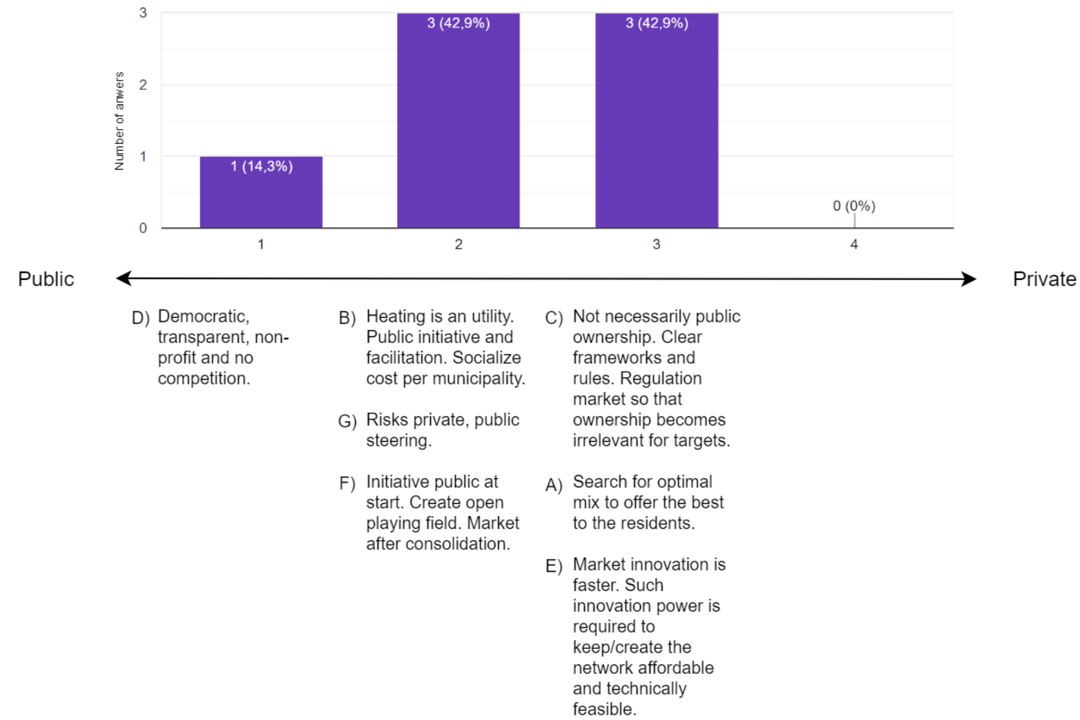

Figure 7.1: Survey answers degree of public ownership

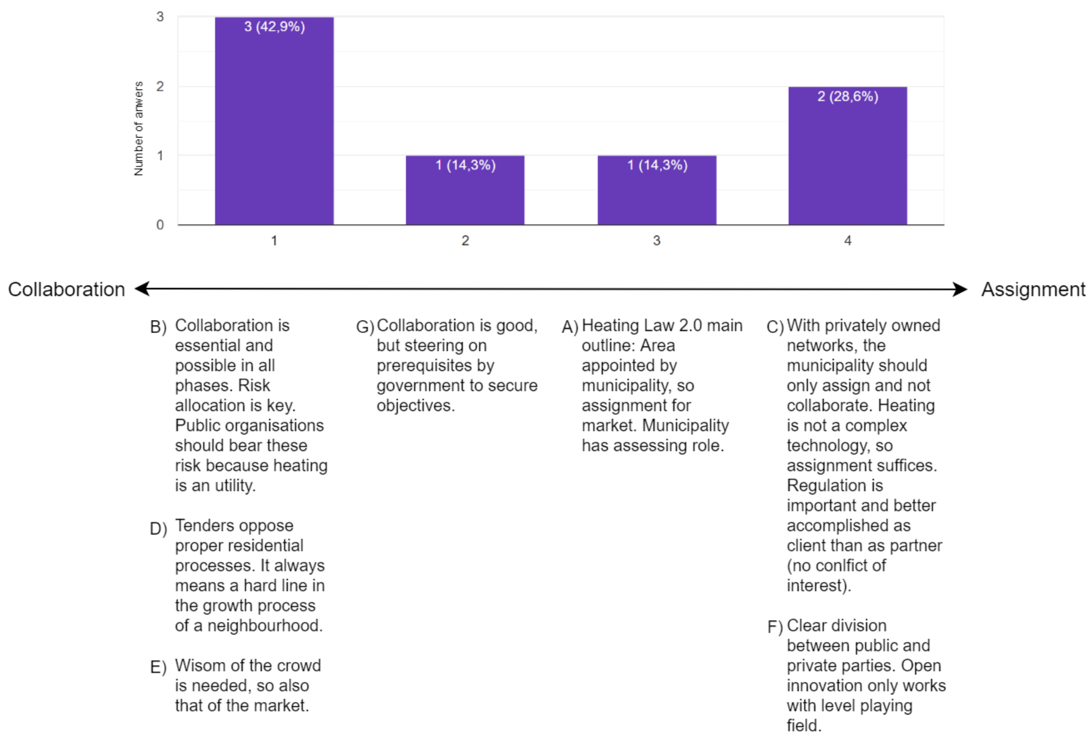

Figure 7.2: Survey answers on preferred procurement model

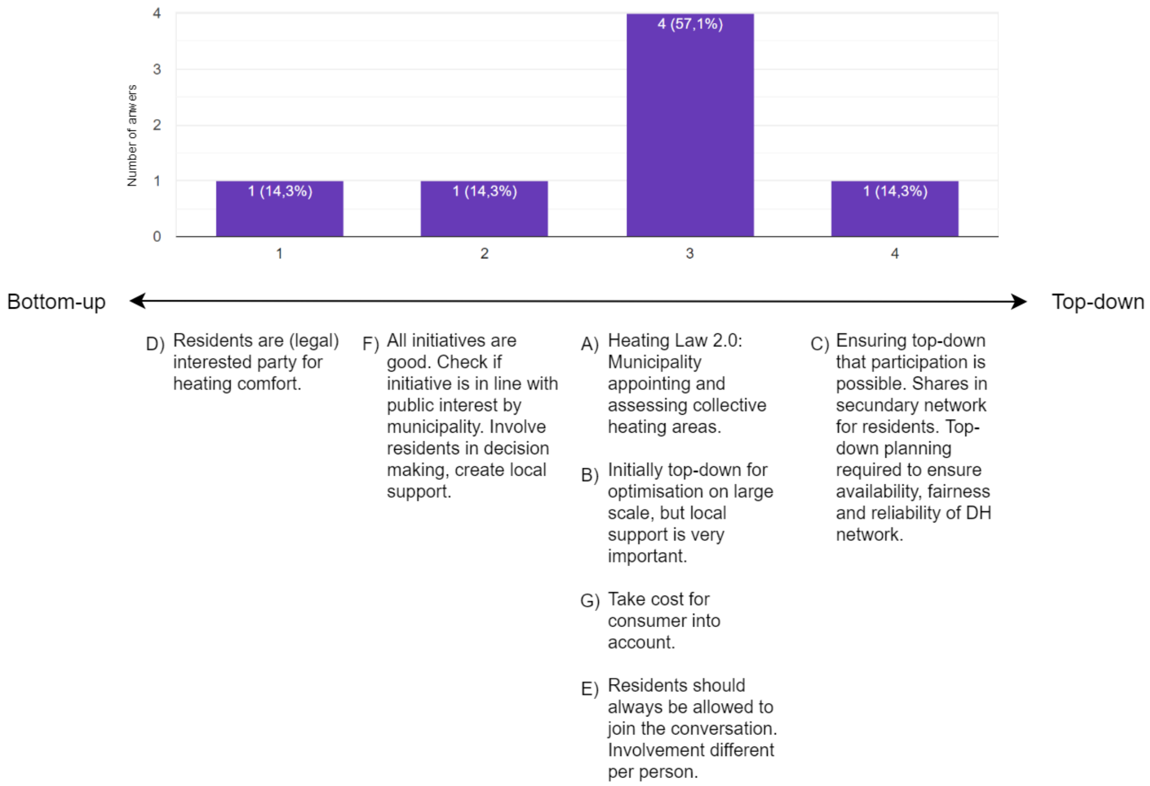

Figure 7.3: Survey answers degree of residential participation

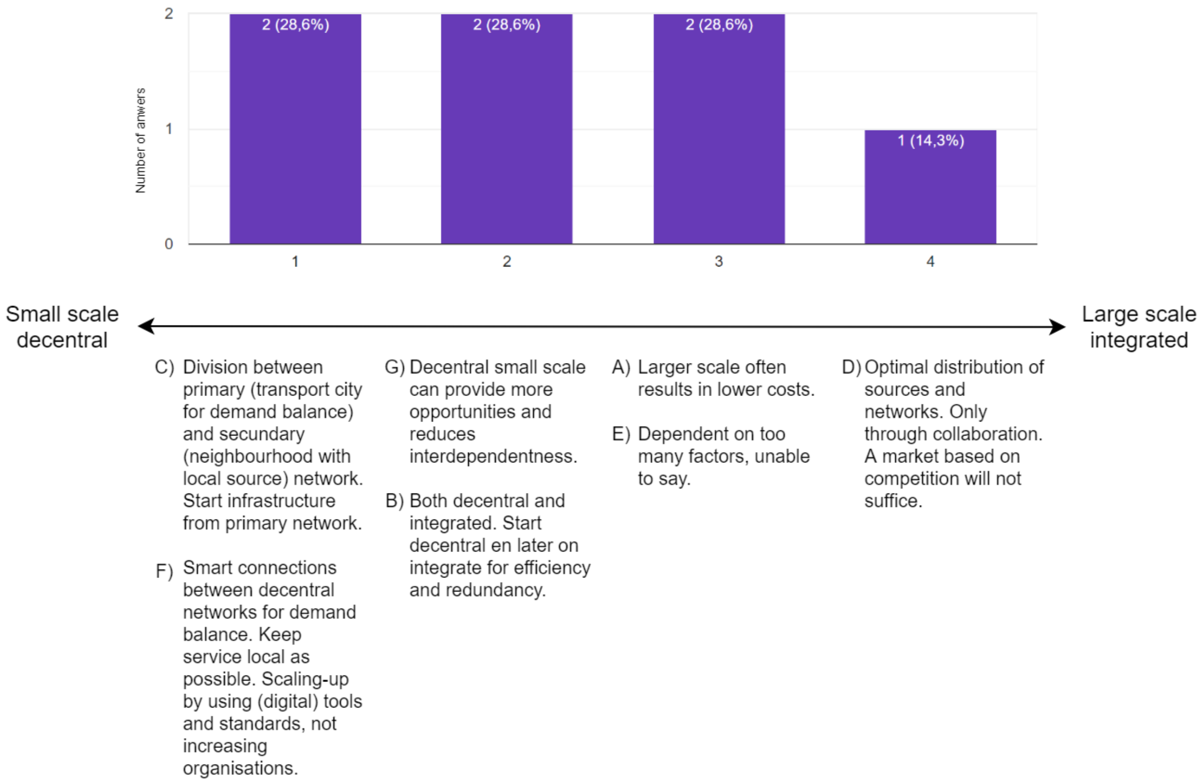

Figure 7.4: Survey answers degree of integration

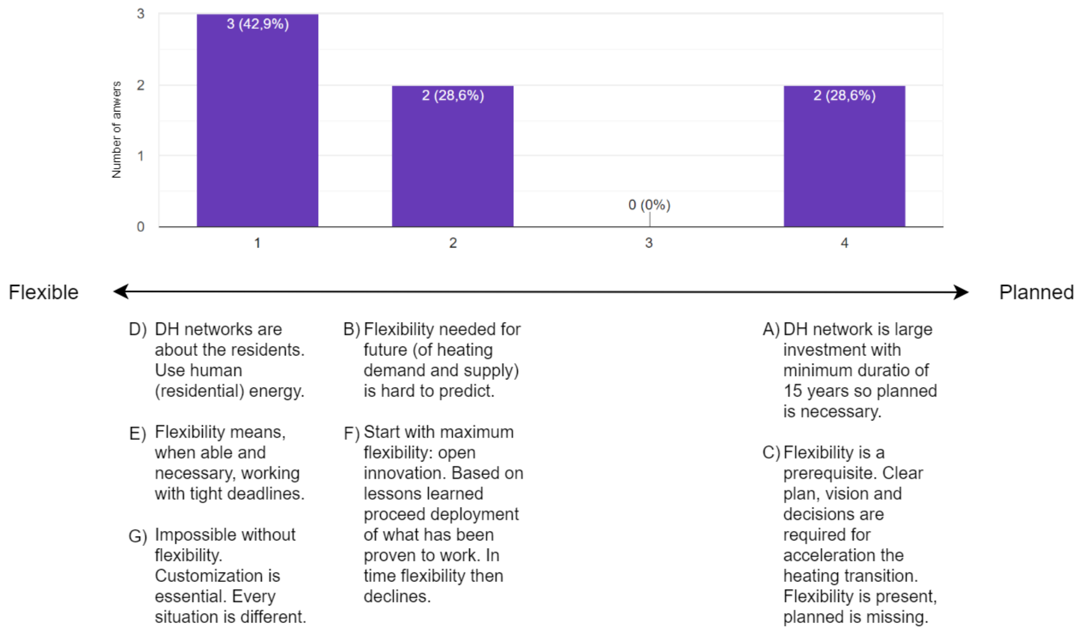

Figure 7.5: Survey answers degree of flexibility

7.3.2. Implications of the survey

Next, a translation from the survey result into what it implies for the transition pathway is presented. Initiative for the heating transition in Amsterdam could be public. In the short-term, the municipality could stimulate DH projects using WH (from DC) to create lift-off in the heating transition. For the longer term, the focus could be more on market organisation, which is in line with the new HL2.0 that provides tools to organise the heating market. This way, the market parties can take over the development of new DH networks, with the municipality in an assessing role to safeguard the public interest of heating (e.g. affordable, reliable, sustainable). Dynamics of the degree of public or private ownership during the transition pathway period is presented in figure 7.6.

The way of organising collaboration in the procurement of DH projects is still ambiguous in the survey. However, the key insights of exploring the Amsterdam heating transition state that almost all actors (that are not related to the municipality) mentioned interest of having formal collaboration/partnership with the municipality in DH projects (section 5.4). So, flexibility in forms of collaboration is necessary for the short-term. The focus could be on reflexivity and learning from different forms of collaboration. By evaluating these projects, an optimal way of procurement can be defined for the longer term. However, the procurement model might be too situation-specific to standardise. An important factor to take into account during these evaluations is if the DH network is owned publicly or privately. This influences the role of the municipality and therefore, the most optimal way of collaboration (i.e. conflict of interest might arise when the municipality is collaborating and examining contractually at the same time). So, with HL2.0 coming into effect, the municipality could assign DH areas to heating parties, whereafter collaboration rises during implementation (figure 7.7). Another element that requires evaluation in the short-term is risk allocation. Should risks be borne publicly or privately? Which provides the most optimal economic environment? These are questions that are needed to be addressed in the learning process.

The transition pathway could consider two levels of addressing residential influence and system integration. On a more extensive (city-wide) scale, the municipality could plan areas for collective heating systems in a top-down manner. However, for the implementation phase on the level of areas (neighbourhoods), possibilities for small scale local initiative could be assessed (e.g. residents' collectives setting up a democratically and locally chosen corporation). Same goes for the WH source for the DH network, which could be organised locally. Short-term aim could thus be decentral and local DH networks. For the longer term, the local systems could be integrated to create possibilities for balance in demand and supply and reliability (multiple sources reduces dependency on the local source). Dynamics of integration and participation during the transition pathway period are shown in figures (7.8 and 7.9.

The heating transition could be flexible in the long term. Possibilities for more efficient sources and energy carriers could be exploited in the future. However, for the short term, the transition could start by the planned implementation of DH networks, for these are systems that are relatively flexible in the degree of sustainability (i.e. switch to renewable or WH sources). This way, it is possible to create lift-off for the heating transition. For new-built, such planned implementation is already facilitated by the municipality with assessment frameworks for heating sources and affordable, open and sustainable. For existing buildings, it is more cost-efficient to integrate DH projects with other ground related work (e.g. sewage renewal). The course of the degree of flexibility is presented in figure 7.10.

As mentioned in section 4.5, these visualisations (figure 7.6 to 7.10) are based on the interpretation of the survey answers by the researcher and are used to provide an overview of the explanation of implications of the survey. There is no quantitative substantiation or validation for the visuals.

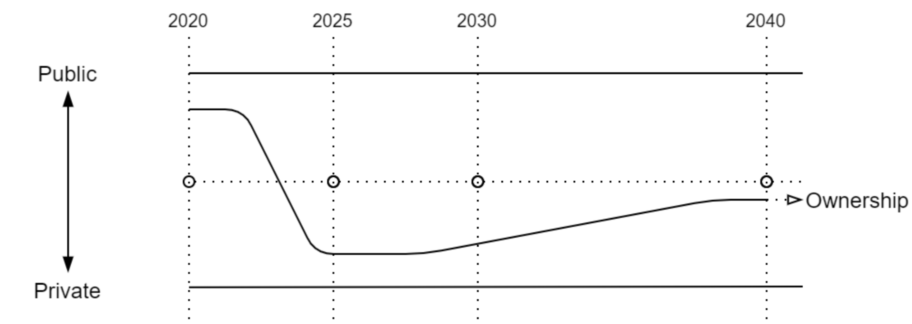

Figure 7.6: Dynamics of degree of ownership during the transition pathway

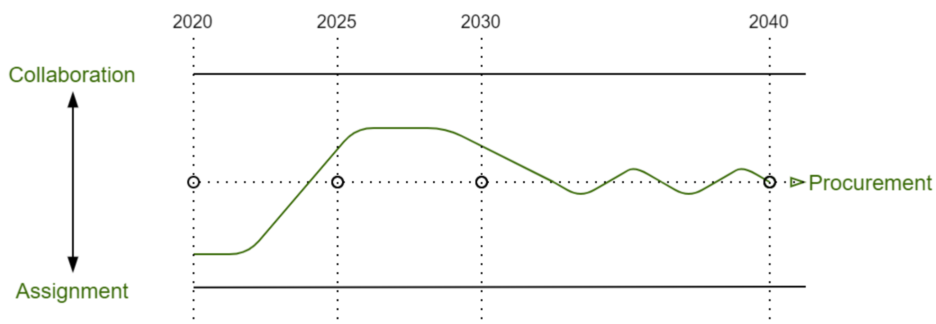

Figure 7.7: Dynamics of the way of procurement during the transition pathway

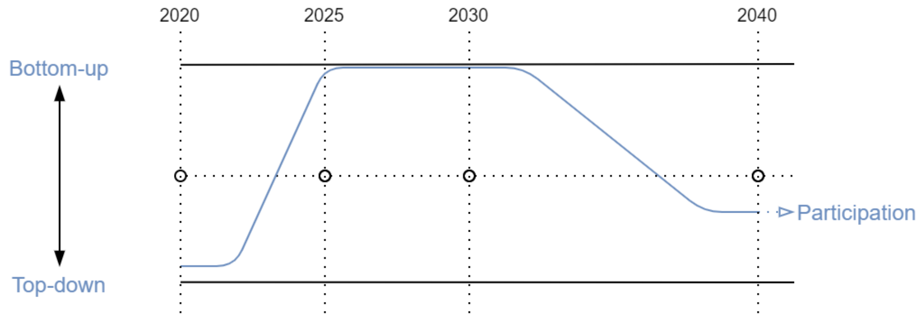

Figure 7.8: Dynamics of degree of participation during the transition pathway

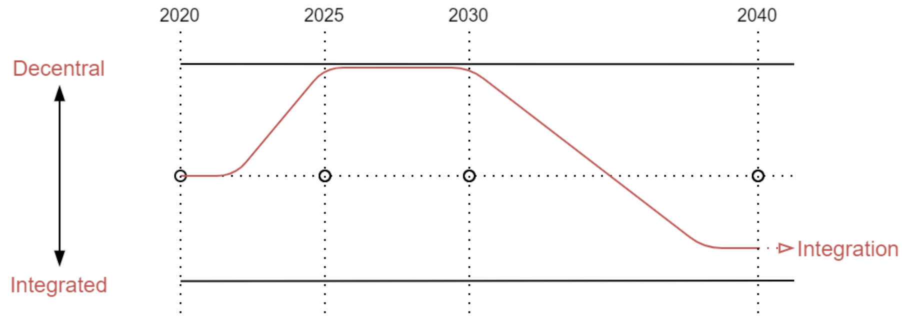

Figure 7.9: Dynamics of degree of integration during the transition pathway

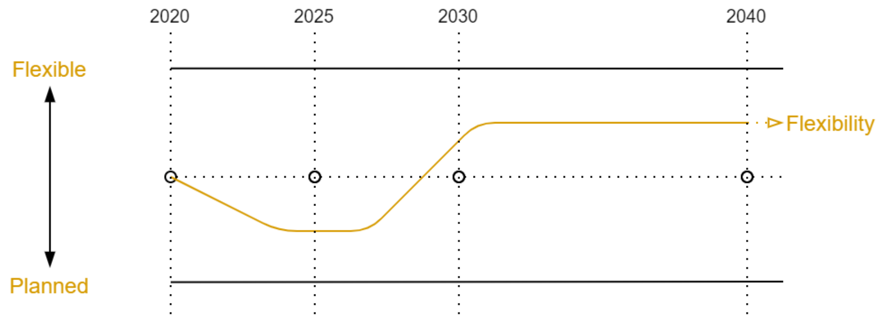

Figure 7.10: Dynamics of degree of flexibility during the transition pathway

7.4. Transition pathway articulation

In this section, the transition pathway is further elaborated as a result of this research. The pathway is divided into three short-term strategic episodes. First, the preparation episode from 2020-2025, where planning, learning and anticipation are key. Current paths and structures of the system and regime continue while actors have the time to prepare for the impact of changes in the legal framework. Second, is the implementation episode from 2025-2030. Here, construction and participation are the focus. Various private parties are awarded by the municipality to engage in the construction of decentral DH systems on a small scale, with the participation of residents. Third, is the integration episode from 2030-2040. During this episode, the emphasis is on connecting decentral DH systems to exploit integration benefits.

The Amsterdam heating transition pathway is explained based on a combination of the analysis of this research and socio-technical developments throughout the three periods.

Table 7.1: Key characteristics of the transition pathway

Key technologies	4th generation open LTDH using WH (from DC); Mutual connection decentral local networks for large scale integration; Smart energy grid systems integration (balance electricity with heating, foresee peak demand).
Key concepts	Open LTDH systems; Local WH sources; Network operator (residents' collective, (semi)public or private party); Collective heating; Large scale top-down municipal planning (area development integration); Participation in implementation (bottom-up incentive); Collective learning programme.
Key actors & roles	Central government in setting climate targets and providing laws and regulation for local governments (province and municipality) to organise markets and enforce sustainability; Municipality takes the initiative in heating transition by facilitating and stimulating DH projects, shift to market organisation, linking role between actors; Incumbent heating party (Vattenfall) owns the majority of the existing (HT)DH network and seek opportunities to collaborate with emerging private parties to create an attractive heating market; residents' collectives for bottom-up implementation; Private parties could optimise their business case for entering the heating market due to clearer laws an policy; DC's as WH source.
Key multi-level patterns	Regime trends: PR, sustainability regulation anticipation, political action; Landscape developments: climate agreements, fossil-fuel-free, natural gas-free, supply security, political action, public interest; Niche developments: reducing monopoly position incumbent party, DC WH use, accelerate transition with a decentral start, open DH networks.
Key learning processes	Integration decentral to central; Collaboration and risk in procurement/project; Implementation of HL2.0 and E&P law; Pros/cons of publicly or privately owned DH networks; Organisation learning programme in the short-term for the municipality and other actors.

Future events in the different levels of the socio-technical system (levels of MLP from Geels and Schot [18] in 3.2.2) are anticipated so that the impact of changes in system and regime, external factors or society (landscape, regime or niche changes) become apparent. These changes are combined with recommendations from the analysis on how to organise the transition pathway.

7.4.1. Current situation

The significant socio-technical landscape development is the climate agreement of the Dutch central government which aims to abandon the use of fossil fuels in 2050 and translated to the landscape development for Amsterdam by the planned target of the City of Amsterdam to be 'gas-free' in 2040. The heating market is unregulated, and there is no formal role for the municipality. Key characteristics of the transition pathway are presented in table 7.1.

7.4.2. Preparation (2020-2025)

At the beginning of this episode (2020 and 2021), HL2.0 and E&P law take effect. These laws will change the way the municipality will cope with the planning of collective heating systems. It provides more tools for the City of Amsterdam to achieve its ambitions of LTDH systems. Combining both laws results in the integration of sustainable heating in area development. This way, it becomes more attractive for other private parties to invest in new DH systems. Because HL2.0 ensures the City of Amsterdam with market organisation and tariff regulation possibilities, it is expected that a more varied heating market comes about (number of different private heating companies rises) and costs become more transparent. Simplifying the complicated legal procedures with clear planning (E&P law) makes it easier for new private parties to anticipate business opportunities. Inter-institutional linkages are strong in this phase because of increased lobbying. The City of Amsterdam assesses the impact of the two laws, trying to optimise them to their preferences by lobbying. A learning environment could be organised to optimise the use of these laws when they come in act and lead to further development of policies.

All actors could work towards the moment these laws come into effect. A focus on the anticipation of these laws is required to keep the momentum provided and create lift-off in the heating transition. It is expected that actors will focus on LTDH systems with WH because that is preferred by Amsterdam politics. DH systems are seen as the bridge towards sustainable heating. A major advantage of DH is that it can be powered by a multitude of sources. So first it can be powered by an existing (fossil fuel) power plant but can switch to a renewable energy source in the future which provides time for the development of these renewable sources, but also the ability to already start with the construction of the infrastructure. This reduces the paradox of having a renewable source without the infrastructure or vice versa, which creates a difficult situation due to the large investments required for such systems. There is no feasible business case for either (system or source) if it has to wait for the other (e.g. infrastructure that is not used in the first few years because the source is not up and running yet). Preference for sustainable heating also led to the development of alternative local heating systems for small scale new-built areas (e.g. heating pumps, local thermal storage systems). However, for larger and more dense areas, collective heating is preferred [7]. So, DH systems are seen as the optimal transition technology for heating in Amsterdam. Also, time to upgrade thermal insulation of the housing stock is provided. Important during this episode is to plan for the newest, most advanced DH systems (4th or 5th generation) to be future proof and to exploit opportunities of smart grid integrations. Besides, anticipating open (third-party inlet) DH systems is essential. Especially for the integration episode (explained in 7.4.4).

The socio-technical regime responds to the landscape trends by incrementally phasing out the use of fossil fuel for the existing DH networks. A large part of the city is already heated with these collective systems, though powered by burning waste and CHP plants. The latter power source is planned to be phased out to abandon the use of natural gas. Plans are to open a large biomass plant with short term biomass (i.e. seasonal cuttings of existing forests instead of deforestation). Some areas already have underlying concessions, granting the incumbent parties to expand the DH system. However, this system is an HTDH network which is seen as unsustainable. Therefore, the preference of LTDH for new-built areas is articulated by politics, which is another landscape development which forms a barrier for the regime but does not hold for the current concessions. Although this preference is expected to play a part in future area development, incumbent parties have an advantage in the business case for existing dwellings. Because they do not have to invest in additional infrastructure to a source, it is easier to expand their system. For new heating parties (i.e. operators and companies with WH like DC's), such infrastructure is an additional investment which may make or break their business case. However, market variety increases competition and decreases the monopoly position of the incumbent party. They could thus reassess the current business cases to anticipate market organisation and tariff regulation. Collaboration with smaller parties, the municipality and residents is necessary to realise these opportunities.

Ownership of the heating transition is public in this episode, which means that the City of Amsterdam could take the public initiative for the planning and preparation of appointment of DH areas to market parties in order to achieve market organisation. So, the City of Amsterdam is shifting from passive (but facilitating) and little regulation to a more stimulating, initiating and steering role. Intra-municipal tensions might arise due to differences in the interests of departments. For example, urban development is urged to solve the housing shortage, while there are requirements for sustainable heating that often slow the process down. Though, these tensions can be avoided by increasing inter-department linkages during the preparation phase. Explicit knowledge sharing via platforms (clear for all related municipal officials) and a joint learning programme are tools to assist in reducing tensions and increase collaboration and success.

Thereby, during the preparation episode, the focus is on local and decentral DH networks with a nearby DC as WH source (or another heating source, to be found in The Amsterdam Sourcebook from 5.1.1). The City of Amsterdam must continue with top-down planning of locations where DH could be implemented to ensure lift-off in the next episode. This creates a clear vision and plan that allows other actors to anticipate the development of DH networks. Residents can already organise themselves and set up a plan of action. Market parties (operators, project developers, housing corporations) can start with a business case by assessing capacity, strategic partnerships, possibilities for SDE++ subsidies and potential WH sources. Also, while planning local networks top-down, the municipality could take the large scale city-wide integration/transport network already into account.

WH sources could be exploited to achieve sustainable heating faster. In Amsterdam, this often means that WH of DC can be used because the centres are located near areas suitable for DH. DC's stated that DH operators could use their WH for free. The investment for the connection to the DH network has to be made by the operator or investor of the DH, even though DC's will have efficiency benefits. Thereby are most DC's unable to guarantee WH for multiple years (it is uncertain how long the DC stays located there, expected is at least 10 to 15 year). This makes the risk of using DCWH higher. Subsidies such as SDE++ (subsidy for WH) could be used to cover the risks for the private parties to overcome the barrier of the inability of DC's to guarantee WH. By the time a DC might move, there could be integration between the decentral networks by a city-wide transport network for balance. Thereby seems it unlikely that DC's will disappear from Amsterdam. The city is a popular data hub. Use of data is expected to keep growing. It is also expected that the price of one GJ heat will rise for suppliers. Together with the SDE++ subsidies and the expected rise of data use, using WH from DC's becomes more attractive during the preparation phase and could lift-off during the implementation phase.

For the transition towards sustainable heating for existing areas, an integrated approach is required. The City of Amsterdam is coping with an increasing amount of renewal projects. The sewage system is lagging on its renewal. Electricity use has increased as such, that congestion is lurking, which also impacts the business climate for DC's, for they use relatively much electricity. Currently, there are strict demands for DC's to locate in Amsterdam. Because some regions of existing neighbourhoods in Amsterdam will have to deal with these groundworks shortly, it is expected that these works will function as a window of opportunity for DH construction. Integrating such projects reduces nuisance and eventually will be more cost-efficient. However, due to the infant status of the heating market, such project integration requires much public investment. To pre-invest in DH systems (like case 2) might not be feasible for the whole city. Diligent allocation of public financial resources is required during the planning of these projects. This is at least necessary in the preparation phase, for it is expected that the heating market will mature with HL2.0 coming into effect. Another significant barrier for the heating transition of existing neighbourhoods is the low quality of housing stock thermal insulation, but this is another discussion, for it has to deal more with privately owned property (as is the connection of the DH network to the individual dwellings).

Top-down planning results in a decrease in flexibility in choosing the heating system during the preparation episode, which reduces the market potential for other alternative heating systems (e.g. heat pumps or thermal storage systems). For less densely build areas with individual dwellings, however, these systems are likely to remain popular. The way of implementation will still be flexible and is further explained in the next short-term strategic episode.

7.4.3. Implementation (2025-2030)

This episode focuses on the construction and implementation of local DH networks. In the previous episode, most of the planning is done, and the new laws integrated sustainable heating in area development. Ownership is shifting towards private parties because of the development of market organisation by the municipality. Competition is growing due to an increase in opportunities. The heating market matures. The organisation of the heating market results in multiple advantages: it reduces cost for the consumer, it drives innovation, and it creates a potential for the municipality to govern more on their demands (e.g. assessment framework 'affordable, open and sustainable'). The incumbent party will probably attempt to secure its monopoly position by lowering prices (i.e. compete smaller parties out of the market). The municipality could use tariff regulation to maintain market competition. So, socio-technical dynamics increase between niche and regime, for niche parties have the opportunity to align oneself with regime parties. The regime is expected to try and strengthen linkages with public organisations such as the City of Amsterdam by lobbying with sustainability and pricing plans.

Top-down planning of the city-wide transport network could be done in this episode to prepare for the integration of decentral DH networks. However, because this episode focuses on decentral DH networks, there is also a shift towards bottom-up implementation. Possibility for participation is important in the realisation of the DH networks because it has a political preference and creates local support. Local support reduces resistance and loading risks, which strengthen the business case.

The disadvantage of participation is that it often slows down the process. There are a lot of interests and expectations to manage. Most actors have to compromise. For instance, the operator will probably have to be more transparent in revenue and profit, the municipality might have to scale up their process management and residents have to organise themselves into a collective with a clear plan of action to grow support.

Although participation is often tricky and time-consuming, residents could be given any opportunity for participation. The municipality could facilitate residents to participate in details of the plan in close collaboration with the exploiting party. This exploiting party could be a private heating company or a residents' collective. With new-built development, it depends on the project if the residents can be included in the planning. Early involvement would be favourable, but sometimes it is the decision of the project developer in combination with the municipality. With redevelopment projects, the extent of participation is based on the assessments made in the previous episode.

With local initiatives, it is up to the commitment of the residents' collective and its members to gather the actual local support by visiting neighbours door by door and hosting information events, convincing them of the need for a sustainable DH network. The strength of a local community lies in social solidarity and goodwill. The municipality could assist residents' collectives in this process to fully utilise the human energy present and can be done on various levels. The municipality could start by assessing the commitment and agenda of a collective because the needs of collectives might be different. Some collectives just want transparency in the cost of heating while outsourcing the exploitation. Others want to form their own (private) heating company as a collective with partnering companies for maintenance and WH supply.

First, the municipality can offer financial assistance in various ways. This can be assistance in how and what subsidies to claim, providing creditworthiness for the collective to acquire a loan from the bank, financial compensation of the (board) members of the collective for their work, and risk coverage agreements or public (pre)investment. Some of these types of financial assistance should be checked if and how they are legally possible. When they are legally possible but unprecedented, they could be input for future projects, which brings us to the second point of municipal support: a city-wide learning programme, which could be managed by the municipality, in close collaboration with the heating sector. For residents' collectives, the learning programme could provide information, experience and knowledge sharing (e.g. governance structures for maximum residential control, legal advice, possibilities for subsidies). Lessons learned from other projects could be documented and re-used to optimise participation. Other benefits of the learning programme for the Amsterdam heating transition are explained later on. Third, the municipality could enter into an official partnership with a residents' collective. This decreases uncertainty for the members of the collective due to the resourcefulness of the municipality. It also expresses trust in the collective, which is found relevant. With an official partnership, it is easier for the collective to use the network of the municipality, both internal and external. Linkages with companies in the heating sector and residents' collectives could increase. Nevertheless, also opportunities for project integration arise due to linkages with companies in other disciplines (e.g. urban area, electricity, sewage). Internally, the municipality could provide a representative for the residents' collective that can lobby for its interests in the municipal 'corridors'. This could reduce the feeling of exclusion by the collective. Fourth, because such collectives are often run in residents' free time, the municipality could be careful in demanding capacity assurances and collaborate in increasing this capacity of the collective. During this process, it is important to continue assessing the capacity, but an emphasis on stimulus is required instead of emphasising the demands. A clear vision in the heating policy of what is expected per residents' collective could help reduce miscommunication and tension.

Thereby, political landscape developments on local, national and European scale (e.g. municipal coalition agreement, HL2.0 and European Commission's Clean Energy for all Europeans Package) drive collective energy projects more towards participation. The EU is working on 'new opportunities for citizens to get actively involved in energy matters' [10, p. 2]. This is mainly for prosumers (e.g. returning electricity from solar PV to the grid, next to their own consumption) to get organised. But there are also examples where community energy initiatives concern electricity grid operation which could make DH network operation also possible. The role of the residents is thus expected to grow in Europe and therefore in Amsterdam. During the preparation phase, the City of Amsterdam could investigate regulatory possibilities regarding energy communities and combine those with HL2.0 and the E&P law.

Degree of flexibility will shift towards flexible for the project approach. This allows contractors and operators to implement the newest technologies for DH. Although DH systems are relatively simple technologies, there are many possibilities for the configuration of the system. Experiments can be done with different sources, intermediate heating upgrade, dwelling connection and substation design. A variety of DH systems will appear, with a multitude of LTDH. Each could contribute to the city-wide learning programme, which could increase knowledge sharing of lessons learned in different configurations of DH systems. This could also cause the linkages between public and private parties to increase and become more dynamic. Because there is more contact between public and private, information about the development of new technologies is more likely to be shared. This way, the emergence of new heating technologies could be anticipated more adequately by institutions and private parties, which leads to more flexibility in the configuration, development and implementation of the most efficient DH systems. Also, the learning programme could be used by the municipality to share the urban development tools of the municipal engineering firm such as the assessment tool for affordable, open and sustainable heating, or the Amsterdam Source book.

The degree of collaboration on the project level could also be assessed based on lessons learned from implementation. This means that the municipality could utilise the learning organisation and apply and force knowledge sharing between all actors, especially for the first projects. The most optimal form of collaboration could be realised by a constant feedback loop for evaluation. CTA is a suitable method to create such collective anticipation, learning and anticipation.

7.4.4. Integration (2030-2040)

The integration episode does not mean that the construction of local DH networks is finished. It continues until all dwellings are free of using natural gas or until a more efficient heating alternative takes over. That being said, this episode focuses on the integration of multiple decentral DH networks. Additional emphasis is on the anticipation of landscape events that might cause regime shifts (e.g. climate change, pandemics, disruptive technologies).

Ownership of DH networks could still be private, but increasingly constraint by regulation. The policy keeps evolving to find the right balance between public interest and a healthy heating market. The results of the learning programme could be noticeable. The integration of DH networks should not cause an increase in the size of heating organisations but could be achieved by digitalisation and increasing collaboration between decentral DH organisations. So the exploitation could still be bottom-up and decentral where the municipality could continue to plan DH systems and oversee the integration. The municipality could also develop policy more towards the Danish model by allowing local actors to file plans for (re)development of heating systems.

Integration of the local DH networks has multiple advantages that become clear as well. Supply and demand can be balanced. Smart operation systems optimise distribution which reduces peak demand. Systems for heating upgrade become less necessary, and synergy with cooling can be optimised. The interconnectedness of local DH networks also reduces dependency on the local source, so the risk of too short DC WH supply duration is reduced. Especially when the system is open, which means third parties can connect and supply their WH. It also enables uniform heating costs for the consumers.

Flexibility could be maximised at this point. More efficient or cost-effective solutions could be able to enter the market relatively easy. Especially innovation in renewable heating sources could be exciting because DH networks lend themselves relatively easy for a variety of heating sources.

Though the future always remains uncertain, there are some changes in the use of heating that might arise during this integration episode. As climate change continues, global warming is expected to keep rising, which may cause an increase in cooling demand. The synergy between heating and cooling becomes more important. So, besides heating sources, cooling sources could be assessed to ensure sufficient cooling supply. For areas where it is challenging to transform the heating system, electrification of the heating system could be a solution (if the electricity system capacity is sufficient). However, electrification of the energy system could also result in less heating demand, which might reduce the feasibility of DH business cases. Such an impact could be assessed to prevent overcapacity and uneconomic projects.

Other possible future changes are more disruptive than others, like the entering of more thermal and cost-efficient technology. Hydrogen is expected to be such a technology. Incumbent heating parties will likely react to the emergence of new technologies by being the first to experiment and invest in its development. But there could also be new parties entering the heating market. Partnerships with these new parties could diversify the field of actors with new and hybrid organisations. For the municipality, it is important to also follow new technologies carefully for an adequate policy response. Because heating projects require several years of preparation, it is important to be able to change quickly to realise the most efficient heating systems. Besides internal disruptions in the heating market, external events could be very disruptive. Large scale disasters are besides disruptive, very sudden. An outbreak of a pandemic, for example, can change heating demand for some time, or permanently. This is seen now during the lockdowns due to Covid-19. Because people are forced to work (as much as possible) from home, heating is balanced over the day instead of a peak when they return from work. Smart systems integration should have enough learning capacity to control such changes adequately, but systems for supplying for peak demand may become useless, and investments might be lost. The higher the possibility of a disruptive change, the more anticipation is required, and alternatives need to be explored.

7.4.5. Roadmap with a set of actions for the City of Amsterdam

In this section, a summary of which role the City of Amsterdam could take during the transition pathway. The summary is again divided into the three short-term strategic transition paths and follows the dynamics of the trade-offs presented in figure 7.11.

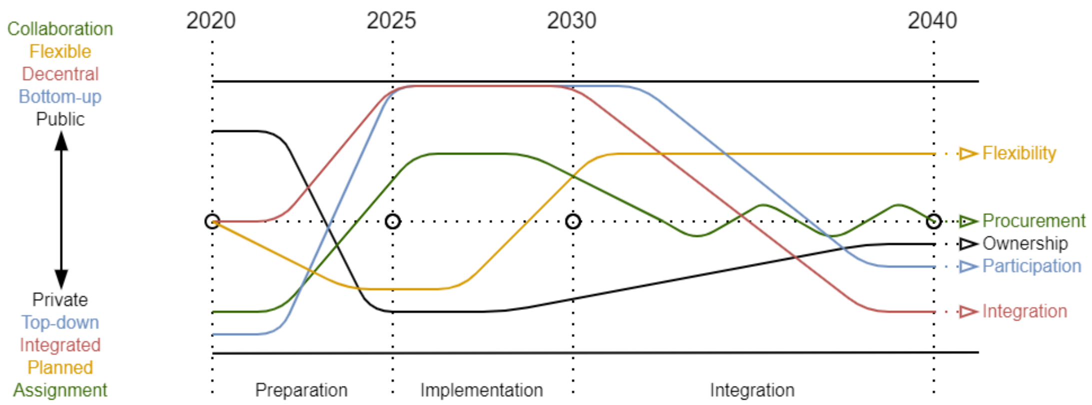

Figure 7.11: Dynamics of the role of the City of Amsterdam during the transition pathway

Preparation (2020-2025):

- Ownership: Take public initiative for the planning and preparation for market organisation, tariff regulation and appointment of (LT)DH areas. Organise a learning programme focused on the optimisation of the new legal frameworks by intra-municipal knowledge sharing, so that every department can learn from each other and tensions could be reduced. When the new legal frameworks come into act, there could be a shift towards private initiative by appointing the locations.
- Participation: Planning of (LT)DH networks could be done in a top-down manner during this episode to create clarity for all actors. Existing residents' collectives which already have plans for the heating transition, have to be taken into account when allocating DH areas. Otherwise, there is a risk dividing existing collectives (by splitting their area into two or more locations for decentral DH systems instead of one) which might decline local support. By planning the implementation in the next episode, the degree of participation is shifting towards bottom-up.
- Integration: During this episode, there is a shift towards local and decentral (LT)DH networks to reduce complexity, increase ability to address projects more location specific and utilise local WH sources.
- Flexibility: Because there is a lack of vision, flexibility could be reduced during this episode to create clarity for all actors towards the implementation episode.
- Procurement: By appointing locations to private parties, the way of procurement is more assignment-like at the beginning of this episode. This switches towards the next implementation episode because collaboration could be beneficial for all actors in learning how to optimise implementation.

Implementation (2025-2030):

- Ownership: Because the implementation is executed by private parties, the ownership is more private during this episode.
- Participation: During the implementation, a bottom-up approach could create broad local support. Residents (collectives) could be assisted and facilitated by the municipality in the decision making and details of the (plans for the) project. The intra-municipal learning programme from the previous episode could be extended with the inclusion of lessons learned on participation during implementation.
- Integration: Focus of this episode is implementing local and decentral (LT)DH networks.

- Flexibility: Flexibility increases during this episode to create room for innovation, adjustment to location specifics and participation. Here, the lessons learned on various project configuration could also be integrated into the learning programme led by the municipality.
- Procurement: There is a collaboration between all actors during the implementation of the projects. These lessons learned could also be used in the learning programme to find the most optimal way of collaboration in DH projects.

Integration (2030-2040):

- Ownership: Policy might develop further through learning, and the system becomes larger and more integrated. Ownership remains private and decentral but is constrained by the necessity for more regulation. Large scale integration is preferred to be realised by increasing collaboration and digitalisation instead of increasing the size of the individual organisations or an overarching one.
- Participation: Decentral DH systems could still be in a bottom-up way and locally exploited by the private company or residents' collective. The municipality could still plan new DH systems and function as an overarching actor for city-wide integration in a top-down way. Development of policy could shift more towards the Danish model where planning is more bottom-up (plans for heating systems filed by private parties or residents' collective) instead of area and system allocation by the municipality. A hybrid system, where both approaches are common, could also arise.
- Integration: There is a shift to integration because this episode focuses on system integration on a city-wide scale.
- Flexibility: During this episode, a flexible approach could increase the possibilities for a new and more thermal and economical heating system.
- Procurement: The way of procurement is undefined (therefore swaying curve). Degree of collaboration could be defined based on lessons learned in the previous episodes.

8
Discussion

Since the urgency of the energy transition continues to grow, it is essential to expand knowledge about specific aspects that contribute to a more sustainable society. This research focuses on the transition towards sustainable heating and contributes to present scientific debates in various ways. This chapter discusses the scientific relevance and additional findings of the study.

Combining the scenario building method Backcasting with traits of CTA into a methodology to construct a full scenario for the transition towards sustainable district heating contributes to the field of transition and scenario studies because it is a novelty. Especially the application of a combination of these methods with an in-depth basis of empirical data for a scenario with actions per actor over time is insightful. The empirical analysis provides an understanding of actors and regime dynamics in the Amsterdam heating transition. Based on this analysis, the methodology of this research (table 4.1) translates the barriers, interests and views of actors together with legal frameworks and policy implications into specific actions for the organisation of the heating transition. So, the transition pathway aims to link long-term policy targets to actions in guiding local initiatives by linking the understanding of actors and transition studies to management approaches (as suggested by Markard et al. [29, p. 962] and Köhler et al. [20]).

The research is performed with an overarching perspective on Amsterdam, but a slight focus on the municipality's role. With each actor this role is different. When managing residential parties, such as a residents' heating collective, the commitment and human energy is vital to preserve. A careful, assisting and facilitating management approach by the municipality could be optimal. For private heating companies, contractors and project developers, the municipality could take in mind that keeping a seat at the table of a is valuable for persevering of grip on the sustainability of DH projects. A collaborative approach with an emphasis on added value (for the private party) is required. Private parties tend to 'fix it themselves' and comply with minimum standards if the municipality only examines contractual requirements which might result in a waste of sustainability potential.

The research adds to the field of scientific literature on DH systems by investigating main barriers in practice, confirming the organisational challenges already presented in the literature. Six of the seven organisational challenges from the literature (section 3.1.5 and table

4.3) were also found in exploring the Amsterdam heating transition. Only awareness is not indicated as a challenge in the Amsterdam situation because benefits of DH are well known (e.g. cooling synergy, use of WH from DC).

Studying the Amsterdam heating transition allows investigation in the presence of facilitators for mitigating the barriers of implementing DH systems. This investigation contributes to the research on the importance of local initiatives (as suggested by Lund et al. [28]). The five suggested facilitators, creating local ownership, empowerment of local actors, providing socio-economic perspective, energy-saving incentives and optimised supply efficiency are all found to be valuable by residents. Sustainability of the heating system is argued to be an additional facilitator for local initiatives. Facilitators that are found difficult to achieve are the creation of local ownership and empowerment of local actors.

In case 2, it is still uncertain if the planned DH network will be owned by the residents' collective (who initiated the construction of the network). Ownership of the network by the residents' collective is uncertain because there are tensions between them and the municipality. The situation is explained in section 6.2. It seems that the municipality did not succeed in creating local ownership and empowerment of local actors. With the municipality's decision for investigating two possibilities for an operator (one with the residents' collective as the operator, one for an alternative party via procurement), the commitment and energy of the residents' collective decreased. Especially because the process is already taking almost two years. Also, the plans of action by the collective are seen as insufficient by the municipality. In contrast, the residents' collective wants to enter into an official partnership to reduce the uncertainty of not getting awarded the exploitation of the network. Thereby, during the research, the residents' collective did not get awarded a subsidy by the municipality because it was 'competing' with two other local initiatives. All in all, their energy and commitment became very low while it is argued that those are the ingredients for the facilitators for mitigating DH implementation barriers. Why does it seem that there is a lack of trust? Perhaps it is because the residents' collective aims to act as a private party with full control over the network, and are municipal officials afraid of double agendas of the residents' collective. This trust issue and residents' collectives acting as private parties might be interesting for further research so that the benefits of increasing local ownership and empowering local actors can be utilised. Nevertheless, those issues seem to be manageable in contracts and partnerships and should not form a barrier to utilising local human energy. The municipality could reassess the necessity for their risk-averse compared to the benefits of increasing local ownership and empowering local actors.

Most interviewees stressed the importance of the path towards sustainable heating rather than the actual outcome. Because the BC method sets off from a normative view on a future situation, one could wonder if it is the correct one to use in the case of the Amsterdam heating transition, where the focus should be more on the path. Perhaps the use of the STSc method is more suitable for the heating transition because it focuses mainly on the path. However, with BC, the target could be simplified to 'sustainable heating'. Then the pathway might become more critical because there is more uncertainty. The pathway division into episodes also increases focus on the path because, after each episode, a reassessment of the following episode could be done for flexibility reasons. Besides, in the Amsterdam situation, the municipality did articulate a preferable system, and by implementing the learning programme in the pathway, the lack of learning processes compared to STSc is decreased. So the BC method is seen as suitable for the Amsterdam heating transition.

9
Conclusion and recommendations

9.1. Conclusion

To conclude this research, the sub-questions are answered first, after which the main research question is answered.

1. *What are useful theoretical insights on transition processes and sustainable district heating?*

Multiple transition theories apply to the case of DH. Besides literature on the technology itself, the organisational challenges experienced in previous DH projects are useful. There are seven categories of organisational challenges found that are useful to consider: legal frameworks, the role of (energy) policy, awareness, ownership, economic feasibility, intra-municipal tensions and collaboration.

Four more general transition theories are found. The first is the Technological Innovation System approach (TIS), a combination of innovations systems theory and industrial economics. Technologies, actors and institutions are the focus. The second is the Multi-Level Perspective (MLP), a combination of evolutionary economics, sociology of innovation and institutional theory. It proposes three analytical levels with processes wherein transitions occur, namely; niches (a protected environment), socio-technical regimes (existing systems with path-dependence and incremental change) and socio-technical landscape (exogenous development). The third is Constructive Technology Assessment (CTA), a form of technology assessment where the focus lies on the early interaction with all actors involved to include them in the design and implementation process to prevent compensation and mitigation by the government. It concentrates on creating discussion among all actors to broaden the design and implementation process. The fourth is Transition Management (TM), which combines complexity studies with governance research to a policy-oriented framework. Policy-oriented means that it is suggested that policy can shape transitions by using four different types of governance activities: strategic (long-term vision), tactical (regime activities), operational (short-term experiments) and reflexive (evaluation).

There are multiple scenario methods found in the scientific literature. Scenario planning is mostly used for social forecasting, decision making and public policy analysis. Division can be made between scenarios with a focus on what will happen, what could happen and what should happen. Four methods can be categorised under the ’what could happen’ methods (forecasting, foresight, road mapping, breakthrough). One method falls under the ’what should happen’ methods (backcasting). The BC method focuses on technological and societal shifts towards a normative future. The changes for actor networks cause by societal shifts are anticipated with the use of interactivity, participation and a shared vision.

2. *How can academic transition theories assist in addressing present actions and a future goal together?*

Academic transition theories can assist in addressing present actions by combining the CTA method with the scenario method backcasting. The backcasting method sets a future goal with multiple pathways towards that goal. The pathways are cut into short strategic episodes, which allow for sets of actions in time. Each episode starts with a present set of actions. Use can be made of CTA to choose one pathway (timeline with a set of actions). This way, all stakeholders create a common view by discussion differences and commonalities with a focus on anticipation, learning (especially articulating underlying values to stimulate understanding) and reflexivity.

3. *What are the interests and views of (key) actors on a transition towards such system?*

The heating transition in Amsterdam is a multi-stakeholder environment. Ten different stakeholders are identified. Some form an actor group. In general, there are four actors: the municipality, (emerging) private parties (heating operators, contractors, project developers, housing corporations), the incumbent party (supplier and producer of DH) and residents organisations/collectives. Some actors are interviewed about the heating transition in Amsterdam, others where interviewed about two specific DH cases.

Analysis of their interests and views resulted in important aspects for the Amsterdam heating transition and five trade-offs for the configuration of a transition pathway. These aspects are that there currently is an unbalanced market for heating in Amsterdam because of a monopoly by the incumbent party. However, the municipality is provided possibilities for adequate policy on market organisation and tariff regulation by HL2.0 and E&P law coming into effect. The municipality is also working on multiple policies for the short-term. However, there is still a lack of a clear vision and policy for the Amsterdam heating transition by the municipality. Societal pressure drives private parties towards sustainability, but it is challenging to create feasible business cases without public finance (e.g. SDE++ subsidy). Financially secure business cases are necessary for DH with DC WH. Difficulties in collaboration with the municipality are experienced by other actors because the municipality is a large organisation. Though, these actors have the interest for formal collaboration with the municipality in DH projects to increase financial resources. The municipality could optimise the organisation of a learning environment, both internally and with external actors.

The five trade-offs are:

- Public vs. private (extend of municipal ownership)
- Collaboration vs. assignment (procurement model)
- Bottom-up vs. top-down (extend of residential participation)
- Small scale decentral vs. large scale integration (extend of integration)
- Flexibility vs. planned (extend of uncertainty)

4. *Which present actions organise collaboration between all actors and influence the transition towards such a system?*

The first short-term strategic episode (7.4.2 Preparation (2020-2025)) of the backcasting analysis presents several actions for the present for all actors in the Amsterdam heating transition. All actors could focus in the beginning on anticipation of planned changes in legal frameworks. HL2.0 and E&P law come into effect in 2020 and 2021 and will change the dynamics of the heating transition.

For emerging private parties in the heating sector, this means that there will be more opportunities to enter the market and gain market share. They could prepare by start planning and assessing capacity, strategic partnerships, possibilities for SDE++ subsidy and potential WH sources. For the incumbent party, this is likely to result in a decrease of their monopoly position. Reassessment of the current business case to anticipate the impact of market organisation and tariff regulation is a present action. They need to work closely with the municipality, smaller heating parties, project developers and consumers. Residents' collectives can prepare for the heating transition by organising themselves, which means they could already set up a plan of action and increase support by recruiting members. The municipality is offered opportunities to organise the heating market and tariff regulation. As present action, they could take public initiative in top-down planning of decentral LTDH locations for new-built areas as anticipation of the new legal frameworks. For existing neighbourhoods, they could integrate the planning and construction of decentral DH networks with other renewal underground works (e.g. sewage renewal). Planning for the city-wide integration of decentral (LT)DH networks could start. In order to implement DH networks bottom-up in the next episode (7.4.3 Implementation (2025-2030)), the municipality could increase assistance of residents' collectives in their organisation hereafter. The municipality must continue the current development of policy frameworks (such as 'affordable, open, sustainable' and 'the Amsterdam Sourcebook') and lobby for optimisation of the upcoming changes of the legal frameworks. The municipality could present a clear vision for the heating transition in Amsterdam to increase anticipation capability of other actors.

5. *How can the transition be guided towards a future way of district heating?*

By making use of the backcasting method, a transition pathway is formed that leads to a future target, based on a configuration of the five trade-offs. The configuration is based on a common view of actors. Initially, this vision could be created by the use of a CTA workshop. However, due to the Covid-19 crisis, in this research, the configuration came about via a survey about the five trade-offs.

For the heating transition in Amsterdam, the configured pathway is divided into short-term strategic episodes, containing changes in the socio-technical system of heating in Amsterdam. Each episode presents a set of actions for actors to anticipate these changes.

The target situation is that the heating system in Amsterdam is (fossil) gas-free by 2040. The desired heating technology is an open LTDH network using (data centre) waste heat or a renewable energy source. There should be one existing neighbourhood where the transition to gas-free heating is achieved by participating with local groups or initiatives. New-built dwellings should not be connected to the existing HTDH network.

The three episodes are preparation (2020-2025), implementation (2025-2030) and integration (2030-2040). First, the preparation episode from 2020-2025, where planning, learning and anticipation are essential. Second, is the implementation episode from 2025-2030. Here, construction and participation are the focus. Third, is the integration episode from 2030-2040. During this episode, the emphasis is on connecting decentral DH systems to exploit integration benefits.

> *How can small-scale local heating transition initiatives be guided towards a future way of district heating envisioned in municipal policy?*

Small-scale local heating transition initiatives can be guided towards a future way of DH envisioned in municipal policy by taking public initiative in top-down planning of decentral DH systems in the first episode (preparation 2020-2025). Features (optional) of the system are that it is connected to a waste heat source (e.g. data centre), open to third-party inlet, low-temperature and of the newest generation (4th or 5th). For existing areas, an integrated approach (e.g. combine with sewage renewal) could be taken into account to exploit economic benefits and reduce nuisance for residents. The municipality could prepare for market organisation, tariff regulation and appointment of locations for DH by organising an intra-municipal learning programme. The implications of the new legal frameworks and planning of DH networks could be indicated to private heating parties and residents' collectives. Private parties could adjust and optimise their business case while residents' collectives could start plan and organise themselves.

In the following episode (implementation 2025-2030), the planned decentral DH systems could be implemented using a bottom-up approach with an emphasis on participation. The intra-municipal learning programme could be extended to a city-wide programme for all actors to optimise participation, collaboration and flexibility. Topics for knowledge sharing are lessons learned in participation, forms of collaboration, DH system configuration and the use of municipal urban development tools. Market organisation becomes more important to regulate the growing competition. Participation of residents in new-built areas could be assisted and facilitated by the municipality in collaboration with the exploiting party. In existing areas, creating local support is important. Residents' collectives could be assisted by providing financial support in various ways, by the inclusion of the collectives in the learning programme and by forming official partnerships. The latter creates trust and provides access to the municipal network so that residents' collective can form other partnerships with private heating parties and parties of other disciplines for an integrated project approach. A municipal representative for each collective could lobby for its interest within the municipality. The municipality could be careful in demanding capacity of the collective to preserve the human energy and commitment of the members of the residents' collectives. Also, the use of energy communities could be investigated to stimulate local influence.

Emphasis could be on the city-wide integration of the decentral DH systems during the last episode (integration 2030-2040) to exploit integration benefits for local initiatives. Integration benefits are the possibility to balance supply and demand and reduce peak demand by using smart operating systems, cooling synergy, minimising the dependence on individual heating sources and uniform heating cost. The municipality could assist by overseeing an increase in digitalisation and collaboration between local organisations (rather than increasing the size of the organisation). This way, the DH networks are still operated bottom-up, but integration oversight is top-down. Policy and legal frameworks could be further developed through the learning programme to optimise sufficient regulation to achieve integration. Implementation of new DH systems could continue, but with flexibility towards new and more efficient heating technologies and renewable heating sources. Potential landscape events (e.g. impact of global warming, hydrogen potential, an increase of electrification) could then be anticipated adequately.

9.2. Limitations and recommendations

This section discusses the limitations as input for further research. During this research, the coronavirus broke out, resulting in a pandemic causing lockdowns over the whole world, including in the Netherlands. A CTA discussion workshop was planned between multiple actors in the Amsterdam heating transition, but due to the lockdown, this was cancelled. As a substitution, a survey was taken among the same actors who provided for sufficient input to configure the transition pathway. However, the research on the combination of CTA and BC as a method for stimulating and guiding local heating initiatives towards a goal set by municipal policy depreciated. With the use of a survey, the direct discussion between actors could not be exploited. The first and third criteria of CTA are still present. The first is the anticipation of the broader societal impact of the technology, which returns in the exploration of the Amsterdam heating transition. The third is reflexivity, where contrast and conflict between technology and society are avoided and to identify different actor roles. Identification of roles also recurs in the stakeholder analysis. The second criteria, societal learning, however, is lacking due to the absence of the discussion workshop. Especially second-order learning (clarifying and relating underlying values to each other) is missing, while this is essential in creating a common view. So, the added value of integrating CTA in the BC method could be further researched. Does CTA increase consensus among actors in the heating sector? Is it the right tool to create a common view among actors? Differences in the use of BC analysis can be investigated to assess if actor involvement and a common view are of added value. Thereby, because CTA shows much resemblance with TM, it might be interesting to investigate a combination between TM and BC further. BC might be used for strategic activities (vision development, strategic discussions, long-term goal formulation, collective goal and norm-setting and long-term anticipation).

It is aimed to interview the whole spectrum of stakeholders in this research. However, there is a majority in municipal officials among the interviewees. Also, among the respondents of the survey are only two non-governmental actors. Similar research with a focus on experiences of private parties in the heating sector could broaden perspective. Knowledge of linkages between public and private parties could be extended to optimise public-private collaboration.

There is a wide variety of characteristics of DH projects. The two cases in this research are seen as two extremes. Many DH projects experience other dynamics. More extensive and in-depth research on the differences between DH projects could result in more concrete recommendations. However, this research explores the general heating transition in Amsterdam, together with the two cases for a comprehensive understanding of the situation.

In the results of the analysis of normative views of actors, DH systems are mentioned often. This might be not very objective because a large part of the interviews is about DH systems, after which the most optimal way of heating for 2040 is asked. It is attempted to reduce this bias by explicitly questioning a reconsideration of optimal heating system.

In section 7.3.2, a series of visuals are presented, which lack quantitative substantiation and are based on the researcher's interpretation of the survey answers. Quantitative research with an outcome similar to these visuals could be valuable as a roadmap for policymaking. The research could take these visuals as a starting point to validate and quantify the transition path presented in section 7.4.

As mentioned in the discussion, research into increasing the value of trust between municipalities and residents' collectives could contribute to the knowledge of utilising local initiatives. This research will probably be more behavioural of origin, but broad insight into the proper management approaches could be valuable for municipalities across the Netherlands.

Recommendations for the City of Amsterdam to guide the heating transition towards sustainable DH are:

- Use BC internally to create transition pathways towards goals set by politics
- Use CTA to involve actors to broaden preparation and design and to create maximum support
- Engage more in collaboration with other actors
  - Be careful with demanding too much of residents' collectives: assist them in organising capacity to utilise their energy and commitment
  - Search for synergy with private parties: involve them in early stages for knowledge sharing
- Actively lobby and anticipate the possibilities of HL2.0 and E&P law and plan actions for area appointment and possible tariff regulation
- Continue development of participation models for local and decentral implementation of DH networks
- Organise a learning programme based on lessons learned, internally between departments and externally with actors for:
  - Degree of collaboration for the most optimal way of procurement and risk allocation
  - Degree of participation with residents
  - Optimisation of policy
- Use the transition pathway (section 7.4) and the roadmap (section 7.4.5) as guidance for the heating transition and to define the role of the City of Amsterdam during this transition period

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A

Interviewees

Table A.1: Interviewee overview

Interview	Organisation	Function
1	Municipal engineering firm	Consultant energy transition
2	Data server technology scale-up	Commercial manager
3	Municipal engineering firm	Integral project manager city district East
4	Municipal engineering firm	Project manager city district East
5	Contractor	Development and pricing manager
6	Municipal engineering firm	Quartermaster energy transition
7	Residents collective	Board member
8	District heating operator	Business developer
9	Data centre association	Policy officer
10	Municipal engineering firm	Project lead and consultant energy transition
11	Municipality area and sustainability	Policy maker

B

Interview questions

- What is your function? (and of your department if municipal official)
- Can you explain the project (case)?
- Who are the stakeholders in the project (case)?
- Who initiated the project? (and who should initiate the the transition in general?)
- What is the role division?
- What is the role of the municipality?
- What are barriers/challenges of the project (case)? (and in Amsterdam in general?)
- How is policy used? Does it need to change? How?
- Is there a learning environment involving all actors in the project? How is this designed? Is there room for experiments?
- Why is there no open LTDH network using WH in Amsterdam yet?
- How do you envision the ideal heating supply in 2040?
- How can we achieve this ideal heating supply in 2040?

C

Barriers

C.1. Barrier network

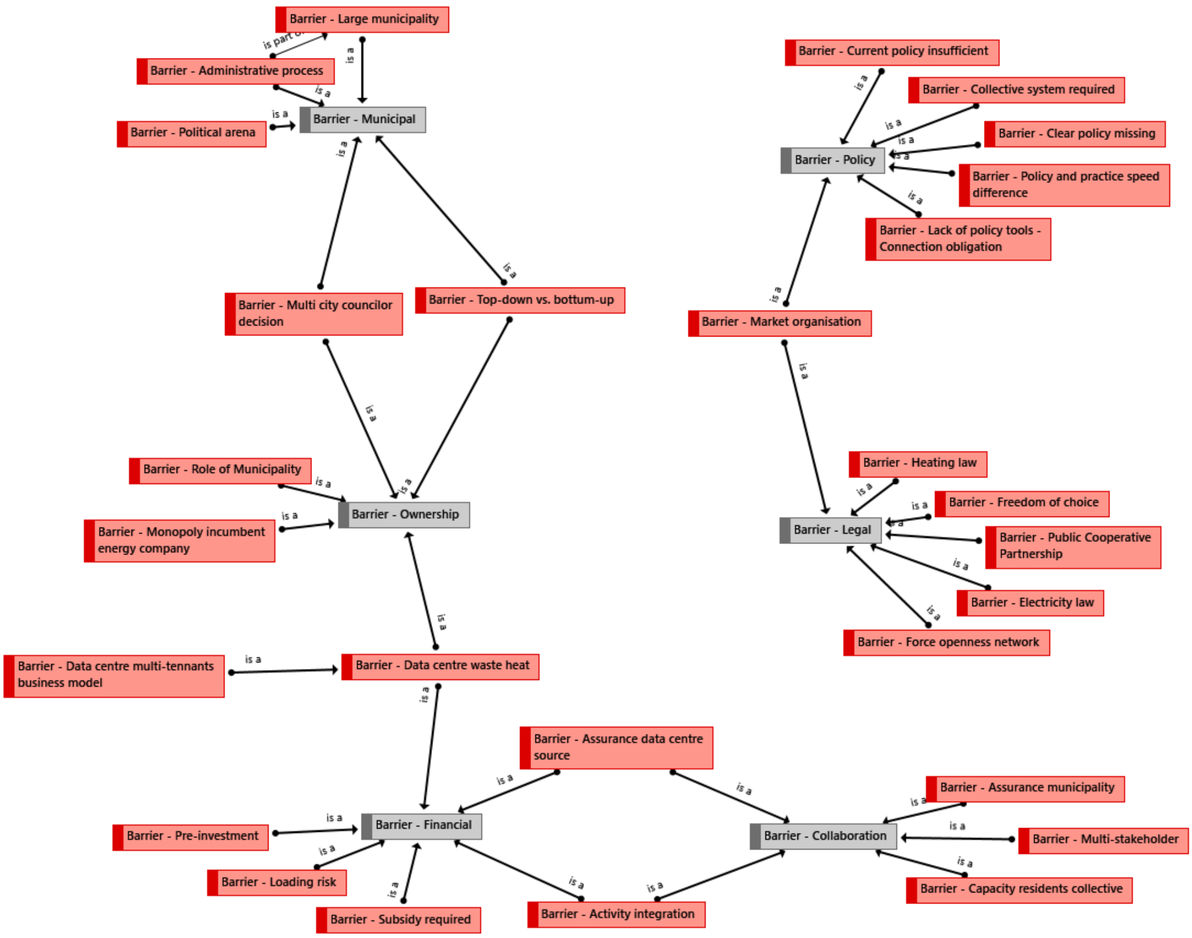

Figure C.1: Barriers categorised by organisational challenges from literature

C.2. Collaboration barriers

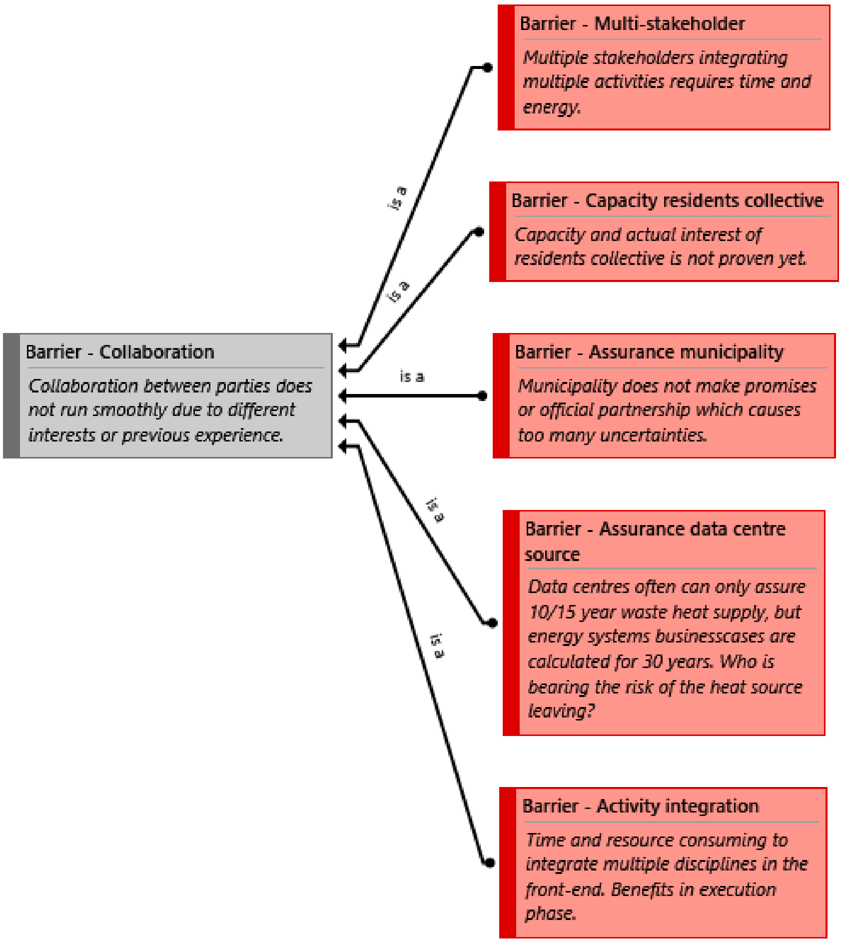

Figure C.2: Collaboration barriers with brief explanation

C.3. Financial barriers

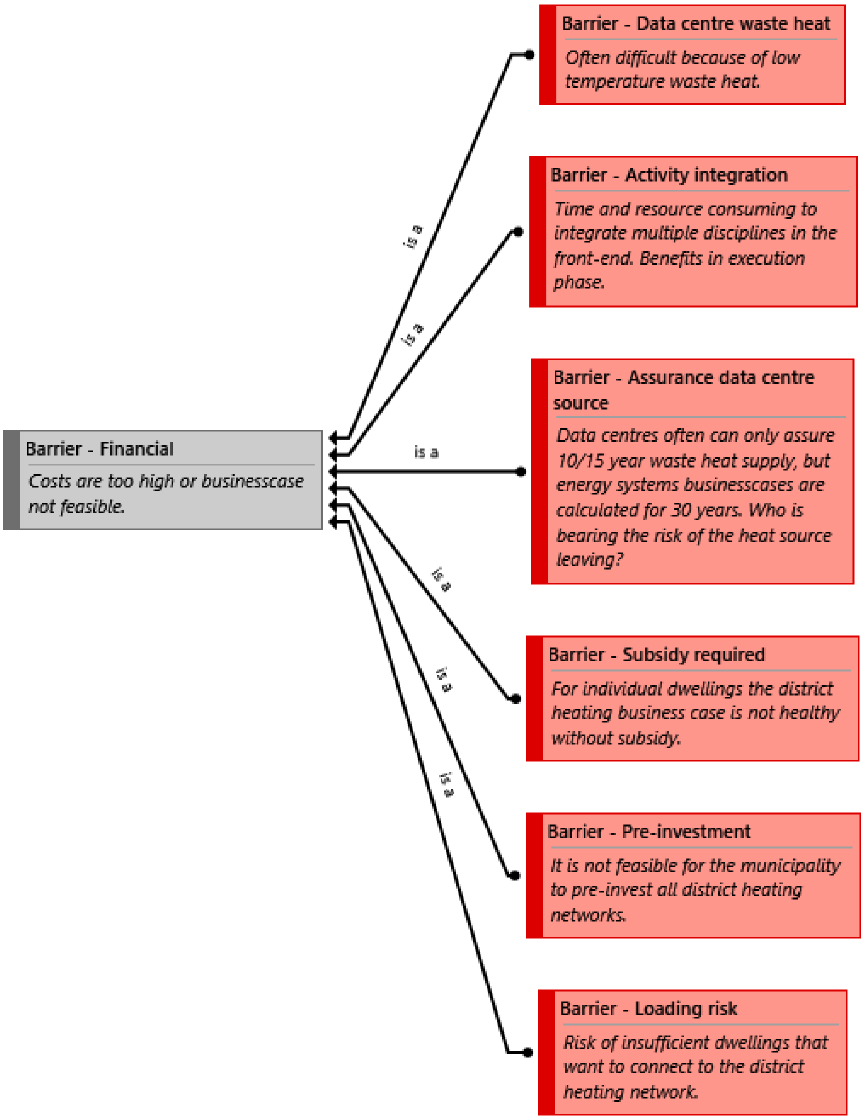

Figure C.3: Financial barriers with brief explanation

C.4. Legal barriers

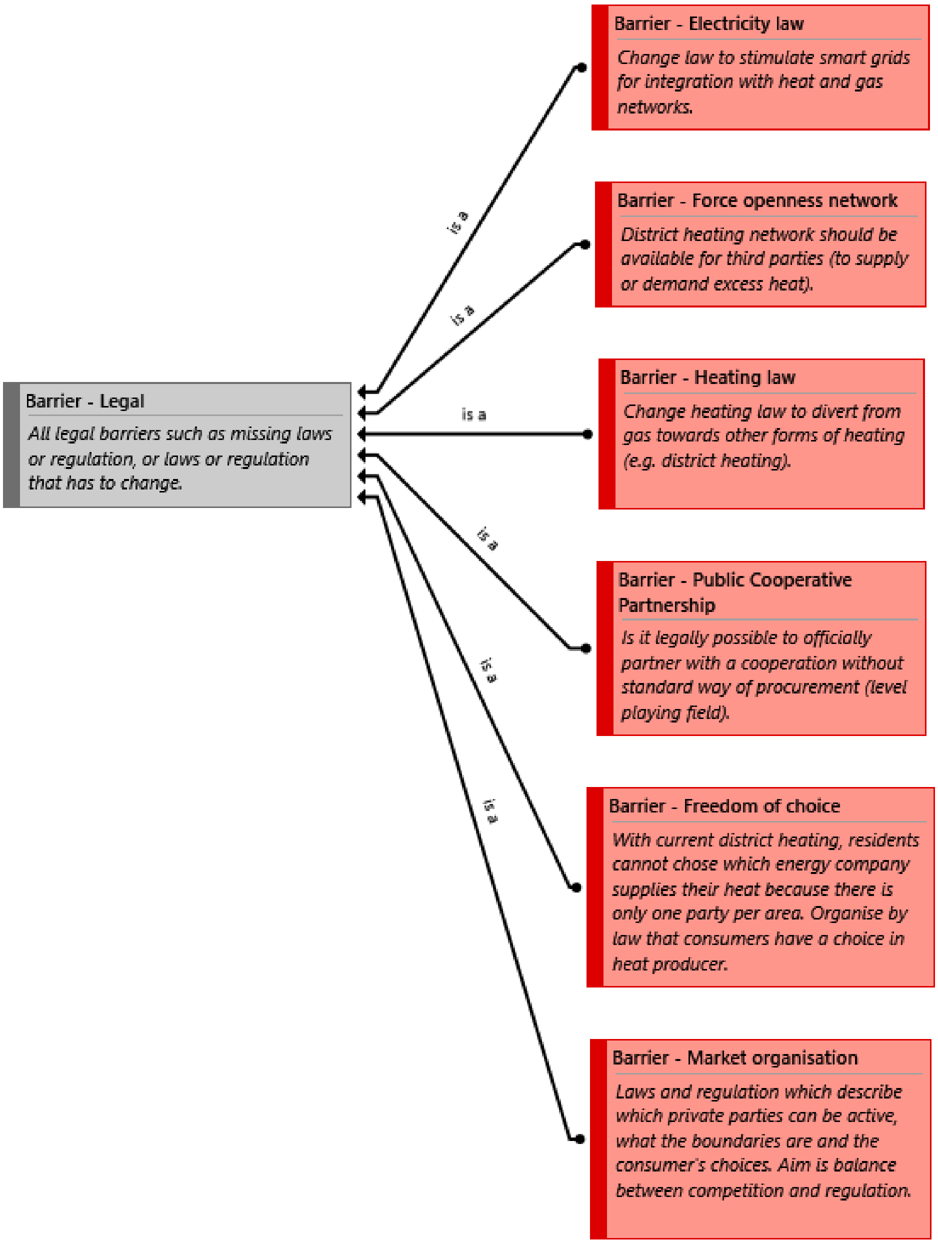

Figure C.4: Legal barriers with brief explanation

C.5. Municipal barriers

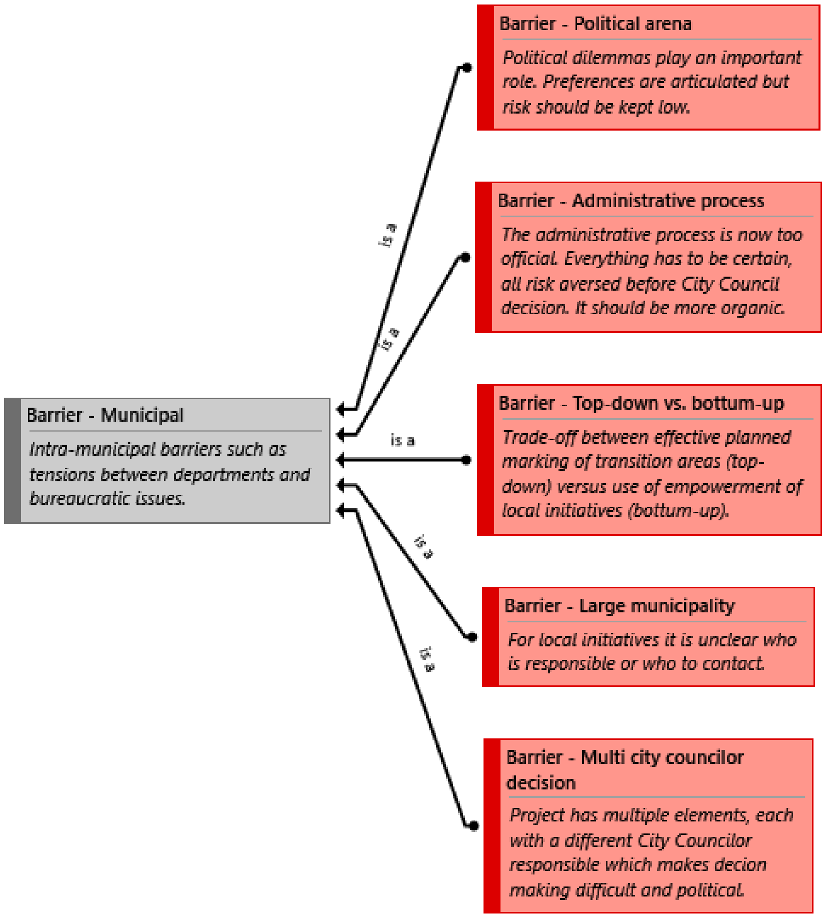

Figure C.5: Municipal barriers with brief explanation

C.6. Ownership barriers

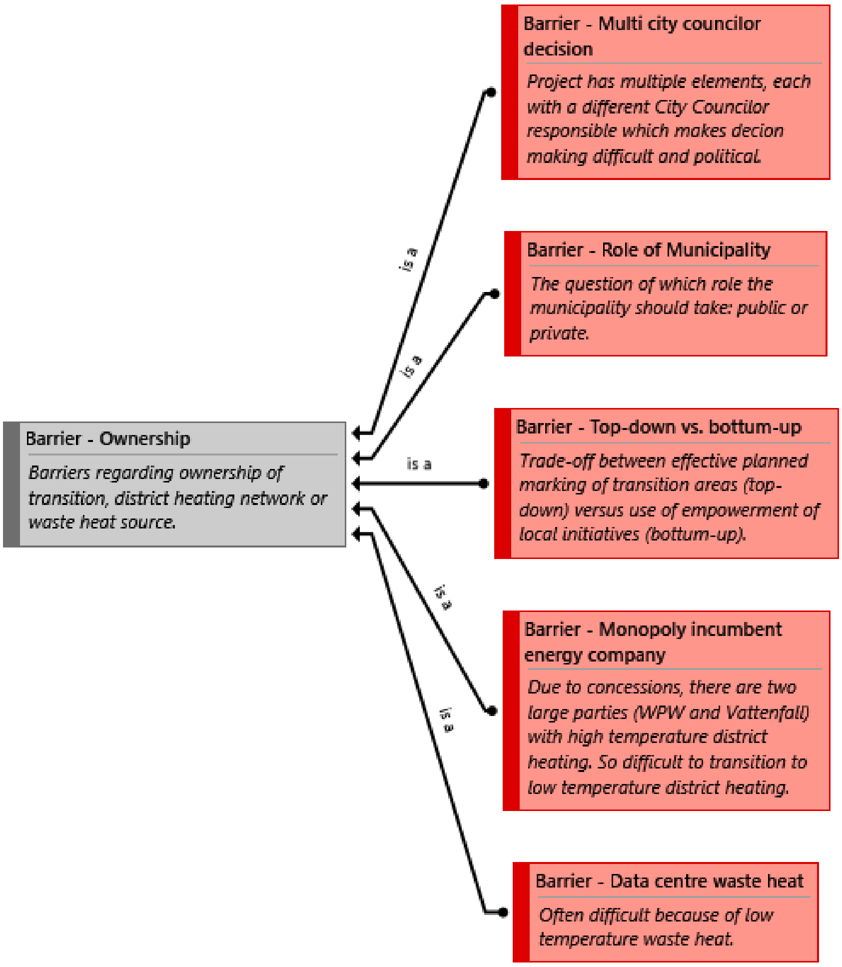

Figure C.6: Ownership barriers with brief explanation

C.7. Policy barriers

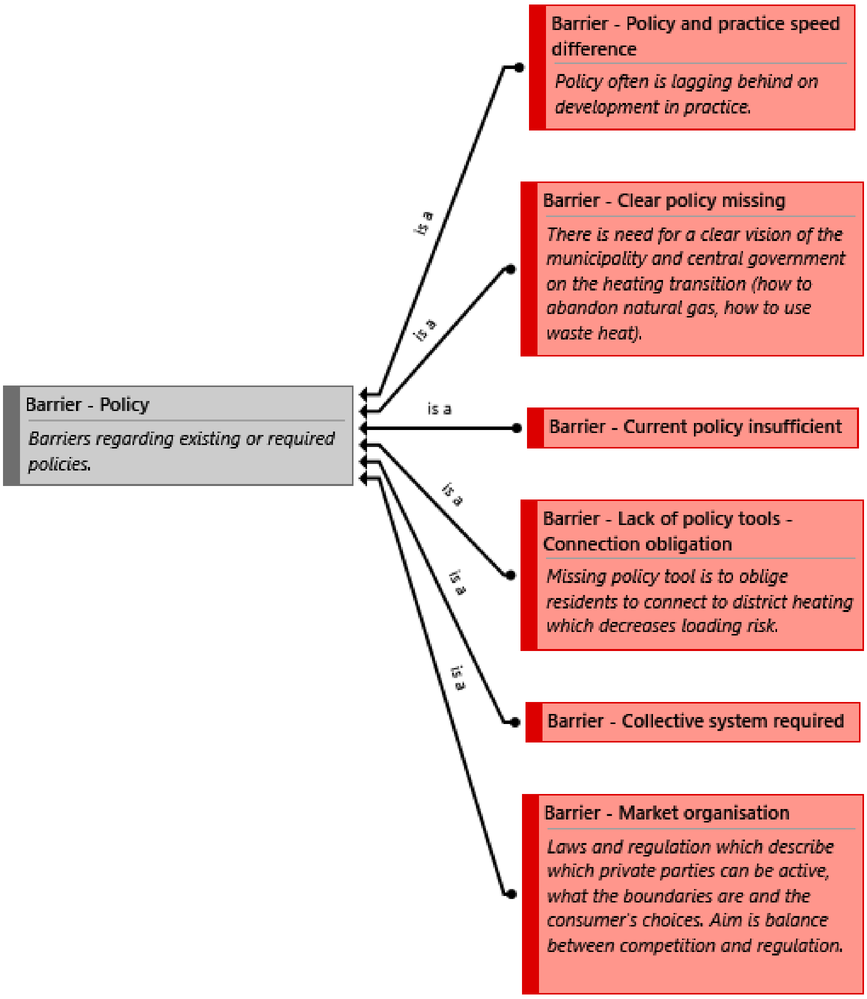

Figure C.7: Policy barriers with brief explanation

C.8. Case 1 barriers

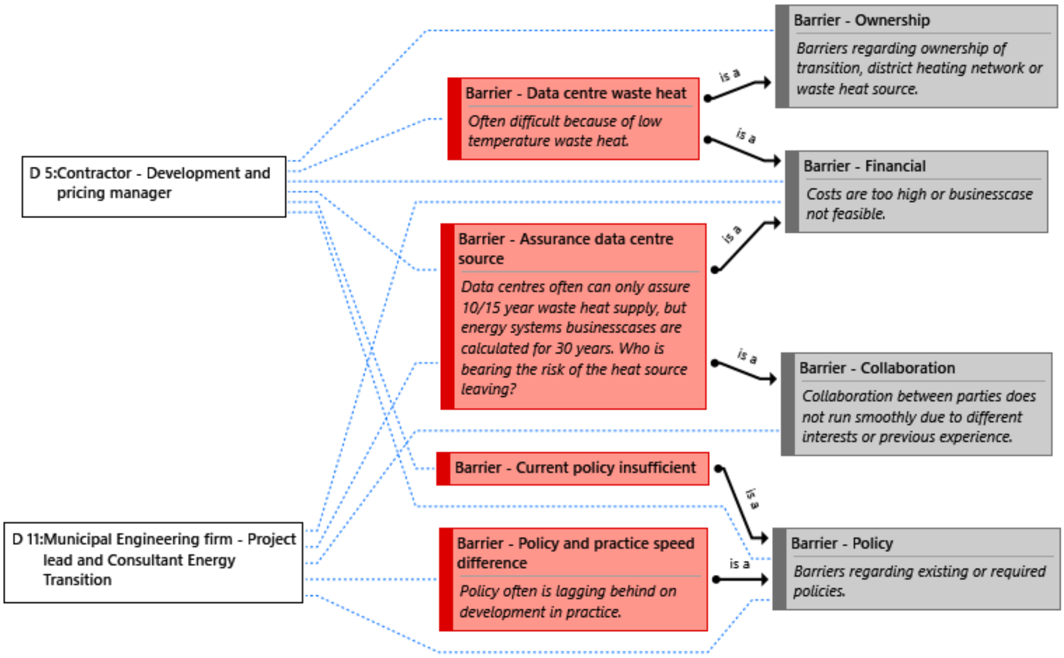

Figure C.8: Main barriers mentioned in interview 5 and 11

C.9. Case 2 barriers

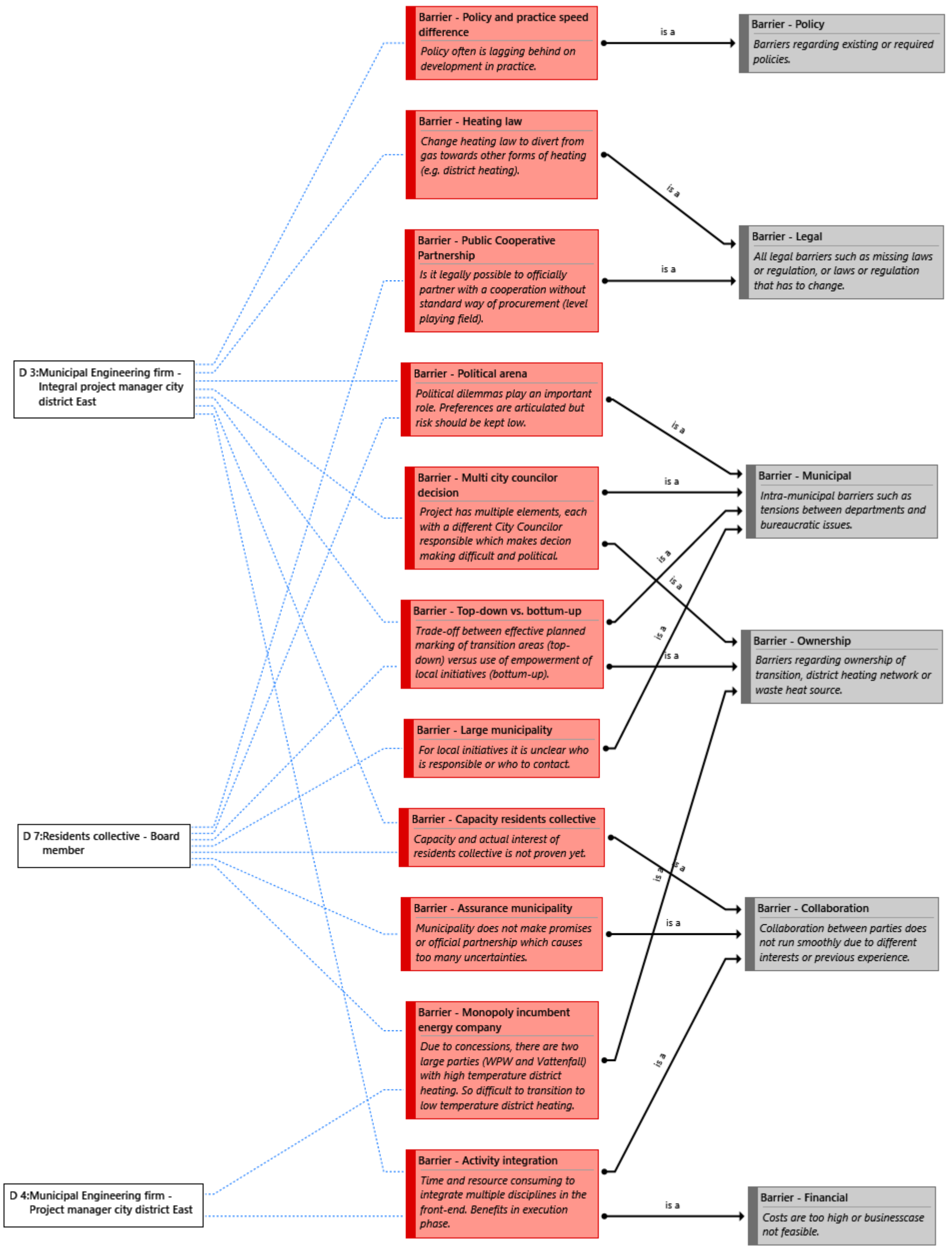

Figure C.9: Main barriers mentioned in interview 3, 4 and 7

D
Interests

D.1. Interest network

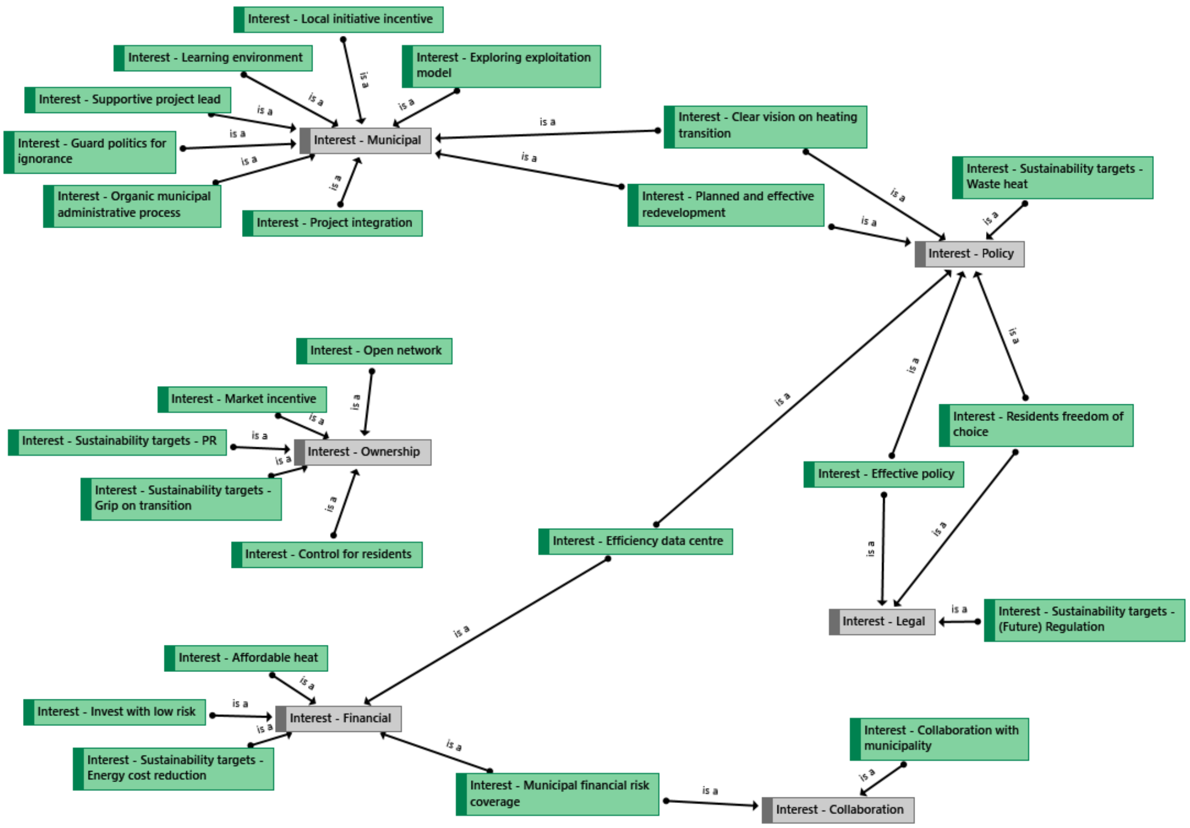

Figure D.1: Interests categorised by organisational challenges from literature

D.2. Collaboration interest

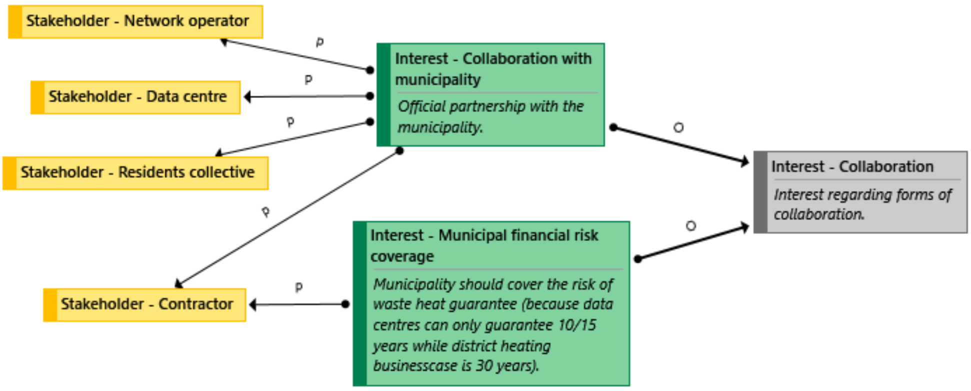

Figure D.2: Collaboration interest with brief explanation

D.3. Financial interest

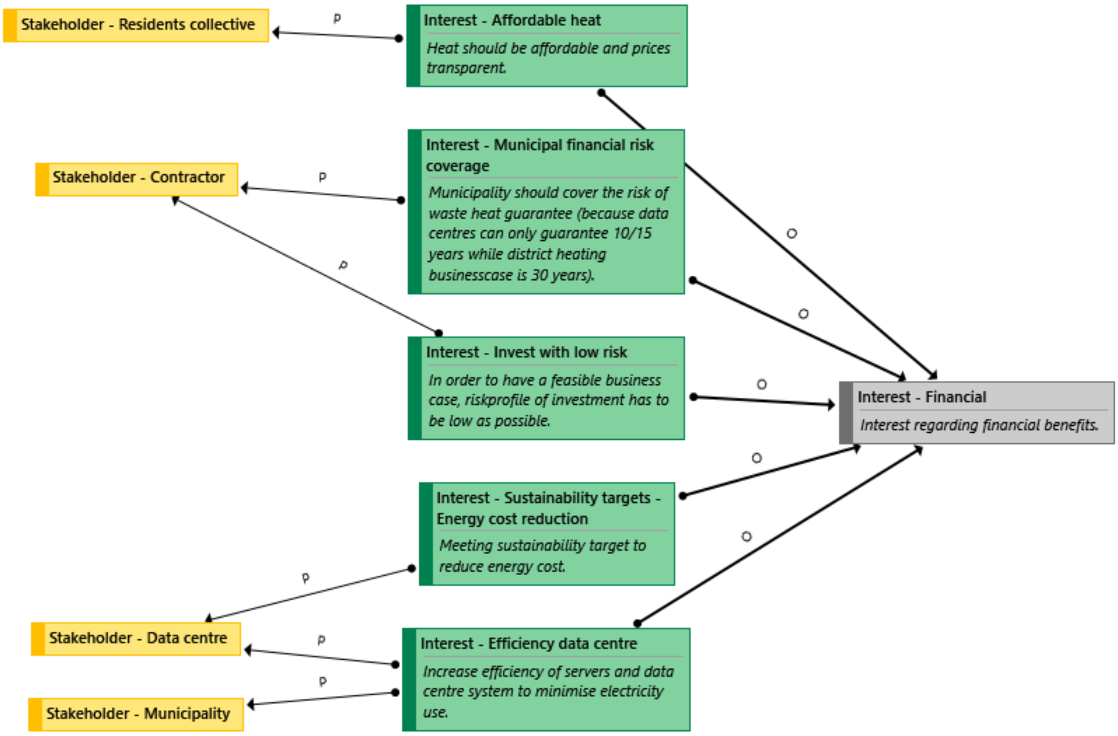

Figure D.3: Financial interest with brief explanation

D.4. Legal interest

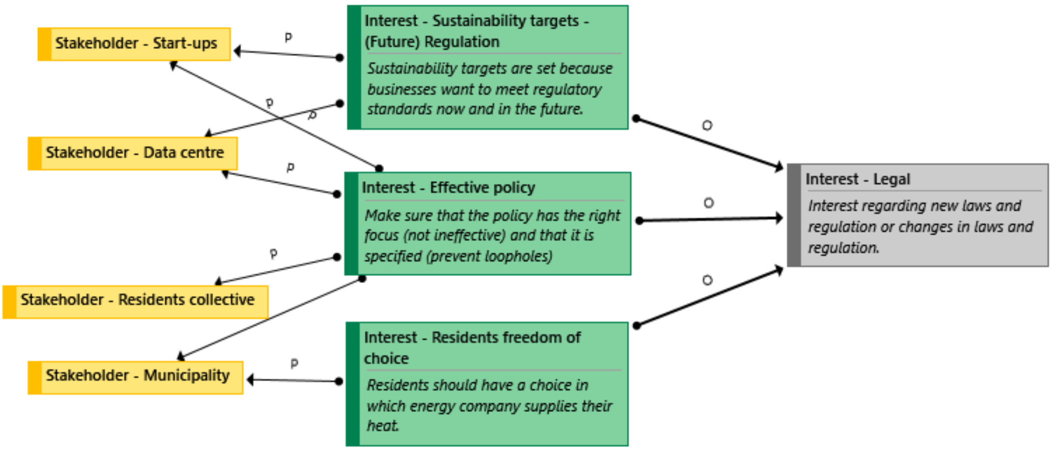

Figure D.4: Legal interest with brief explanation

D.5. Municipal interest

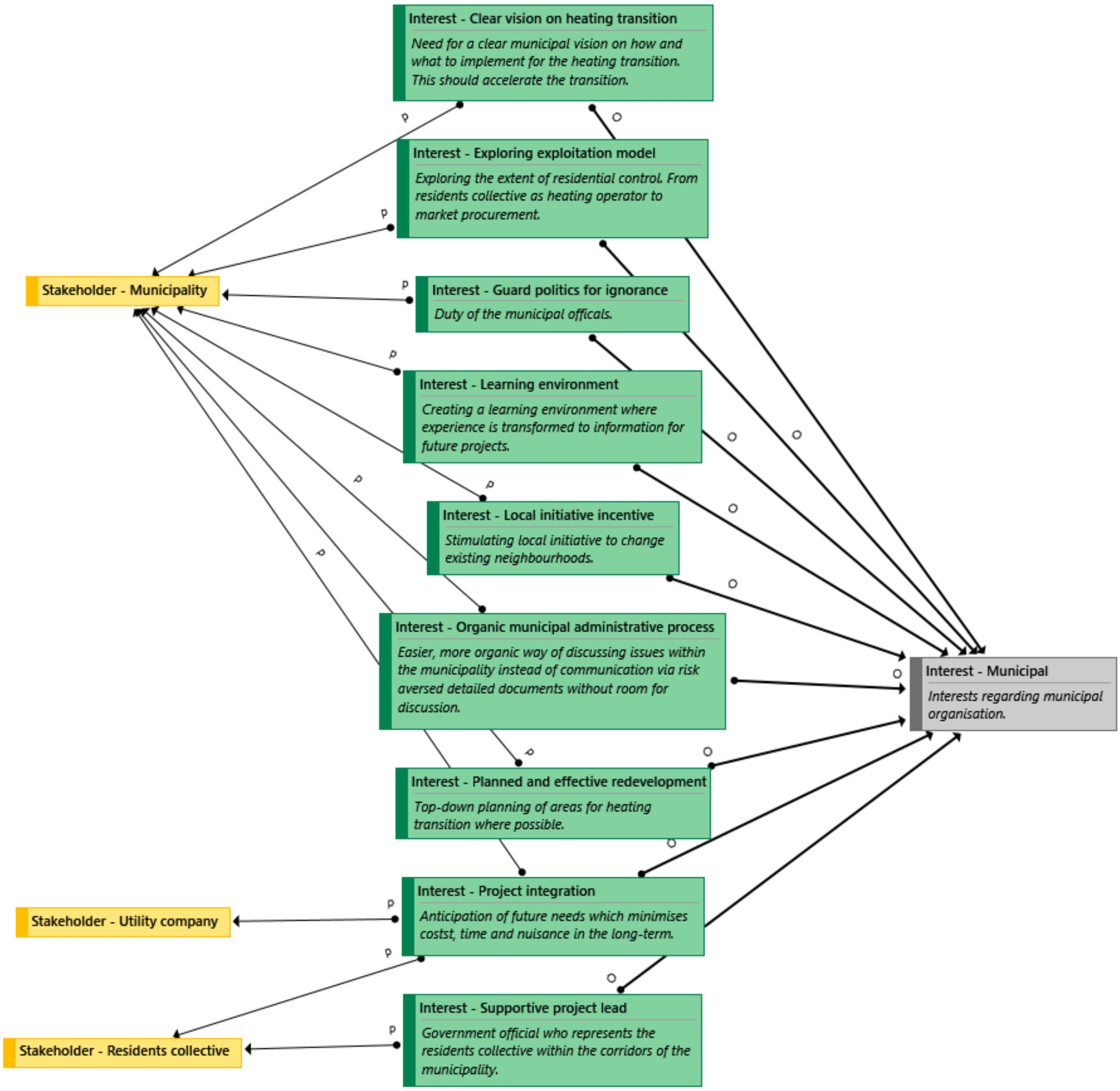

Figure D.5: Municipal interest with brief explanation

D.6. Ownership interest

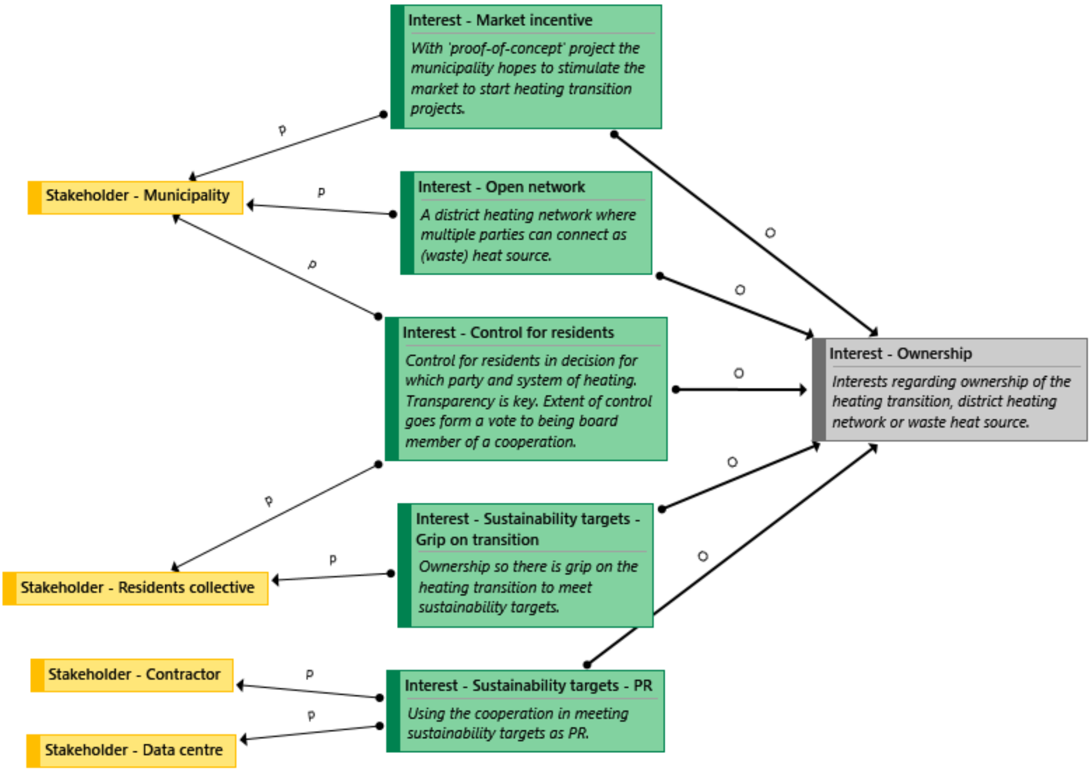

Figure D.6: Ownership interest with brief explanation

D.7. Policy interest

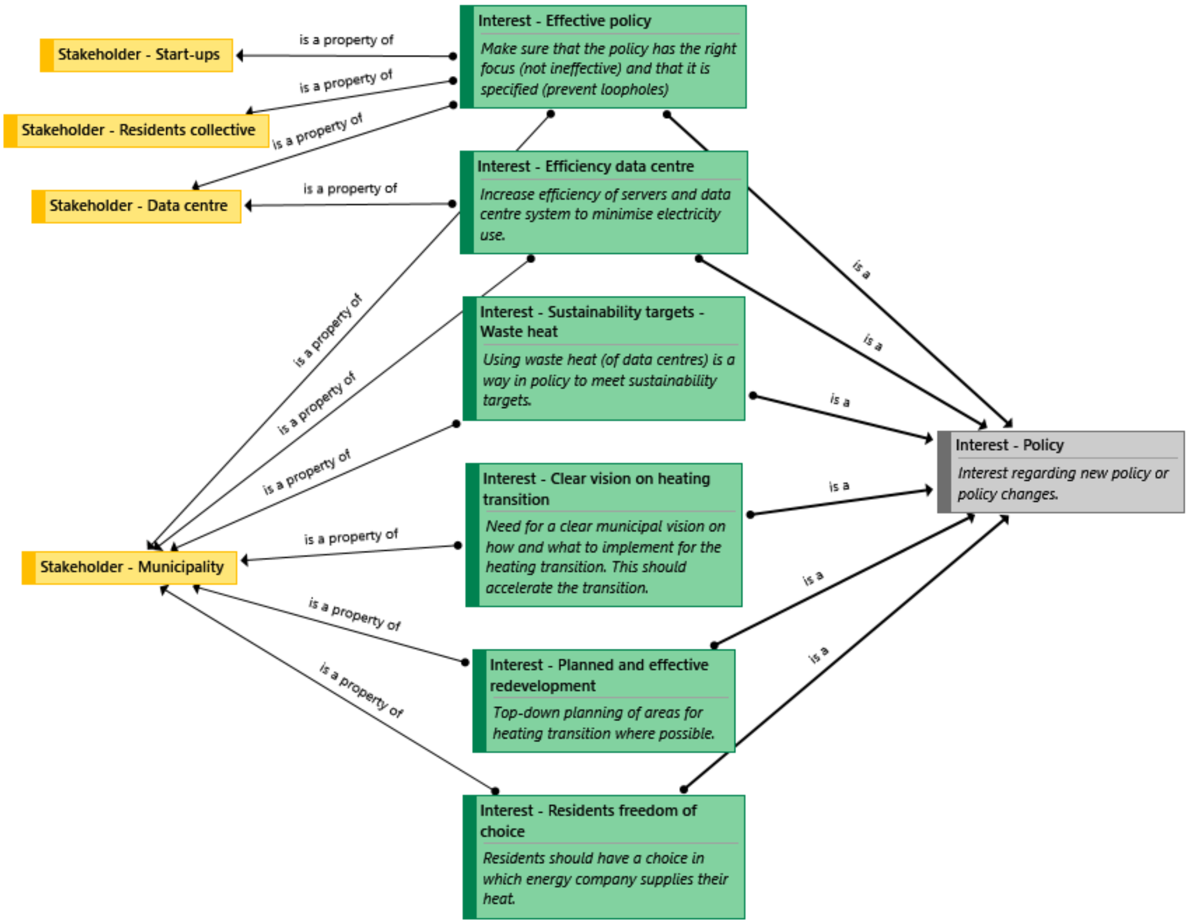

Figure D.7: Policy interest with brief explanation

E

Stakeholder interests

E.1. Municipality interests

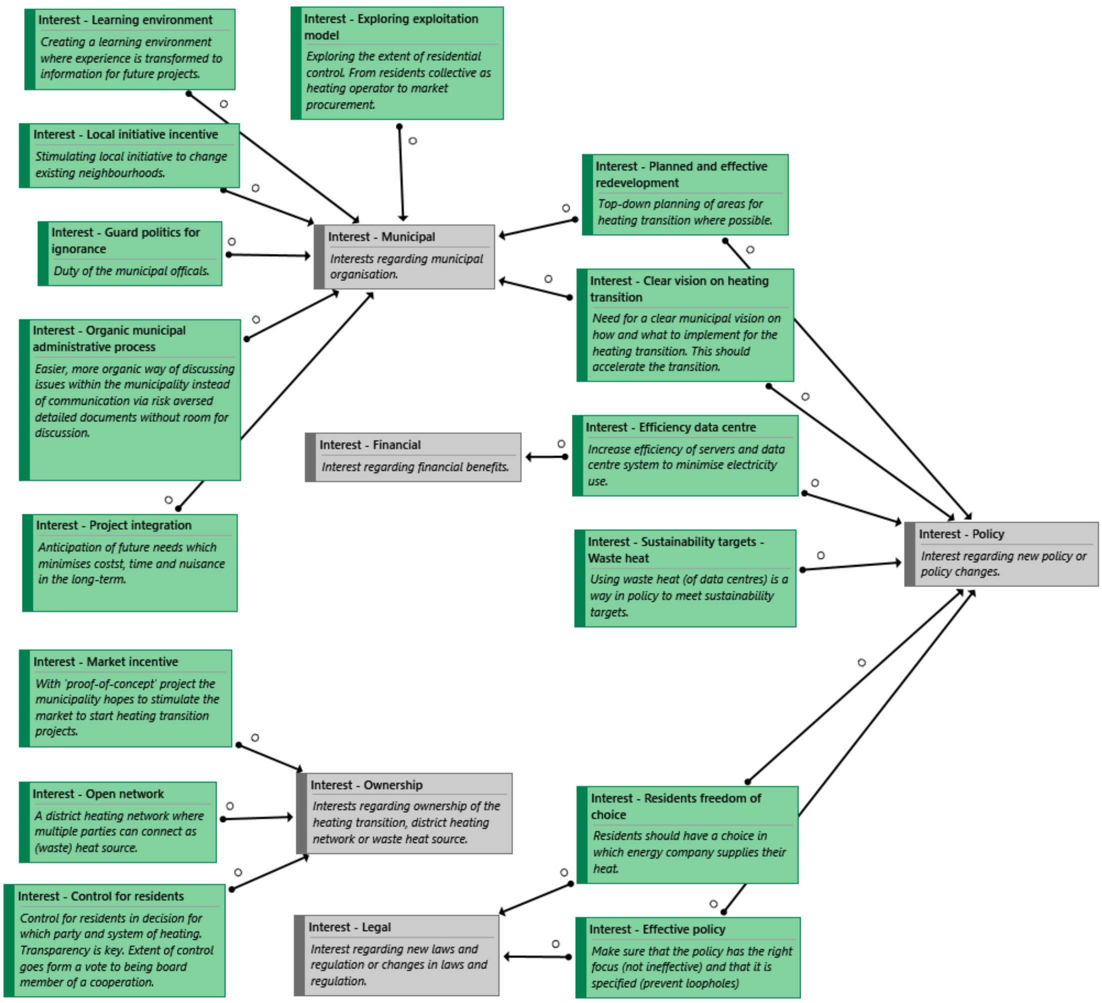

Figure E.1: Interests of the municipality

E.2. Contractor (and project developer) interests

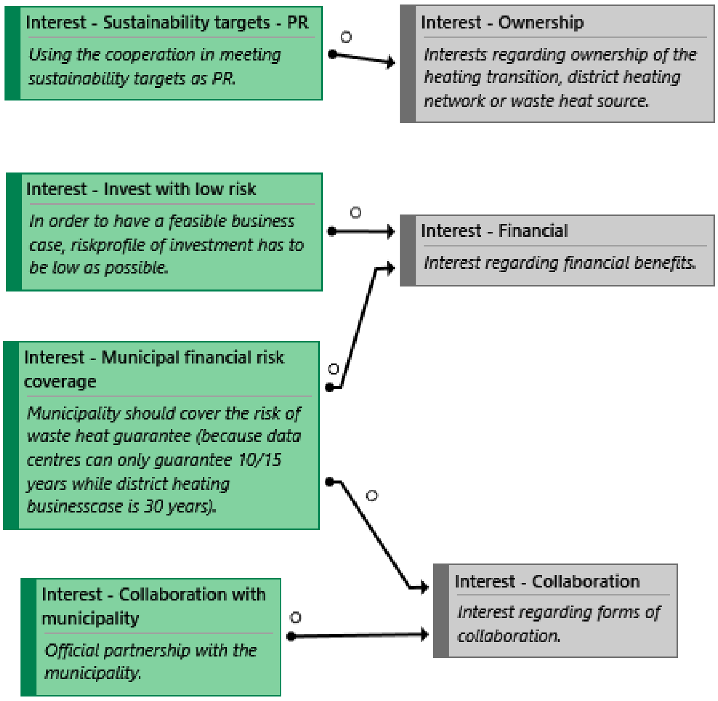

Figure E.2: Interests of the contractor

E.3. Network operator interests

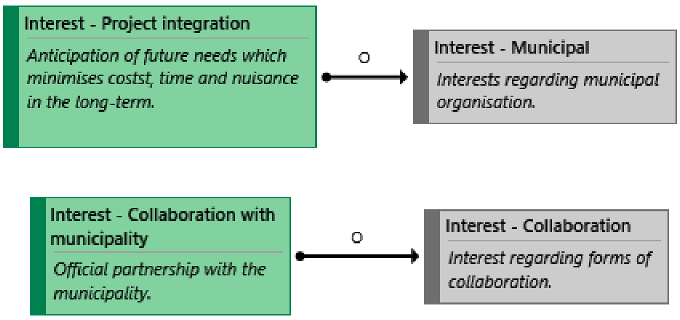

Figure E.3: Interests of the network operator

E.4. Data centre interest

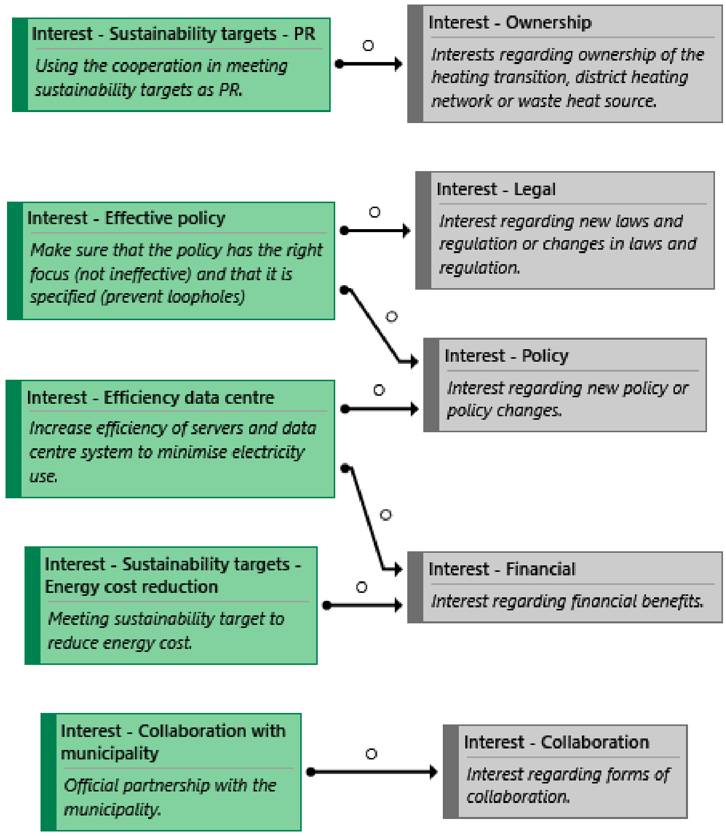

Figure E.4: Interests of data centres

E.5. Start-ups interests

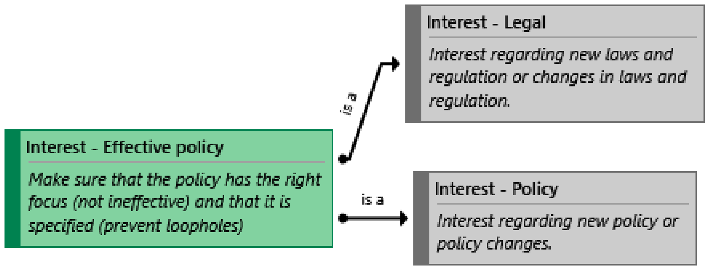

Figure E.5: Interests of start-ups

E.6. Residents collective interests

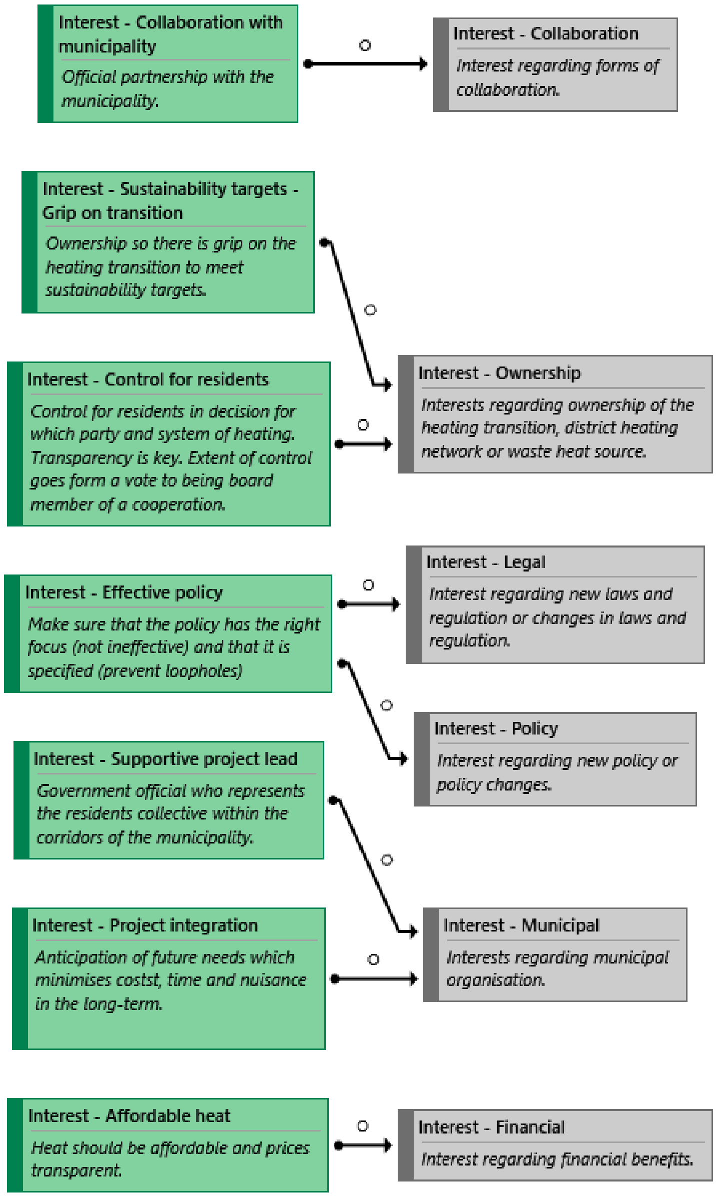

Figure E.6: Interests of the residents collective

E.7. Case 1 interests

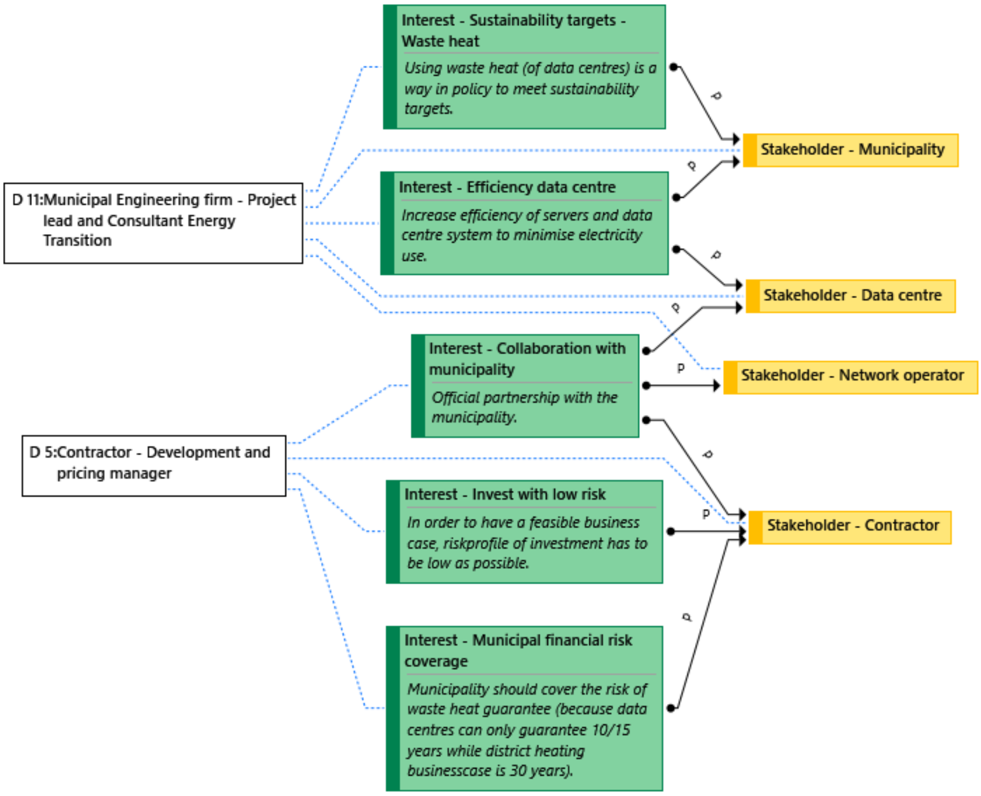

Figure E.7: Stakeholders and their interests (Interview 5 and 11)

E.8. Case 2 interests

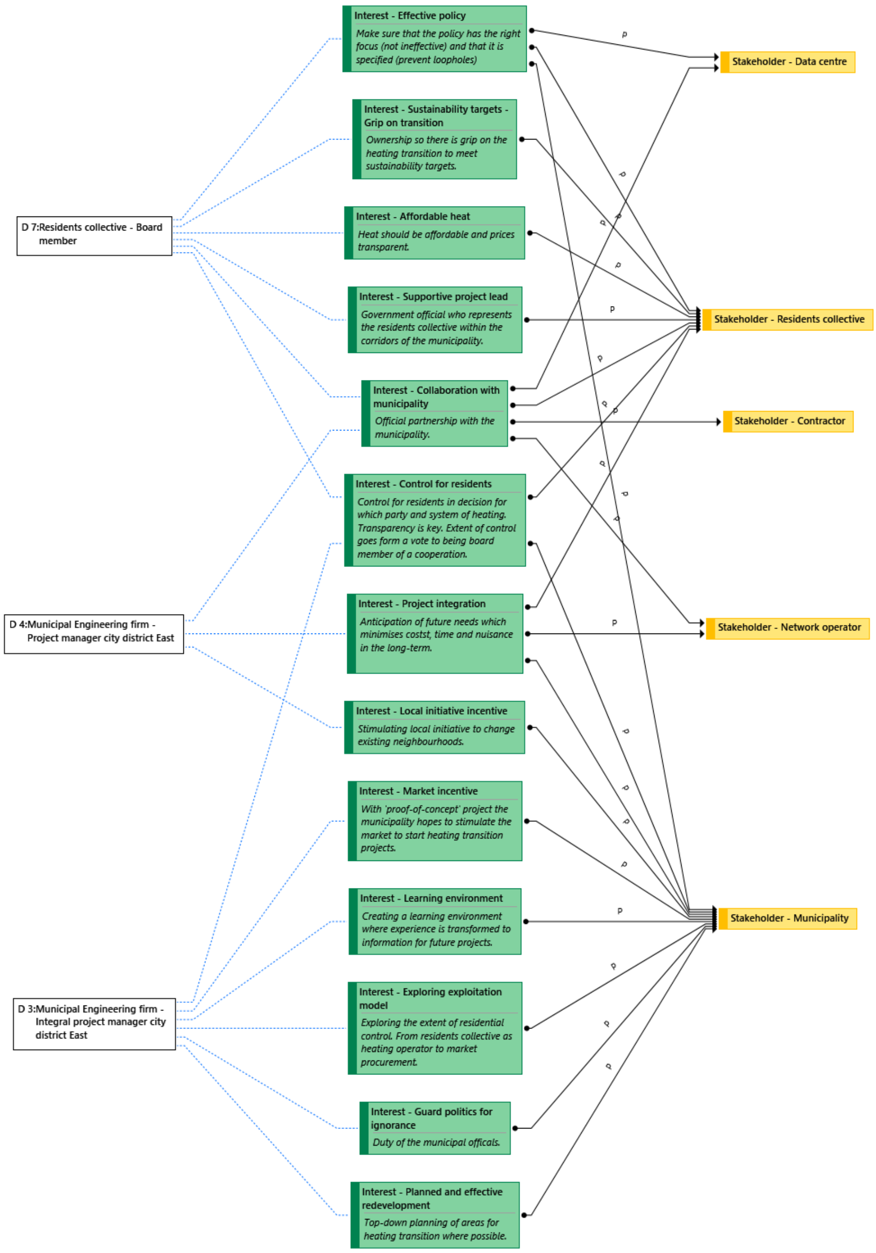

Figure E.8: Stakeholders and their interests (Interview 3, 4 and 7)

F

Transition paths

F.1. Transition path network

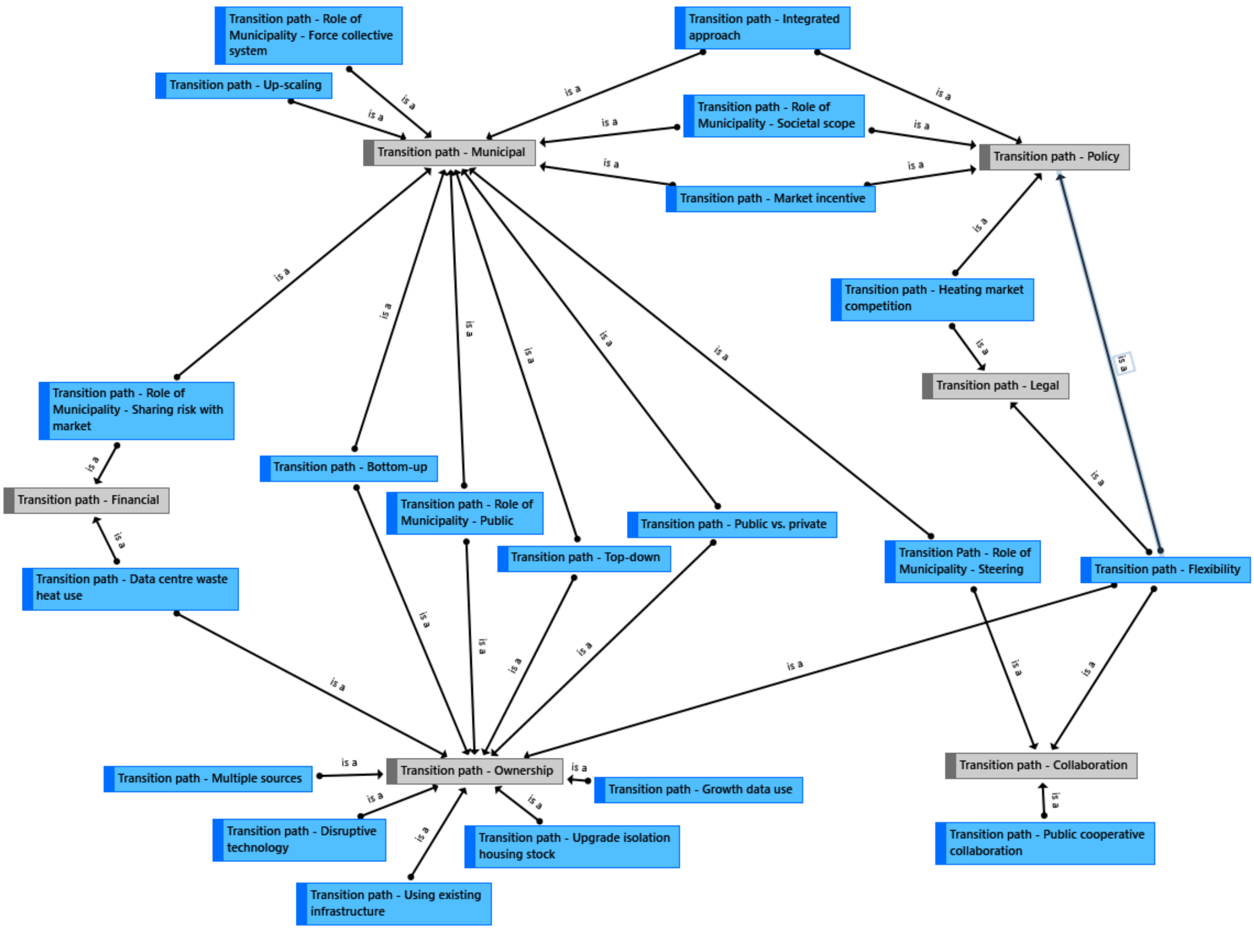

Figure F.1: Transition paths categorised by organisational challenges from literature

F.2. Collaboration transition path

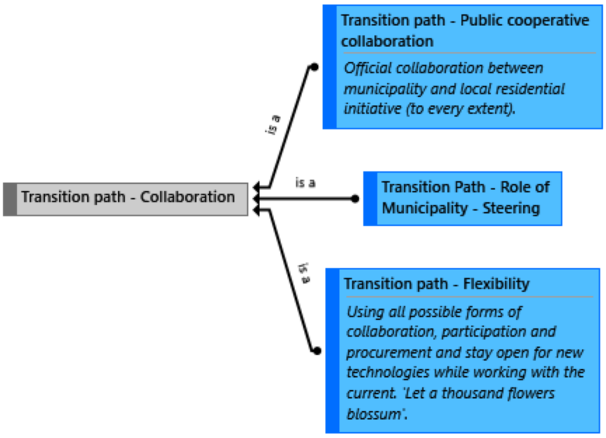

Figure F.2: Collaboration transition paths with brief explanation

F.3. Financial transition path

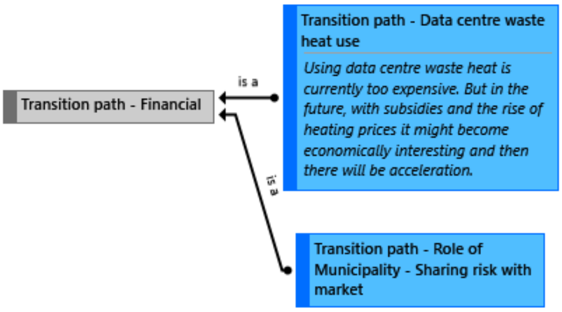

Figure F.3: Financial transition paths with brief explanation

F.4. Legal transition path

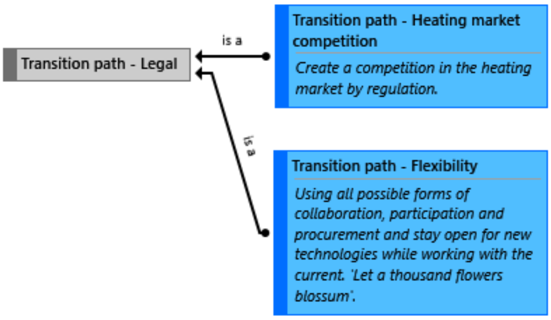

Figure F.4: Legal transition path with brief explanation

F.5. Municipal transition path

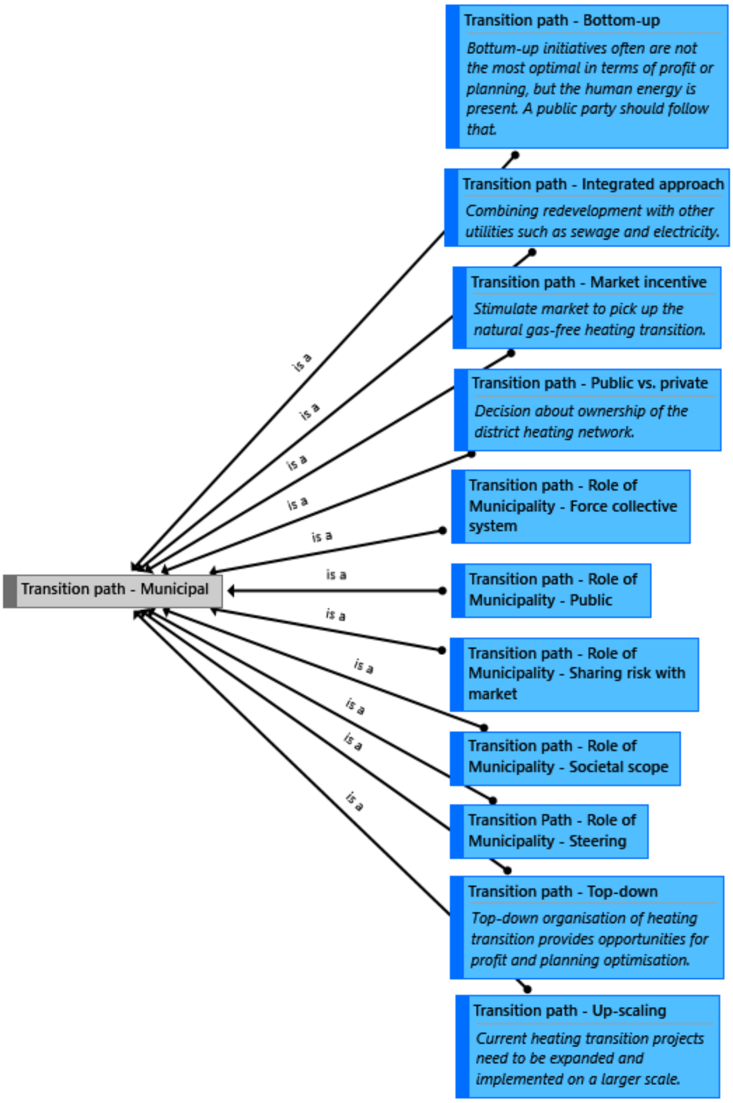

Figure F.5: Municipal transition path with brief explanation

F.6. Ownership transition path

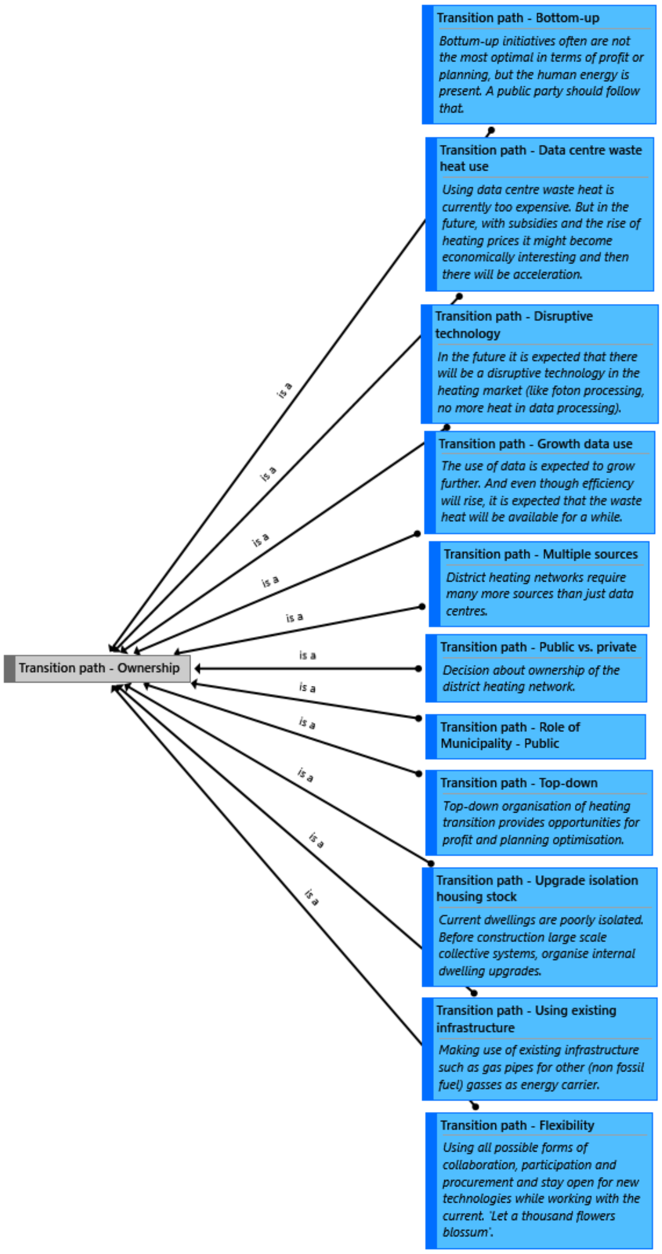

Figure F.6: Ownership transition path with brief explanation

F.7. Policy transition path

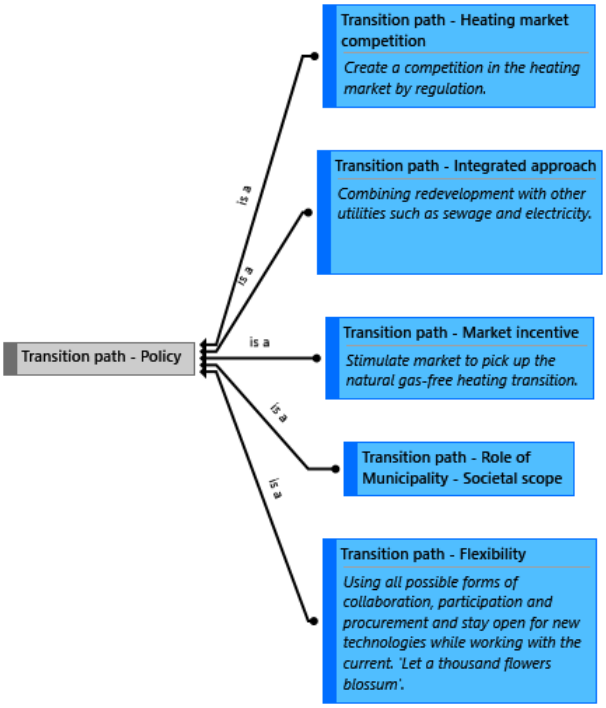

Figure F.7: Policy transition path with brief explanation

G

Normative views

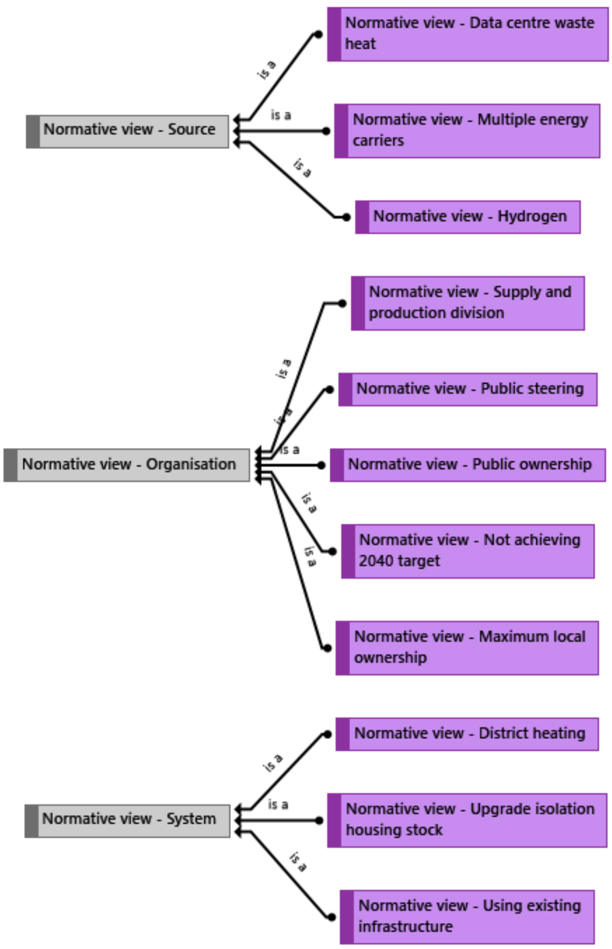

Figure G.1: Normative view codes