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A Case Study into Municipal Heat Transition:

A Data-Driven Policy-making Tool

TU Delft

A Case Study into Municipal Heat Transition:

A Data-Driven Policy-making Tool

By

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Delft University of Technology

“Sometimes you make the right decision, sometimes you make the decision right” (Phil McGraw)

“We cannot only rely on the ethics or the moral of the people” (Fatih Birol)

Preface

It has been one of the best two years of my journey, where life has such dynamics; it is full of meaningful lessons, fruitful ideas, and diverse people.

In the writing process of this thesis, energy does not stand still; it keeps transitioning. As I gradually become a better writer in every stroke of a letter, humankind gradually seeks to reduce its 761 tonnes of carbon equivalent per-second emission. As part of humanity, having a fortunate opportunity to study in CoSEM faculty, I bear the responsibility to contribute ideas, seeking means to pass resources for the future generation. The future generation bears the burden not only with their carbon emission but also with today's --our emissions.

I am happy that this thesis comes to an end as this means a new journey to the new research ---or at least I hope so.

It is impossible to complete this thesis without constant support and guidance of people surrounding me. I am incredibly grateful for that.

First and foremost, I would like to thank my supervisor Anneke Zuiderwijk- van Eijk. Thank you very much for your support, guidance, and always sparing time for my thesis. Your insight and advice are extremely valuable and insightful. Thank you for setting up my thesis network. Thank you for keeping up with my thesis, as well as wellbeing; you have proved that a professional relationship can also be engaging.

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I also thank all fourteen participants who were willing to be interviewed for this thesis. I thank all of my peers; thank you for your feedback and for sharing your story.

Last but not least, I would like to thank my mother and my late father. Thank you very much for trusting and loving me unconditionally. When I am not feeling good enough, I know you both love me nevertheless, and it never fails to make me feel better afterwards.

Two years have passed. I wish to see this moment as the start --for a better me and the Netherlands' wise transition.

Mustika S. Hajarini

Delft, August 12th, 2020

Executive Summary

Research context

Climate change is an urgent global problem. The Netherlands anticipates this problem with both public cooperation (e.g. climate agreement) and policy-making (e.g. climate act and energy agenda). One of the main sustainability goals of the Netherlands is to eliminate natural gas usage by 2050. As part of the strategy, the Dutch government plans to phase out natural gas by utilising municipal leadership.

However, although guidances have been offered, municipal heat transition policy is a tricky matter that the municipal policy-makers struggle to grasp. They are puzzled on how they can influence the citizens to make a voluntary investment on heat transition. Policy-makers are currently in a tough situation where they have been mandated as the director of the heat transition without legal power to make citizens shift their heat source. Moving peoples will voluntarily is a complex problem that the policy-makers wish to cover.

This study is meant to provide the municipal heat transition policy-makers in the Netherlands with a refined empirically enhanced design, namely refined **H**eat **T**ransition **Po**licy-**Ma**king (HeTPoM) **D**ecision **S**upport **S**ystem (DSS) framework, that can be used to help policy-makers in to systematically design, assess, and evaluate municipal heat transition policy.

Research question and approach

The main research question is formulated as follows: ***What decision support system framework can systematically assist municipalities in the heat transition policy-making process?*** To answer that question, design science research approach was applied in four steps: 1) problem identification, 2) identification of possible solutions, 3) design and development, and lastly, 4) evaluation. In the first phase of the thesis research, problem identification, a Systematic Literature Review (SLR) was conducted. In the second phase of the thesis research, identification of possible solutions, a case study (of Zoetermeer municipality heat transition policy-making) with interviews as the main source of data was executed (in combination with a qualitative analysis method). Then, the HetPoM DSS framework was designed in the third phase of thesis research (design and development) utilising an engineering design method. Lastly, an artificial ex-ante evaluation (in a form of expert workshop) was used to evaluate HeTPoM DSS framework. The evaluation phase generated a refined HeTPoM DSS framework that is created based on the discussion with experts in the evaluation workshops.

Findings

To answer the main research question, four research questions are designed as follows.

1. What aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?

DSS framework is defined as an artefact that envisions a basic structural model of a DSS. DSS frameworks are formed by three main elements: 1) database, 2) decision model, and 3) decision dialogue. Database of the system is represented using heat transition influencing factors, while the decision model is represented by the policy-making process and actors who are involved in the policy-making as shown in the table below.

	Decision model			Database		
	Process		Actors	Heat transition influencing factors		
	Conceptual	Pragmatic		Social	Economy	Technical
	1) Prediction and problem definition 2) Design and experimentation	1) Defines goals 2) Steer heat transition	1. Heat transition policy-makers	1) Attitude 2) Individual knowledge 3) Individual perception	1) The organisational affair 2) Ownership	1) Production 2) Consumption 3) Physical transport infrastructure

DSS Framework	3) Implementation and evaluation	3) Lead heat transition 4) Enable heat transition	2) Energy (service) providers 3) Housing providers 4) Citizens	4) Behaviour 5) Economic power 6) Individual empowerment 7) Established social network 8) Fairness	3) Path dependency 4) Profitability 5) Energy demands 6) Negotiation 7) Energy national regulation 8) Data regulation	4) Energy service 5) Data service

At the process side, we can see the policy-making process based on the policy cycle. The simplest presentation came from van Veenstra and Kotterink, (2017) who presents a framework based on three phases namely 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation.

In this process, four groups of actors are involved. First, the heat transition policy-makers who coordinates heat transition through regulation. Second, a service provider (companies) who provides the energy to the houses as well as transporting it. The third group is the housing providers represented by the social housing corporations and private real estate business in the existing case. The fourth group is the citizen who uses this energy (i.e., house owners and tenants)

At the data side, to support database creation of the DSS, eight social influencing factors, eight economic influencing factors, and five technical influencing factors (total of 21 influencing factors) are derived. These eight social heat transition influencing factors are presented as follows: 1) attitude (acceptance), 2) individual knowledge, 3) individual perception, 4) behaviour (participation), 5) household economic power, 6) individual empowerment, 7) established social network, and lastly, 8) fairness. Then eight economic heat transition influencing factors are identified as follows: 1) organisational affair, 2) ownership, 3) path dependency, 4) profitability, 5) energy demands, 6) negotiation, 7) energy national regulation, and 8) data regulation. Lastly, five technical heat transition influencing factors are identified as follows: 1) production, 2) consumption, 3) physical transport infrastructure, 4) energy service, and 5) data service. These results are then used as the base for the case study that is used to answer the next question.

2. What are the needs for a decision support system framework to assist municipal heat transition policy-making?

We derived the five main needs for the municipal heat transition DSS framework using a case study approach based on Yin (2018) guidance. In this case study, thirteen interviews were used as the primary information sources. These sources then coded to structure more comprehensive information. From this information, we conclude five main needs for the municipal heat transition DSS framework.

The first need is that it shall support an open, transparent, and equal municipal policy-making process. Second, the process needs to be able to support key actors need management. These actors are the energy department of the municipality, Stedin, and social housing corporations (Vestia, Vidomes, and De Goede Woning). However, this set of municipal heat transition actors is expanding to now include the social department of the municipal office, private house real estate, citizen, and citizen initiatives. Then, the third need is to support modularity.

Fourth is the need to support turning the policy-making substance into process-based governance. This process can be divided into three phases of policy cycles: 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation.

And lastly, it needs to be a data-driven process to keep ensure the legitimacy of municipality policies legitimacy. This data includes twenty-seven influencing factors that need to be considered in the policy-making that is summarised in the table below.

Heat Transition influencing factors from the Zoetermeer municipal heat transition policy-making case study		
Social	Social	Social
1) Behaviour 2) Attitude 3) Capability 4) Social cohesion 5) Stakeholder engagement 6) Demographic profile 7) Stakeholders profile 8) Fairness 9) Uncertain behaviour 10) Stakeholders motivation	1) Behaviour 2) Attitude 3) Capability 4) Social cohesion 5) Stakeholder engagement 6) Demographic profile 7) Stakeholders profile 8) Fairness 9) Uncertain behaviour 10) Stakeholders motivation	1) Behaviour 2) Attitude 3) Capability 4) Social cohesion 5) Stakeholder engagement 6) Demographic profile 7) Stakeholders profile 8) Fairness 9) Uncertain behaviour 10) Stakeholders motivation

We found ten social influencing factors that required to be included in the municipal heat transition policy-making, nine economic heat transition influencing factors and lastly, eight technical municipal heat transition influencing factors. These ten social influencing factors are 1) Behaviour, 2) Attitude, 3) Capability, 4) Social cohesion, 5) Stakeholder engagement, 6) Demographic profile, 7) Stakeholders profile, 8) Fairness, 9) Uncertain behaviour, and lastly, 10) Stakeholders motivation. Economic heat transition influencing factors are defined as 1) Society cost, 2) Path dependency, 3) Financial feasibility, 4) Market proposition, 5) National regulation, 6) Responsibility and power to make a decision, 7) Organisational affair, 8) Data gathering and utilisation regulation, and 9) Conflict of interest. And lastly, eight technical municipal heat transition influencing factors are derived including 1) Building criteria, 2) Data digitalisation and utilisation, 3) Technical operation, 4) Technology maturity, 5) Heat source plan, 6) Maintenance and path dependency, 7) Neighbourhood density, and 8) Future uncertainty.

3. What decision support system framework can systematically assist municipalities in making decisions concerning municipal heat transition policy?

Municipal HeTPoM DSS framework is derived from Zoetermeer heat transition policy-making needs. These needs are based on Head (2008) three lenses of policy perspectives (i.e. policy-makers, researchers, and practitioners). This design is framed under four main subjects, 1) actors, 2) influencing factors, 3) policy-making process, 4) policy cycles, and 5) customer journeys.

The main purpose of HeTPoM DSS framework creation is to support policy-makers to systematically design, evaluate, and assess a municipal heat transition policy. The heat transition policy-making (HeTPoM) DSS framework provides policy-making with activities that are guided by a profile that is determined in the first step of the activity (prediction and problem definition phase), such as data collection, stakeholders needs, and requirement analysis and policy target profiling.

Besides their main function, HeTPoM is also proposed to be able to support two additional functions. The first one is to support heat transition policy co-design, co-evaluation, and co-assessment between policy-makers, researchers, and heat transition stakeholders. The second one is to support the development of a computerised municipal heat transition policy-making DSS.

4. What are the potential positive and negative effects of using the municipal heat-transition policy-making decision support system framework?

The functionality of HeTPoM DSS framework was stated to potentially be able to be used in the joint process of co-creation of policy (in design, assessment, and evaluation activities). In the expert evaluation workshop activity, it was disused that HeTPoM can be used by professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. It was discussed that HeTPoM can be used to make people aware of the policy-making process at the municipal level and can be used by the municipality to support citizen inclusion in their policy-making. However, some limitations were also examined in the evaluation in the case of ease of use, structural modularity, and completeness.

At the end of the evaluation, a refined HeTPoM DSS framework was derived from the recommendations that are given in the expert workshop. These improvements are listed as follows: 1) a refined customer journey map, 2) expanding the role of the citizens, 3) expanding the policy-making activities, and 4) increasing the ease of use of the HeTPoM DSS framework (by providing additional legend, HeTPoM DSS framework manual documents, and video manual to use the refined HeTPoM DSS framework).

Societal contributions

This research contributed to society primarily by supporting municipal policy-maker in realizing heat transition. This thesis research contributed by providing a refined HeTPoM DSS framework that can be used to 1) support policy-makers to design, assess, and evaluate heat transition policies systematically, 2) support policy-makers and heat transition stakeholders in a co-creation of heat transition policy by providing a common framework to communicate the policy, and 3) increase awareness of the heat transition municipal policy-making for professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. Furthermore, the refined HeTPoM DSS framework can potentially be used as a base to create a computerised municipal heat transition policymaking DSS.

Scientific contribution

This research enriched the body of knowledge on the evidence-based policy research as well as policy lab research by providing an evaluated empirical municipal heat transition DSS framework of municipal heat transition policy-making (HeTPoM). Gachet & Sprague (2005) mentioned that it is important that a DSS framework is made within a context. However, literature in the DSS framework on the municipal heat transition policy-making is still scarce, mostly ones that also provide the geographical context in the Netherlands. On the other hand, there is a knowledge gap of an integrated DSS framework with the policy system (policy cycle) that is context-specific on the municipal heat transition. This thesis enriched the knowledge of the context-based DSS framework for a municipal heat transition in the Netherlands.

Future research

For future research, we propose four main future research from this thesis. The first one is to increase the number of evaluation respondents as well as to change the evaluation from a workshop that discusses a conceptual idea (artificial), to the workshop that uses natural setting with real case and policy-makers. The second recommendation is to expand the case study design from a single case study into a multiple case study. Multiple case study can be done for either comparison study (to see the differences between municipalities) or confirmation (for theory building). The third one is to extend the range of SLR to create causation of each component in the refined HeTPoM DSS framework with bigger literature base. And lastly, is to develop a computerised municipal heat transition policy-making DSS based from the refined HeTPoM DSS framework.

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List of abbreviations

Abbreviation	Stand for
ATES	Aquifer Thermal Energy Storage
CoSEM	Complex System Engineering and Management
DES	Distributed Energy System
DS	Design Science
DSS	Decision Support System
EPA	Engineering Policy Analysis
HeTPoM	Heat Transition Policy-Making
IT	Information Technology
MoT	Management of Technology
PCM	Phase Change Material
PCMTS	Phase Change Material Thermal Shield
SD	System design
SLR	Systematic Literature Review

1 Introduction

This introductory chapter is presented based on the Swales (2011) step model of introduction. First, the centrality of the research is described in section 1.1 as key concepts. Then the niche is established in section 1.2 as the introduction to the problem. Lastly, the niche is occupied by outlining the purpose of the research (section 1.3), presenting the approach (section 1.4), describing research relevance to society and science (section 1.5), and illustrating the structure of the report (section 1.6).

1.1. Overview of the heat transition, municipal policy-making, and decision support system

Climate change is an immediate global problem. A joint force of the global community is the only way to contest climate change (Climate Focus, 2015) by gradually reducing fossil fuel usage. Climate change has brought recent challenges to the world such as extreme earth reformation, environmental instability, problems for global food production, health issues, and consequently impact our economy (Fischer & Knutti, 2015; Helmke et al., 2020; Mitchell et al., 2016; Nardone et al., 2010; New et al., 2011; Rogelj & Knutti, 2016). Specifically in the Netherlands, the fossil fuel reduction is also driven by the threat of the earthquake that is potentially related to the gas facility located in the Groningen (Mulder & Perey, 2018; Roest & Kuilman, 1994; van der Voort & Vanclay, 2015)

Therefore, the Netherlands acted on the concern of fossil fuel reduction by utilising both regulation (e.g. climate act and energy agenda) as well as public cooperation (e.g. climate agreement) (Climate Council, 2019; Ministry of Economic Affairs and Climate, 2016). One of the primary goals of the government of the Netherlands is to phase out natural gas by 2050 (Planning Office for the Living Environment, 2019). For this purpose, the Dutch government is mandating the case to the leadership of the municipality (Government of the Netherlands, 2019). The reason for this decision is to get closer with the practical decision-makers in the heat transition (the citizens in this case). As shown in Figure 1.1 (blue box), heat transition in the Netherlands is part of the activities of the national climate agreement that is derived from the Paris climate change Agreement (Climate Council, 2019b). The Dutch national government has delegated heat transition to the municipalities (blue box in Figure 1.1) as part of the global execution of climate agreement (in the built environment sector).

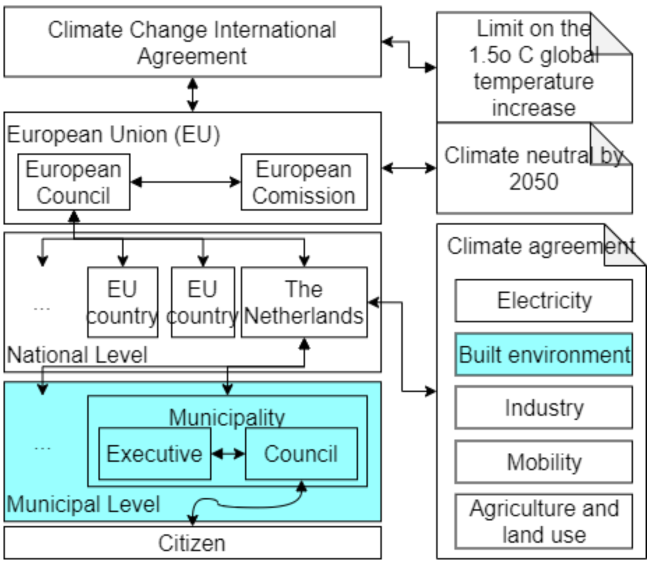

Figure 1.1 Gas transition position in the global Climate Change Agreement (Climate Council, 2019b; Figee et al., 2008)

Three key concepts of this thesis are presented in these sections. These key concepts are 1) heat transition, 2) municipal data-driven decision making, and 3) decision support system.

1.1.1 Heat transition as part of the energy-transition

Heat transition in the Netherlands is a shift of energy sources for heating purposes into renewable sources (e.g. biogas, renewable electricity, or renewable heat (Expertise Centrum Warmte, 2019)) from the existing conventional source (natural gas). As natural gas is the primary heat source in the Netherlands, heat transition is indispensable to the Dutch government if they want to reach their climate change goal. Changing the source of the Netherlands' heat source could significantly impact the country, as natural gas provides 66.5% energy for cooking, 89.4% water heating energy, and 86.7% energy for space heating (Eurostat, 2019).

Heat transition is a complex transformation process that is influenced by interdependent actors, as visualised in Figure 1.2. With the municipality as the director of the heat transition, the stakeholders of heat transition (i.e., citizens, building owners, energy supplier companies, network operators, and water companies) are expected to be interacting with each other. Consequently, heat transition policies need to be made to support both citizens (downstream) and companies that are facilitating these energies supply (upstream). Moreover, there is also a need for infrastructure development that provides new renewable heat source(s) from the energy supplies companies to the citizens. The needed infrastructures vary based on the chosen energy source (i.e. part of the policy) (Scholten & Künneke, 2016). These interdependencies (between actors, infrastructures, and policies) then create complexity that leads to a wicked problem where no optimal solution exists (Janssen & Helbig, 2018; Millard, 2018).

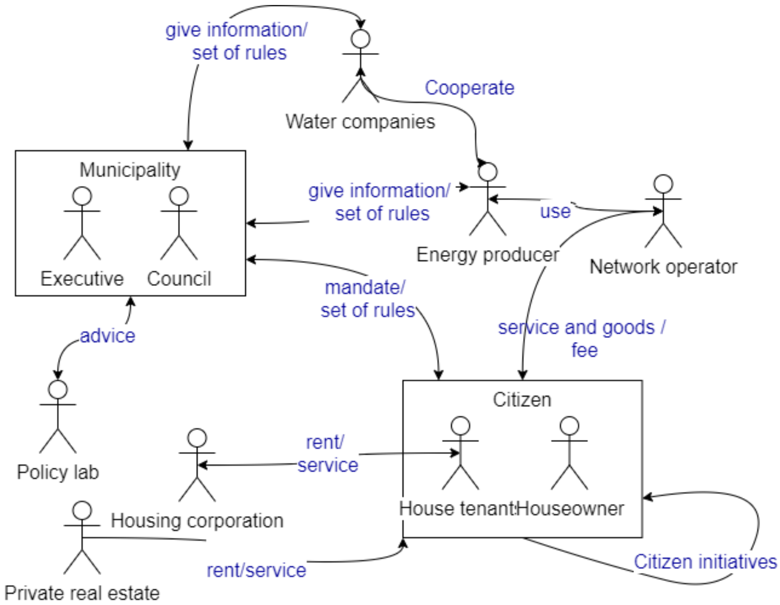

Figure 1.2 Actors interdependencies in municipal heat transition, inspired by Bush and Bale, (2019), Diran et al. (2020), and Expertise Centrum Warmte (2019)

In the heat transition process in the Netherlands, the municipality is expected to make sure that all citizens (e.g. tenants, or building owners) are comfortable with the gradual changes to the full heat transition, as informed by the Climate Council (2019a). These citizens can either be a tenant (that can be either connected to the private real estate agents or housing corporation) or a homeowner. This need of comfort must be applicable in both financial as well as physical aspects of their life.

1.1.2 Municipal data-driven policy-making

The municipality is a local authority that is geographically closest to the citizen (see Figure 1.1). The municipalities work as both intermediaries of national government decisions (co-government) as well as an autonomous local government for the local interests. In other words, the municipality is responsible for missions that are directly correlated to the municipal inhabitant (Rijksoverheid, 2020b). Their responsibility is also widened due to the decentralisation. The municipalities are given autonomy to perform decentralised tasks that comes from the national government, such as heat transition policy (Rijksoverheid, 2020a).

A policy is a government action that decides on the incentive (or punishment) that can be given to certain actors based on a particular motive called societal goal or government intention (Birkland, 2019; C. E. Cochran et al., 2015; C. L. Cochran & Malone, 1999, 2010). As the end product, policy-makers shall decide on doing (or not doing) a specific activity (Dye & Dye, 1992). For example, making no statement over an issue can be seen as a statement to do nothing (Birkland, 2019). These policies influence the life of the citizens who live under those policies (Peters, 2018). These policies can be laws, regulations, rulings, decisions, orders, or their combination (Yuen & Karperien, 2019; Birkland, 2019). In the heat transition case, the societal goal is to slow down global warming (Climate Focus, 2015); an example of a policy can be the phase-out of natural gas by 2050.

Data-driven policy-making is the process of creating government action toward societal goals (Birkland, 2019; C. E. Cochran et al., 2015; C. L. Cochran & Malone, 2010) that utilises analysis of data rather than instinct and hunch (Provost & Fawcett, 2013). Data-driven policy-making can promote the co-creation of policies with the citizens (van Veenstra & Kotterink, 2017). This data can be taken from (real-time) sensors, new data sources like open-data, or big data utilisation (Bertot & Choi, 2013; Janssen et al., 2012). This new data can be used in policy-making using traditional statistics and innovative data processing (Poel et al., 2015). A new way to use data accompanying the policy cycle was described by van Veenstra & Kotterink (2017): the policy lab approach for data-driven policy-making. This new cycle consists of 1) foresight and early warning, 2) modelling and simulation, and 3) monitoring and impact assessments. This cycle is paired with the policy cycle that consists of 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation. Hence, for a data-driven way of creating policies, the right data should be generated (or taken) in each of these phases of the cycle.

The municipality, as the closest official to the citizen, is expected to be able to gain insight from this data as well as being able to co-create their policy with the heat transition stakeholders. With the right infrastructure and institutional measures, public engagement might be gained (Janssen et al., 2012; Paiho & Saastamoinen, 2018) for this co-creation process.

1.1.3 Decision Support System (DSS) framework

The Decision Support System (DSS) was firstly defined as an interactive computer-based system which supports decision-makers to solve unstructured decisions using data and decision models (McCosh & Morton, 1978). The purpose of DSS is to enhance decision-making for the managerial level (Sprague, 1980) by utilising the value of a machine and information system with a specific purpose (Power, 2004; Shim et al., 2002).

The DSS framework can be defined as an artefact that envisions a basic structural model of a DSS (Sage, 1991b). In other words, a DSS framework (or DSS box (Sprague, 1980)) is a conceptual model that is used to virtualise DSS capabilities, DSS components, and interaction between DSS components. DSS frameworks are formed by three main elements: 1) database, 2) decision model, and 3) decision dialogue (Sage, 1991a, 1991b; Sprague Jr & Carlson, 1982).

1.2 Problem Introduction

1.2.1 Municipal heat transition policy-making

By the end of 2021, municipal policies on heat transition are required to be ready in every municipality (Climate Council, 2019). Expertise Centrum Warmte (2019) informs that each municipality needs to create a decision on heat transition based on the local information.

Although many guides have been offered, municipal heat transition policy is a tricky matter that the municipal policy-makers struggle to grasp. The policy-makers are puzzled on how they can make a voluntary investment by heat-users (S. Scholte et al., 2020). Municipal policy-makers are currently in a tough scenario where they have been mandated as the director of the heat transition without legal power to make citizens shift their heat source.

Moving people towards a voluntary heat transition is a complex matter that involved not only technical and economic consideration but also social consideration (e.g. citizens attitude). This complexity increases in the situation where heat transition requires enormous investment from the citizens, as the current situation in the Netherlands (Pieters, 2020). A diverse population (different motives, economic power, and attitudes towards heat transition) also added complexity into the problem. Therefore, to effectively target these different groups of people, several different policy approaches are needed (profiling).

Thus, heat transition is a complex unstructured problem that needs to be solved not only with the techno-economic focus but also including the social domain. And these processes of data-driven municipal heat transition policy-making have not been yet systematically conferred. For that purpose, we propose the usage of a DSS for municipal heat transition policy-making that serves the whole cycle of policy-making.

DSS can help policy-makers to systematically design, assess, and evaluate their municipal heat transition policy, as it has helped the high-level managerial decision in medicine (Hussain et al., 2020), medical diagnosis (Fathi et al., 2020), and government service (Sivcevic et al., 2020). To create a DSS, a specific context-based DSS framework is needed (Gachet & Sprague, 2005). In this case, the context is municipal heat transition policy-making in the Netherlands from 2020 to 2050.

1.2.2 Knowledge gaps

Despite the needs, *research on the Dutch municipal heat transition policy-making context-based DSS framework is still scarce.* There are studies on the DSS that answer part of the questions that need to be known to create a municipal heat transition policy-making such as CEGOIA by (CE Delft, 2020) or Vesta MAIS by PBL (2017) that give information to the policy-makers on which energy source can give lowest societal cost. These two models help policy-makers in the design and experimentation phase to understand technical-economic effects on the decision of heat sources.

There is growing support for experimentation phase of the policy (cycle) in the energy transition, as seen in the high number of developed technical-economic energy models as reviewed by Zhou et al. (2016), Friege and Chappin (2014), and Hesselink and Chappin (2019). These technical-economic energy models are beneficial to be used in the design and experimentation phase of the policy cycle. These technical-economic factors in heat transition are usually focussed on the economic benefit of the energy-transition, like energy price, cost of energy changes, return of investment on a particular technology, or energy supply and demands.

However, research has mainly focused on the technical-economic policy design and experimentation. Only a few studies include social factors in the heat transition policy considerations. For example, Organ et al. (2013) who wrote about how "motivation" influences the heat transition. Also, D. Lee et al. (2016) who published their research on the public opinion on heat transition. Some social heat transition influencing factors (e.g. trust, irrationality, or inertia) were also discussed by Hesselink and Chappin (2019). Nonetheless, these influencing factors have not yet been linked to the phases of the policy cycle.

The literature on DSS that covers social, economic, and technical heat transition influencing factors is still uncommon. Literature also discusses social heat transition technical influencing factors (e.g. El Geneidy and Howard (2020) consumer behavioural change, or the effect of policy on the behaviour of the citizen). However, this knowledge has not been integrated into the form of a DSS, policy cycle, or end-users profiling. In addition, literature that gives information on the DSS in the context on the policy has not yet adequate to inform an integrated DSS with the policy-making concept (policy cycle) nor policy target profiling.

In conclusion, *there is a knowledge gap of an integrated DSS framework with both policy target profiling and policy system (policy cycle) that is a context-specific for the municipal heat transition policy-making in the Netherlands.*

1.3 Research question and approach

Based on the problem and the knowledge gap defined in the previous section, an objective is made for this thesis research: *to design a decision support system framework that can systematically assist municipalities in the Netherlands in the heat transition policy-making process*.

This objective then leads to the **main research question** formulated as follows.

What decision support system framework can systematically assist municipalities in the heat transition policy-making process?

To answer this question, this research applied a design science research approach. The design science research approach is useful to support the creation of successful artefacts (Peffers et al., 2007). In this case, the mentioned artefact is defined as a Decision Support System (DSS) framework. Design science research is meant to widen the limit of human capability by creating an artefact that supports human activity (Hevner et al., 2004). The mentioned activity in this thesis research is municipalities heat transition policy-making process.

This thesis study has derived four common design science research phases based on March and Smith (1995), Peffers et al. (2007), and Ofermann et al. (2009). These four phases are 1) problem identification, 2) identification of possible solutions, 3) design and development, and lastly, 4) evaluation. Based on these four phases, four research questions were derived with four research methods to answer them, as shown in Figure 1.3.

Each research question is answered using one adopted method. In this method, the next research phase can only be done with the deliverables from the previous questions. Therefore, this research process is done serially (with iteration within each phase). The disadvantage of using this design science research approach is that the next research phase starting time is dependent on the earlier research phase. This method is mentioned to be effective (Peffers et al., 2007). However, this approach might create complex activities that are also time-consuming. Therefore, suitable planning of the research method is essential. In Section 1.4, a summary of this research method is presented.

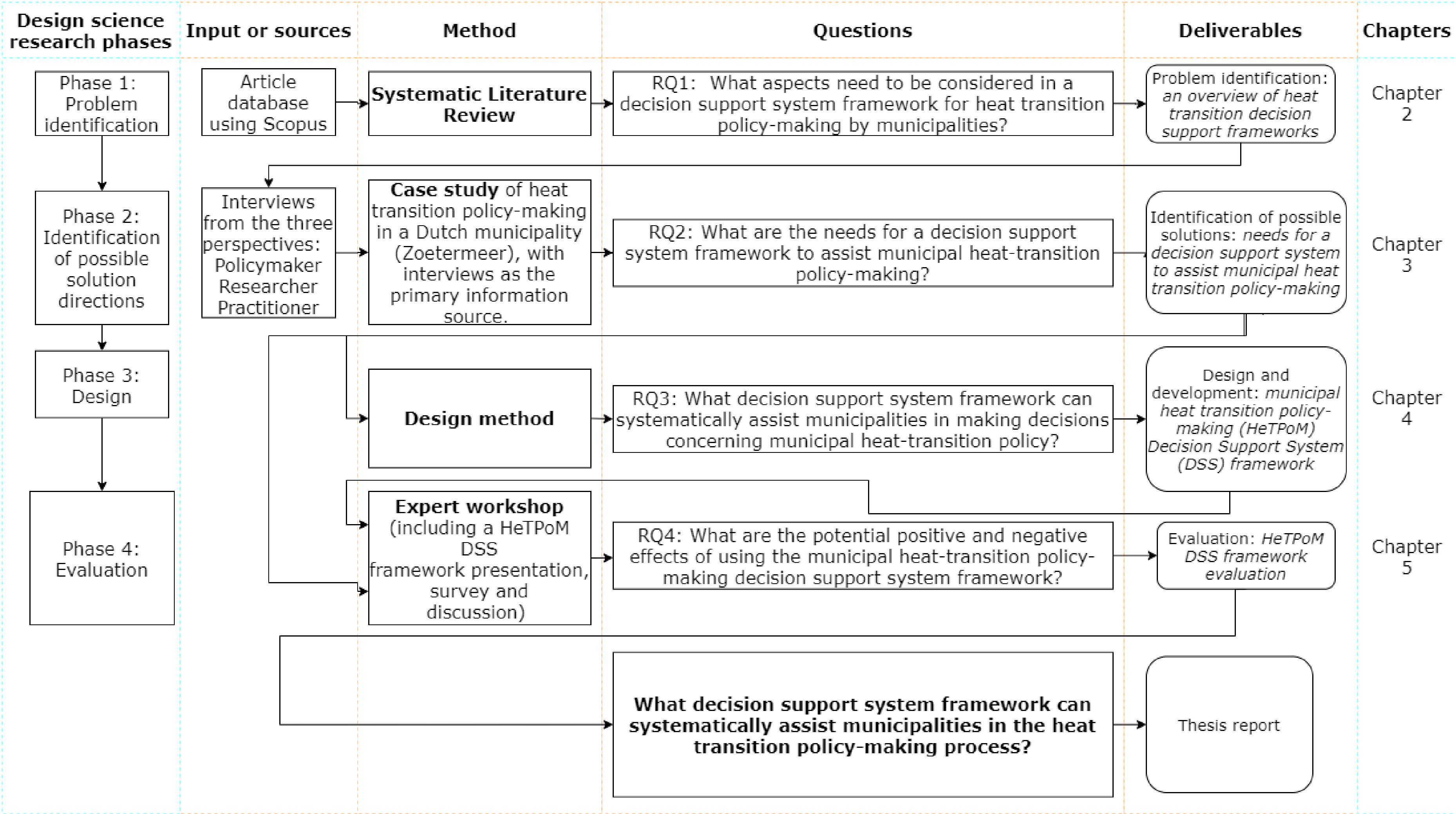

Figure 1.3 Research Method Diagram

1.4 Research methods

As mentioned in Section 1.3, the research will be done in four research phases: 1) problem identification, 2) identification of possible solutions, 3) design and development, and lastly, 4) evaluation. Research methods for each phase of the thesis are planned and executed as follows.

1.4.1 *Method for the first phase of the thesis: A systematic literature review*

In the first phase of the research, a systematic literature review (SLR) was used to answer: *What aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?* An SLR can be intended to denote the research contribution to the body of knowledge (Hart, 1998; Marshall and Rossman, 1989) and provide a conceptual model (Creswell, 1994). In this case, an SLR is used to provide a conceptual model of aspects that need to be considered in a municipal heat transition policy-making DSS framework. This SLR was done using an adapted SLR framework from Kitchenham and Charters (2007), Levy and Ellis (2006), Webster and Watson (2002) and Okoli and Schabram (2010). The output of this phase is used as a starting point of the case design in the next phase of the research.

1.4.2 *Method for the second phase of the thesis: A case study of* Zoetermeer municipality heat transition policy makings

In the second phase of the research, the case study guidelines by Yin (2018) were used as guidance for conducting a case study. This guidance defines that a case study is generally conducted in six phases: 1) planning, 2) design, 3) preparing, 4) collecting, 5) analysis and 6) sharing. These phases are adapted into three case study phases in this research: 1) planning and design phase, 2) preparation and data collection phase, and 3) analysis and report phase. Using the output from the SLR conducted in the first phase, design and preparation was done.

Then a qualitative data analysis was conducted supported by middle approach coding. This approach is more guided than grounded theory (Glaser et al., 1967) but more flexible than a tight approach (the predefined code list). These three steps were used in this analysis, 1) data reparation, 2) coding cycle and 3) derived analysis (adopted from Glaser et al. (1967), Kuckartz (2019), and Williams and Moser (2019) qualitative research scheme). In the coding process, three phases of coding were done namely, 1) open coding, 2) axial coding, and 3) selective coding.

In the end, a list of stakeholder needs for a DSS framework to assist municipal heat transition policy-making are derived. These stakeholders input are taken based on the perspectives of Head (2008) three lenses of policies (policy-makers, researchers, and heat transition practitioners) in the case of Zoetermeer municipality heat transition policy-making.

1.4.3 *Method for the third phase of the thesis: An engineering design method*

Then the third phase, the design phase was conducted based on the stakeholder needs that are derived in the second phase. This phase uses an adaptation of functional visual communication design from Karjaluoto (2013) and the engineering design method from Dym and Little (1999). This study uses five steps that are described by both authors: 1) problem definition, 2) conceptual design, 3) preliminary design, 4) detailed design, and 5) design communication. This then produced the detailed design of the Heat Transition Policy-making (HeTPoM) DSS framework.

1.4.4 Method for the fourth phase of the thesis: An artificial ex-ante evaluation

The last phase of the research is the evaluation that is done in an artificial ex-ante evaluation. Ex-ante evaluation indicates the evaluation was done based on the possible result (ex-prediction) (Peffers et al., 2007; Pries-Heje & Baskerville, 2008). Artificial evaluation indicates that the evaluation does not explore the performance of a solution in its real environment (Nunamaker Jr et al., 1990; Venable, 2006). On the other hand, naturalistic evaluation or observation is performed in a real environment.

The reason for this evaluation selection is the COVID-19 situation that only allows online meetings to be conducted instead of face to face meetings. Therefore, creating an ex-post activity (evaluation based on the result (Peffers et al., 2007; Pries-Heje & Baskerville, 2008)) was not feasible. An artificial evaluation was chosen over naturalistic because the whole cycle of the policy has not been completed yet. Thus, it is better to make an artificial ex-ante evaluation as the first evaluation for this HeTPoM DSS framework. In this phase, HeTPoM DSS frameworks are produced with a set of evaluated functionalities and limitations.

To execute this evaluation, a semi-structured expert workshop was done with three experts in public administration, Policy lab, data and evidence-based policy-making, and multi-actor management and framing. This workshop covers three activities: 1) questionnaire, 2) HeTPoM presentation, and 3) discussion for the HeTPoM DSS framework, and 4) discussion for the Zoetermeer municipality heat transition policy-making activities.

1.5 Contributions from this research

1.5.1 Contributions to society

This research contributed to the society mainly by supporting municipal heat transition policy-maker to systematically design, evaluate, and assess heat transition policies. As the step by step of policy-making that is based on policy-target profiling is explicit in the refined HeTPoM DSS framework, a systematic guide for policy-making in the municipal heat transition can be potentially assisted.

The HeTPoM DSS framework can also be used in the process of policy design co-creation for the municipality policy-makers, researchers, and municipal heat transition stakeholder (e.g. citizen initiatives, housing corporations) by providing a common framework to communicate the policy. This can be done because the HeTPoM DSS framework can be used to ease communication of the municipal heat transition policy-making for professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives.

Moreover, the refined HeTPoM DSS framework can also be used to help to share municipal policy-making in heat transition for education purpose. This framework can be used by teachers or policy-makers to share their knowledge for students or other stakeholders of the municipal heat transition policy-making. Therefore, increase awareness of the municipal heat transition policy-making.

Furthermore, the refined HeTPoM DSS framework can potentially be used as a base to create a computerised municipal heat transition policymaking DSS. In the development of municipal heat transition policy-making DSS, the refined HeTPoM DSS framework can be used as a communication tool between system developers, policy-makers, and researchers.

1.5.2 Scientific contributions

As previously mentioned in Section 1.2.2, in literature there is a lack of an integrated DSS framework with the policy system (policy cycle) that is context-specific to the municipal heat transition. This thesis enriched the knowledge of the context-based DSS framework for a municipal heat transition in the Netherlands. In the process of creating an empirical context-based DSS for a municipal heat transition in the Netherlands, we derived three additional scientific contributions.

This thesis provides an empirically tested municipal heat transition influencing factors as well as their classifications. Literature mentioned these influencing factors (e.g. El Geneidy & Howard, 2020; Paiho & Saastamoinen, 2018; Späth & Rohracher, 2015). However, their research either lacks geographical context (e.g. El Geneidy & Howard (2020)) or was conducted from other countries which might experience different influencing factors (e.g. Paiho & Saastamoinen (2018) research in Sweden or Späth and Rohracher (2015) research in Germany). Localisation is critical for social influencing factors because they are dependent highly to the government strategy as well as local culture.

In addition, we added the body of knowledge in the municipality policy-making by mapping empirically derived municipality activities to define, assess, and communicate municipal heat transition policy-making in the Netherlands into policy cycles. In literature like Bush and Bale (2019) these activities have been done for Germany. However, this thesis contributes differently by providing information for the Netherlands.

1.6 Reading guide

This thesis report is made using the IBARM outline presented by Johnson (2011): introduction, background, approach, result, and meaning structure, as shown in Figure 1.1.

Chapter	Section	Function
Chapter 1: Introduction	1.1. Context	Introduction of the thesis
	1.2. Problem statement	Background of the thesis
	1.3 Main research question and approach 1.4 Research questions and methods	The approach of the thesis
	1.5 Contribution 1.6 Reading guide	Support
Chapter 2: Problem identification: an overview of heat transition decision support frameworks	Introduction	Introduction and background of RQ 1
	2.1 Systematic literature review method	The approach of RQ 1
	2.2 Conducting a systematic literature review 2.3 Heat transition policy-making based on the literature	Execution and result of the method for RQ 1
	2.4 Conclusion	Meaning of RQ 1
Chapter 3: Identification of possible solutions: needs for a decision support system to assist municipal heat transition policy-making	Introduction	Introduction of RQ 2
	3.1 Case study approach	The approach of RQ 2
	3.2 Case study planning and design 3.3. Case study research preparation and data collection 3.3 Case study qualitative analysis and report	Execution and Result of RQ 2
	3.4 Conclusion	Meaning of RQ 2
Chapter 4: Design and development: municipal heat transition policy-making (HeTPoM) Decision Support System (DSS) framework	Introduction	Introduction of RQ 3
	4.1 Approach for the design	The approach of RQ 3
	4.2 HeTPoM Decision Support System (DSS) framework design process	Result of RQ 3
	4.3 Conclusion	Meaning of RQ 3
Chapter 5: Evaluation: HeTPoM DSS framework evaluation	Introduction	Introduction of RQ 4
	5. 1 Evaluation method	The approach of RQ 4
	5. 2 HeTPoM DSS framework evaluation 5.3 Using HeTPoM DSS framework to evaluate the current Zoetermeer policy-making process	Result of RQ 4
	5. 4 Conclusion	Meaning of RQ 4
Chapter 6. Conclusion	Introduction 6.1 Conclusion 6.2 Contribution to the research and society 6.3 Limitation and recommendation 6.3 Reflection	Meaning of the entire thesis

Table 1.1 Reading guide

2 Problem identification: an overview of heat transition decision support frameworks

This chapter answers the first thesis research question, *"what aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?"* A systematic literature review (SLR) is used to answer this question. The answer from this question is then used to design the case study that is presented in Chapter 3. This chapter is structured as follows. In the first section, the SLR method is described (Section 2.1). Second, the systematic SLR conduction phase is shown (Section 2.2). Third, the SLR is reported (Section 2.3). Lastly, Section 2.4 summarizes this chapter and answers the first research question.

2.1 Systematic literature review method

An SLR can be intended to denote the research contribution to the body of knowledge (Hart, 1998; Marshall & Rossman, 1989) and to provide a model on the concept importance (Creswell, 1994). Also, they need to have a clear and logical approach (Hart, 1998) to define a conceptual construct based on previous studies (Ridley, 2012). This literature review was conducted using an adapted method from Kitchenham and Charters (2007), Levy and Ellis (2006), Webster and Watson (2002) and Okoli and Schabram (2010) (refer to Figure 2.1. This adapted SLR method consists of three main activities: 1) Planning phase, 2) Conducting the SLR, and 3) Reporting the result of the SLR.

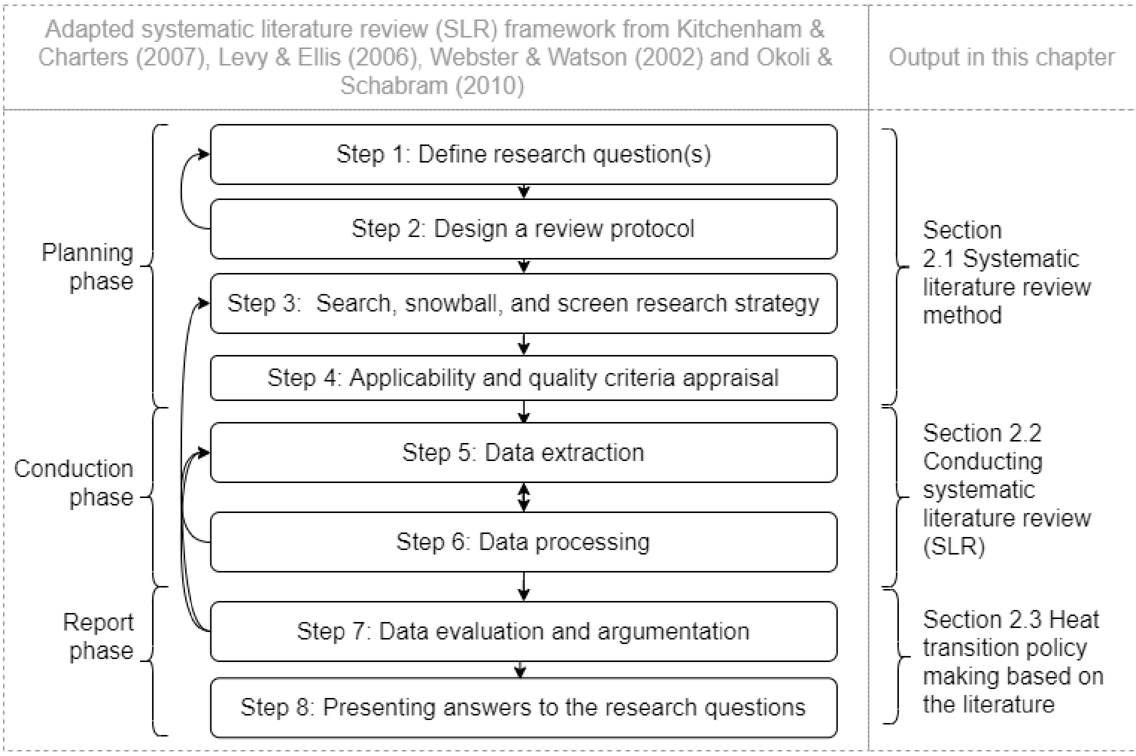

Figure 2.1 Adapted systematic literature review (SLR) framework from Kitchenham and Charters (2007), Levy and Ellis (2006), Webster and Watson (2002) and Okoli and Schabram (2010)

2.1.1 Step 1: Define research questions

Regarding the first SLR phase (planning phase), Kitchenham and Charters (2007) and Okoli and Schabram (2010) describe that an SLR needs to be explicit for the reader by defining a study purpose and protocol. This purpose can be executed by the first step of the SLR, research questions definition (Kitchenham & Charters, 2007).

The purpose of this SLR is to answer four sub-questions: as follows: 1) what are the characteristics of a DSS for high-level decision-making? 2) what are the steps in a municipal data-driven policy-making process? 3) which actors are associated with the municipal heat transition policy-making process? 4) what are the heat transition influencing factors that can be used to support the municipal heat transition process?

The first SLR sub-question is used to define DSS and to identify their components. Then based on the DSS components, model and data (Sage, 1991a; Sprague & Watson, 1979), the second and fourth SLR sub-questions were defined. The second research question focuses on the process model on the policy-making (model) while the fourth research question focusses on the data that needs to be considered when policy-makers need to create a legitimate decision. The third question is used to support the second question on the policy-making process model. As an energy system is complex and involves many actors, a process of policy-making needs to also be viewed from the needs of the involved actors. Thus, the actor's analysis was also included in the SLR.

2.1.2 Step 2: Design review protocol

Kitchenham and Charters (2007) emphasize that an SLR protocol is essential as this can reduce researcher bias. Furthermore, to ensure reproducibility on the practical screening in SLR, it is essential to follow a detailed protocol (Okoli & Schabram, 2010). Yet, an SLR protocol also needs to allow enough space for creativity, especially in the data evaluation and argumentation step. An SLR protocol consists of four components: 1) literature search method 2) study selection procedures and criteria, 3) quality assessment procedure, and 4) data extraction strategy.

2.1.3 Step 3: Search, snowball, and screen research strategy

The literature search is conducted using a keyword search, backward snowballing, and forward snowballing, as described by Levy and Ellis (2006). Keyword search is the primary method that was used in this research. These search processes are explained as follows.

2.1.3.1 Keywords search

Keyword search is a cold start of the research that uses specific words (keywords) to find relevant literature in the database engine. Levy and Ellis (2006) and Webster and Watson (2002) argue that keyword search should not be the only step of SLR due to keyword limited "life span" and possible use of "buzz words" may limit the search to a much smaller sample. Therefore, snowballing is used in this research.

2.1.3.2 Backwards and forward snowballing

After being proposed by Webster and Watson (2002), snowballing is recognized as an essential addition to SLR to gain a more profound knowledge into the topic by exploring more relevant articles of the topic (Jalali & Wohlin, 2012). Snowballing is done by referring to the process of identifying additional literature by seeking them in the reference list of the works of authors of with essential findings or papers that are using the work of the particular authors (Wohlin, 2014). This snowballing process was done backwards and forwards. Backwards snowballing gives insight on why a certain theory was made. While forward snowballing gives insight on how a certain theory can develop.

2.1.3.3 Stopping the literature research

Iteration was done in this research to make sure the research questions are answered. Each iteration includes keyword search and snowballing. This process was stopped when no additional relevant information for the research questions could be found.

2.1.4 Step 4: Applicability and quality criteria appraisal

Kitchenham and Charters (2007) defined the systematic literature selection procedure. This procedure is also useful to manage literature selection reproducibility in the SLR. In this SLR procedure, selection criteria are listed as follows: 1) keywords, 2) subject areas (as shown in Table 2.1), and 3) title and abstract.

Criteria	*SLR sub-question 1*	*SLR sub-question 2*	*SLR sub-question 3*	*SLR sub-question 4*
Keywords	"decision support system", "system engineering", management, generation	heat, transition, data, policy	heat, transition, stakeholder	heat, transition, building, urban
Subjects	engineering, social science, decision science, business	energy, social science, business		energy, environmental science, engineering, material science, social science

Table 2.1 Combinations of keywords and subjects used in this study's SLR

First, a keyword search was done using the Scopus database. The keywords as depicted in Table 2.1 were combined to search in the document titles, abstracts, and keywords. Second, based on the result of the first automatic search, literature subjects (the subject of study) are used to filter the literature. Subjects are selected based also from the research question.

Subjects from the first SLR sub-questions are selected based on the focus of the question in the decision science and engineering. System engineering was used to limit the scope only to decision support system definitions to the field of system engineering. Generation and management are used so that the search will also specifically address the needs of a higher level of decision-maker, such as the policy-maker.

Subjects from the second SLR sub-question and the third SLR sub-questions are the same due to their same purpose (to answer the model of policy-making), to see how policy-making model works in the municipal heat transition. These subjects include energy systems in social science and business. The fourth SLR sub-question subjects are broader than others because factors that influence residential heat transition can be varied (e.g. energy, environment, material, or social science).

The third step is the manual process of reading and analysis. Titles and abstracts for all identified papers were read to find their relevance with the SLR sub-questions. First, the title relevance was checked. Then, if the title looked promising, the abstract was also checked. The result of applying these selection criteria produced a literature of which the quality needed to be checked before data extraction (see Section 2.1.4.1).

2.1.4.1 Quality assessment procedure

Kitchenham and Charters (2007) defined a quality assessment procedure that uses a quality checklist to assess the studies. A high-quality SLR should be able to provide appropriate 1) clarity 2) consistency, and 3) depth. Levy and Ellis (2006) stated that quality resources are required as a solid foundation to explain the issue explored in the SLR. Thus, inclusion and exclusion criteria are made to be consistent with selecting literature.

Inclusion criteria are selected as follows: 1) literature must contribute in answering one (or more) SLR research questions, 2) literature must be peer-reviewed by the research community (Davison et al., 2005; Rouhani et al., 2015), 3) literature must be published in a scientific journal or conference

(Kitchenham et al. 2009), 4) the full text of the literature must be accessible (Rouhani et al., 2015) in English, and 5) literature from any geographical area are considered.

To filter literature with less quality, the following aspects are selected as **exclusion criteria:**

1. Less trusted literature publication including grey publications (Rouhani et al., 2015)
2. Corporate sponsorship or non-independent organisation publications (Hozack et al., 2003).
3. Non-comprehensive literature that either is published in less than six pages (Rouhani et al., 2015) or published without clear methodological support (Gurstein, 2011; Palomino et al., 2019). To check this exclusion criterion, articles were scanned to find a specific section that defines their method or terms that are used to define methods (e.g. method, methodology, approach).
4. Tertiary studies and conference abstracts (Palomino et al., 2019).
5. Literature that is considered outdated (published before 2015) since heat transition is a contemporary phenomenon that is just growing after the Paris Agreement in 2015. Taking literature older than 2015 might create confusion of the term. However, this exclusion is not used in the case of the first SLR sub-question because the concept of decision-making is much older than the concept of heat transition. For this first SLR sub-question, no literature is considered outdated.
6. Literature that is inaccessible using a TU Delft or TNO account due to the research fund limitations.
7. Duplicated studies (Palomino et al., 2019)
8. Literature found to be irrelevant to the research questions.

2.1.4.2 Data extraction strategy

Explicit and implicit information shall be extracted from the literature (B. Kitchenham & Charters, 2007). There are two types of data gathered in this literature extraction. The first one is used to identify the paper quality and sources while the second extraction is used to gather information needed to answer the SLR sub-questions.

The first extraction was constructed using one table to list the information of the literature. This table is constructed while we performed the quality assessment procedure of the SLR (see Section 2.1.4.1). The extracted data in this table include: 1) author details, 2) type of publication, 3) year of publication, 4) publication details (publisher, publication edition, and page number), 5) geographic affiliation, and 6) title of the publication.

Furthermore, the second extraction is used to gather information needed to answer the SLR research questions using four tables, each for one research question. For that purpose, first, a classification on which article answers which question was made. Then from this result, the extraction of the answer to the SLR sub-question was noted.

2.2 Conducting the systematic literature review

2.2.1 Step 5: Data extraction

The SLR was conducted from March 13th, 2020 until April 27th, 2020 using the predefined protocol and extracted 57 articles as shown in Table 2.2. Fifty-three of these articles are scientific articles published in twenty-five different scientific journals (see Appendix I.2). Four publications came from scientific conferences proceedings. Appendix I.2 presents the details of the scientific articles that are used in this SLR. Indexes used in Appendix I.2 are explained in Appendix I.1. The literature publication years ranges from 2015 till 2020. This topic emerged after the Paris Agreement in 2015 (Climate Focus, 2015), which lead to a wide range of research from institutions in Europe, Asia, and America.

Process	*DSS definition*	*Policy-making process*	*Heat transition actors*	*Heat transition influencing factors*
First search	23	38	27	6822
Inclusion criteria and subject	16	15	24	673
Exclusion criteria and manual screening	2	11	13	17
Snowballing	8	14	13	22
Literature to be reviewed (final)	57			

Table 2.2 SLR articles selection process

2.2.2 Step 6: Data processing

The literature data was extracted to answer the four questions of the SLR. As shown in Table 2.3, four types of information were extracted consistently with the SLR sub-questions. This information consists of 1) Definition of DSS, 2) policy-making process and requirements, 3) actors in the heat transition and 4) influencing factors that need to be considered when making a municipal heat transition (separated in social, economic, and technical influencing factors). The extracted data is reported in Section 2.3.

Author and year	DSS	Policy-making process	Actors	Social factors	Economic factors	Technical factors
Abdurafikov et al. (2017)						X
Aberilla et al. (2020)				X	X	X
Artur et al. (2020)				X	X	X
Astudillo et al. (2017)						X
Barron et.al. (1999)	X					
Bickel (2017)			X			
Bloemendal et al. (2018)						X
Busch et al. (2017)			X	X	X	
Bush and Bale (2019)		X		X	X	
Bush et al. (2016)			X			
Büttner and Rink (2019)		X	X			
Calise et al. (2017)						X
Chwieduk (2016)						X
Darby (2017)				X	X	X
Debizet et al. (2015)			X			
Diran et al. (2020)			X			
Domenech et al. (2019)		X			X	
El Geneidy and Howard (2020)				X	X	X
Fabiani et al. (2019)						X
Finck et al. (2018)						X
Gachet and Sprague (2005)	X					
Gan and Xiang (2020))						X
Gillich et al. (2019)		X		X	X	
Gorroño-Albizu (2020)				X	X	X
Han et al. (2018))						X
Hondula et al. (2018)		X		X		

Janssen and Helbig (2018)		X				
Jensen et al. (2015)				X	X	
K. O. Lee et al. (2015)						X
Kerimray et al. (2018)				X	X	X
Knobloch et al. (2019)				X	X	
Konsynski and Sparague (1986)	X					
Leurent et al. (2017)						X
Li et al. (2015)					X	
Long et al. (2016))						X
Nciri and Miller (2017)						X
Paiho and Reda (2016)						X
Paiho and Saastamoinen (2018)		X	X		X	X
Pearson and Arapostathis (2017)			X			
Qu et al. (2019))						X
Rissman et al. (2020)					X	
Sage (1991)	X					
Sager-Klauß (2016)				X		X
Sernhed et al. (2018)		X				
Shaffer et al. (2018)			X			
Shim et.al (2002)	X					
Späth and Rohracher (2015)		X	X		X	X
Sprague and Watson (1979)	X					
Sprague (1980)	X					
Sprague (1987)	X					
Stropnik et al. (2019))						X
Upham et al. (2018)				X	X	X
van Veenstra and Kotterink2017)		X				
Viétor et al. (2015)			X			
Wahlroos et al (2017)						X
Wijesuriya et al. (2018)						X
Zdankus et al. (2016)						X

Table 2.3 Data extraction overview from the SLR

2.3 Heat transition policy making derived from the literature

This Section covers the seventh and the eighth step of the SLR method (see Figure 2.1) ("Data evaluation and argumentation" and "Presenting answers to the research questions"). In this section, firstly, the DSS is defined (Section 2.3.1). Then the stakeholder analysis is presented (Section 2.3.2), followed by the process of the data-driven policy-making process (Section 2.3.3). Furthermore, to understand data that is needed to make a legitimate heat transition policy, heat transition influencing factors were derived (Section 2.3.4). This analysis then will be used to conclude the aspects that need to be considered in a municipal heat transition policy-making (Section 2.4).

2.3.1 What are the characteristics of a DSS for high-level decision-making?

In this subsection, DSS and DSS framework characteristic is described to answer the first SLR sub-question, *"what are the characteristics of a DSS for high-level decision-making?"* At the end of this subsection, the correlation between DSS components the second, third, and fourth research question is mentioned.

2.3.1.1 Definition of DSS

Decision Support Systems (DSS) were first defined as interactive computer-based systems which support decision-makers to make unstructured decisions using data and decision models (McCosh & Morton, 1978). The purpose of DSS is to enhance decision-making for the managerial level (Sprague, 1980) by utilising the value of machines and information systems with a specific purpose (Power, 2004; Shim et al., 2002). In addition, some authors extended the term to include any information system that assists decision-makers to decide on unstructured decision options. As a result, any decision support that is not involving transactional processing systems (that is based on a balanced exchange concept) can be viewed as a DSS (Barron et al., 1999; Sprague, 1980).

2.3.1.1.1 Function of DSS

DSS functioning can be seen from their characteristics. Sprague and Watson (1976) provided six characteristics of a DSS. The first one is that DSS's main purpose is a decision support. Therefore, attention to the information flows, report structure, and database design is mandatory. Second, DSS needs to be interactive to allow users to access both the model and the data. Third, DSS needs to be flexible enough to satisfy different levels of management. Fourth, DSS need to integrate data and models and need to prevent sub-optimisation. Fifth, DSS is dynamic to that it will not be modified too often to meet the current needs of the decision system. Lastly, DSS is sophisticated in a way that it employs appropriate management science and information processing technology.

Contextually, DSS is meant to integrate both structured and unstructured decisions (Sprague, 1987). This means that from structured information, we can also derive support for an unstructured decision that involves multiple stakeholders (Hettinga et al., 2018) by combining more structured decisions (e.g. as energy label and energy-saving potential).

DSS is widely used in various domains, e.g. in study program design (Hope & Sharp, 1989), air traffic control (Malakis et al., 2014), transportation network control (Balakrishna et al., 2008), and medical decisions (Schnittker et al., 2017). These decisions have one thing in common: the decisions are unstructured. The decision dialogue will not tell users which decision to take but will provide users with information about possible alternatives to be considered. Therefore, "the last say" is not designed to be the DSS system responsibility.

2.3.1.1.2 DSS compared to other similar terms

Different from an Expert System (ES), which is a more advanced form of DSS where expertise reasoning ability is simulated (Barron et al., 1999), DSS provides only the information while the decision is still made by humans. DSS is an essential data-driven technique for a complex decision where the situation is too complex to be simulated like an ES is. This is the situation for heat transition that can be seen as a wicked problem where no one optimal solution exists (Janssen & Helbig, 2018; Millard, 2018).

Different from a Management Information System (MIS) that focusses on giving information, a DSS has more focus on decision creation (Barron et al., 1999; Sprague, 1980). Therefore, MIS' focus on the information flow makes them suitable for the middle manager. The provided information from MIS are not transactional data that are needed by lower operational level of the organisation, but more into a middle managerial level information support. This means that MIS and DSS touch each other's scope (Sprague, 1980) except that DSS is meant to be used only for higher levels of management.

2.3.1.2 Definition of DSS frameworks

Although the definition of DSS where a computer based-system is mandatory is not agreed upon in the literature (Konsynski & Sprague, 1986; Sprague, 1980), many authors have been defining a DSS as a combination of a machine-human decision system (e.g. Malakis et al. (2014), McCosh and Morton (1978) Power (2004), and Shim et al (2002)). Therefore, to reduce confusion of the artefact that is meant to be produced in this work, the term DSS framework is used.

A DSS framework can be defined as an artefact that envisions a basic structural model of a DSS (Sage, 1991b). In other words, a DSS framework (or DSS box (Sprague, 1980)) is a conceptual model that is used to virtualise DSS capabilities, DSS components, and interaction between DSS components. It is different from DSS that are directly used by their users to support their unstructured decision-making as the main purpose of DSS frameworks is to organise the process of decision-making capabilities of DSS (Sprague, 1980).

The DSS framework definition then gives three implications of their characteristics. First, since no machine is mandatory to create a DSS framework, a DSS framework does not need an interactive user interface. However, it is still important to keep the information flows and structure shown in the DSS framework, enabling the framework to be used as a communication interface between future DSS users and software developers (Sprague, 1980). Looking at this communication function, DSS frameworks need to carry the characteristic of DSS from Sprague and Watson (1976), flexibility toward the various level of users. Therefore, DSS frameworks can also be used to communicate policy decisions process to a diverse audience.

2.3.1.3 DSS framework components

Despite the wide variety of DSS, DSS frameworks always operate by providing decision-oriented information to the users (Sage, 1991a) as they give a basic structural model of a DSS. DSS frameworks are formed by three main elements: 1) database, 2) decision model, and 3) decision dialogue (Sage, 1991a, 1991b; Sprague Jr & Carlson, 1982) (see Figure 2.2).

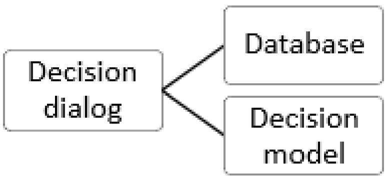

Figure 2.2 Three main elements of DSS (Sage, 1991a, 1991b; Sprague Jr & Carlson, 1982)

The decision dialogue is part of the DSS that will communicate with the user (in this case, policy-maker) (Sage, 1991a; Sprague, 1980). In other words, the decision dialogue decides on the interaction (or no interaction) between humans and the support tool. This interface is essential to ensure that users can get an optimum insight from the database and decision model (Sage, 1991b). Norman's (1986) interface generation model can be used to guide the development of a decision dialogue. This model describes seven action phases to produce a human-machine interface as follows: 1) goal framing, 2) intention framing, 3) action identification, 4) action execution, 5) result of action perception, 6) system state interpretation, and 7) (final) outcome evaluation.

Although decision dialogues is an important part of a DSS framework, this shall not be further explored in this thesis. The reason is the current phase of the research is still too early to work on the DSS decision dialogue framework. More focus is given to the database and decision model.

To create the database design, first, we need to know what data is needed to support the policy-makers in their decision process. This discovery is essential as none of the DSS frameworks can fit all applications for a wide variety of DSS goals, scope, and depth (Gachet & Sprague, 2005). This customisation is essential to fit the context of the decision. By mapping the data needs based on the context of the problem, a contextual DSS framework can be made specific. That way, DSS exclude considerations that are irrelevant to the context that problem owner (policy-makers) interest and focus on a more necessary process (Gachet & Sprague, 2005).

Therefore, to design the DSS data framework for municipal heat transition policy-making, factors that influence municipal heat transition were derived. These influencing factors are treated as potential data that policy-makers will need to formulate a municipal heat transition policy.

Just like how the DSS database framework needs to be customised, the decision model also needs to be customised. For example, the DSS framework developed by Hettinga et al. (2018) is designed to works on the "multi-stakeholder energy" context. In this context, they focus on the complex process of multi-stakeholder of the energy system. Hettinga et al. (2018) see that in an energy system, rapid response is not part of the need. On the other hand, in this context, decision making needs to focus on creating a decision that is optimum based on the tradeoff that is multi actors agree to make. On the other hand, Zografos and Androutsopoulos (2005) emergency material transportation DSS framework needs a decision model that facilitates the urgency status of the condition. Therefore, different DSS decision model frameworks need to be developed based on their requirements. In the case of this decision model, this decision model is made based on the decision process (Section 2.3.4) as well as involved actors in the policy-making process (Section 2.3.2 and Section 2.3.2).

In this section, DSS characteristic, that is to support a high-level unstructured problem, is described. To create a DSS, a context-specific DSS framework is essential. A DSS framework is made from three main components, decision dialogue, database, and decision model. In this study, the database is translated into influencing factors in heat transition and decision model is translated into the process that the municipality is using.

2.3.2 What are the steps in a municipal data-driven policy-making process?

This subsection discusses the policy-making process and the requirements of the policy-making process to answer the second SLR sub-question, *"what are the steps in a municipal data-driven policy-making process?"* Discussion on the policy-making process is done by reviewing five articles as follows: Birkland (2019), Bush and Bale (2019), Büttner and Rink (2019), Janssen and Helbig (2018), and van Veenstra and Kotterink (2017). Then policy-making requirements are discussed using the studies by Bush and Bale (2019), Paiho and Saastamoinen (2018), and Späth and Rohracher (2015).

The policy-making process can be described based on the policy life cycle (policy-cycle) or pragmatically. The first one, the policy cycle, is a representation of the development of policies (Lasswell & Lerner, 1951). Policy cycles have been widely used as a rule of thumb for policy-makers to analyse policies.

The policy cycle is described differently by several authors: Birkland (2019), Janssen and Helbig (2018), and van Veenstra and Kotterink (2017). Their formulation of policy cycles can be described in six phases as follows: 1) predictive and problem definition, 2) design, 3) experimentation, 4) implementation, 5) enforcement and 6) evaluation (see Table 2.4). First, in the prediction and problem definition phase information is gathered to understand the problem that needs to be governed. This information can be taken from an expert or in the future from the various actors (problem owners) as long as this information can be recognised as an emergent matter that needs the governments' attention. Second, the design phase is the phase where policy-makers analyse and create a solution space of policies alternatives. Bush et al. (2016) give an example of the design phase using multicriteria analysis of policy activities that consist of 1) selecting multiple techno-economic criteria and relevant indicators, 2) weighting criteria, and 3) the interface of the result of the criteria. Then, third, this design needs experimentation for its feasibility and effectiveness (impact assessment). Fourth, in the implementation phase, the decision is given to be executed in public. In this phase, resources and partners are mobilised to execute the policy. Then fifth, the enforcement phase where reward and punishment are given. Followed by the sixth phase, the evaluation phase, where policy success is measured.

Policy cycles	*Birkland, 2019*	*van Veenstra and Kotterink, 2017*	*Janssen and Helbig, 2018*
Predictive and problem definition	Problem definition	Predictive and problem definition	Problem definition
Design	Policy formulation	Design and experimentation	Policy development
Experimentation	Political feasibility		
Implementation	Policy implementation	Evaluation & implementation	Policy implementation
Enforcement	-		Policy enforcement
Evaluation	-		Policy evaluation

Table 2.4 Policy cycle (Birkland, 2019; Janssen & Helbig, 2018; van Veenstra & Kotterink, 2017)

Büttner and Rink (2019) discuss a more pragmatic process of policy-making that is taken in Germany. As their study uses the case of Germany, the suitability with the Dutch system needs to be examined further. Büttner and Rink (2019) explained that the policy creation process starts with the city council defining goals for the city administration. Then the city administration needs to lead the energy transition program while also reporting to the mayor and city council. In the process, the city administration also needs to enable involved actors in the heat transition (who are actively implementing the heat transition) and develop a climate concept (that is coordinated to the heat transition actors). From this analysis, we can see that city administration hold a really important role in this transition.

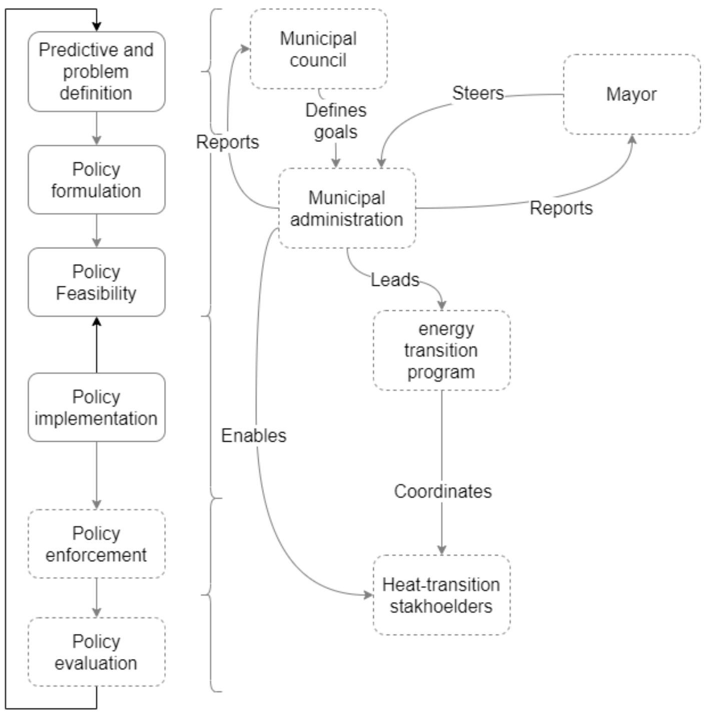

Figure 2.3 Municipal policy-making process illustration

Büttner and Rink's (2019) pragmatic process can be aligned with the six phases of the policy cycle that is more into conceptual guidance of policy-making as shown in Figure 2.3. In this case, currently, problem definition is given by the citizen representation (city council) and the mayor. Then the city administration and their specialised energy transition program work on the policy design and experimentation. Lastly, this policy needs to be implemented to the policy target (heat transition stakeholders).

Authors Bush and Bale (2019), Paiho and Saastamoinen (2018), and Späth and Rohracher (2015) proposed requirements to support an effective policy-making in their work. Fifteen requirements for effective municipal policy-making were found in the literature. The first one is that policies need to ensure compliance with regulations (Bush & Bale, 2019). However, the government cannot ask for compliance without thinking whether their policy is fair (Späth & Rohracher, 2015) and consistent within a long period (Paiho & Saastamoinen, 2018). Second, policies need to facilitate stakeholder engagement (Bush et al., 2016) and provide room for negotiation between them so that it can resolve the conflict of interest (Späth & Rohracher, 2015), including niche stakeholders. The policy also needs to be legitimate by providing evidence (backed up by data) to point policy-makers consideration in their decision (Bush et al., 2016). This legitimacy can also be achieved using digitalisation to connect with the public (Paiho & Saastamoinen, 2018) to promote transparency (Bush et al., 2016). Bush et al. (2016) also mentioned the need for a policy to include public concern into decision making and to support early stages of transition. Thus, tools to support the policy-making process needs to be clear how to be used allow the decision to be optimised in multidimensional criteria. Lastly, Paiho and Saastamoinen (2018) also mentioned that it is important for policy-makers to include local solutions and cooperation and to have cooperation with various aspects of public needs. But most importantly, willingness to experiment and to create pilots are essential for creating good policies.

In this section, the process that the municipality is taking to make policies can be divided into two ways of thinking: theoretically and pragmatically. In theory, the policy is made in a policy cycle. The policy cycle research has been growing after it is first introduced as it simplifies the process of policy-making. The simplest form can be seen from 1) prediction and problem definition phase, 2) design and experimentation phase, 3) implementation and evaluation phase.

2.3.3 Which actors are associated with the municipal heat transition policy-making process?

This subsection discusses the associated actors who are associated with the policy-making process to answer the second SLR sub-question, *"which actors are associated with the municipal heat transition policy-making process?"*

In the heat transition system, Debizet et al. (2015) and Späth and Rohracher (2015) mention three main groups of actors in the heat transition system. The first group are the policy-makers (1), who coordinate the heat transition through regulation. The second group are companies (2), who make sure heat is delivered to the citizens (3), who make up the third group of actors.

The definition of policy-maker is then enriched. Policy-makers can be divided into local government (1.1) (Bickel, 2017; Bush et al., 2016; Diran, 2019; Paiho & Saastamoinen, 2018; Viétor et al., 2015; Von Wirth et al., 2018), national government (1.2) (Paiho & Saastamoinen, 2018), and urban city planners (1.3) (Büttner & Rink, 2019; Heinisch et al., 2019). Both the local and national government can be divided into administration and council (Büttner & Rink, 2019). The national government guides the local government at the municipal level. The municipality is mandated with the responsibility to work on the heat transition (Rijksoverheid, 2020b). Urban city planners are not directly involved in the heat transition. However, since they are correlated closely to the issue, they also give supports to the municipal government in a form of guidance and advice.

These policy-makers although have no power to create a decision for the citizens, have the power to create policies that can be used to incentifies citizens decision on their investment. Therefore, their role in the heat-transition policy-making can be immense. Unfortunately, at the municipal level, their power in the economic incentive might not be as big as the national government. The municipal policy-makers power lied in their closeness to the citizens. Therefore, the social approach (including educational) can be powerful at this level.

Second, companies can also be divided into several categories: information technology (IT) services providers (2.1) (Diran et al., 2020; Paiho & Saastamoinen, 2018), heat providers (2.2) (Bickel, 2017; Busch et al., 2017; Bush & Bale, 2019; Büttner & Rink, 2019; Diran, 2019; Diran et al., 2020; Lygnerud, 2018; Paiho & Saastamoinen, 2018; Viétor et al., 2015), network operators (2.3) (Bush et al., 2016; Büttner & Rink, 2019; Diran et al., 2020), installation contractors (2.4) (Bickel, 2017; Busch et al., 2017; Bush et al., 2016; Diran et al., 2020; Viétor et al., 2015), consultancy agencies (2.5) (Busch et al., 2017; Diran et al., 2020; Viétor et al., 2015), university researchers (2.6) (Diran et al., 2020), real estate businesses (2.7), and heating and cooling service providers (2.8) (Bickel, 2017). The network operator can be divided into the local heat distributor (2.3.1) (Bickel, 2017; Diran et al., 2020; Lygnerud, 2018; Paiho & Saastamoinen, 2018; Seidl et al., 2019; Viétor et al., 2015) and grid operator (2.3.2) (Von Wirth et al., 2018). These companies can be a private or government-owned company (Lygnerud, 2018). For example in real estate businesses, there are government-owned social housing corporations (Bush et al., 2016; Büttner & Rink, 2019; Diran et al., 2020; Viétor et al., 2015) and private real estate businesses (Diran et al., 2020; Von Wirth et al., 2018).

These companies power lies in the economic power that they have, technological knowledge capability, as well as their capability to decide on the infrastructure investment. However, companies seem to see the energy transition as a new competition area to take the opportunity to create a new business. Therefore, in their position, their influence in the policy-making mostly lies in their knowledge. Even in the economic position, they are quite dependent on government policies (Paiho & Saastamoinen, 2018).

Lastly, citizens can be further divided (Bickel, 2017; Diran, 2019; Späth & Rohracher, 2015). Citizens can be seen as either the tenant (3.1) (Diran et al., 2020) or the private homeowner (3.2) (Diran et al., 2020; Von Wirth et al., 2018). Both private homeowners and tenants are living in the house, the difference is the building owner. On the other hand, both private homeowner and real estate for renting purpose both owned the building, but the difference is that private homeowners use the house. Groups of citizen (who are commonly living in the area) can also form a group called community (Von Wirth et al., 2018).

We can also categorise citizens as to how they consume and produce their energy. They can be either consumer (4.1) ((Busch et al., 2017; Debizet et al., 2015; Diran et al., 2020; Heinisch et al., 2019; Viétor et al., 2015) or prosumers (4.2) (Diran et al., 2020; Von Wirth et al., 2018). Consumers only use energy without producing any independently. Differently, prosumers generate energy in the house and are thus both a consumer and producer of energy. This categorisation can also be done using the types of usage of the building, like private use, business, or public building (Shaffer et al., 2018).

These citizens hold the sole power to decide what will be used in their house and the time to renovate their house. Although some standard can be given to the houses of the citizens, their power to also select policy-makers also gives another pressure to the policy-makers. However, the citizens might not be too close with the needed capital for heat transition. In the case of a negative business case, the easiest strategy for citizens is to do nothing.

The most important need is to find who are the instigators and the major stakeholders (Busch et al., 2017). Currently, the municipal governments are the most important actors in the heat transition as they need to direct the heat transition (Bickel, 2017). In contrast with the energy sector which has capital but only has a very weak influence on heat transition policy-making at the municipal level. Then other actors that need to be focussed on are the citizens. The problem is that the citizens are diverse and can be categorised from various angles. Nevertheless, citizens as users of heat have the legal power to change the heat source in their home. However, the presence of capital is questionable as well as their ability to join the policy-making process.

In the end, four groups of actors are defined in this chapter. The first group is the heat transition policy-makers who coordinate the heat transition through regulation. The second group is the service providers (companies) who provide and transport energy. Then the third group is the housing providers, which can be social housing corporations and private real estate businesses. The fourth group is the citizen who uses this energy. These citizens can be either house owners or tenants.

2.3.4 What are the heat transition influencing factors that can be used to support the municipal heat transition process?

In this subsection, influencing factors related to the heat transition system is listed to answer the fourth SLR sub-question, *"what are heat transition influencing factors that can be used to support the municipal heat transition process?"*

Starting with 106 raw influencing factors, a classification process was started by finding different words with a similar definition. The first step is needed since the raw list was made using articles authors words that might be diverse for the same meaning. The first classification derived 42 new classifications of influencing factors. From here, the next classification was done by looking if there is a more general category that can be used to cover several vocabularies that are used in the previous classification. In the end, 21 influencing factors are used. These 21 heat transition influencing factors are: 1) eight social heat transition influencing factors, 2) eight economic heat transition influencing factors, and 3) five technical heat transition influencing factors.

These influencing factors are divided into three parents categories of economic, social, and technical factors, as shown in Table 2.5. The classification in the economic (including political), technical, and social is taken from Ho, (2014). Economic factor (including political factor) is defined as anything that defined as 1) macroeconomic condition, 2) microeconomic condition, and 3) government intervention and lobbying. Social factor relates more into individual (and community) characteristics. This social factor covers 1) social, cultural, and demographic measure, and 2) behaviour and attitude. Lastly, a technical factor relates to 1) technology-related activities, 2) physical related material, and 3) new technology advancements.

Parent categories	Identified influencing factors	Influencing factors definition	References
Social: 1) social, cultural, and demographic measure, and 2) behaviour and attitude	Attitude (acceptance)	Construct that characterises an entity	Artur et al. (2020); Büttner and Ring (2019); Paiho and Saastamoinen (2018); Seidl et al. (2019); Upham et al. (2018); Perloff (2010); Aberilla et al. (2020); Gorroño-Albizu (2020); Seidl et al. (2019); Von Wirth et al. (2018); Lygnerud (2018)
	Individual knowledge	Information that can make sense to the individual	Darby (2017); Paiho and Saastamoinen (2018); Sernhed et al. (2018); Seidl et al. (2019)

	Individual perception	The way human deriving information from data	El Geneidy & Howard (2020); Fabiani et al. (2019); Long et al. (2016); Paiho & Saastamoinen (2018); Bush & Bale (2019), Aberilla et al. (2020); Von Wirth et al. (2018); Seidl et al. (2019), Lauridsen & Jensen (2013); Lygnerud (2018)
	Behaviour (participation)	Response to the attitude, capability, and perception	El Geneidy & Howard (2020); Paiho & Saastamoinen (2018); Seidl et al. (2019)
	Household economic power	The financial capability of the household to afford heat transition	Artur et al. (2020); Darby (2017); Bush & Bale (2019); Kerimray et al. (2018).
	Individual empowerment	Control of an individual toward a heat transition policy	Paiho & Saastamoinen (2018)
	Established social network	The closeness of people within the neighbourhood	Dyaram & Kamalanabhan (2005); Lygnerud (2018); Seidl et al. (2019).
	Fairness	Relative justice and reason	Späth & Rohracher (2015)
Economic: 1) macroeconomic condition, 2) microeconomic condition, and 3) government intervention and lobbying	Organisational affair	Form of the organisation and their access to resources	Lygnerud (2018); Paiho & Saastamoinen (2018)
	Path dependency	The burden of the past from each decision	Rissman et al. (2020); Späth & Rohracher (2015); Finck et al. (2018); Gorroño-Albizu (2020); Paiho f Saastamoinen (2018); Heinisch et al. (2019); Knobloch et al. (2019)
	Profitability	Operating flow from annual income and annual cost	Kerimray et al., (2018); Paiho & Saastamoinen (2018); Astudillo et al. (2017); El Geneidy & Howard (2020); Heinisch et al. (2019); Knobloch et al. (2019); Li et al. (2015); Qu et al. (2020); Späth & Rohracher (2015); Wijesuriya et al. (2018), Li et al., (2015);
	Energy demands	Scale of energy that is needed by the consumers	Artur et al. (2020); Bloemendal et al. (2018); Bush & Bale (2019); Chwieduk (2016); Darby (2017); El Geneidy & Howard (2020); Fabiani et al. (2019); Finck et al. (2018); Han et al. (2018); Kerimray et al. (2018); Lee et al. (2015); Long et al. (2016); Paiho & Saastamoinen (2018); Sager-Klauß (2016); Späth and Rohracher (2015); Stropnik et al. (2019); Von Wirth et al. (2018); Von Wirth et al. (2018); Astudillo et al. (2017); Qu et al. (2020); Wijesuriya et al. (2018)
	Negotiation	Political interest that comes from the various stakeholder	Jensen (2016); Paiho and Saastamoinen (2018); Sager-Klauß (2016); Späth and Rohracher (2015)
	Building ownership	Legal right to control building properties	Paiho and Saastamoinen (2018)
	Energy regulation	The social construct that is made to regulate energy	El Geneidy and Howard (2020); Paiho and Saastamoinen (2018); Rissman et al. (2020); Rissman et al. (2020); Aberilla et al. (2020); Gorroño-Albizu (2020); Von Wirth et al. (2018)
	Data regulation	The social construct that is made to	Diran et al. (2020); Paiho and Saastamoinen (2018)

		regulate data flow and usage	
Technical: 1) technology-related activities, 2) physical related material, and 3) new technology advancements	Consumers	Energy demands properties that need to be satisfied at the downstream level of energy infrastructures	Artur et al. (2020); (Qu et al. (2020); Fabiani et al. (2019); Kerimray et al. (2018); El Geneidy and Howard (2020); Zdankus et al. (2016);e.g. Astudillo et al. (2017); Chwieduk (2016); Darby (2017); Lee et al. (2015); Long et al. (2016); Paiho and Saastamoinen (2018); Qu et al. (2020); Aberilla et al. (2020)
	Producers	Energy supply properties that is produced at the upstream level of energy infrastructure	Artur et al., 2020; Darby, 2017; Gan and Xiang, 2020; Han et al., 2018; Heinisch et al., 2019; Knobloch et al., 2019; Long et al., 2016; Wijesuriya et al., 2018; El Geneidy and Howard, 2020; Zdankus et al., 2016; Abdurafikov et al., 2017; Artur et al., 2020; Astudillo et al., 2017; Han et al., 2018; Heinisch et al., 2019; Knobloch et al., 2019; Leurent et al., 2017; Paiho and Reda, 2016; Paiho and Saastamoinen, 2018; Wahlroos et al., 2017; Zdankus et al., 2016; Bloemendal et al., 2018; Finck et al., 2018; Han et al., 2018; Heinisch et al., 2019; Stropnik et al., 2019
	Physical transport device	The physical infrastructure that needs to be used to transport energy from producer to consumers	Abdurafikov et al. (2017); Knobloch et al. (2019); Han et al. (2018); Paiho and Reda (2016); Paiho and Saastamoinen (2018); Upham et al. (2018); Gorroño-Albizu (2020); Heinisch et al. (2019)
	Energy services	Service to ensure energy availability, reliability, and response time.	Heinisch et al. (2019); Finck et al. (2018); Paiho and Saastamoinen (2018);
	Data services	Data accessibility, security, utilisation, and digitisation standardisation	Diran et al. (2020); Paiho and Saastamoinen (2018);

Table 2.5 Heat transition influencing factors from SLR

2.3.4.1 Social heat transition influencing factors

Eight social heat transition influencing factors are presented as follows: 1) attitude (acceptance), 2) individual knowledge, 3) individual perception, 4) behaviour (participation), 5) household economic power, 6) individual empowerment, 7) established social network, and lastly, 8) fairness (as summarised in Table 2.5). To explain the difference between attitude, behaviour, and perception, we use the behavioural control model of Reasoned Action by Ajzen and Fishbein (2011). From the process area, the behaviour is created from three components, attitude, perceived norm, perceived behavioural control, and actual control.

Behaviour is presented by El Geneidy and Howard (2020) and Paiho and Saastamoinen (2018) as a factor that is connected to individual perception, energy demands, and profitability**.** Behaviour can be seen as a manifestation from intention and resources to realise the mentioned intention (Ajzen & Fishbein, 2011). This factor also includes participation and willingness to invest that is correlated to the attitude and path dependency (a factor derived from Seidl et al., 2019).

Behaviour can also be seen as a response based on a certain set of input (Elizabeth & Lynn, 2014). And one of this input is the **attitude** (derived from Artur et al. (2020), Büttner and Ring (2019), Paiho and

Saastamoinen (2018), Seidl et al., (2019), Upham et al. (2018)) toward the behaviour (Ajzen & Fishbein, 2011). Attitude is a construct that characterises an entity (Perloff, 2010). This factor also includes acceptance (a factor derived from Aberilla et al. (2020), Gorroño-Albizu, (2020), Seidl et al. (2019) and Von Wirth et al. (2018)), adoption potential (a factor derived from Gorroño-Albizu, (2020), Seidl et al. (2019) and Von Wirth et al. (2018)), customer value (a factor derived from Seidl et al. (2019) and Von Wirth et al. (2018)), personal value (derived from Lygnerud (2018).

Individual knowledge is information that can make sense to the people. This factor is also one of the background factors described by *Ajzen & Fishbein (2011)* theory. This influencing factor includes awareness (a factor derived from Musall & Kuik, 2011), communication (a factor derived from Darby, 2017; Paiho and Saastamoinen, 2018; Sernhed et al., 2018), personal knowledge (a factor derived from Darby, 2017; Paiho and Saastamoinen, 2018), and program promotion (Seidl et al., 2019).

Individual perception (*Ajzen & Fishbein (2011)* called them perceived norm) is the way human deriving information from data (a factor derived from Schacter et al., 2011). This can also be seen as an individual interpretation of a person without any influence from their surrounding (unlike attitude). Individual perception is the base that decides attitude. For example, “I see that ten degrees inside the house in winter is fine for me”. That is the perception that leads to a positive attitude toward not using a heater in the winter. Individual perception can be in a form of comfort perception (a factor derived from El Geneidy and Howard (2020), Fabiani et al. (2019), and Long et al. (2016), easiness perception (a factor derived from Paiho and Saastamoinen, 2018), lifestyle (a factor derived from Bush and Bale (2019), perceived local benefit (a factor derived from Aberilla et al. (2020) and Von Wirth et al. (2018), perceived responsibilities (a factor derived from Seidl et al. (2019), perspectives (a factor derived from Lauridsen and Jensen (2013); Paiho and Saastamoinen (2018), preference (a factor derived from Aberilla et al. (2020), Knobloch et al. (2019), and Paiho and Saastamoinen (2018), trust (a factor derived from Lygnerud (2018), Von Wirth et al. (2018), and spatial relatedness (a factor derived from Von Wirth et al. (2018)

Household economic power is the capability of the household to work on the heat transition based on their capital and access to capital. As heat transition is expensive, it is important to know if people can easily afford to pay for heat transition. This factor shall allow a household to convert from intention to behaviour (Ajzen & Fishbein, 2011). Household economic power derived from household income (a factor derived from Artur et al. (2020) and Darby (2017) and poverty status (a factor derived from Bush and Bale (2019) and Kerimray et al. (2018).

Individual empowerment is defined as the control of an individual toward a certain decision. Paiho and Saastamoinen (2018) describe that both abilities to choose and ability to influence the policy-making process can be essential for some individual. This might be related to fairness. **Fairness** is related to justice and reason. This is one factor that the municipality needs to consider with talking to the citizens, as fairness can come in various ways. Späth and Rohracher (2015) argue that fairness is important to be considered in the policy-making. However, the notion of fairness might change in different time and place.

Established social network means the closeness of people within the neighbourhood. This network creates a social cohesion that will allow a group of people to stick together (Dyaram & Kamalanabhan, 2005). This cohesion can be seen on how often they talk to each other or how often they meet. They can be in the form of the frequency of social interaction (Lygnerud, 2018), presence of local social networks, or social proximity between neighbours (Seidl et al., 2019).

2.3.4.2 Economic heat transition influencing factors

As previously mentioned, economic heat transition influencing factors are also defined to include an organisational and political aspect of the business. Eight economic heat transition influencing factors are identified: 1) organisational affair, 2) ownership, 3) path dependency, 4) profitability, 5) energy demands, 6) negotiation, 7) energy national regulation, and 8) data regulation (as summarised in Table 2.5). These factors derived from the literature study that is compared to the classification that is used by Mirata (2004) and Park et al. (2018) in their study.

The first and second factors come from the organisational and motivational classification. This class then divided into two subclasses, organisation capacity and availability and the right who make decisions (who can make decisions?) (Mirata, 2004; Park et al., 2018). We call the first one as the organisational affair and the second one is translated to the ownership (as the building ownership determined the right to decide changes in the house).

Organisational affairs are mentioned by Lygnerud (2018) and Paiho & Saastamoinen (2018). Lygnerud (2018) describes that a business model may affect the value of an entity. Then at the end, defined an entity attitude toward a certain new case, such as heat transition. On the other hand, Paiho & Saastamoinen (2018) mentioned that it is also essential to understand the organisational affair so we can know how can we get an entity fund to accelerate heat transition. For example, as a household, I will need end-users might only take a maximum of five years investment while for a company, a longer-term contract can be made easier.

Paiho & Saastamoinen (2018) expressed that **building ownership** is considered the main challenge in defining a heating system. This factor includes questions like, who is responsible to decide for changes in this building? Or what financial relief can be arranged for this kind of ownership status? The same question can also be given to the upstream area (if any), who will own this district heating? Who will distribute them?

In the financial aspect, guided by Mirata (2004) and Park et al. (2018) definition, we derived three factors that influence heat transition that is path dependency (size of capital investment in both previous and future installation, profitability, and the economy of scale that is defined by energy demands. Path dependency is one of the characteristics of a complex system (Van Dam et al., 2013). **Path dependency** shows the burden of the past. Example of path dependency is the government decision of research fund shall determine the technology with the least carbon emission in the future (Rissman et al., 2020). A more concrete example is the burden from huge capital needed for connection and distribution (Späth & Rohracher, 2015), common infrastructure installation (Finck et al., 2018; Gorroño-Albizu, 2020; Paiho & Saastamoinen, 2018), and private house installation (Knobloch et al., 2019) that made up total investment cost (Heinisch et al., 2019; Knobloch et al., 2019). When a municipality has chosen a certain solution for a certain neighbourhood, most likely there shall be lesser flexibility for this area to change their decision in the future.

Profitability comes from the operating flow of annual income and annual cost (Kerimray et al., 2018). This profitability depends highly on the heat pricing system (Paiho & Saastamoinen, 2018) that will determine the retail price at the end. Retail price is an extremely important factor that is supported by many authors (Astudillo et al., 2017; El Geneidy & Howard, 2020; Heinisch et al., 2019; Knobloch et al., 2019; Li et al., 2015; Paiho & Saastamoinen, 2018; Qu et al., 2020; Späth & Rohracher, 2015; Wijesuriya et al., 2018). Other factors that decide profitability are marginal cost (Li et al., 2015; Paiho & Saastamoinen, 2018), operation cost (Heinisch et al., 2019), and discount rate (Kerimray et al., 2018). Furthermore, there are also competitions (Paiho & Saastamoinen, 2018) to be considered to create the price.

Another factor that comes from financial classification is the scale of the implementation (Mirata, 2004; Park et al., 2018). **Energy demand** factor is used to present the scale of the implementation (Von Wirth et al., 2018). The basic principle is the lower the energy demands (that can be gained via efficiency or passive house choices), the lower price you need to pay. This is agreed by many authors (Artur et al., 2020; Bloemendal et al., 2018; Bush & Bale, 2019; Chwieduk, 2016; Darby, 2017; El Geneidy & Howard, 2020; Fabiani et al., 2019; Finck et al., 2018; Han et al., 2018; Kerimray et al., 2018; Lee et al., 2015; Long et al., 2016; Paiho & Saastamoinen, 2018; Sager-Klauß, 2016; Späth & Rohracher, 2015; Stropnik et al., 2019; Von Wirth et al., 2018). Although, in the supplier side, more energy consumption might be needed to build an affordable energy system as the bigger the energy system scale, most likely the smaller the common cost will be (Späth & Rohracher, 2015). However, high peak demands give an unnecessary load that will burden the community to build a bigger infrastructure. Therefore, a peak demand cut is needed to be considered in the system (Artur et al., 2020; Astudillo et al., 2017; Qu et al., 2020; Wijesuriya et al., 2018).

Political aspect explained by Mirata (2004) and (or institutionally based on Park et al. (2018)) as factors that defined by stakeholders pressure and government regulations. To make it precise, the regulation is classified as energy regulation and data regulation. The first factor is called **negotiation** factors that are defined by the political interest that comes from the various stakeholder of the municipal heat transition policy-making (Jensen, 2016; Paiho & Saastamoinen, 2018; Sager-Klauß, 2016; Späth & Rohracher, 2015) that might end with an agreement that is formed from a considerably fair trade-off for all involved party (Späth & Rohracher, 2015).

The second factor from the political aspect is **energy regulation**. Some energy regulation that can affect heat transition works by giving financial advantages to the low carbon energy system (e.g. carbon pricing (Rissman et al., 2020), direct financial incentives (El Geneidy & Howard, 2020; Paiho & Saastamoinen, 2018; Rissman et al., 2020)). Energy regulation can also work by giving a certain quality standard to either consumer or producers (e.g. house energy efficiency standard system or procurement standard (Rissman et al., 2020), a minimum standard of housing appliances (Rissman et al., 2020). Some also used in the measure of a geographical area to support higher proximity between consumer and the system (e.g. usage of local resources (Aberilla et al., 2020) or incentive for local co-ownership (Gorroño-Albizu, 2020; Von Wirth et al., 2018)). Most importantly, Paiho and Saastamoinen (2018) argue that incentives need to be stable to secure public expectation from their decision.

Lastly, **data regulation** consist of regulation that works on data security, accessibility, and standardisation (Diran et al., 2020; Paiho & Saastamoinen, 2018). This data regulation is including the European General Data Protection Regulation (GDPR).

2.3.4.3 Technical heat transition influencing factors

Five technical influencing factors are classified using an adapted Scholten and Künneke (2016) Complex Adaptive System (CAS) infrastructure commodity flow that is production, transportation, consumption and management of energy. In the production area, we also include storage as the subject of consideration. The second comes from the consumption level that will consider activities that determine demand and scale of the system. Transportation and distribution are divided into physical devices choices and services. The service is given divided again into information services and energy quality services. These technical influencing factors summary is presented in Table 2.5.

The **production** level energy is where energy is produced or where the source is gathered (Künneke, 2013). Literature is abundant on the choices of energy producers, environment (e.g. weather), energy sources, and choices of storages. All of these articles show that different kind of set of means (combinations of energy source, energy producer, energy storage) can give a certain performance under specific influences (see Table 2.6). The environment needs also be taken into consideration when talking about this factor.

Energy producer	Artur et al., 2020; Darby, 2017; Gan & Xiang, 2020; Han et al., 2018; Heinisch et al., 2019; Knobloch et al., 2019; Long et al., 2016; Wijesuriya et al., 2018
Environment	El Geneidy & Howard, 2020; Zdankus et al., 2016
Energy sources	Abdurafikov et al., 2017; Artur et al., 2020; Astudillo et al., 2017; Han et al., 2018; Heinisch et al., 2019; Knobloch et al., 2019; Leurent et al., 2017; Paiho & Reda, 2016; Paiho & Saastamoinen, 2018; Wahlroos et al., 2017; Zdankus et al., 2016
Energy storage	Bloemendal et al., 2018; Finck et al., 2018; Han et al., 2018; Heinisch et al., 2019; Stropnik et al., 2019

Table 2.6 Consumers technical considerations from SLR

The **consumers** technical influencing factors mostly concerning the energy demands that need to be satisfied at the downstream level of energy infrastructures. This includes load management (Artur et al., 2020) and load fluctuation (Qu et al., 2020) that can be derived from occupancy rate (mentioned by El Geneidy & Howard, 2020; Fabiani et al., 2019; Kerimray et al., 2018) and weather condition (El Geneidy & Howard, 2020; Zdankus et al., 2016). One recommended way to reduce energy consumption, as well as fluctuation, are passive house choices. A lot of research has been done in this subject to bring passive house climate control by introducing coating in the roof, window, or wall (e.g. Astudillo et al., 2017; Chwieduk, 2016; Darby, 2017; El Geneidy & Howard, 2020; Fabiani et al., 2019; Kerimray et al., 2018; Lee et al., 2015; Long et al., 2016; Paiho & Saastamoinen, 2018; Qu et al., 2020). This factor is also added to the comfort of the consumers that are formed by local air pollution and human health (Aberilla et al., 2020). For example, using firewood might be sustainable, but some people might find the pollution from burning the firewood is bad for health.

The **transportation physical devices** consider infrastructure age (Abdurafikov et al., 2017; Knobloch et al., 2019), location and landscape (Han et al., 2018; Paiho & Reda, 2016; Paiho & Saastamoinen, 2018; Upham et al., 2018), the possibility of cross-sector integrations (Gorroño-Albizu, 2020), network interconnectivity (Heinisch et al., 2019; Paiho & Saastamoinen, 2018). Furthermore, **energy transmission service** is a factor on how the operation of previously mentioned physical devices can ensure availability (Heinisch et al., 2019), the response times (Finck et al., 2018), and system reliability (Paiho & Saastamoinen, 2018). On the other hand, **data related service** consists of data accessibility, data security, data utilisation, and digitisation standardisation (Diran et al., 2020; Paiho & Saastamoinen, 2018).

In this section, 21 heat transition influencing factors from SLR are described. From these 21 factors, eight are social heat transition influencing factors, another eight are economic heat transition influencing factors, and another five are technical heat transition influencing factors. These influencing factors show what kind of data is needed in creating a heat transition policy at the municipal level.

2.4 Conclusion for the SLR

In this chapter, we describe the aspects that need to be considered in creating a heat transition policy-making using a systematic literature review (SLR) adapted from Kitchenham and Charters (2007), Levy and Ellis (2006), Webster and Watson (2002) and Okoli and Schabram (2010). Thus, the first research question was answered: *"what aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?"* This SLR used the following approach. First, in the planning phase, both research questions and SLR protocol were prepared. Second, in the SLR conduct phase, search and screen strategy, quality screening, and data snowballing were done to select the article. Then data extraction to answer research questions were done. Lastly, in the reporting phase, data processing and analysis were made.

From SLR, the aspects that are important to be considered in a DSS for heat transition policy-making by municipalities are database that is presented as influencing factors (SLR sub-question 4) and decision model that is presented in the actors (SLR sub-question 3) and decision-making process (SLR sub-question 2). To dig more into these aspects, this chapter has answered four SLR sub-questions as follows.

1) What are the characteristics of a DSS for high-level decision-making?

DSS was firstly defined as an interactive computer-based system which supports decision maker to solve unstructured decision using data and decision models. While DSS framework is defined as an artefact that envisions a basic structural model of a DSS. We can also see the DSS framework as a conceptual model that is used to virtualise DSS capabilities, DSS components, and interaction between DSS components. DSS frameworks are formed by three main elements: 1) database, 2) decision model, and 3) decision dialogue. Database of the system is represented using heat transition influencing factors while the decision model is represented by the policy-making process and their involved actors.

2) What are the steps in a municipal data-driven policy-making process?

The policy-making process can be described based on the policy life cycle (policy-cycle) or pragmatically. A policy cycle is a representation of the development of policy as a rule of thumb for policy-makers to analyse policies. Policy cycles consist of six phases as follows: 1) predictive and problem definition, 2) design, 3) experimentation, 4) implementation, 5) enforcement, and 6) evaluation. We can also use three steps of 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation. On the other hand, pragmatically, a policy-making process is an intertwined chain of interaction between stakeholders that are the government as the lead and regulator, companies who provide services to the consumer, and the citizen.

3) Which actors are associated with the municipal heat transition policy-making process?

Four groups of actors are derived in this SLR. The first group of actors is the heat transition policy-makers who coordinate the heat transition through regulation. The second group of actors is service providers (companies) who provide and transport energy. The third group is the housing providers, which can be social housing corporations and private real estate businesses. And the fourth group is the citizen who uses this energy. These citizens can be either house owners or tenants.

4) What heat transition influencing factors can be used to support the municipal heat transition process?

To support database creation of the DSS, eight social influencing factors, eight economic influencing factors, and five technical influencing factors (total 21 influencing factors) are derived. Data that are needed to decide on "what?" and "when?" are derived as follows and summarised in Table 2.7.

Heat Transition influencing factors derived from the SLR		
Social	Economy	Technical
1) Attitude 2) Individual knowledge 3) Individual perception 4) Behaviour 5) Economic power 6) Individual empowerment 7) Established social network 8) Fairness	1) The organisational affair 2) Ownership 3) Path dependency 4) Profitability 5) Energy demands 6) Negotiation 7) Energy national regulation 8) Data regulation	1) Production 2) Consumption 3) Physical transport infrastructure 4) Energy service 5) Data service

Table 2.7 Heat Transition influencing factors derived from the SLR

First, social heat transition influencing factors are presented based on behavioural control theory as follows: 1) attitude (acceptance), 2) individual knowledge, 3) individual perception, 4) behaviour, 5) household economic power, 6) individual empowerment, 7) established social network, and lastly, 8) fairness. Secondly, economic heat transition influencing factors are also defined to include an organisational and political aspect of the business. Eight heat transition influencing factors are presented as follows: 1) organisational affair, 2) ownership, 3) path dependency, 4) profitability, 5) energy demands, 6) negotiation, 7) energy national regulation, and 8) data regulation. Lastly, technical influencing factors are classified using an adapted Complex Adaptive System (CAS) infrastructure commodity (i.e transportation, consumption, and management of energy). In the production area, we include storage as the subject of consideration. The second comes from the consumption level is based on activities that determine demand and scale of the system. Transportation and distribution are divided into physical devices choices and services. The service is divided again into information and energy quality services. These factors are summarised as follows: 1) production, 2) consumption, 3) physical transport infrastructure, 4) energy service, and 5) data service.

In conclusion, there are two main aspects of DSS that need to be defined when making a DSS framework. The first aspect that is critical to be considered in a DSS for heat transition policy-making by municipalities is a database that is presented as influencing factors (SLR sub-question 4). And the second one is the decision model that is presented in the actors (SLR sub-question 3) and decision-making process (SLR sub-question 2). These SLR sub-questions are used to answer the first research question of this thesis.

What aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?

Answers from these SLR sub-questions have led to the answer of the first research question of this thesis, *"what aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?"*

In the creation of DSS framework, two main components are found to be essential in creating a DSS framework, the database and the decision model. In the heat transition policy-making context, these components are translated into three main aspects: 1) data-driven heat transition policy-making, 2) actors associated with the heat transition policy-making, and 3) heat transition influencing factors in the heat transition activities. These aspects can be summarised as shown in Table 2.8.

	Decision model			Database		
	Process		Actors	Heat transition influencing factors		
	Conceptual	Pragmatic		Social	Economy	Technical
DSS Framework	1) Prediction and problem definition 2) Design and experimentation 3) Implementation and evaluation	1) Defines goals 2) Steer heat transition 3) Lead heat transition 4) Enable heat transition	1. Heat transition policy-makers 2) Energy (service) providers 3) Housing providers 4) Citizens	1) Attitude 2) Individual knowledge 3) Individual perception 4) Behaviour 5) Economic power 6) Individual empowerment 7) Established social network 8) Fairness	1) The organisational affair 2) Ownership 3) Path dependency 4) Profitability 5) Energy demands 6) Negotiation 7) Energy national regulation 8) Data regulation	1) Production 2) Consumption 3) Physical transport infrastructure 4) Energy service 5) Data service

Table 2.8 DSS framework aspects summary from the SLR

This research derived two approaches to the policy-making process from literature. The first one is the conceptual policy cycle process. Policy cycles define that policy is made in three phases, 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation. This policy-making process can also be seen pragmatically as an intertwined chain of interaction between policy-making actors that are the government as the lead and regulator, companies who provide services to the consumer, and the citizen.

In the context of heat transition policy-making, these mentioned actors, five main actors were derived from literature. These five actors are listed as follows: 1) heat transition policy-makers, 2) service provider companies (for both supplier and transportation), 3) house provider companies (social housing corporations and private real estate business), 4) citizen who are using the service (both ones who own the house or renter from house provider). These actors interaction is each policy-cycle process defines the decision model of the DSS framework.

These actors interact within a certain group of heat transition influencing factors which need to be considered based on the available (or future) data. These data are classified into three parents groups of heat transition influencing factors (i.e. 1) social heat transition influencing factors, 2) economy heat transition influencing factors, and 3) social heat transition influencing factors) as shown in Figure 2.7 and Figure 2.8.

First, social heat transition influencing factors are listed as follows: 1) attitude (acceptance), 2) individual knowledge, 3) individual perception, 4) behaviour (participation), 5) household economic power, 6) individual empowerment, 7) established social network, and lastly, 8) fairness. Second, economic heat transition influencing factors are listed as follows: 1) organisational affair, 2) ownership, 3) path dependency, 4) profitability, 5) energy demands, 6) negotiation, 7) energy national regulation, and 8) data regulation. And last, technical influencing factors are listed as follows: 1) production, 2) consumption, 3) physical transport infrastructure, 4) energy service, and 5) data service.

3 Identification of possible solutions: needs for a decision support system to assist municipal heat transition policy-making

In the previous chapter, we obtained insight concerning the aspects that need to be considered in the municipal heat transition policy-making Decision Support System (DSS). In this chapter, we use these aspects as a base to conduct a case study. This case study research was done to derive the needs from the three perspectives of policy-making (from the municipality of Zoetermeer) for the development of a decision support system framework to support municipalities in making decisions concerning municipal heat transition policy-making. Hence, this chapter answers the second research question: *"what are the needs for a decision support system framework to assist municipal heat transition policy-making?"* The answer to this question is then used to develop the municipal heat transition policy-making DSS framework that is presented in Chapter 4.

This chapter is structured as follows. First, the case study approach is explained (section 3.1) including a presentation of the case study approach itself. Then planning and design of the case study is described in Section 3.2 followed by data collection and preparation in Section 3.3. Then Section 3.4 provides the case study is analysis and report. Finally, Section 3.5 summarizes this chapter, provides our conclusions, and answers the second research question.

3.1 Case study approach

Yin (2018) provides general guidelines for conducting a case study. This guidance defines that a case study is generally conducted in six phases: 1) planning, 2) design, 3) preparing, 4) collecting, 5) analysis and 6) sharing. These phases are adapted into three case study phases in this research: 1) planning and design phase, 2) preparation and data collection phase, and 3) analysis and report phase (see Figure 3.1). Each of these phases is presented in a section of this chapter.

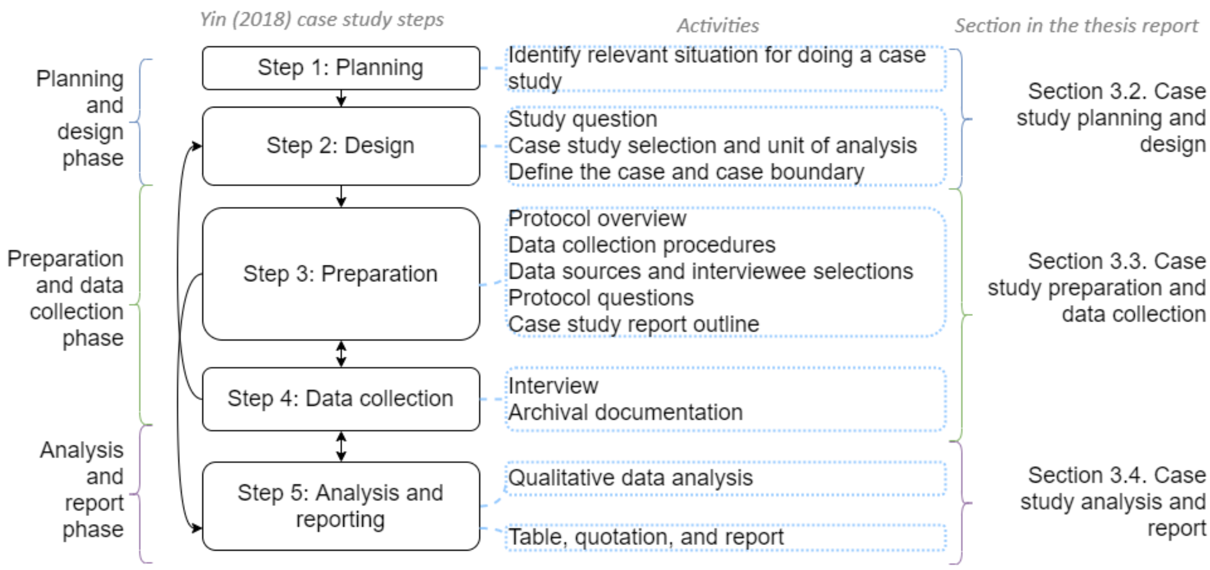

Figure 3.1 This case study research approach adapted from Yin (2018) case study guidance

3.1.1.1 Planning and design phase method

In the planning and design phase, four activities need to be done. These activities are listed as follows: 1) identify relevant situation for doing a case study, 2) deploying study questions, 3) case study selection and unit of analysis, and lastly 4) define the case and case boundary (Yin, 2018).

3.1.1.2 Preparation and data collection phase

In the preparation and data collection phase, a case study protocol was made and data collection was conducted. In the protocol that is prepared, five types of information are presented: 1) protocol overview, 2) data collection procedures, 3) data sources and interviewee selections, 4) protocol questions, and 5) case study report outline. Data collection consisted of two activities: interview and archival documentation. The documentation, in this case, are interview transcripts and archived articles.

3.1.1.3 Analysis and report phase method

In this analysis, the middle ground theory was used. The middle theory is executed by having the initial code list informed by theory and code list then inductively evolve the code during analysis. This approach is more guided than grounded theory (Glaser et al., 1967) but more flexible than a tight approach (the predefined code list).

The qualitative analysis was executed using adapted from Kuckartz (2019) of qualitative content analysis (QCA) and Williams and Moser (2019) nonlinear process of qualitative research. These three steps were used in this analysis, 1) data reparation, 2) coding cycle and 3) derived analysis (see Figure 3.2).

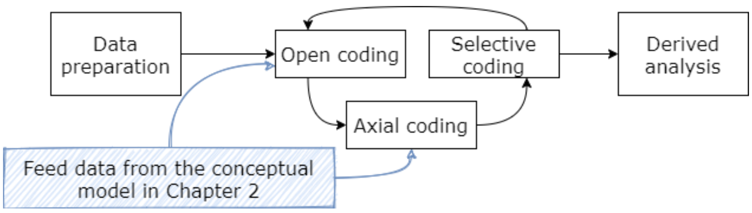

Figure 3.2 Case study qualitative analysis scheme adapted from Glaser et al. (1967), Kuckartz (2019), and Williams and Moser (2019)

First, data was prepared by reading through the interview data and supporting documents that are extracted from the interviews and the additional data are re-read to get a good idea of what are these data represented. Then these data are uploaded and grouped accordingly. These groupings were based on their perspective, whether they are main data or additional data, and if they are website, social media post, or published documents.

Then second, five main categories of codes that were deducted from the literature review in Chapter 2 were taken (this also used as the case study question). As shown in Figure 3.3, these five main groups consist of 1) perspectives, 2) actors, 3) characteristic of wanted heat transition policy making, 4) policy-making process and 5) influencing factors to support policy-making. The perspectives are using the concept from Head (2008), so we coded them in the same way as to how we were collecting the data. More information about these deducted categories is explained in Chapter 2.

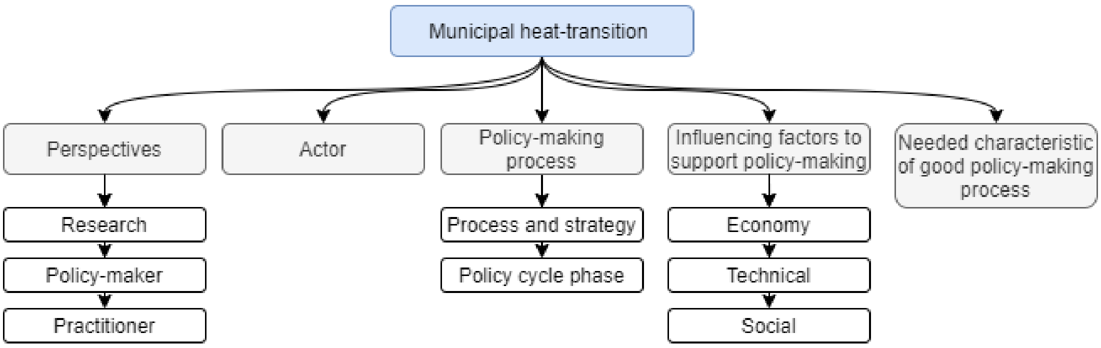

Figure 3.3 Case study analysis of coding categories

Third, an open coding was conducted. Open coding was done after reading each interview transcript line by line. Some codes are generated from relevant chunks of sentences that are marked. The difference between Strauss (1987) theory and this research open coding is that in this research, the text was subjected to interpretation and categorization based on the classification that already been used in Chapter 2. However, if that was not possible, changes were made. Then in axial coding, the relationship between category was defined and the need for additional codes are added. Third, in the reduction phase: core categories code was identified. Then transcripts were then read again to identify all the derived core categories in the analysis fit the transcript data.

Then lastly, an analysis was made by comparing interviewee statements and by comparing the number codes has been mentioned in the main data source. Cross-checking was done by visiting the website or document interviewee was mentioning in the interview to check the validity of this information. This was then followed by report creation. Reporting was made in the form of word, table, and images representation. This step concludes as the analysis and report activities.

3.2 Case study planning and design

To start a case study, planning and design need to be done. Planning phase checks if the research should be done using the case study of some other alternatives. In the design phase, the case study basis is chosen (including case study type and boundary).

3.2.1 Step 1: Case study planning

In the planning step, Yin (2018) states that the researcher needs to identify the relevant situation that leads the research in using the case study method. There are four main reasons to use case study compared to other research methods. Firstly, Yin (2018) states that it is relevant to choose a case study research method if in-depth empirical evidence to answer a “How” and “Why” related to a contemporary events question is needed to be taken. Heat transition policy-making is a contemporary problem that needs to be addressed in a limited amount of time. The question of “what need,” although did not use the word “how,” is a “how” question as they imply an investigation on “how should a specific system looks like.“ This question is especially true for a case where context influence is high. In this case, the Netherlands is a unique place due to its geographical area and population. This was seen by the Dutch government as they mandate a local approach to create a heat transition policy.

Moreover, a case study is used for a situation where control over phenomena behaviour is either undesirable, unneeded, or impossible (Yin, 2018). This criterion is essential as they differentiate a case study research and experiment research. In this context of the searching of a system need, control over behaviour is unneeded. Also, since this research is aimed to explore the complexity of the heat transition policy making, control over behaviour is undesirable.

Furthermore, a case study is especially useful when the boundary between phenomena and context is not evident. This situation is true when research is done in the complex real-world. Lastly, the case study is chosen because of the potential of a vast number of variables of interest compared to the number of data points. The research is done to find data convergence instead of statistical evidence.

3.2.2 Step 2: Case study design

In the design step, Yin (2018) states that the researcher needs to 1) determine the research questions and proposition, 2) define case study selection and unit of analysis, 3) define case study boundaries, and lastly, 4) evaluate the case design strength.

3.2.2.1 Case study sub-questions

To answer the research question mentioned in the introduction, *“what are the needs for a decision support system framework to assist municipal heat transition policy-making?”* four case study questions are made. Four case study sub-questions are derived as follows: 1) what are the needed characteristics of good municipal heat transition policy-making process? 2) what are the main actor's dynamics in the data-driven municipal heat transition policy-making that support a good policy-making process? 3) what activities are used by the municipality to define, assess, and communicate a municipal heat transition policy-making? and lastly, 4) what are heat transition influencing factors that need to be considered for a legitimate data-driven municipal heat transition policy?

These questions are made based on the SLR that is presented in Chapter 2. Based on the SLR, two main components need to be explored to develop a DSS framework, database, and a decision model. The first question is about the data that are needed to decide “what?” and “when?” transition need to be done. The second and third ones derived from the decision model’s needs. The last one is used by both (database and decision model) to explicitly determine the goal of the process that is needed to ensure the creation and the assessment of a good heat transition policy-making.

3.2.2.2 Case study selection and unit of analysis: Zoetermeer municipality heat transition policy-making 2020

To assess these questions in Section 3.2.2.1 above, a “single case study in the heat transition policy-making in the municipality of Zoetermeer for 2021 till 2050 heat transition program” case is selected. The reason for this case selection are listed as follows: 1) the need to find a case that can answer the case study sub-questions are mentioned in the case study planning, 2) a limited research time resources compared to the broad aspects of policy-making that is presented in the case study sub-questions, and lastly, 3) the commitment that is given by municipality of Zoetermeer into the research project.

For the first reason, we found that the case of the Netherlands municipal heat transition policy-making case is needed to answer all four case study sub-questions. The first sub-question is meant to see the case of municipal heat-transition policy-making characteristic. Then the second one is meant to see the municipal heat transition policy-making actors. The third one is meant to study the current (and future) municipal heat-transition policy-making activities. Then lastly, the case study sub-question is meant to know what kind of influencing factors are used in the municipal heat-transition policy-making. These four concerns can be answered by analysing the case of municipal heat transition policy-making.

Second, a single case study is selected to give focus to the broad aspects of policy-making as presented in the sub-questions above. With a single case study with limited resources, both time and manpower can be focussed to have a deep analysis of the subject (Lobo et al., 2017). This resources and wide aspect of research is the reason for this study to focus on a single case study.

Lobo et al., 2017 also mentioned that commitment from the stakeholders is essential to decide on the case study. Commitment is an important matter in a case study as it requires a big amount of time, careful preparation, and intensive communication with numbers of people (Lazar et al., 2017). Thus, in this context, a commitment from one municipality in the Netherlands was one of the advantages that need to be taken. In this case, we derived research stakeholders commitment by relating this research into the existing project that is running at TNO, which led to the third reason for choosing this case.

Third, the reason for the geographic area choice, the municipality of Zoetermeer is used in the case study is because of the guaranteed commitment from the heat transition policy-makers to support the research. As this research has gained commitment from the TNO project, “Aardgasvrij Wijken Zoetermeer,” engagement and openness from the municipality of Zoetermeer was guaranteed. This commitment includes resources as follows: 1) time allotment, 2) resources access and recommendation toward Zoetermeer heat transition policy-making data, and 3) expert recommendation for further analysis.

An additional reason for Zoetermeer to join the research are listed as follows: 1) the need from Zoetermeer municipality to create a heat transition policy before 2021, 2) the need to create a gas-free city in 2050 for Zoetermeer, and 3) the lack of empirical data in the case of Zoetermeer municipality heat transition policy-making.

Therefore, the combination of the case that is needed to answer the case study sub-questions, resource limitation, and the guaranteed commitment from the municipality of Zoetermeer has brought this case study to be bounded to "the single case study in the heat transition policy-making in Zoetermeer for 2021 till 2050 heat transition program"

3.2.2.3 Case study definition and boundaries

The case study is focussing on the heat transition policy-making process of Zoetermeer municipality. To scale down the focus of this study, more boundary should be set. The case study is bounded by four categories as described as follows.

The geographical area of the study is set to Zoetermeer municipality. However, this does not restrict the analysis to only work with Zoetermeer as a municipality, but also as a district in the municipality. The reason for this boundary choice is because, in the municipality of Zoetermeer, policy planning is designed to focus on each neighbourhood of Zoetermeer.

The municipality of Zoetermeer has nine districts and 27 neighbourhoods. These neighbourhoods are Balijbos, Buitengebied-West, Meerpolder, Scheidingszone, Van Tuyllpark, Westerpark c.a., Buytenwegh, De Leyens, Dorp, Driemanspolder, Palenstein, Stadscentrum, Hoornerhage c.a., Lansinghage c.a., Rokkehage c.a., Zoeterhage c.a., Meerzicht-Oost, Meerzicht-West, Noordhove-Oost, Noordhove-West, Oosterheem-Noord-Oost, Oosterheem-Zuid-West, Rokkeveen-Oost, Rokkeveen-West, Seghwaert-Noord-Oost, and Seghwaert-Zuid-West (AlleCijfers, 2020; Postcode.site, 2020). However, this case mainly evaluated the case on where the municipality have done their pilot in Palenstein and the new planning project to work in Meerzicht-Oost and Meerzicht-West.

The second boundary comes from the component of the required focus that will be used in this case. This need will focus on four dimensions of information, 1) heat transition influencing factors 2) the main actor's dynamics, and 3) activities to define and assess a municipal heat transition policy-making.

The third boundary comes from the policy cycle phases. The case study will cover all phases of a policy cycle, namely, 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation.

Lastly, the heat transition policy that analyses are bounded to lead to answer the question of "what technology needs to be taken" and "when should this transition happening?" This boundary is used because this is the main question of Zoetermeer municipality that should be answered at the end of 2021. Thus, we want to also align this case study with the need of the municipality.

To sum up this planning and design phase, a single case study of the municipal heat transition policy-making process in Zoetermeer is selected because of the resource availability as well as the need to the needs of the municipality of Zoetermeer. After the case study concept is designed, research preparation and data collection are presented in Section 3.3. bellow.

3.3 A case study research preparation and data collection

In the preparation and data collection step, Yin (2018) defines two main activities that were iterated after each data gathering activities: case study protocol and data collection. In this section, the design that has been made in Section 3.2 is extended into a protocol. Then from data collection shall be done based on the protocol that has been made. Both are presented in this section as follows.

3.3.1 Step 3: Case study protocol preparation

A case study protocol is essential in focussing data collection (Yin, 2018). This protocol is not intended to be used as data collection means. Instead, this protocol is used to guide the researcher to keep their focus on the case.

3.3.1.1 Case study protocol overview

This case study is conducted by a master student of TU Delft as a graduation project with cooperation with TNO Policy Lab project is Zoetermeer. Case study question in section 3.2.1 is used as the basis of the study protocol. This guide is used for each data collection to keep research focus during data collection.

3.3.1.2 Data collection procedures

Data collection was done using semi-structured interviews. Interview sources are selected based on the volunteers with criteria's as follows:

Head, (2008) policy lenses	Criteria	Possible actors
Policy-makers	The decision-maker who works for the municipality of Zoetermeer Have responsibility for heat transition either in the project or supporting area (e.g. social department) Still working in the Zoetermeer municipality Have experience with Zoetermeer heat transition pilot, either with Palenstein or Meerzicht, either from the municipal perspective or neighbourhood perspective.	Heat transition policy-maker in the energy transition and sustainability sector and social sector.
Researcher	The researcher is Involved in either modelling or research in the heat transition area in the municipality of Zoetermeer. Still working in the Zoetermeer municipality case or worked in the Zoetermeer municipality case (not more than two years ago), mostly in the Palenstein or Meerzicht cases.	An expert from either university or research institute
Practitioners	The practitioner is involved (or planned to be involved) in the heat transition either as a consumer, (services or goods) a producer, or a prosumer in the municipality of Zoetermeer.	Social housing companies, energy distribution companies, and citizen representation.

Table 3.1 Interviewee profiles

Other than these criteria's, another two criteria for the interviewee is stated as follows: 1) able to communicate in English, and 2) not categorized as a vulnerable population. These criteria are taken to ease the interview process.

Data were collected until gained information became saturated. If the data has not yet been saturated, the source of data collection shall be used as the resource of the next candidate for the data source. This recommendation by the interviewees was archived and used when needed. Within data collection, it is necessary to keep the safety and comfort of participants, privacy and data protection (animosity, privacy, and legal needs), informed consent on what to do with result and data, and interviewer shall provide the interview with briefing and debriefing. Thus, it is necessary to provide relevant information for the participant, both written and oral. This information has been standardized as an informed consent form and email that is presented in the case study book.

3.3.1.3 Case study questions

Case study questions consist of two groups of questions. The first group covered the set of question that is used to remind the researcher (not interview questions) of the goal of the data collection. After data collection, evaluation questions (second group of questions) are used to evaluate the data collection process.

The first group of questions is derived from the case study sub-questions (see Section 3.2). From these four sub-questions, eleven interview questions topic are derived as shown in Table 3.2. These topics then made into questions for three types of the respondent as presented in Table 3.1. This set of interview questions is presented in Appendix II.

	Introduction	Influencing factors	Actors	Activities	Characteristics of a DSS
Q1: Information about the respondent	x		x		
Q2: Respondent activities in the municipal heat transition policy-making	x			x	
Q3: Good set of activities that need to be used in the municipal heat transition policy-making				x	x
Q4: Influencing factor in the municipal heat transition policy-making		x			
Q5: Actors in the municipal heat transition policy-making			x		
Q6: Actors activities in the municipal heat transition policy-making			x	x	
Q7: Characteristic of good support system in the municipal heat transition policy-making					x
Q8: Data collection activities in the municipal heat transition policy-making				x	
Q9: Alternative activities in the case of missing data in the municipal heat transition policy-making				x	
Q10: Heat transition barriers that need to be considered by municipal heat transition policy-makers		x	x	x	
Q11: Heat transition opportunities that need to be considered by municipal heat transition policy-makers		x	x	x	

Table 3.2 Interview questions topic

The second set of questions are regarding the quality of data gathering activities. These questions need to be answered by interviewer after the end of each interview. These questions are listed as follows 1) was the interview finish on time? 2) was all topic covered? 3) what went wrong in the interview? And 4) what can be done better?

3.3.2 Step 4: Data collection

As the protocol has been set, data collection was ready to be conducted. This subsection describes activities that were done in the data collection process of this case study.

3.3.2.1 Data gathering process activity

Primary data collection was done with either Skype or Microsoft Teams starting from April 24th, 2020 to June 11th, 2020. Thirteen 60-110 minutes interviews were done with fourteen respondents. Five respondents represent the policy-makers view, five respondents represent the practitioner view, and four respondents represent the researcher view.

Interviews were all done in a form of semi-structured conversation in English except for one interview with PO03 and PO04. For this interview, all questions were spoken in English, but the answer can be either spoken in English or written via Microsoft Teams text messages in Dutch.

3.3.2.2 Data source information

The interview list is shown in Table 3.3. The interview from the municipality consists of two departments. The sustainability department that has its direct contact with heat transition policy (PO01 and PO02) and the social department (PO03, PO04, and PO05) that is collaborating with the sustainability department in this heat transition project. PO03 and PO04 have their speciality in the district approach while PO05 has a bigger area concern, Zoetermeer municipality. In the sustainability department, PO02 have more hand-on experience with scenarios. On the other hand, PO01 have a more holistic view where he works not only in heat transition, but the whole sustainability matter in the municipality of Zoetermeer.

The practitioner (or policy target) interviews comes from four organisations, 1) DEZo, 2) Netverder, 3) Stedin, and 4) Vestia. This arrangement is done based on the main stakeholders that are found in Chapter 2, the literature study. DEZo and Vestia are meant to shows the perspective of the user. Vestia as a company and DEZo as citizen initiatives. Differently, Netverder and Stedin are meant to shows the perspective of the network operator. Stedin is responsible for the electricity and natural gas network development and operation. Complementary, Netverder provides development and operation of other types of energy such as biomass, steam, or heat. While Stedin has been involved with the current policy-making process, Netverder has not been part of this process yet.

The role of research was filled based on their previous and present research on the topic of Zoetermeer heat transition policy-making. TNO was the source for their involvement in the previous heat transition policy-making in Palenstein, Zoetermeer. In Delft University of Technology, their master student researched the heat transition policy-making acceptance in one small neighbourhood in Zoetermeer. CE Delft was interviewed for their knowledge in their project to evaluate the sustainable Zoetermeer, including heat transition in 2019. Lastly, The Hague University was interviewed for a running project of data-driven policy-making for heat transition in the Zoetermeer area.

ID	Role	Presented organisation	Speciality	Role in heat transition policy-making	Data collection
PO01	Policy-maker	Gemeente Zoetermeer	Sustainable and Green Zoetermeer	The main team from the municipality	12-May-20
PO02	Policy-maker	Gemeente Zoetermeer	Sustainable and Green Zoetermeer	The main team from the municipality	12-May-20

PO03	Policy-maker	Gemeente Zoetermeer	Neighbourhood team for social issue	Collaborator	28-May-20
PO04	Policy-maker	Gemeente Zoetermeer	Neighbourhood team for social issue	Collaborator	28-May-20
PO05	Policy-maker	Gemeente Zoetermeer	Municipality level of social issue	Collaborator	14-May-20
PR01	Practitioner	DEZo	Sustainability citizen initiatives	Possible future team	27-May-20
PR02	Practitioner	Netverder	Heat distribution	Possible future team	26-May-20
PR03	Practitioner	Netverder	Heat distribution	Possible future team	3-Jun-20
PR04	Practitioner	Stedin	Network operator	Main team	2-Jun-20
PR05	Practitioner	Vestia	Housing corporation sustainability program	Main team	8-Jun-20
RE01	Research	The Hague University	Data science and business analytics	Advisor	29-May-20
RE02	Research	CE Delft	Sustainability in the built environment	Advisor	22-May-20
RE03	Research	TU Delft and HVC	District approach heat transition	Past research	15-May-20
RE04	Research	Erasmus University and TNO	Energy Transition and Decision Making	Past research	8-Jun-20

Table 3.3 Case study data collection source and gathering time

3.3.2.3 Transcription process

Thirteen audio recordings were transcribed. In the transcription process evaluate, some word that is spoken in Dutch was translated into English. Examples of these are “Gemeente” or “Wijk.” Furthermore, some grammar changes were done to increase the transcript readability. Lastly, some of the repeated sentences or fill-in words were deleted. This transcription was then checked to make sure that no wrong impression of the interview was transcribed. Lastly, the transcript was sent to the respondent for approval.

3.3.2.4 Additional documents recommendations

After the interview, sources also recommended some document to be read for this case. Most of the referred documents and website are in Dutch. Therefore, each website in Dutch is translated using Google Translate plugin. On the other hand, documents that are in Dutch are translated using DocTranslator website. More documents were taken from the archive from TNO “Aardgasvrij Wijken Zoetermeer.” Moreover, to check the online activities of energy-transition in the Zoetermeer are, tweets with “#Zoetermeer” hashtag were queried between 5th June to 11th June and 26th June to 3rd July 2020. Tweets were also retrieved from @raadZoetermeer within January till June 2020.

3.3.2.5 Exceptions

Several exceptions were made during this data collection procedure. The first exception comes from the joint interview (of PO03 and PO04) in a mix of English conversation and Dutch chatting messages. This was done to solve the language limitation that is happening between interviewee and interviewer. The second exception came from one failed recording transcription. Since there was an audio quality issue with the recording, the first 20 minutes of the interview was only summarised but not transcribed. The third exception comes with the transcription from PR04 where they specified that they would like to be a source but did not agree to be quoted. Thus, PR04 data will not be quoted in any way.

3.4 Step 5: Case study analysis and report

This section reports the result from the analysis that has been done in this case study, the fifth (and last) step of the case study research approach (see Figure 3.1). Section 3.4.1. describes the influencing factors that can be used in the municipal heat transition policy-making, followed by section 3.4.2. describes the dynamics of municipal heat transition actors. Section 3.4.3. describes the activities that are used to define and assess the policy-making for a municipal heat transition. Then lastly, section 3.4.4. describes the characteristics that are needed for a municipal heat transition policy-making to be successful. Then lastly, in Section 3.4.5., a set of needs for the municipal heat transition policy-making frameworks is described.

3.4.1 What are the needed characteristics of good municipal heat transition policy-making process?

From our analysis, there are five characteristics that we can take from this case study on the needed policy-making in the municipal heat transition. These five characteristics are found to be needed to lead a successful policy. These are listed as follows: 1) support an open, transparent, and equal municipal policy-making process 2) support key actors need management (support financing risk and responsibility plan and support key actors to convey their needs and need in the policy-making), 3) support turning the policy-making substance into process-based governance, 4) support the existing policy target profiling that the municipality currently has and support the policy target profiling that the municipality is planning to have, and lastly, 5) support data-driven policy-making to keep the municipality policies legitimate.

The first need comes from the division of power between the stakeholders. The municipality, even when they are the director of the heat transition, they think that this is the only way how heat transition can be running as they have no control over anyone (no enforcement power). PO02 also support this good process approach by saying openness and transparency are the most important aspects in creating a good decision.

> *… if you can make a good process, with trust in each other and equality. At this moment is the most important because that is the only way it is possible … (PO01, 2020)*

The second need came as the municipality cannot work by themselves. They always need cooperation from heat transition stakeholders. Therefore, support from the right stakeholders in this process is essential. You cannot have too many stakeholders involved as this might cause a lock-in situation, but an adequate amount of perspectives, need to be gathered so everyone's interest can be represented well. More information about actors' dynamics is presented in Section 3.4.2 below.

The third need is to turn context focus into process focus is a common method used in process management (Bruijn et al., 2010; Bruijn & Ten Heuvelhof, 2008). The reason for doing this is to reduce conflict by activating not the issue but a good process. The example for this case we want to get information from a citizen in neighbourhood A. To make sure that more people agree on the heat transition urgency, instead of making this gathering is all about energy, that will gather specific types of people, it is better to focus on the process of gathering itself. The gathering can be about everything, for the sake of process, if broadening the agenda is needed, then they can broaden the agenda to make everyone happy.

The fourth need came as to the citizen's diversity in the neighbourhoods of Zoetermeer municipality. This diversity can come from house ownership, house types, and demographic profiles. A different process is needed for different types of neighbourhoods. This area should not be too small as it might breach privacy law (European-Comission, 2020), but also not too big to minimise the damage of the wrong decision. On the way, the municipality can learn more about how to implement heat transition.

The fifth one comes to keep the legitimacy of the decision. The municipality needs to be able to be confident in their decision. Therefore, the right data need to be used in their decision. This is important as evidence can help the municipality to explain policies they are making. For that purpose, first, the municipality needs to get the right data. This data is shown in the form of influencing factors that are presented in Section 3.4.4 below.

3.4.2 What are the main actor's dynamics in the data-driven municipal heat transition policy-making that support a good policy-making process?

There are 43 actors with various roles mentioned in the interview. Based on their roles, we can see that these actors can be classified as a subset of another category of actors. For example, citizen "A" is owning a house in Zoetermeer and part of citizen initiatives. Thus, in this case, citizen "A" can be seen as a citizen, house owner, or as citizen initiatives. Citizen is one very big part that consists of both tenants and building owners as shown in Figure 3.4. The same happens with the housing corporations. Housing cooperation is part of the Green Deals team who made the heat transition planning. They are chosen as one of the main actors in the policy-making is because they are the building owners of social housing that are rented for people.

In this section, firstly, the main actors were determined to limit the scope of analysis. Firstly, we determine them from the number of interviewees who mentioned them in the interview. The logic is, the more important you are, the more you will be remembered by the other actors. This definition of importance fit with Newman (2008) who imply that the more important a node is, the more connection they have. In this case, all the perspectives and mentioned actors are treated as nodes and the edge is whether one node mentioning the other or not. The most important actor who are connected (have edges) to all of these perspectives is the citizen. Followed by the municipality, social housing corporations, Stedin, national government, and private houses.

However, this centrality measures do not always measure node importance (Golbeck, 2013; Hansen et al., 2011). Therefore, a cross-check with qualitative data from the interviews sentences was made to confirm these actor's importance. RE02 confirm that the most important actor in the heat transition is the municipality although the municipality does not have the same opinion. This is because although a heat transition policy mandate has been given to the municipality, no form of enforcement can be given. This statement was given as a dilemma by most of the interviewee. But also, that reinforcement is not the way the municipality wants to do it.

We don't have any special power to force anything. I don't think we want to do it even if we can. (PO01, 2020)

In the municipality perspective, building owners are the most important actor in the heat transition as they hold the decision power in the house. On the other hand, the role of the municipality as the director of the municipal heat transition is a fact that is supported by practitioners and researchers.

Currently, the municipality thinks that the most important actors in the heat transition are the social housing corporations (i.e. De Goede Woning, Vidomes, and Vestia). Social housing corporations group is also mentioned by Diran et al. (2020) in their work. In the case study, we found that these housing corporations are committed to contributing to the heat transition as this is in line with their sustainability vision. This commitment can be seen in their role in the green deal for Palenstein project (Palenstein Zoetermeer, 2017; Zoetermeer Nieuws, 2017).

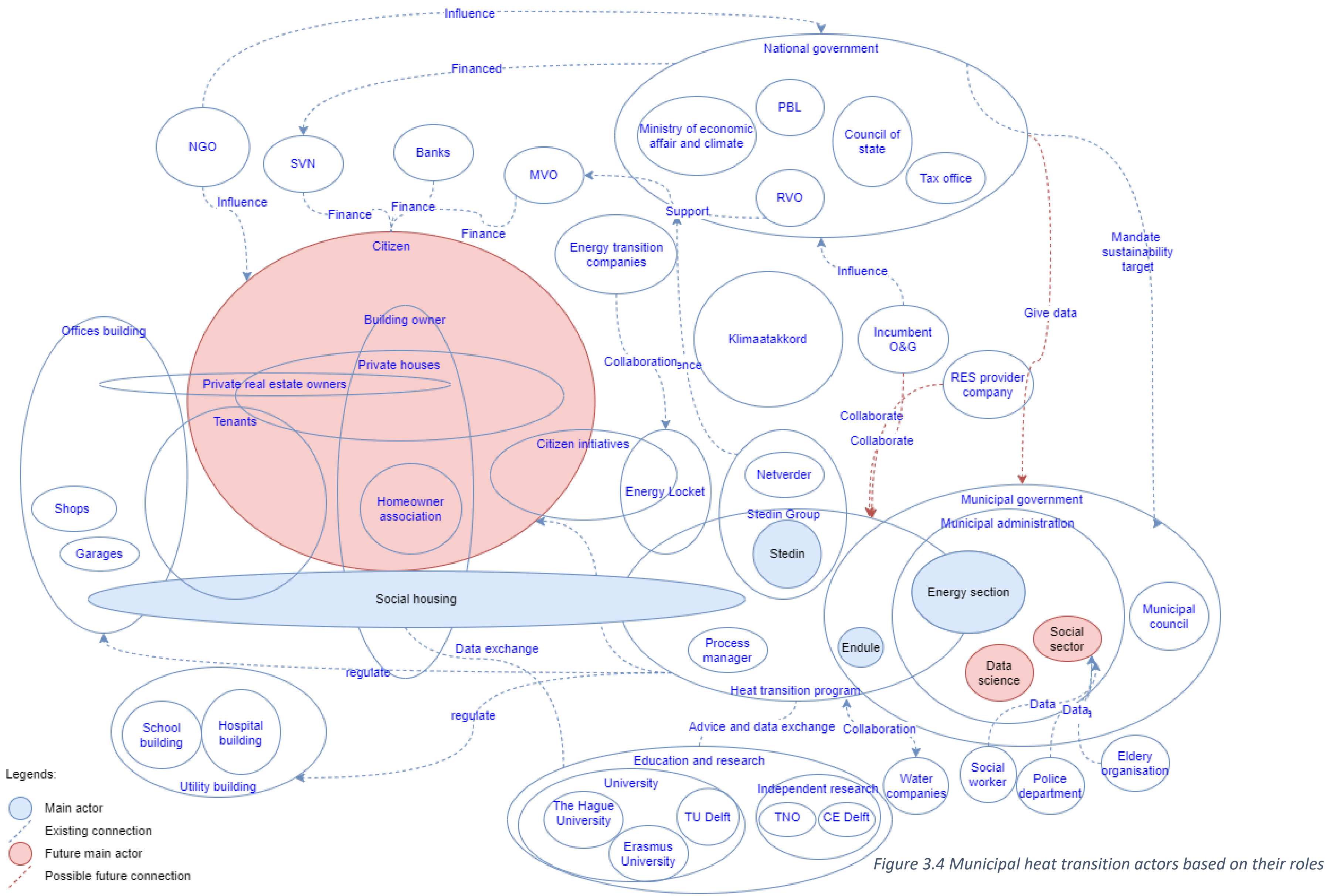

Figure 3.4 Municipal heat transition actors based on their roles

From the perspective of the citizen initiatives, they see themselves as one of the most important actors in this heat transition with the municipality and network operator (Stedin). However, the municipality government think that these initiatives are a very small group of early adaptors who are inspiring but cannot represent the whole population. On the other hand, their involvement in the heat transition can be seen from their green project with the municipality such as "Palenstein Energy Neutral" (DEZo, 2020). Their existence is based on their vision and will keep on growing in this heat transition. Hence, energy initiatives are included in the main actor in the heat transition due to their unique position as both target and motor of the energy transition as well as policy target in the heat transition.

3.4.2.1 The infrastructure and choices that citizen and the municipality can make

Stedin, as the regulated body that provides service on the transportation side of the energy in the Netherlands, plays an important role in this heat transition. And they also play a role in the policy-making in the municipal level not because they want to join the decision-making, but more into the effort to get to know the planning of this heat transition so they can do their job in maintaining their energy transportation system infrastructure.

Besides Stedin, inside Stedin group, there are also Netverder. A party that also work on energy transportation that is no electricity or natural gas. Currently, they have not been involved in the policy-making in the municipality level because no planning on the district heating has been decided for Zoetermeer.

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most of these municipalities said, "we would like Stedin to play an important role in this heat transition because we expect that district heating will be a major part in the heating." (PR03, 2020)

To support this policy-making, the Expertise Centrum Warmte (2019) developed municipal guidance for heat transition. This guidance has already described the needed policy to achieve one of the five strategies for heat transition. These five scenarios are individual electric heat pump, heating network with a high-temperature source (e.g. industrial heat waste or geothermal), district heating with a low-temperature source (e.g. industrial heat waste, heat storage, or collective heat pumps), green gas with hybrid heat-pumps, and green gas with boilers.

To visualise this heat transition, see Figure 3.5, Scholten and Künneke (2016) energy infrastructure complex adaptive socio-technical systems framework is used. This energy infrastructure consists of a source, production, trade, transmission, refinement, distribution, metering, retail, and consumption. The transition from natural gas infrastructure (green) to choices – or a combination of them- of electricity (blue), green gas (green), or heat (red). Each option meant a different set of both technological and institutional infrastructures (Künneke, 2013).

Type of energy choices means much more than just changing an energy carrier because of the infrastructure that is coming with each choice the municipality and the citizen make. First, citizen control over their energy can be an increase or decrease. The citizen was always in the left end side of Figure 3.5, as a consumer. But with this heat transition is an opportunity to be less dependent on the central system and becoming prosumers instead of the consumer. However, on the other hand, if the heat district is made, then their control over the price of their energy became lesser as the monopoly nature of the heat district. Therefore, citizens see that it is important for them to join the policy-making so that they can decide on their future.

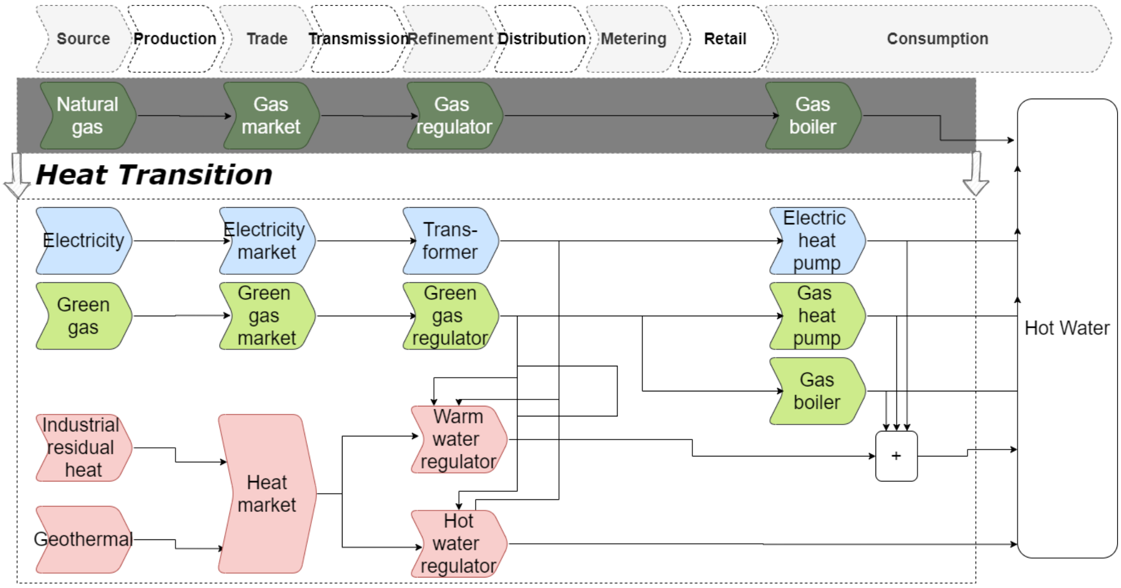


Figure 3.5 Heat transition adapted from Expertise Centrum Warmte, (2019) *presented using Scholten and Kunneke (2016) energy infrastructure frameworks*

In conclusion, three main groups of actors are interacting to create the new heat system. They are 1) the user area including the social housing corporations, private real-estate, citizen initiatives, and citizen in general, 2) the companies that provide the infrastructure that provides and transport users energy, and 3) the government and their policy-making creation process. A short introduction to the mentioned infrastructure is done to shows how these actors correlated with each other.

3.4.3 What activities are used by the municipality to define, assess, and communicate a municipal heat transition policy-making?

In these sections, activities that the municipality do in each phase of the policy cycle is examined. We use three phases of the policy cycle from van Veenstra and Kotterink (2017) to examine these activities. These three phases are 1) prediction and problem definition, 2) design and experimentation and 3) implementation and evaluation.

3.4.3.1 Prediction and problem definition phase

In the problem definition phase, six activities are examined in the case study. These activities are 1) data collection, 2) profiling, 3) target setting, 4) stakeholders capability mapping, and 5) stakeholders needs and needs map, 6) broaden the agenda (see summary in Table 3.4).

Data collection here can be in the form of data gathering or data transferring. Some data gatherings are still manual such as neighbourhood meeting, survey, or interview with people in the neighbourhood. Some other data already exist in the other entity database. However, this data can be not freely accessible, stale, or inaccurate. The municipality also really want some data that another government entity has. However, these data are protected by General Data Protection Law (GDPR) and cannot be used accordingly.

The idea is to make profiling to determine the right way to communicate some idea. It does not need to be restricted to the heat transition, but this can also be used for heat transition. Profiling is an important area of both planning the heat transition technically as well as when the government would like to tailor the information and contact with the citizen. Based on the interviews, there are at least three dimensions of profile that the government are making within their (approximately) 500 m^2 grid, 1) building types and ownership profile, 2) transition journey profile, and 3) neighbourhood profiles (see Figure 3.6). For building types, at least, seven groups are made, 1) the housing corporations, 2) private 3) municipal buildings, 4) private real estate, 5) tenants 6) shops, and 7) garages. The transition journey profiles show the level of behaviour of the user as a profile. In this transition journey profile, four different phased were described, 1) willingness to be aware, 2) willingness to analyse, 3) willingness to act, and 4) willingness to adapt. Lastly, the neighbourhood profiles are something that comes up as the cooperation between energy and social sector in the municipality is planned. Both the energy and the social department are having a target to connect social data and energy data so they can make a collaboration that gives mutual benefit for both targets.

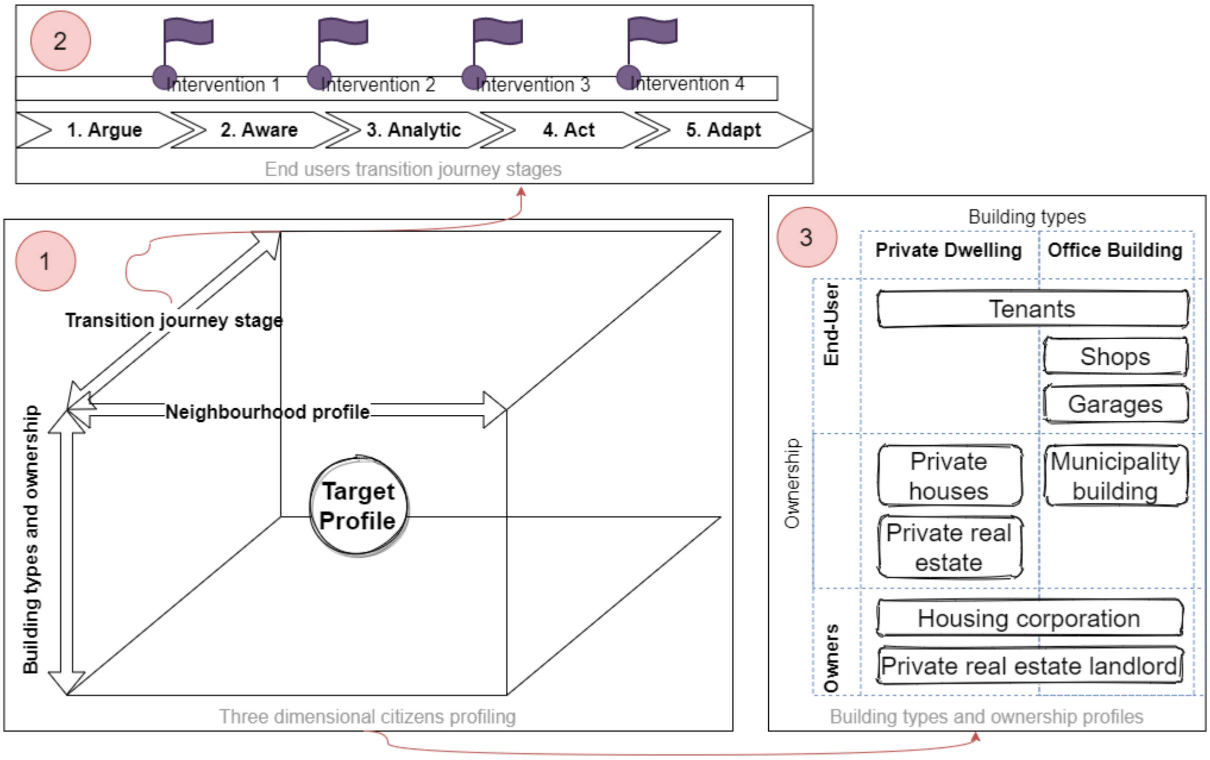


Figure 3.6 Citizen profiling that is planned by (1) the municipality of Zoetermeer, (2) profiling by customer journey phases, and (3) profiling by building types and ownership

The other thing that the municipality needs to do is to broaden the agenda of energy-transition. The reason for this is to increase participation and attract more than just the "usual suspect" of the heat transition process. This is also part of activities that are mentioned in the process management that is explained by Bruijn et al. (2010) and Bruijn and Ten Heuvelhof (2008). Process management introduces an approach to creates the decision-making process in a complex environment setting.

To make sure this Zoetermeer municipality heat transition is happening, everyone needs to be on-board, not only the early adopters. And sometimes, not everyone already in the phase where they are willing to spare their time to looking for a solution space (willingness to analyse). Thus, create a diversity that needs to be recognised by the municipality. In that diverse space, diverse citizens need can be analysed.

So I think that to organize an inclusive transition, in which you don't target only the usual suspect, so the early movers, or how you want to describe them, but you want to talk to a bulk of people, you need to bring them pretty close to home. Should be about people's streets, about their houses, they should recognize the data, it should be very touching on people's home environment. (RE02, 2020)

Citizens are not the only stakeholders of heat transition. All the other stakeholders also might need to be considered such as the private real estate or the housing corporations. They are providing houses for many citizens of Zoetermeer. To gather this kind of data, the way the municipality doing it now is by talking to these stakeholders.

Before knowing their needs, it is important to know their capability and how they can fit in this transition. For example, Stedin has some resources of knowledge for heat transition and it is their mission to maintain the gas network. Therefore, it is good to include Stedin in the policy-making as they can provide technical advice with their resources.

And then lastly, a target needs to be set for this policy. As we see before that to make sure that we can find the right answer for the “when?” and “what?” questions about heat transition, we need to make sure to get the citizen attention and feasible means. As the municipality said that they do not want disturbance or panic created for people.

3.4.3.1.1 Design and experimentation phase

The design and experimentation phase has eight areas of designs and experimentations, 1) search of solution space for heat transition 2) search for the right marketing strategy, 3) data collection strategy, 4) involvement of models and scenarios, 5) policy codesign, 6) responsibility division, and if needed 7) cooperation with another municipality (see summary in Table 3.4).

In the solution space area, mainly design goes with the question of what and when (Expertise Centrum Warmte, 2019). In this case, the municipality and their partners are looking for the available feasible solutions (both financially and technically) for a neighbourhood. The criteria are quite strict, that is the capital invested by private house owners will be gained back from the energy bill reduction. This was opposed by some citizen as they think that the government need to be honest and accept that heat transition will cost money.

Our goal is to make business cases that can be paid off by the cost of maintenance of the building for 30 years. (P001, 2020)

The second activity is the marketing design that comes with profiling. A different approach is meant to be given to a different group of people. For example, if someone is not even a little bit interested in heat transition are forced to hear the options of heat transition, they might even grow a negative feeling and withdraw their support. Or if people care about the park, maybe energy-transition should also include the talk about the sustainable park in the discussion to gain attention in the neighbourhood where the awareness is still low.

The third activity is about how the municipality can gain more data. As many data still need to be taken. One activity is to decide on the sample are to map the citizen profile. Zoetermeer has decided that 500m^2 is a sufficient area. And in some exception, with some procedure, the municipality might be allowed to take an even smaller area. Once again, the same with the profiling, this area is something that the municipality needs to try and analyse to know the best-suited area can be used for this profiling.

To create this policy, the municipality is not alone, they also have their partner to do this. This policy-making activity is still a co-design process of only three big parties, the municipality of Zoetermeer, the housing corporations (Vestia, Vidomes, and De Goede Woning), and Stedin. However, many more actors are interested in joining the process and joining the process such as energy initiatives or Netverder.

In this codesign policy-making, models and scenarios are used. For example, Stedin provides calculation from their model Openingsbod for municipalities that calculate best-case scenarios for each neighbourhood in the Zoetermeer. Openingsbod is a combination of Vesta Mais from *Planbureau voor de Leefomgeving* (PBL), Energy Transition Model (ETM), and CEGOIA from CE Delft which scenarios are being aligned.

Then there is also design on the responsibility division of the new heat system. Who will be responsible for this? Who will lead the execution? Who will need to hold the financial risk? In the executed projects in social housing, the financial risk-taker is the social housing corporations. However, the municipality is helping in the marketing of the new system. In this responsibility division, everyone needs to be satisfied to keep their participation in the group. Lastly, cooperation with another municipality might also happen. As all municipality holds the same target, it is important to keep everyone updated what works and what is not.

3.4.3.1.2 Implementation and evaluation

In the implementation, the municipality is trying a diverse effort to support the municipality citizen to decide on the heat transition. The municipality has not been far in this process yet (in the willingness to act from the citizen). The reason for that is because of the high price of renewables and low price of gas. So it is always easier and cheaper to stay with natural gas. Thus, to ensure the citizen wants to do this, the municipality designed feasible options for the citizen. This feasible option comes from whether it is possible to get back investment money after a certain period using a technically feasible solution. In the case of no feasible option, the municipality will stop the process. However, if feasible, the municipality can inform the citizens about feasible options and advise them in decision making.

> *So we cannot have many discussions because the options are poor. So it is more informing and reassure people that we won't do anything if there are no good opportunities. (PO01, 2020)*

Since not many communications about feasible option as taken now, the municipality is working mostly on the effort to create a good information structure design to inform the citizen. They want to be able to communicate energy transition implication for the citizen, give information and reassure citizen that nothing will give them a disadvantage. They also give the educational process for new needed skill so that it is ready when needed. This is mostly done in a meeting called neighbourhood meeting that is held by the municipality to communicate with the citizens. They also think that heat transition matter can also be part of the conversation between neighbours that in the end can create a network that can improve social cohesion.

This situation is a little bit frustrating for some other parties like housing corporations who feel the responsibility to change. They think that making progress has been hard because of this decision to stop. However, the municipality does not have any economic power either to support the transition economically. In this case, the richer municipality might be having a relatively easier situation than the poor municipality (PR04, 2020).

So, in this area, the municipality should use enforcement when it is possible (RE03, 2020). Enforcement is not possible for the citizen but can be done for business and offices. That is why once again, users profiling is essential in this heat transition (in the problem defi46nition phase). In summary, in the implementation and evaluation, ideally, activities revolve around 1) enforcement where possible, 2) advising citizen on decision-making, 3) communicate energy transition implication for end-user, 4) communicate feasible options, 5) create a network to improve social cohesion 6) give the educational process for new needed skill, and 7) informing and reassuring citizen.

To conclude, activities in these three phases of the policy cycle is summarised in Table 3.4.

No	Prediction and problem definition activities	Design and experimentation activities	Implementation and evaluation activities
1	Data collection	A search of solution space for heat transition	Advising citizen on decision-making
2	Policy target profiling	Search for the right marketing strategy	Communicate energy transition implication for the citizen
3	Target setting	Data collection strategy	Communicate feasible options
4	Stakeholders capability mapping	The utilisation of models and scenarios	Create a network to improve social cohesion
5	Stakeholders need mapping	Policy codesign	Give the educational process for new needed skill
6	Broadening the agenda	Responsibility division	informing and reassuring citizen
7	-	Cooperation with another municipality	Enforcement where possible

Table 3.4 Activities around van Veenstra and Kotterink (2017) *policy cycle*

3.4.4 What heat transition influencing factors need to be considered for a legitimate data-driven municipal heat transition policy?

In this subsection, influencing factors definition that was used in Chapter 2 is used again. These influencing factors are divided into three big groups, economic, social, and technical factors. This classification was adapted from Ho, (2014). Economic factor (that include legal and political factor) is defined as anything that defined as 1) macroeconomic condition, 2) microeconomic condition, and 3) government intervention and lobbying. Then social factor relates to individual (and community) factors that influence heat transition. This social factor includes both 1) social, cultural, and demographic measure, and 2) behaviour and attitude. The technical factor includes 1) technology-related activities, 2) physical related material, and 3) new technology advancements.

Iterations of analysis and coding derived 1) ten social influencing factors, 2) nine economic influencing factors, and 3) eight technical influencing factors. These factors are described in the following subsection. These numbers are less than categorisation that was derived in Chapter 2 because the scope of the area is lower and the data source is smaller.

3.4.4.1 The social municipal heat transition policy-making influencing factors

There are ten social municipal heat transition influencing factors derived from this study. These social factors 1) Behaviour, 2) Attitude, 3) Capability, 4 Social cohesion, 5) Stakeholder engagement, 6) Demographic profile, 7) Stakeholders profile, 8) Fairness, 9) Uncertain behaviour, and lastly, 10) Stakeholder motivation. Some adaptation from Chapter 2 was made as shown in Table 3.5.

NO	**Social heat transition influencing factors**	**Chapter 2 social heat transition influencing factors as derived from the SLR**
1	Behaviour	Behaviour (participation)
2	Attitude	Attitude (acceptance), individual knowledge
3	Capability	Household economic power, individual empowerment
4	Social cohesion	Established social network
5	Stakeholder engagement	-
6	Demographic profile	-
7	Stakeholders profile	-
8	Fairness	Fairness
9	Uncertain behaviour	-
10	Stakeholder motivation	Individual perception

Table 3.5 Social heat transition influencing factors derived from the case study

Behaviour can be seen as a manifestation from intention and resources to realise the mentioned intention. Behaviour factor, in this case, is subcategorised into four steps of customer journey phases: 1) willingness to be aware, 2) willingness to analyse heat transition options, 3) willingness to act on heat transition, and 4) willingness to adapt on the new system.

Behaviour can also be seen as a response based on a certain set of input (Elizabeth & Lynn, 2014). And one of this input is the **attitude** toward the behaviour (Ajzen & Fishbein, 2011). Attitude is a construct that characterises an entity (Perloff, 2010). In this case, attitude is especially meant on how people perceive the problem. For example, is their attitude toward the last flag, willingness to adapt. They have already spent money to renovate their house because another 70% of the surrounding house already they agree to this. But being in the side where it was not their choice to change, they have a negative attitude toward this change. And that makes them hard to adapt (behaviour). On the other hand, citizen with a good attitude toward this adaptation process might not feel burdened with consequences that they might encounter in the adaptation

In this case, attitude also covers the perception of personal benefit. Personal benefit relates to the proximity of the problem. That means, the more apparent the benefit of heat transition, the better the attitude of the citizen. For example, some people might not think that the risk of using gas in the future is something imminent. But maybe the heatwave that will come in summer is a more imminent problem that can drive them to do something.

The **capability** relates to the power to do heat transition (Ajzen & Fishbein, 2011). This has something to do with citizen empowerment. In this heat transition case, five sub-categories were made for this category, 1) capability to be aware, 2) capability to be reached, 3) capability to change, 4) capability to handle the construction and 5) education of renewable energy system.

Demographic profile means analysis on how people are living their lives in their neighbourhood. This factor includes their health, their environment safety, their jobs, their diversity in the neighbourhood, their environmental condition within the neighbourhood, poverty number in the neighbourhood, or youth problems. The municipality also called them the neighbourhood analysis. At this moment, the component of this demographic profile is still in the design and experimentation phase.

Fairness is about whether the decision is just and reasonable. This is one factor that the municipality needs to consider while talking to the citizens because fairness can come in various ways. For example, should everyone pay the same amount of money for heat transition? But what about the less fortunate ones? Can the less fortunate ones afford the same amount of investment as the more fortunate ones? The policy-maker thinks that this is important and needs to think about. But the fairness that they see is that everyone needs to find heat transition affordable and realistic.

> *Fairness is very very important, we have made a rule that only if there is an affordable, realistic solution for the energy transition, then we will decide to put it through. But only then. (PO01, 2020)*

More about fairness also comes from the freedom to choose. Although it is fair for everyone to have freedom of choice, some balance is needed. As the policy-maker said that full freedom is just too expensive. However, some citizens enjoy their freedom to choose something, they want it and they will not be happy if they need to let go of their right to choose their heating system.

> *I think total freedom is very expensive because you have to find the balance between the cost for society will be (common cost) and the private cost. So if everyone has total freedom then the common price will be very high. (PO01, 2020)*

On the other hand, this can also be confusing for some people, mostly because the role of infrastructure is about collective goods. And collective goods are a restraint to the freedom of choice. So, this can be a difficult subject to think about. Then the most important social factors that policy-makers need to see is citizen motivation. It is about their priority, their interest, their complaint, their demands, and their perception of comfort (heat comfort). This factor means that the municipality needs to be aware of why (or why not) the citizen wants to join this energy transition. It is also connected to demographic profile factors. For example, what can be the motivation of the elders to join heat transition when the change is not about their people, but more for future generations. Does it matter to them? Or do they need more trigger for these changes?

> *… you still have the freedom of choice for citizens. So you can't come up with just only one solution. And in decision making, is partly come up with solutions those were meant for where people could choose from. (PR01, 2020)*

Then there is **social cohesion**. Social cohesion is described by policy-makers as the closeness of people within the neighbourhood. This cohesion can be seen on how often they talk to each other or how often they meet. Social cohesion holds an important aspect I heat transition because they can grow because of heat transition. And as feedback, they can also accelerate heat transition. This positive feedback relation is something that the municipality needs to consider in the process.

Stakeholder engagement factor includes the point of contact with the people, the number of contacts they can make, and how engaging the contact that is made with the stakeholders. This can be an important thing to consider because this will determine the strategy that the municipality can do in the implementation of the policy (e.g. how to gather masses)

Lastly, there is also **uncertain behaviour** of the citizen. This behaviour includes behaviour that is uncommon (or unique). For example, some people might think that changing from gas is a bad idea because they are using the stove that their grandmother used, and they do not want to use anything else to cook. Something like this might exist but maybe not need to be considered at this moment.

3.4.4.2 The economic municipal heat transition policy-making influencing factors

There are nine economic municipal heat transition influencing factors derived from this study. These economic factors are 1) Society cost, 2) Path dependency, 3) Financial feasibility, 4) Market proposition, 5) National regulation, 6) Responsibility and power to make a decision, 7) Organisational affair, 8) Data gathering and utilisation regulation, 9) Conflict of interest. The difference between found factors in Chapter 2 is shown in Table 3.6.

NO	Economical heat transition influencing factors	Chapter 2 economic heat transition influencing factors as derived from the SLR
1	Society cost	-
2	Path dependency	Path dependency
3	Financial feasibility	Profitability
4	Market proposition	Energy demands
5	National regulation	Energy regulation
6	Responsibility and power to make a decision	Ownership
7	Organisational affair	Organisational motivation
8	Data gathering and utilisation regulation	Data regulation
9	Conflict of interest	Negotiation

Table 3.6 Economical heat transition influencing factors derived from the case study

Society cost consists can be society cost that is paid by the government or individual cost that paid directly by the municipality. Currently, this is the main indicator to choose a solution for heat transition. They are also part of models that the municipality often use, such as CEGOIA and Vesta Mais.

The second economic factor is also essential, path dependency. The policy-makers have said that their strategy is to make sure that this transition can happen also in the natural moment of investment. Although sometimes, this might create a conflicting agenda between one party and the other, which is part of the conflict of interest topic.

The most important part of our strategy. We use the natural moment of investment to make a combination with improving the energy performance of the building and to make an energy transition. So that you will have as little as much investment or lost values of former investment. (PO01, 2020)

Then financial feasibility of the citizen to pay for the transition is also part of the planning. This financial feasibility planning includes the financial status of the citizen, the rational payback period for them, the business model that they have, the financial options that users can take, an investment plan that they have, investment price they need to pay, and maybe also subsidy that they can have.

Market proposition talks about the number of the proposition that the market has also their stability. The case is that there is the economy of scale where buying more will cost you cheaper. Then the proposition is different for one house or 10 houses. That means the price for individuals will be higher than the ones for cooperation.

The other problem is the uncertainty of market price. Prices might change between seasons and that makes it hard for the municipality to advise the users on how much it is cost. The price just keeps on changing and this might reduce the willingness to act from the users' side.

They say at the price of the heat pump; the same heat pump is different in autumn than in spring, just because of demand and supply and demand. So it's not so easy to get a good price and make sure that people get that price when they are asking for a quote from a company. (RE03, 2020)

National governments law also provide a critical environment that the municipality needs to think about and keep on giving feedback to. The municipality has talked about how national law is essential and need to be updated to stimulate the process. The national law will create an environment that enables or disable a certain route in the process and reduce uncertainty.

Then comes to the who can decide and who should decide, the responsibility and power to decide. As previously mentioned, this responsibility also connected to the ownership or tenants of a house as well as the purpose of the buildings. It is also about the power of the municipality to direct this transition. In this process, the municipality need to keep on asking the questions, who are responsible for this? And in the implementation of the policy, the people who are going to be responsible to operate and to gain profit from this energy business also need to be decided.

Some organisational affairs need to be taken care of as well. This includes the core mission of a certain organisation and how to contact certain stakeholders. In a housing corporation, for example, at least 70% of tenants need to agree on a decision before changes can be made. And that can be quite an effort. For that, some organisational affairs need to be arranged. Furthermore, the same thing needs to be done also in private houses. In private homeowners, organising these people might be even more challenging.

It is private, we cannot use it, but it is available, but we cannot use it because of privacy law. I think it is good that we have the privacy law so we have to think about the solution on which level we can use it. (P005, 2020)

Lastly, there are also factors from data regulation on gathering, sharing, and utilisation. The municipality needs to be responsible to handle their data and data sharing between partners in this heat transition. Some data can be sensitive and problematic. And some data can also be generalised in a certain area that ensures privacy. This privacy is also the reason why the municipality is trying to make aggregated data to be used for their analysis purposes.

3.4.4.3 The technical municipal heat transition policy-making influencing factors

There are eight technical municipal heat transition influencing factors derived from this study. These technical factors are 1) Building criteria, 2) Data digitalisation and utilisation, 3) Technical operation, 4) Technology maturity, 5) Heat source plan, 6) Maintenance and path dependency, 7) Neighbourhood density and 8) Future uncertainty. How the difference between case study and SLR technical heat transition influencing factors (see Table 3.7) mostly lie in the naming as the people are more familiar with the name that is found in the case study. In the interview, the interviewer seems puzzled with the way technical influencing factors are described. Therefore, these naming changes as follows.

NO	Technical heat transition influencing factors	Chapter 2 technical heat transition influencing factors as derived from the SLR
1	Building criteria and existing connection	Consumers
2	Data digitalisation and utilisation	Data related service
3	Technical operation	Consumers, production
4	Technology maturity	Production
5	Heat source plan	Production
6	Maintenance and path dependency	Transportation physical device and energy transmission service
7	Neighbourhood density	Consumers
8	Future uncertainty	-

Table 3.7 Technical heat transition influencing factors derived from the case study

The first technical factors that are important for heat transition is the building criteria. This factor is a really important factor that is connected to various data about the house. These data consist of the existence of collective heat source, floor plan, existing heat producer, the age of the house, insulation criteria, space, and types of building.

Then there is also a case of path dependency about the distribution infrastructure capacity or the flexibility (to change) of the system that also need to be considered. The good thing about technical factors is that they are pretty straightforward. But they are also connected strictly to both social and economic factors of heat transition influencing factors. Like this path dependency problem will influence the attitude of the people to choose a technology. Or the part where maintenance needs to happen technically affect the path dependency of economic influencing factors to be more feasible to be executed (investment natural moment is equal to maintenance natural moment).

Although it is straightforward, these factors also give hope to people about technology maturity. Although there are not that many options today, some policy-makers also put their hope in the uncertainty of technology advancement to get this technology matured and cheaper.

3.4.5 Needs for a municipal heat transition policy-making DSS framework

To make the right heat transition policy-making, the municipality needs a good process that engages stakeholders' interest and resources (See Section 3.4.1). This good process was translated into five characteristics that can be translated into the needs of the decision support system that help policy-makers to create policy.

The first and third needs are 1) to support an open, transparent, and equal municipal policy-making process and 3) to support turning the policy-making substance into process-based governance. For these purposes, processes policy-making that needs to be supported is presented in Section 3.4.3. The second need on the actors is investigated in Section 3.4.2. The fourth and fifth needs are 4) support the existing policy target profiling that the municipality currently has and support the policy target profiling that the municipality is planning to have, and 5) lastly and support data-driven policy-making to keep the municipality policies legitimacy. For these purposes, profiling activity is examined in Section 3.4.3 and heat transition influencing factors are examined in Section 3.4.4.

3.5 Conclusion for the case study research

In this chapter, the second research question was answered: *"what are the needs for a decision support system framework to assist municipal heat transition policy-making?"* A single case study method was used. This case study was bounded geographically in the municipality of Zoetermeer and the content of the case was also bounded in the municipal heat transition policy-making. Thirteen interviews were done with three perspectives (Fourteen people) of policy, policy-makers, practitioners (policy target), and research from June 8th, 2020 till May 12th, 2020. These interviews were recorded, transcribed, and analysed qualitatively using Atlas.ti. Reports were made in table, graph, and quotes.

To answer that question, four case study sub-questions are answered in this chapter. These case study sub-questions are answered as follows.

1) What are the needed characteristics of good municipal heat transition policy-making process*?*

From this analysis, we found that the five main needs for the municipal heat transition DSS framework. First is that it shall support an open, transparent, and equal municipal policy-making process. The first need comes from the disability of the municipality to enforce the matter of "what" and "when" heat transition should be happening to the key actors. Thus, every actor stands on an equal ground analogous to a spider's web where everyone connected equally but with interdependence that creates complexity in their relationship.

Secondly, the process needs to be able to support key actors needs management. Connected to the first need in an equal ground, the spiders need to have a reason for staying on the web. Therefore, it is required to support needed actors in to stay in the process until the end. One of their needs is the third need, to support financing risk and responsibility plan. They need to be able to communicate where they can and want to be able to the responsible in the planning.

Then the municipality also needs everyone to be on board. Thus, they also need to be supported in the marketing strategy making which eventually lead to attracting stakeholder engagement. For that purpose, staying strict only in one substance, heat transition, might not be enough. Hence, it is important to also require a broadening of substance and go into more process-based governance.

But then again, modularity is also part of the process that the municipality already doing and plan to keep in doing this. The policy-making process needs to be as customised as possible for the citizen. Therefore, each profiling criteria will create a different policy-making process, then lastly create a different policy set in a set of time.

2) What are the main actor's dynamics in the data-driven municipal heat transition policy-making that support a good policy-making process?

To make these needs clearer, first, we need to know the policy-makers are who are going to do this open, transparent, and equal process with. The first proposition "The municipality is the main stakeholder in the policy-making of Zoetermeer heat transition and they decide the best-case scenario for the people based on the lowest societal cost" was proven to be wrong, instead, a complex co-design between key actors on an equal basis in the way these heat transition policies was made. In their previous project, the heat transition team from the municipality of Zoetermeer were doing this co-design with social housing corporation (Vestia, Vidomes, and De Goede Woning), and Stedin. Then presently, they are trying to add new players with the social department of the municipal office, private house real estate, citizen, and citizen initiatives.

3) What activities are used by the municipality to define, assess, and communicate a municipal heat transition policy-making?

In this chapter, policy-making activities are discussed in the van Veenstra and Kotterink (2017) three phases of policy cycles: 1) prediction and problem definition, 2) design and experimentation and 3) implementation and evaluation. In the problem definition phase, six activities are examined in the case study. These activities are 1) data collection, 2) profiling, 3) target setting, 4) stakeholders capability mapping, and 5) stakeholders needs and needs map, 6) broaden the agenda. The design and experimentation phase has eight areas of designs and experimentations, 1) search of solution space for heat transition 2) search for the right marketing strategy, 3) data collection strategy, 4) involvement of models and scenarios, 5) policy codesign, 6) responsibility division, and if needed 7) cooperation with another municipality. However, not many have been done in the evaluation, some part that can be used are 1) enforcement where possible, 2) advising citizen on decision-making, 3) communicate energy transition implication for end-user, 4) communicate feasible options, 5) create a network to improve social cohesion 6) give the educational process for new needed skill, and 7) informing and reassuring citizen. This summary is provided also in Table 3.4.

4) What heat transition influencing factors need to be considered for a legitimate data-driven municipal heat transition policy?

Since the municipality is not the sole decision-maker in this process, for the policy-makers, all their policy required the usage of transparent influencing factors. We found ten social influencing factors that required to be included in the municipal heat transition policy-making, i.e. 1) Behaviour, 2) Attitude, 3) Capability, 4 Social cohesion, 5) Stakeholder engagement, 6) Demographic profile, 7) Stakeholders profile, 8) Fairness, 9) Uncertain behaviour, and lastly, 10) Stakeholder motivation (see Table 3.5). We found nine economic heat transition influencing factors in the municipality of Zoetermeer, i.e. 1) Society cost, 2) Path dependency, 3) Financial feasibility, 4) Market proposition, 5) National regulation, 6) Responsibility and power to make a decision, 7) Organisational affair, 8) Data gathering and utilisation regulation, 9) Conflict of interest (see Table 3.6). And lastly, we found eight technical municipal heat transition influencing factors, i.e. 1) Building criteria, 2) Data digitalisation and utilisation, 3) Technical operation, 4) Technology maturity, 5) Heat source plan, 6) Maintenance and path dependency, 7) Neighbourhood density and 8) Future uncertainty (see Table 3.7). These factors are also summarised in Table 3.8 below.

In the end, these case study sub-question is used to answer the second research question of this thesis: ***What are the needs for a decision support system framework to assist municipal heat-transition policy-making?***

Answers from these case study sub-questions have led to the answer of the first research question of this thesis, *“what are the needs for a decision support system framework to assist municipal heat-transition policy-making?”* From this case study of Zoetermeer, we derived five main needs for the municipal heat transition DSS framework. These needs are 1) to support an open, transparent, and equal municipal policy-making process 2) to supports key actors need management (support financing risk and responsibility plan and support key actors to convey their needs and requirement in the policy-making), 3) to supports turning the policy-making substance into process-based governance, 4) to supports modularity (support the existing policy target profiling that the municipality currently has and support the policy target profiling that the municipality is planning to have), and lastly, 5) data-driven process to keep the municipality policies legitimacy.

The process that is mentioned in this need can be divided into three phases of the policy cycle: 1) prediction and problem definition, 2) design and experimentation and 3) implementation and evaluation. These activities are summarised in Table 3.4. In each phase of the cycle, different activities are used. Also, different actors need to be considered in each phase of the policy cycle. There are three main actors in the Zoetermeer municipality heat transition policy-making. They are 1) the user area including the social housing corporations, private real-estate, citizen initiatives, and citizen in general, 2) the companies that provide the infrastructure that provides and transport users energy, and 3) the government and their policy-making creation process.

Also, in these phases of the policy cycles, different data are needed. Therefore, different influencing factors are derived to specify municipal heat-transition policy-making in the municipal of Zoetermeer. Those heat transition influencing factors can be divided into three, 1) social, 2) economy, and 3) technical as summarised in Table 3.8.

Heat Transition influencing factors from the Zoetermeer municipal heat transition policy-making case study		
Social	Economy	Technical
1) Behaviour 2) Attitude 3) Capability 4) Social cohesion 5) Stakeholder engagement 6) Demographic profile 7) Stakeholders profile 8) Fairness 9) Uncertain behaviour 10) Stakeholders motivation	1) Society cost 2) Path dependency 3) Financial feasibility 4) The market proposition 5) National regulation 6) Responsibility and power to make a decision 7) The organisational affair 8) Data gathering and utilisation regulation 9) Conflict of interest.	1) Building criteria 2) Data digitalisation and utilisation 3) Technical operation 4) Technology maturity 5) Heat source plan 6) Maintenance and path dependency 7) Neighbourhood density 8) Future uncertainty

Table 3.8 Heat Transition influencing factors from the Zoetermeer municipal heat transition policy-making case study

Ten social influencing factors need to be included in the municipal heat transition policy-making (i.e. 1) Behaviour, 2) Attitude, 3) Capability, 4 Social cohesion, 5) Stakeholder engagement, 6) Demographic profile, 7) Stakeholders profile, 8) Fairness, 9) Uncertain behaviour, and lastly, 10) Stakeholder motivation (see Table 3.5)). Nine economic influencing factors need to be included in the municipal heat transition influencing factors in the municipality of Zoetermeer (i.e. 1) Society cost, 2) Path dependency, 3) Financial feasibility, 4) Market proposition, 5) National regulation, 6) Responsibility and power to make a decision, 7) Organisational affair, 8) Data gathering and utilisation regulation, 9) Conflict of interest (see Table 3.6)). And lastly, eight social influencing factors need to be included in the municipal heat transition influencing factors (i.e. 1) Building criteria, 2) Data digitalisation and utilisation, 3) Technical operation, 4) Technology maturity, 5) Heat source plan, 6) Maintenance and path dependency, 7) Neighbourhood density and 8) Future uncertainty (see Table 3.7)).

4 Design and development: municipal heat transition policy-making (HeTPoM) Decision Support System (DSS) framework

In the previous chapter, we obtained insight concerning the needs of the three perspectives of policy-making (from the municipality of Zoetermeer) for the development of a decision support system framework to support municipalities in making decisions concerning municipal heat transition policy-making. In this chapter, we take these needs as the basis to develop the DSS framework. Hence, this chapter answers the third research question: "what *decision support system framework can systematically assist municipalities in making decisions concerning municipal heat transition policy-making?*"

This chapter is structured as follows. First, the design method is explained (section 4.1), followed by a presentation of the method itself (to which we refer with the term HetPoM DSS framework) (section 4.2). Section 4.3 summarizes this chapter, provides our conclusions, and answers the third research question.

4.1 Approach for the design

This research uses an adaptation from functional visual communication design from Karjaluoto (2013) and the engineering design method from Dym and Little (1999). Engineering design is a method that is widely used by engineers to identify and solve problems by breaking down a complex problem into smaller parts (Dym & Little, 1999). On the other hand, a data visualisation is a strong tool to systematically reveal a pattern for either persuasive or guiding purpose (Dur, 2014). This design process is described by Karjaluoto (2013). In our analysis, we use six steps that are described by both authors as shown in Table 4. 1: 1) problem definition, 2) conceptual design, 3) preliminary design, 4) detailed design, 5) design communication, and 6) application.

Design steps	Dym & Little (1999) engineering design method	Karjaluoto (2013) functional visual communication design method	This study design method	Output in this Chapter
-	-	Discovery	Identification of possible solution directions	Refer to Chapter 3
Step 1	Problem definition	Planning	Problem definition	Section 4.1.1. Requirement breakdown structure for HeTPoM decision support system framework
Step 2	Conceptual design	Creative	Conceptual design	Section 4.2.2. System synthesis for HeTPoM DSS framework
Step 3	Preliminary design		Preliminary design	Section 4.2.3. Preliminary HeTPoM DSS framework
Step 4	Detailed design		Detailed design	Section 4.2.4. Detailed HeTPoM DSS framework
Step 5	Design communication	-	Design communication	Openly sharing the findings of this research through the TU Delft Repository in a form of thesis report https://repository.tudelft.nl/
Step 6	-	Application	Application	Not covered

Table 4. 1 Design method adapted from Karjaluoto (2013) and Dym and Little (1999)

The problem definition step defines requirements structure based on the requirements taken from Chapter 3. This structure is given in the form of a requirement breakdown structure (RBS). This structuralising was done to understand stakeholders' requirements better before the conceptual design is made. Using RBS, lower or higher-level requirements can be identified. RBS was made by 1) analysing requirements that we got from Chapter 3 into a mission statement. Then this mission statement was broken down into multiple levels of means, i.e. the requirements can be functional and non-functional. Each functional requirement will be translated into a subsystem in the next step, conceptual design, while non-functional requirements are used to select the best option.

The second step is the conceptual design that was done using a system synthesis process (Dym & Little, 1999) in a morphological chart. This phase is also the start of the creative process from Karjaluoto (2013). This step explores potential design direction based on the lowest level requirements generated in the RBS (the answer to the RBS) into the concept of the subsystem. This phase includes ideation from the mental process (concept generation) that is commonly used in the engineering design process (Ertas, 1996) that can be presented in a morphological chart.

The third step is the high-level design, preliminary design. This step produces an early design configuration (Ertas, 1996). Preliminary design can also be seen as a means of feasible conceptual design (Blanchard et al., 1990). Independent iteration process was done by experimenting with the possible ways to combine feasible means generated in the conceptual design step.

Preliminary design step leads to the fourth step, detailed design. Detailed design is the optimisation of the preliminary design (Dym & Little, 1999). The optimisation was done by reducing redundancy on the preliminary design and increasing the DSS framework comprehension. This process was done with support from an expert at TNO who works in the field of municipal heat transition. Questions and feedback from the expert were taken to improve preliminary design into the end product, detailed design. This detailed design is presented in Chapter 5 of this report.

Fifth, HeTPoM DSS framework was communicated by a report of the final HeTPoM DSS framework. This step includes the creation of HeTPoM DSS framework legends and user manual. All documentation that was made along the way was also tracked and organised as suggested by Dym and Little (1999). Moreover, a verbal presentation was also done to an expert in energy transition policy analysis from TNO to get a preliminary evaluation of the HeTPoM DSS framework value. Lastly, the application step tested HeTPoM DSS framework usage in a (mock) case. This step is used to test and refine the detailed HeTPoM DSS framework. This will not be covered in this study.

4.2 HeTPoM DSS framework design process

4.2.1 Requirement breakdown structure (RBS) for HeTPoM (DSS) framework

This step derived the requirement breakdown structure (RBS) for HeTPoM decision support system (DSS) framework based on the needs produced in Chapter 3. These needs are 1) to support an open, transparent, and equal municipal policy-making process 2) to supports key actors need management (support financing risk and responsibility plan and support key actors to convey their needs and requirement in the policy-making), 3) to supports turning the policy-making substance into process-based governance, 4) to supports modularity (support the existing policy target profiling that the municipality currently has and support the policy target profiling that the municipality is planning to have), and lastly, 5) data-driven process to keep the municipality policies legitimacy.

These needs were analysed and then formed into one mission statement "Support municipalities policy-makers in their effort to create a feasible heat transition policy that is supported by diverse municipal heat transition main actors in an equal decision-making ground." This mission then answered by a requirement tree forming a Requirement Breakdown Structure (RBS) that is shown in Figure 4. 1. Since these requirements came from the case study made in Chapter 3, the rationale of these requirements also generated from Head (2008) three lenses of policy-making.

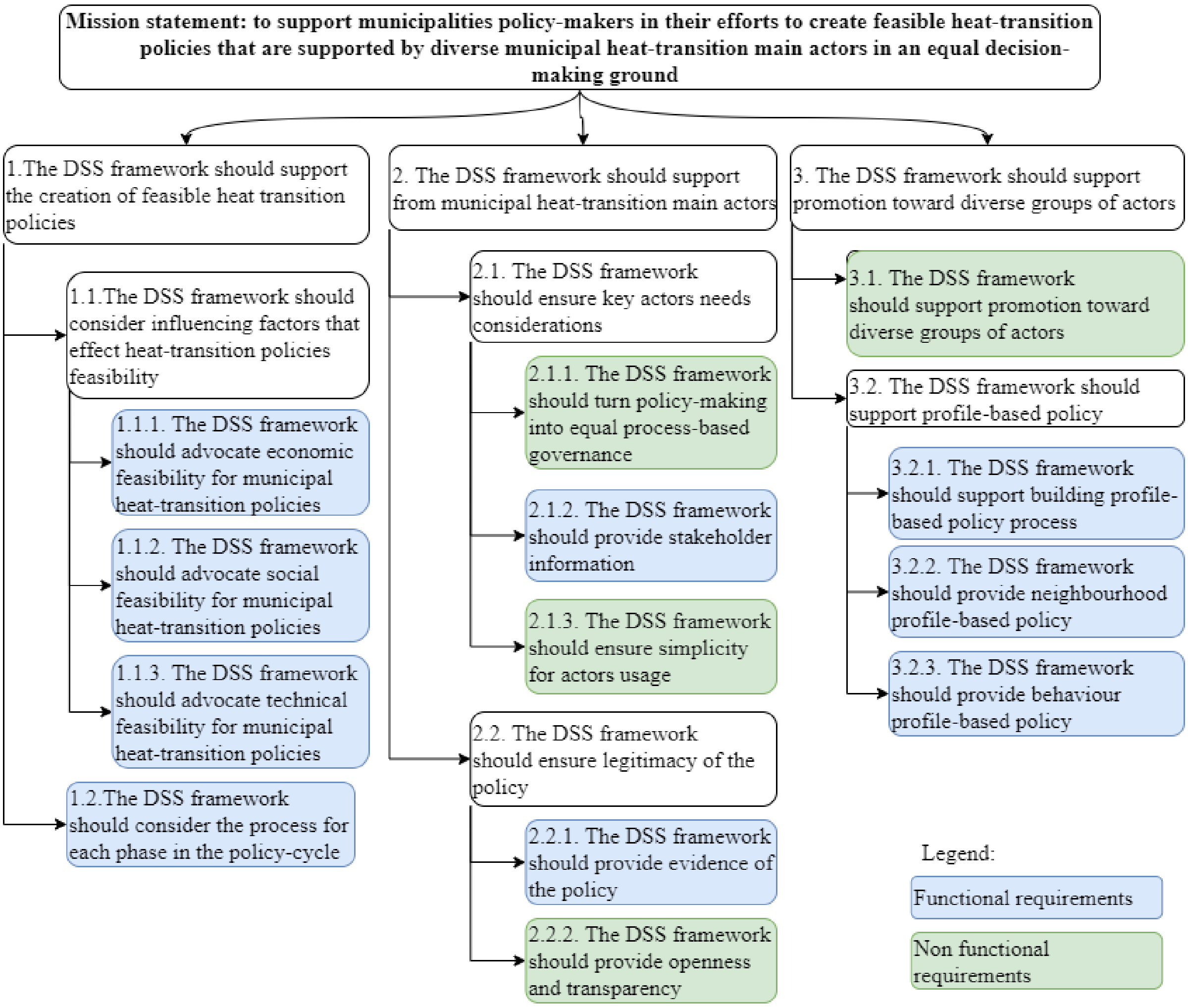


Figure 4. 1 Requirement breakdown structure for HeTPoM DSS framework (blue boxes are functional requirements and green boxes are non-functional requirements)

4.2.2 System synthesis for HeTPoM DSS framework

In the system synthesis, means were generated from functional requirements using a mental process of ideation. These ideas are shown in Table 4. 1. Chosen means can be identified from their blue boxes. These mean choices were done also by considering three design constraints. The first constraint is an equal ground for all actors as the municipality has no legal power to force building owners or tenants to adopt a new heat system. The second constraint is that policies should be ready at the end of 2021. The third constraint is that the operation needs to be within the municipality as the policy will be done at the level of the municipality.

Functional requirements	Mean 1 (M1)	Mean 2 (M2)	Mean 3 (M3)
F1: The DSS framework should advocate economic feasibility for municipal heat transition policies	Include economic influencing factors from Zoetermeer case study in Chapter 3	-	-
F2: The DSS framework should advocate social feasibility for municipal heat transition policies	Include social influencing factors from Zoetermeer case study in Chapter 3	-	-

F3: The DSS framework should advocate technical feasibility for municipal heat transition policies	Include technical influencing factors from Zoetermeer case study in Chapter 3	-	-
F4: The DSS framework should consider the process for each phase in the policy-cycle	Janssen and Helbig, (2018) policy cycle	Birkland (2019) policy cycle	van Veenstra and Kotterink (2017) policy cycle
F5: The DSS framework should provide stakeholder information	Include only the main actor	Include all actors	Suggest actor analysis
F6: The DSS framework should provide evidence of the policy	Shows needed data as evidence as part of DSS	Adapt Sage's (1991) DSS framework	Provide a computerised DSS based on Sage (1991)
F7: The DSS framework should support building profile-based policy process	Use a different branch to show different building ownership profiles	Show profile as one of the economics influencing factors	-
F8: The DSS framework should provide neighbourhood profile-based policy	Use a different branch to show different neighbourhood profile	Show profile as one of the social influencing factors	-
F9: The DSS framework should provide behaviour profile-based policy	Use a different branch to show different customer journey phase	Show profile as one of the social influencing factors	-

Table 4. 2 Functional requirements of HeTPoM DSS framework

Means selection was done from F1 to F9 in consecutive order. The optimum solution in this step is chosen based on the optimum functional requirements based on four non-functional requirements. These functional requirements are 1) the DSS framework should support promotion toward diverse groups of actors, 2) the DSS framework should ensure simplicity for actors usage, 3) the DSS framework should turn policy-making into equal process-based governance, 4) the DSS framework should provide openness and transparency.

First, functional requirements F1 until F3 means are chosen as they are the only candidate for these functions. Second, for the functional requirement F4, the tendency for all of these functional requirements was all the same except for the non-functional requirement "ensure simplicity for actors usage." For this non-functional requirement on simplicity, van Veenstra and Kotterink (2017) policy cycle has an advantage. The reason is that a minimum number of phases given by van Veenstra and Kotterink (2017) policy cycle (three phases) gives a simpler presentation to the users.

Third, is the choice for F5. Based on the non-functional requirement "ensure simplicity for actors' usage," "include all main actor" wins over "actors' analysis" and "include all actor". Fourth, for F6, "Adapt Sage's (1991) DSS framework " and "Provide a computerised DSS based on Sage (1991)" win over "Shows needed data as evidence as part of DSS" because of non-functional requirements "provide openness and transparency." This is because with only data transparency but no model transparency, decision legitimacy will be less. The reason why "Adapt Sage's (1991) DSS framework " wins over "Provide a computerised DSS based on Sage (1991)" is that "Provide a computerised DSS based on Sage (1991)" can only be made if "Adapt Sage's (1991) DSS framework " is finished (Sprague, 1980). However, since "Adapt Sage's (1991) DSS framework" is not yet ready, the development of "Provide a computerised DSS based on Sage (1991)" is not yet possible.

Fifth, F7, F8, and F9 will be chosen in one process. The rule of this set is that only one can take M1 while others need to take M2. The reason for that is once again "simplicity." If the profile is made in three dimensional, the framework will be harder to read and discuss. The reason to choose F9 is that user journey phase profile is unique because this is not only part of the profiling, but also the target of the municipal heat transition.

"User journey profile flags" is a quite important aspect in this modularity that will determine a different policy applies to the same target in a different time. If a policy-target is an agent-based perspective, this journey flag can be seen as a “point of no return” for them. Technically they can return, but after they pass one flag, either the knowledge or the investment is already theirs and they need an enormous amount of resources to turn back to the previous state. And we think that is very likely.

Thus, in this modularity, “the building criteria and policy target profile” and “neighbourhood profile” shall be included as one of the influencing factors. On the other hand, the users' journey profile shall be drawn as a different cycle for each journey flag. However, since we can only know where the user’s journey is are after we passed the problem definition phase, the problem definition phase for each policy cycle is made to be the same.

Therefore, four components are used in the conceptual idea of the HeTPoM DSS framework, 1) Sage (1991) DSS framework, 2) municipal-heat transition influencing factors established in Chapter 3, 3) customer journey profile branches, and 4) van Veenstra and Kotterink (2017) policy cycle. These components are chosen in 1) a process of ideation from functional requirements, 2) constraint screening, and 3) non-functional requirement qualitative comparison that we did in the previous six paragraphs.

4.2.3 Preliminary HeTPoM DSS framework

The preliminary design produces an early design configuration from the chosen feasible conceptual design (Ertas, 1996). The focus of this phase is to connect answers from the conceptual design step need to be arranged harmoniously. With independent iteration, a preliminary design that is presented in Figure 4. 1 was made. The preliminary HeTPoM DSS framework can be used as follows.

1. In the first phase of the policy cycle, policy-makers need to define the heat transition policy problem as well as the profile of policy-target. This includes engaging stakeholders to join the process (if needed) to gain knowledge about their interest and needs. Data collection is also essential in this phase. Three profile is made in this phase, one of them, customer journey phase will decide on the next box policy-makers needs to consider.
2. In the second phase of the policy cycle, based on the heat users (citizen) behaviour profile, policy-makers can go to the next step of policy design and experimentation. In the design and experimentation phase, activities can be varied. Some activity might be to find out which marketing strategy is the best suited for a certain condition. Also, can be to find a solution space for heat transition technology that can be used. In this phase, scenarios are made to help with the analysis.
3. In the third phase of the policy cycle, the user can go to the next step of policy implementation and evaluation. In this phase, the result of the evaluation will update the first phase of problem definition where user can start over the process until policy targets are adapted with the new renewable heating system.

This process is valid for a certain profile that is planned to be based on area. In each of these steps, policy-makers are guided by the list of influencing factors that need to be calculated in that step. An example of a use case is presented as follows.

4.2.3.1 The use case for the usage of the HeTPoM DSS framework

For this use case, a heat transition policy-maker team need to decide on the policy that needs to be executed on a 500m^2 in an imaginary neighbourhood area in Meerzicht-Oost Zoetermeer profile. This is a row house area with ten households within the area. All the houses are privately owned. In the last data gathering, no data can be gathered about their current behaviour currently only two of ten respondents reply to the questionnaire given to them. But we know that in the neighbourhood profile that three houses were having a problem when COVID-19 strikes the Netherlands. This situation has caused some problem to some of them that they have not been able to work. Looking at the attitude influencing factor, we see a little sense of urgency in the heat transition matter caused by non-tacit proximity of heat transition to the citizen. The more tacit problem that they have right now is the job problem (see Chapter 3). On the other hand, we also see that in the organisational affair area, the point of contact to manage this specific neighbourhood is not yet existed (see Chapter 3).

In this kind of situation, the heat transition policymakers need to use the first policy-cycle. The reason is that in this location, the citizens' profiles show that climate change urgency is not yet part of their priority. As the Zoetermeer policymakers said, "when you have a lot of personal issues, the proposition of the renovation of your homes is not the most important." In this case, the heat transition policymakers target will be gain attention to the case of heat transition.

Internally, we (as heat transition policy-maker responsible for the area) make a discussion with the social department who is responsible for this area and talked about the social problem that they are having. Since we see that nothing about heat transition can be brought up yet, we decided to make a collaborative information package that will be used when the social department talks with people from this neighbourhood. In this case, the municipal heat transition policymakers will have to talk with the social heat transition policymakers to include heat transition marketing strategy into their program to help the neighbourhood in their COVID-19 situation.

In the implementation phase, the purpose is more into finding more data and give a general idea about climate change as well as finding someone who might be able to be the point of contact in this neighbourhood. This is because their profile shows that talk about house renovation into this house is not yet possible. The principle of "stopping when it is not feasible" shall be used in this situation, but the information should always be given to the citizen accordingly. In this case, the same actors, both municipal heat transition policymaker and municipal social policymakers need to collaborate to help citizens to recognise the needs of heat transition.

4.2.4 Detailed HeTPoM DSS framework

In this step, we describe the components of the framework in detail.

4.2.4.1 Profiling criteria using policy-target journey map (Area 1 in Figure 4.6)

As mentioned in Chapter 3, the municipality of Zoetermeer is currently trying to make a specific policy based on a specific profile of the citizen in a certain (approximately) 500m^2 area. This is represented in the HeTPoM DSS framework in two ways, 1) vertical customer journey map and 2) heat transition influencing factors (both 1) building types and ownership profile and 2) neighbourhood profiles)

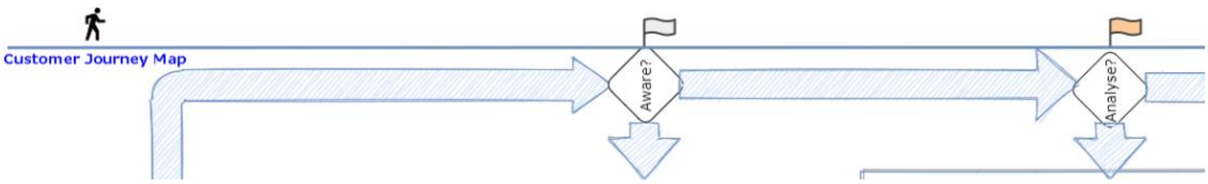


Figure 4.1 Customer Journey Map

The customer journey is used to describe the phases of the heat transition for the end-user. These phases are divided into 1) willingness to be aware, 2) willingness to explore the possibility, and 3) the willingness to act on the heat transition, and 4) willingness to adapt to the heat transition. Willingness to be aware means that that the citizen in that area already agree that heat transition is urgent and need to be happening fast. The next journey of a customer is to be willing to explore the possibility of choices of transitioning their heat inside their house. Activities of consumer who is in this journey phase are 1) browse around on the cheapest way to heat the house sustainably, 2) browse around on the alternatives way to cook (instead of the gas stove), or 3) browse for a contractor to insulate the house better. Willingness to act on heat transition is the phase where they hire a contractor to renovate their house, change their heating system, and start to live with their new sustainable heat. Then lastly, is to adapt to the new system, adapt to the new way of cooking, adapt to the new bill, adapt to the new rent, or adapt to the new temperature setting in the house (as the new system might have different reaction time with the old system).

These phases are part of the social influencing factors but derived differently because of the unique position of these influencing factors. Each user can only have a building profile and one neighbourhood profile. However, for these behaviour phases, each citizen can have all these four phases depending on how far they are in the heat transition. And this will affect the policy-making design phase in the policy cycle (see Area 1 in Figure 3.6).

4.2.4.2 Four policy cycles (Area 2(-, A, B, C, D) in Figure 4.6)

As can be seen from Figure 4.6, four policy cycles are presented in HeTPoM DSS framework. Each policy-cycle present the policy-making process based on the customer journey phase (behaviour) of the end-used. The first cycle (Area 2 and 2A) is the policy cycle if the end-user is still resistant to the idea of heat transition. The second cycle (Area 2 and 2B) is the policy cycle if the end-user is supporting heat transition but cannot still (capability influencing factor) analyse the solution that they can take on this matter. The third cycle (Area 2 and 2C) is the policy cycle if the end-user is already aware of the solution space that they can take but still cannot act on heat transition. The fourth cycle (Area 2 and 2D) is the policy cycle if the end-user has adopted a new heat source in their house but have not yet adapted to the new system.

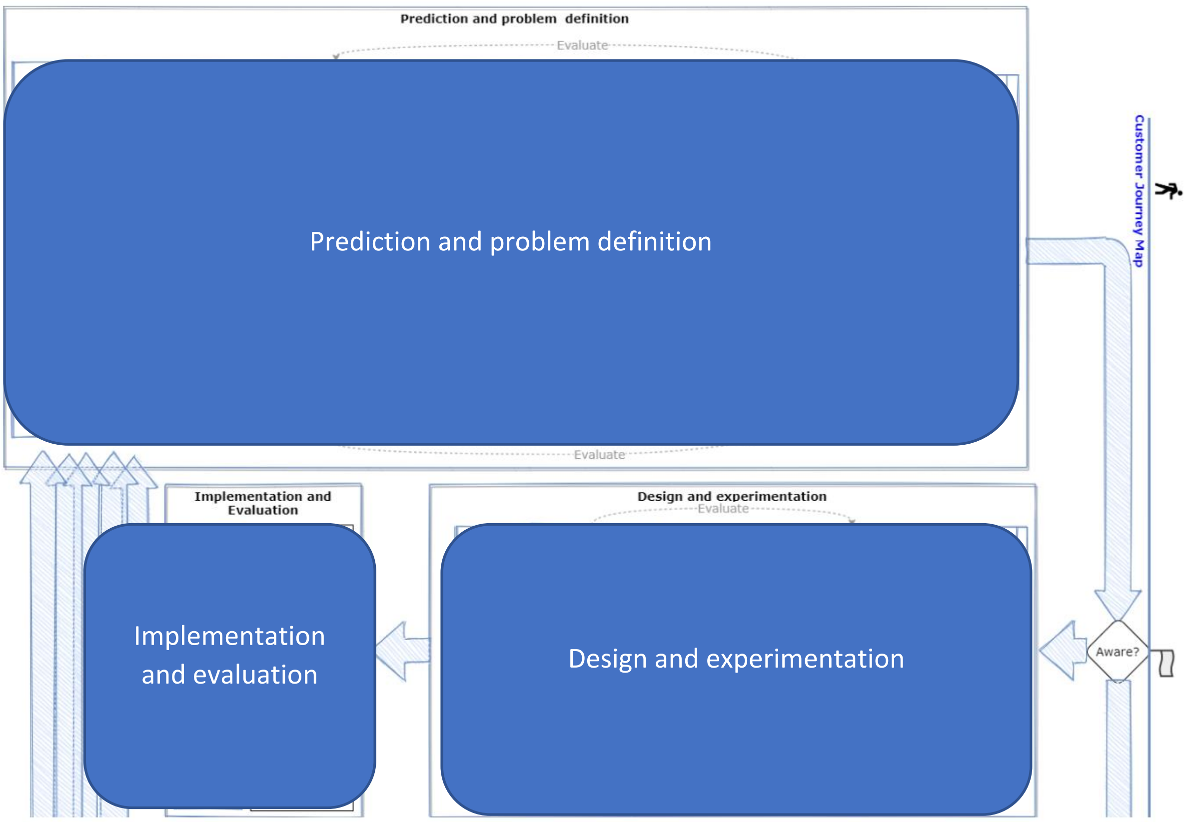


Figure 4.2 One cycle from four cycles in the HeTPoM DSS framework

Each cycle are using van Veenstra and Kotterink (2017) policy-cycle that consists of three phases, 1) prediction and problem definition, 2) design and experimentation, 3) and implementation and evaluation. The cycle shares the same first phase since before the profile are determined (in the prediction and problem definition phase) are needed to know which branch of policy cycles are going to be used at that moment.

4.2.4.3 Decision support system (Area 3(A, B, C, D) in Figure 4.6)

In the first and second phases of the policy cycle, Sage (1991) decision support system (DSS) concept is used. The decision support system describes that a decision (Area 3A) comes from two input, 1) data (Area 3B) and 2) decision model (Area 3C). Thus, this model was adapted in HeTPoM DSS framework to present how data (based on the influencing factors) are used in the decision-making process based on a decision model.

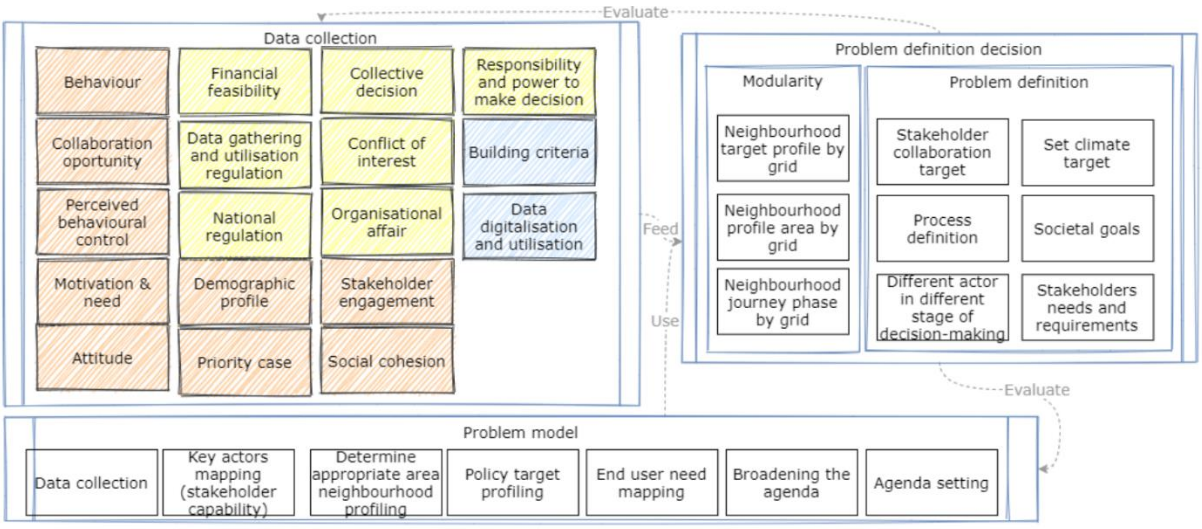


Figure 4.3 The decision support system framework inside HeTPoM

4.2.4.4 Actors (Area 4 in Figure 4.6)

The actors presented in the HeTPoM DSS framework are only the most important actor in the heat transition (Area 4), 1) the municipality, 2) Stedin, 3) Housing corporation, 4) Citizen. The blue actors are actors that already involved in the previous policy-making process. And orange actors are actors who are going to be involved in the policy-making. The citizen concept here is broad as they represent many parties that can be surmised as citizens, 1) private house owners, 2) renters, and 3) citizen initiatives.

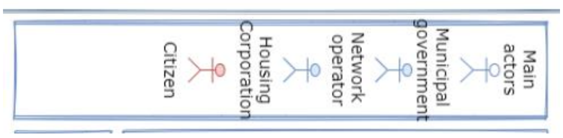


Figure 4.4 Actors presentation in HeTPoM

4.2.4.5 Influencing factors and process (smallest squares in Figure 4.6)

Influencing factors and processes are presented with the smallest boxes in the HeTPoM DSS framework. Influencing factors are presented with coloured boxes, 1) blue for technical influencing factors, yellow for economic influencing factors, and 3) orange for social influencing factors. These influencing factors can be reviewed more in Chapter 3. These influencing factors are also used to identify needed data that need to be taken to make a decision.

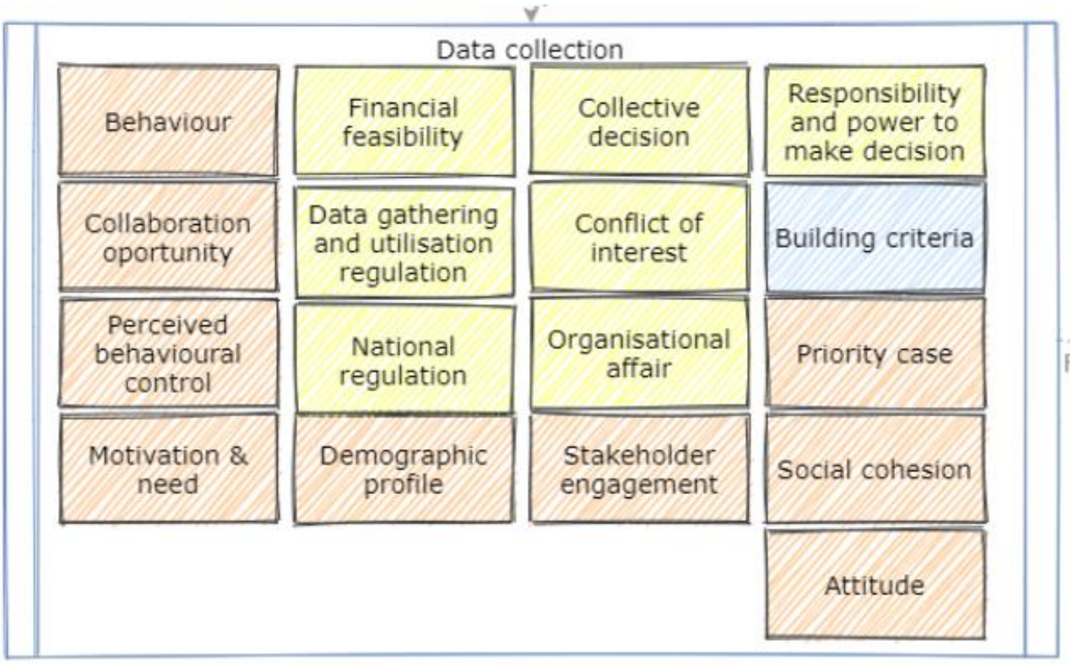


Figure 4.5 Influencing factors in the data collection box in the HeTPoM DSS framework

On the other hand, processes are presented in small white boxes in the HeTPoM DSS framework. This process boxes suggest what process are used in the municipal heat transition policy-making. This suggestion does not necessarily mean that all process should be followed. But these processes mentioned in HeTPoM are more into the suggestion of what kind of process can be done in the municipal heat transition policy-making.

4.2.5 Combining the components and proposed functionality

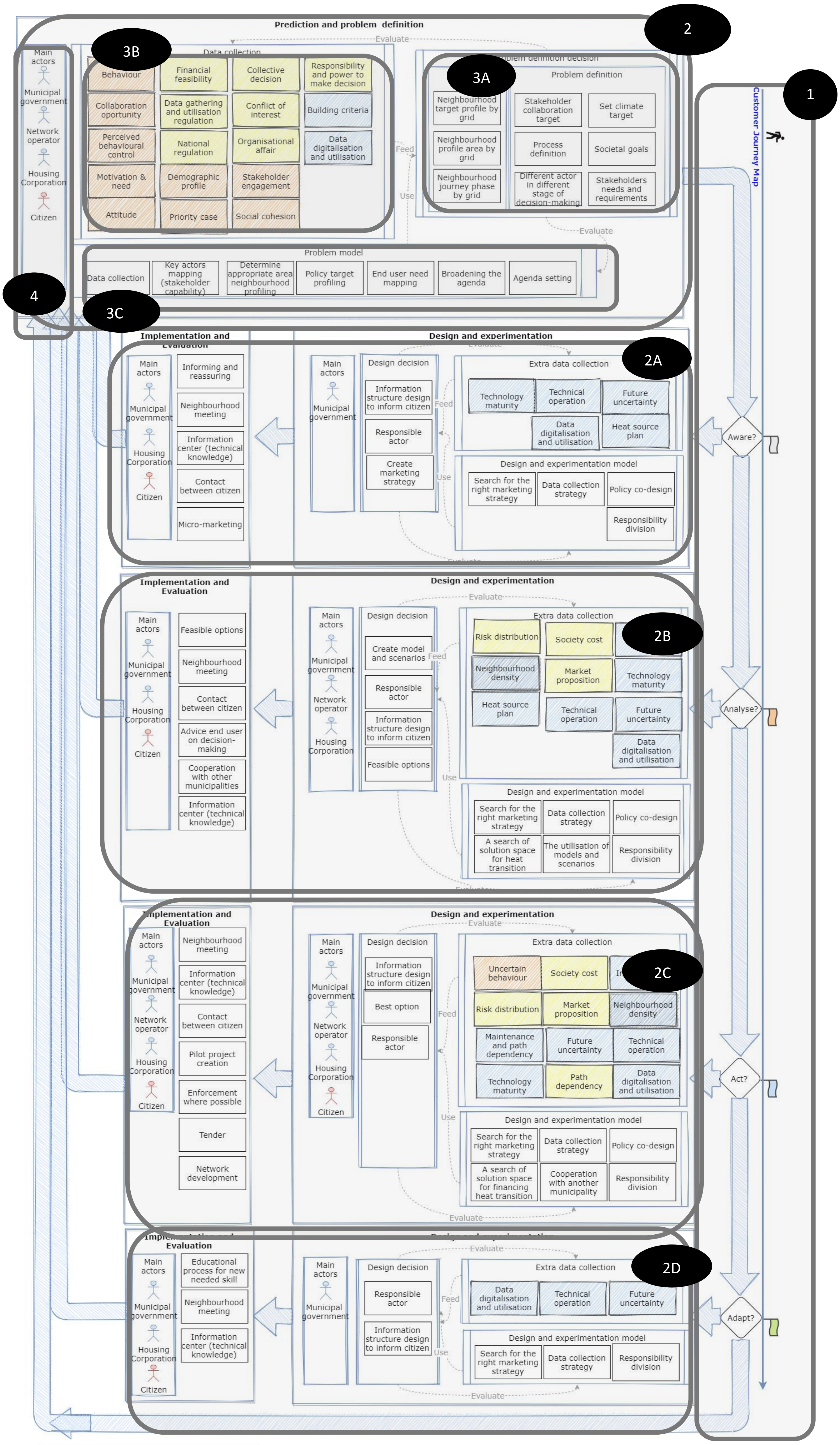
In this section, the detailed design of the HeTPoM DSS framework is combined in Section 4.2.5.1. Then, the HeTPoM DSS framework functionality is proposed.

4.2.5.1 Combining the components

A detailed presentation of HeTPoM DSS framework is provided in Figure 4.6. In the detailed design, consultation with an expert (in energy transition and data governance) from TNO was executed. In this step, the focus of the design is clarity. To support process-based governance means that the design should be attractive and promote discussion between users. This can be done by putting the colour code on each component. That way, the system can be easily analysed, and members of the collaboration can easily add or deny the components that are put in the framework by recognising them as one of their specialities. For example, if the user is an engineer, the user would not want to be bothered too much by the behavioural or policy aspects of the model. In this situation, if the user knows that red is the colour of technical influencing factors, the user can just investigate that part of the model. That way, the user can focus only on the interesting elements instead of struggling with information that the user does not need.

4.2.5.2 HeTPoM DSS framework proposed functionality

Two main functions are proposed from the HeTPoM DSS. The first functionality is related to the direct usage of HeTPoM DSs framework for municipal heat transition policy-makers, researchers, and heat transition stakeholders. HeTPoM DSS framework is proposed to be able to assist design, evaluation, and assessment of municipal heat transition policies. This systematic support in policy design, evaluation, and assessment, ultimately can also support open, transparent, and equal municipal policy-making process that is data-driven.



Legends:

Coloured boxes: Heat transition influencing factors
- Orange: Social factors
- Blue: Technical factors
- Yellow: Economic, regulation, and political factors

White boxes: Process of heat transition policymaking
Human icon: main actors
- Blue: existing main actors
- Red: future main actors

Diamond: Customer journey flag

Figure 4.6 Municipal heat transition policy-making (HeTPoM) decision support system (DSS) framework detailed design

The HeTPoM DSS framework was designed based on the needs of the municipality of Zoetermeer. Therefore, the usability of the HeTPoM DSS framework is still limited to the municipality of Zoetermeer or municipalities that have similar characteristic as Zoetermeer. These characteristics are presented as follow: 1) located within the area of the Netherlands, 2) each neighbourhood in the municipality is occupied by a diverse population, 3) in the municipality, exist communities that are extremely active in the energy transition as well as communities who are apathetic to the heat transition, 4) in the municipality, exist, people, who are too occupied by their problem to start to think about heat-transition, 5) have not decided on any district heating system in their area.

The second functionality is for both policy-makers and system developer to crease a municipal heat-transition DSS. As previously mentioned that DSS framework is used to guide the development of a DSS (Sage, 1991b; Sprague Jr and Carlson, 1982). As this purpose, we develop the HeTPoM DSS framework using SLR, case study, and DS. The basis of this DSS framework needs to be developed further in the technical base part (e.g. database architecture, interface design). However, the HeTPoM DSS framework has provided information on the needed data and process model to crease a DSS.

4.3 Conclusion for the design of HeTPoM DSS framework

In this chapter, we describe the designed method to support municipalities in making decisions concerning municipal heat transition policy-making. Hence, the third question was answered: "what *data-driven decision support system framework can help municipalities in making decisions concerning municipal heat transition policy?"* To develop the decision support system (DSS) framework, we used the following approach. First, the requirements were structured. Second, sub-system solution concepts for each functional requirement were chosen based on the non-functional requirements and constraints filter. Third, the preliminary design was made to integrate chosen conceptual sub-systems. Fourth, a detailed design was made to increase readability and completeness. And finally, the heat transition policy-making (HeTPoM) decision support system (DSS) framework was communicated.

The purpose of heat transition policy-making (HeTPoM) DSS framework creation is to support policy-makers. The heat transition policy-making (HeTPoM) DSS framework provides policy-making with activities that are guided by a profile that is determined in the first step of the activity (prediction and problem definition phase), such as data collection, stakeholders needs and requirement analysis and policy target profiling. Also, the heat transition policy-making (HeTPoM) DSS framework provides suggestions regarding influencing factors, processes, and involved actors in each of these activities. Policy-makers can use this suggestion as a systematic guide for their process in creating municipal heat transition policy as well as communication tools to be used together with stakeholders. That was, both can communicate on how they want to co-design the municipal heat transition policy.

Heat transition policy-making (HeTPoM) DSS framework serves its function by integrating five main components in Section 4.2. First is three dimensions profiling of policy-target. These three dimensions are 1) neighbourhood profile (presented as a social influencing factor), 2) building ownership profile (presented as an economic influencing factor), and policy target behaviour (presented as a branch in the policy-cycle). The second component is a four policy cycle (based on the policy-target behaviour stage) with shared "prediction and problem definition" phase. The third component is the data-driven decision support system framework that is needed in each phase of the policy. This decision support system framework is replicated to make the decision support system framework for the whole cycle of the policy. The fourth component is the main actors in each phase of the policy cycle. Both existing and future actors are mapped here. The last component is municipal heat transition (social, economic, and technical) influencing factors that filling in the data and model input of the meta decision support system inside heat transition policy-making (HeTPoM) DSS framework.

The method part of heat transition policy-making (HeTPoM) DSS framework defines that first, users need to define the problem as well as the profile of policy-target. Second, based on the behaviour profile, a user can go to the next step of policy design and experimentation. Third, the user can go to the next step of policy implementation and evaluation. In this phase, the result of the evaluation will update the first phase of problem definition where user can start over the process until policy targets are adapted with the new renewable heating system. This process is valid for a certain profile that is planned to be based on area. In each of these steps, users are guided by the list of influencing factors that need to be calculated in that step.

The heat transition policy-making (HeTPoM) DSS framework is proposed to support the municipality level policy-makers in their efforts to create feasible heat transition policies that are supported by diverse municipal heat transition main actors in an equal decision-making ground. This mission was made based on the requirements that are generated in Chapter 3 of this thesis report. Furthermore, the refined HeTPoM DSS framework can potentially be used as a basis to create a computerised municipal heat transition policymaking DSS.

Although these contributions are designed from local needs of the municipality of Zoetermeer, municipalities in the Netherlands might also be able to use the same system when they carry these characteristic as follow: 1) located within the area of the Netherlands, 2) each neighbourhood in the municipality is occupied by a diverse population, 3) in the municipality, exist communities that are extremely active in the energy transition as well as communities who are apathetic to the heat transition, 4) in the municipality, exist, people, who are too occupied by their problem to start to think about heat-transition, 5) have not decided on any district heating system in their area. However, further research to confirm generality needs to be conducted before a further conclusion is made.

5 Evaluation: HeTPoM DSS framework evaluation

This chapter answered the fourth research question "what *are the potential positive and negative effects of using the municipal heat-transition policy-making decision support system framework?*" We answer this question by empirical HeTPoM DSS framework that was made in Chapter 4, Municipal heat transition policy-making (HeTPoM) DSS framework. In this chapter, first, the design method explained (section 5.1). Then empirical municipal heat transition policy-making (HeTPoM) DSS framework evaluation is presented (section 5.2). Afterwards, a conclusion is presented in Section 5.3.

5.1 Evaluation method

An evaluation can be done either with two-dimensional characteristics, 1) ex-ante or ex-post evaluation and 2) naturalistic or artificial (Pries-Heje & Baskerville, 2008). Artificial evaluation or experimentation is an evaluation that does not explore the performance of a solution in its real environment (Nunamaker Jr et al., 1990; Venable, 2006). So, they can be laboratory experimentation, simulations, or theoretical arguments. On the other hand, naturalistic evaluation or observation is performed in a real environment. Although natural evaluation can provide the test with the complexities nature offers, they also offer variables that are not part of the system interest which might hinder the focus of the research (Sun & Kantor, 2006). Ex-ante and ex-post, just like their name, indicate whether the evaluation is done based on the result (ex-post) or possible result (ex-prediction) (Peffers et al., 2007; Pries-Heje & Baskerville, 2008).

5.1.1 Evaluation method selection

For this thesis, a criteria-based evaluation in a semi-structured workshop was done. A criteria-based evaluation can be done in an artificial environment for both ex-ante and ex-post (Venable et al., 2012). However, in this case, an ex-ante is chosen (see Figure 5.1). The reason for this selection is the COVID-19 situation that only allows the online meeting to be conducted instead of the real ones. Therefore, creating an ex-post activity was not likely to be easy. Artificial was chosen over naturalistic because the whole cycle of the policy has not been completed yet. Thus, it is better to make an artificial ex-ante evaluation as the first evaluation for this HeTPoM DSS framework.

	Artificial	Naturalistic
Ex post		
Ex ante	**HeTPoM DSS framework evaluation method**	

Figure 5.1 HeTPoM Evaluation method (ex-ante artificial)

To perform this evaluation 3 steps were done, 1) evaluation criteria were prepared, 2) evaluation was executed, 3) evaluation were analysed.

5.1.2 Evaluation criteria

Some part of Johannesson and Perjons (2014) evaluation criteria of design science research was adopted: system functionality, structural quality, and user perception. Only some part of the evaluation was taken due to minimum respondent availability. The most important ones are the system functionality as this will complete the detail design of the framework by pro0viding a list of the functionality on how users can use the HeTPoM DSS framework.

So, the most important part that we would like to know from this research is the system functionality of HeTPoM for policy-makers, research, and practitioner (other stakeholders) and how easy it is to use the framework.

The second one is about the structural quality of HeTPoM, 1) coherence, 2) modularity, 3) conciseness, and 4) completeness. Coherence means how logical and how consistently does the structure of

HeTPoM in the evaluator examination. Then modularity is about how far can HeTPoM components can be independent of each other and separated or recombined. Conciseness is used to measure whether no unnecessary components are presented in HeTPoM. Then completeness is to measure how HeTPoM can holistically help policy-makers in viable policy design.

Then usage perception, is also used to measure 1) perceived usefulness, 2) ease of use, and 3) social influence. Perceived usefulness to measure on how HeTPoM can help the policy-makers to make the policy (easiness, effectiveness, or quickness). Ease of use is used to measure how easy HeTPoM can be used. Then social influence is to measure if HeTPoM can attract communication about the system users in a form of recommendations.

Lastly, for the overall impression, we would like to know if using HeTPoM is a good idea. These criteria shall be asked after a series of presentation and discussion as shown in Figure 5.2.

5.1.3 Evaluation respondent criterion

For this evaluation, a set of expertise was needed to be included in this qualitative workshop. In this interview, four expertise was needed, 1) Public administration, 2) Policy lab, 3) Data and evidence-based policy-making, and 4) Multi actor management. This expertise can come from either independent research or the university.

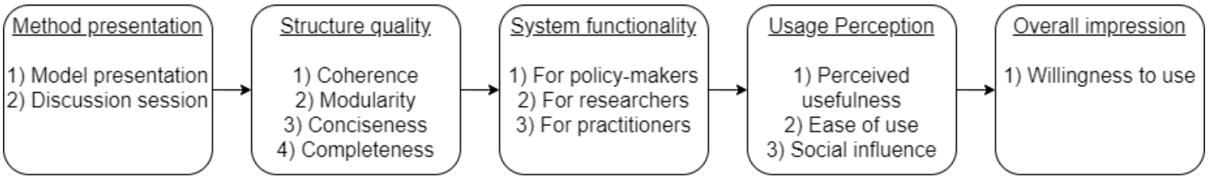


Figure 5.2 HeTPoM evaluation method based on criteria adapted from Johannesson and Perjons (2014)

5.2 HeTPoM DSS framework evaluation

The execution of HeTPoM DSS framework evaluation was done on June 30th, 2020.

5.2.1 Evaluation execution

The execution of HeTPoM DSS framework evaluation was done by three experts from both TNO and Delft University of Technology (see table 5.1). Two experts are working on data and evidence-based policy-making. One expert is working on multi-actor management and framing. Lastly, one expert was working in public administration research.

Expertise / Evaluator	Public administration	Policy lab	Data and evidence-based policy-making	Multi actor management and framing
Evaluator 1 (TU Delft)		x	x	
Evaluator 2 (TNO)	x		x	
Evaluator 3 (TU Delft)				x

Table 5.1 Evaluators expertise

The workshop sixty minutes were filled with discussion, question, and suggestion summarised in Appendix III.2. After this discussion finished, the respondent filled in a questionnaire (for questionnaire questions see Appendix III.1. The result of the questionnaire is a ranged value (1 means completely disagree and 10 means completely agree) scale from questions that are made based on evaluation criteria (see subsection 5.1.2.).

5.2.2 Using HeTPoM DSS framework to evaluate the current Zoetermeer municipality policy-making process

In the expert workshop that was done, HeTPoM DSS framework was done to also evaluate the current policy-making that is used in the municipality of Zoetermeer. Using HeTPoM DSS framework, two critics and recommendations were made as follow.

The first critic comes in the minimum involvement of the citizen initiatives in the Zoetermeer municipality heat transition program. Although an open and equal process that was done in the municipality of Zoetermeer is a good approach, the municipality of Zoetermeer is still seen to be lacking in the involvement of the citizen subjects. We see that this shortcoming needs to be evaluated to support a successful policy-making process. Evaluators are confident that the municipal heat-transition policy-making can be better with more citizen inclusion. This statement is also corroborated by Hoppe (2012) who investigates local government support and citizen initiatives. We discussed that in parallel with the municipality of Zoetermeer plan to base their policy on the social data, collaboration with citizen initiatives is essential for a successful municipal heat transition. Thus, municipal policy needs to include them as well.

The second critic comes from the absence of the exit strategy activity in the Zoetermeer municipality policy-making. An exit strategy can be seen as the mean to mitigate failure or the mean to leave the investment (Hawkey, 2002; Phillips, 2006). We discussed that without an exit strategy, citizens support might be hard to gather as they are scared to be trapped with their choices. Although this the exit strategy might not be plentiful, an exit strategy needs to be discussed with the citizen. Also, this exit strategy needs to be negotiated as the outset of the heat transition project (Grigoras, n.d.). That way, citizens trust and support can be gained more sustainably.

5.2.3 Evaluation analysis

5.2.3.1 HeTPoM DSS framework overall impression

The overall impression of the model is rated as useful. One of the respondents were quite happy about HeTPoM and think that HeTPoM can also be used to help Energy-SHIFTS consortium. Energy-SHIFTS is a European-Union funded project with core activities to provide insight for both short term and long term mechanism to enable evidence-based energy social sciences and humanities insight to reach the policy executors (Energy-SHIFTS, 2020). A presentation about HeTPoM was discussed but not yet set.

> *"This is a good and comprehensive model that can be used with another research that is happening"*
> *Evaluator 1*

Improvement on the willingness to use have something to do with the ease of use of the HeTPoM that is perceived bad.

5.2.3.2 HeTPoM DSS framework functionality

The functionality of HeTPoM DSS framework was stated to potentially be able to be used in the joint process of co-creation of policy to design, assess, and evaluate the policy. Thus, it was stated that HeTPoM can be used by professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. It was discussed that HeTPoM can be used to make people aware of the policy-making process at the municipal level and can be used by the municipality to support citizen inclusion in their policy-making. Once again, the functionality was hindered by the ease of use of HeTPoM.

5.2.3.3 HeTPoM DSS framework perceived usefulness

The perceived usefulness of HeTPoM is also neutral positive except for the ease of use of the model that was rated in the neutral negative. The rate for social recommendation is also still neutral positive. This can also be seen from how the respondent asked question on where some component locates in the HeTPoM. Or why does a component is not in HeTPoM (when the component is there)?

From the flow of discussion, we can see that respondent was first looks sceptical with the model but highly interested as to how the last 50 minutes were full of questions from the respondent. This can be a good thing for communication, but also means that guidance is mandatory to use HeTPoM as it is not self-explanatory.

5.2.3.4 HeTPoM DSS framework quality structure

The coherence of HeTPoM modules is considered enough with some improvements recommended. To improve the coherence, some module needs to be replaced, renamed, or split as recommended by evaluators. The modularity of HeTPoM needs to be improved as well as the completeness. Some recommendation for the completeness subject will be discussed in the next subsection.

5.2.3.5 HeTPoM system improvement recommendations

5.2.3.5.1 HeTPoM system improvement recommendations for completeness

From the workshop, six recommendations were discussed to improve the completeness of the HeTPoM DSS framework. These recommendations are presented as follows.

The first recommendation is to add differentiation between the adoption target (adopting agents) citizen and citizen cooperative who are more active to drive heat transition needs to be done. This is because citizen initiatives are a currently small group who have the potential to grow bigger and gives a big impact on the heat transformation in Zoetermeer. We also see that this input is right based on the last interview with DEZo. Energy initiatives club has big ambition and needs to get more attention in the policy-making.

The second recommendation is to include the citizen initiatives organisation aspiration need into the future actors to be included in the municipal heat-transition policy-making scheme. Since they are not yet in the policy-making in the Zoetermeer municipality, we have not brought them in the design of the DSS framework. However, there is a need to be a place where actors aspiration can be addressed in HeTPoM. We discussed that these citizen initiatives should be included starting from the problem definition phase. Citizen initiatives organisations can be used to both represent the citizens aspirations as well as a tool to communicate municipal heat transition policy to the citizen in the policy implementation phases.

The third recommendation is to include the influence of the existing social structure (e.g. church, mosques, social club, etc) that can be used to smoothen the communication with the citizen. Just like citizen initiatives, these existing social structures are easy to approach (compared to the direct communication with the citizen) as they usually have community representation (or leader) that can be taken as one point of communication. Therefore, this community can help the policy-makers to resolve the organisation structure problem in the subject of communication.

The second and third recommendation is made to support the fourth recommendation that is to add a co-creation process with the citizen to increase acceptance and political legitimacy. However, citizens and policy-makers policy-creation are not easy due to the number of citizens and their diversity. If models are used to simplify the policy assessment, then the need to include cultural bias in the model is emerging. It is best to be reminded that in Zoetermeer, language diversity is also needed to be considered as it will affect the communication method that the municipality needs to organize. These considerations need to be included in the HeTPoM DSS framework to define the citizen inclusion in the model (i.e. to show the area where citizen inclusion is processed in the model).

The fifth recommendation is to include the financial capability in the problem definition phase. Currently, financial capability is now presented by the neighbourhood profile. This introduction of financial capability in the problem definition phase is recommended as this influencing factor will be needed to implement subsidy mechanism needs mechanism the implementation and evaluation phase of the third and fourth policy cycles (action and adaptation cycle). It was also recommended to the separate private cost and societal cost information. Currently, both societal cost and private cost are presented as influencing factors, societal cost. The reason is to be able to connect financial capability and the private cost influencing factor.

Finally, we also discussed the need for the policy-maker to provide an exit strategy in case citizens are not happy with the result (or process) of heat transition. This exit strategy needs to be communicated starting from the analysis policy-cycles (to the adaptation policy cycle) to keep the good relationship between citizen and the government. The citizens need to know what can they do in case something wrong is happening.

5.2.3.5.2 HeTPoM system improvement recommendations for usability

To increase the usability of HeTPoM, several recommendations were made in the workshop session. These recommendations are listed as follows:1 1) Need to make a better presentation on the dimension of policy-making (customer journey, demographic profile). Need to clarify that data in the problem definition will also be used in the next phase of the cycle

1. Need to pop out the presence of four policy cycles that is using one problem definition phase process over and over.
2. Need to explain that this model is more general and cover not only one type of technology decision-making process but more into the process on how a decision can be made.
3. Need to change act phase into adopting phase for easier understanding
4. Video documentation and tutorial need to be attached to the HeTPoM to give guidance to use HeTPoM. HeTPoM is a complex DSS framework and might not be able to make it easier to use it. Thus, training and tutorial is a better solution rather than trying to simplify the model.

5.2.3.5.3 HeTPoM system further evaluations recommendations

Furthermore, more evaluation needs to be done for HeTPoM DSS framework. Two evaluation recommendations are provided as follows. First, the next evaluation workshop is recommended to be made with policy-makers involvement. It would be better to use a real case of a certain area in the neighbourhood (Ex-ante naturalistic evaluation). This will give feedback on HeTPoM on the complexity of the real world. Second, an evaluation recommendation is made to create an evaluation to a wider audience using a video tutorial and questionnaire. In the questionnaire, there should also be respondent profiling questions to know the background of the respondent and their expertise.

5.2.4 Refined HeTPoM DSS framework

Recommendations from the evaluation workshop were then used to refine the HeTPoM DSS framework that is presented in Figure 5.3 as the Refined HeTPoM DSS framework. Four refinements are made to help to improve both completeness and usability of HeTPoM DSS framework.

5.2.4.1 The refined customer journey map

The first improvement of the HeTPoM DSS framework is to refine the customer journey map (See Figure 5.3 (1)). This was done because of the confusion on the presence of four policy cycle. To improve the readability of the connection of the customer journey phases and policy cycles. In the refined HeTPoM DSS framework, we use colour different lines to define the flow of the policy cycle in each case of customer journey phase. Also, we change the naming of “action phase” to the “adoption phase,” as it is expected to be able to give more insight for policy-makers.

5.2.4.2 Expanding the role of the citizens

The second improvement is the refinement of the citizen role in the policy-making (See Figure 5.3 (2)). In the refined HeTPoM DSS framework, roles of active citizens (citizen initiatives) and passive (policy targets) are differentiated. The role of existing social constructs is also included in the case as either citizen initiatives (if they agree to actively promote heat transition) or policy target. This information shall be included in the HeTPoM DSS framework manual.

5.2.4.3 Expanding the policy-making activities

The third improvement of the HeTPoM DSS framework is to refine the decision activities in the municipal heat transition (See Figure 5.3 (3)). The decision activities are expanded by activities such as exist strategy (support) and heat transition incentives. Although heat-transition incentives are usually managed at the national level, this activity is included to also be considered in the municipal policy level.

5.2.4.4 Increasing the ease of use of the HeTPoM DSS framework

The fourth improvement of the HeTPoM DSS framework is to refine the supporting information for HeTPoM DSS framework usage. These supporting information include the additional legend in the refined HeTPoM DSS framework (See Figure 5.3 (4)), HeTPoM DSS framework manual documents, and video manual to use the refined HeTPoM DSS framework.

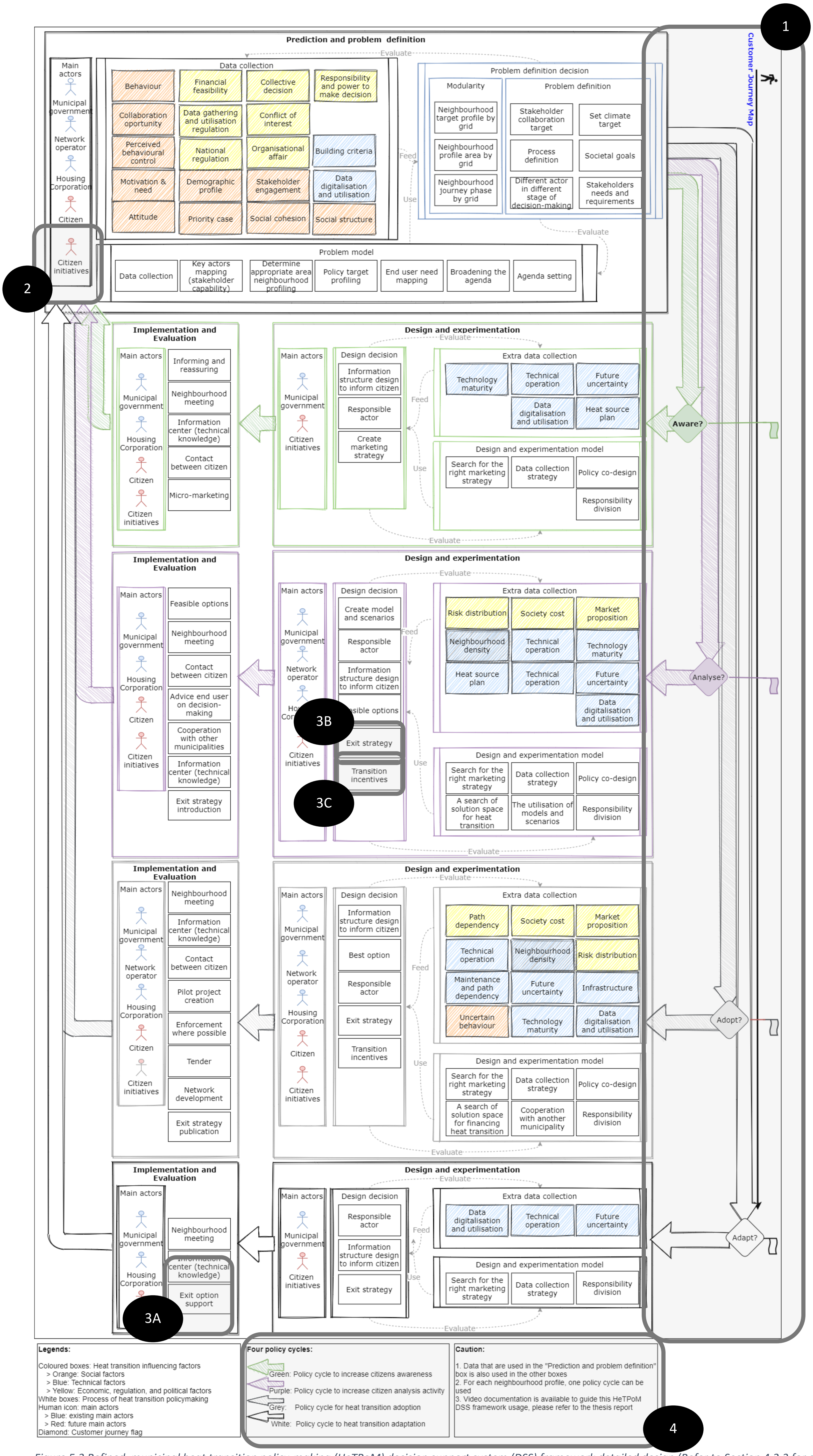


Figure 5.3 Refined municipal heat transition policy-making (HeTPoM) decision support system (DSS) framework detailed design (Refer to Section 4.2.3 for components detail)

5.3 Conclusion for the evaluation of HeTPoM DSS framework

In this chapter, the fourth research question was answered: "what *are the potential positive and negative effects of using the municipal heat-transition policy-making decision support system framework?"* To answer that question, an ex-ante artificial evaluation was done in the form of a one-hour workshop on June 30th, 2020. This evaluation uses theoretical arguments.

The HeTPoM DSS framework is evaluated with several usages on 1) functionality to be used by research, policy-makers, and practitioner, 2) coherence design, and 3) good overall impression. The functionality of HeTPoM DSS framework was stated to potentially be able to be used in the joint process of co-creation of policy to design, assess, and evaluate the policy. Thus, it was discussed that HeTPoM can be used by professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. It was concluded that HeTPoM can be used to make people aware of the policy-making process at the municipal level and can be used by the municipality to support citizen inclusion in their policy-making.

This positive effects on the usage of HeTPoM DSS framework were also demonstrated when the HeTPoM DSS framework was used to examine the Zoetermeer municipality policy-making process for heat transition. In the end, we examine that two improvements can be done in the municipality of Zoetermeer, 1) to increase the involvement of the citizen initiatives in the Zoetermeer municipality heat transition program and 2) to develop an exit strategy activity in the Zoetermeer municipality policy-making process.

However, some limitations were also examined in the evaluation 1) low ease of use of HeTPoM reducing the perceived usefulness, 2) structural modularity of HeTPoM need to be improved is this model is intended to be used for a different purpose, 3) the completeness to the module also needs to be improved. Recommendations to fix the limitation of HeTPoM has been made as well as more evaluation recommendation (Section 5.2.2.5.). The most urgent one is the need to provide guidance documents as HeTPoM DSS framework is not self-explanatory.

At the end of the evaluation, a refined HeTPoM DSS framework was derived from the recommendations that are given in the expert workshop. These improvements are listed as follows: 1) a refined customer journey map, 2) expanding the role of the citizens, 3) expanding the policy-making activities, and 4) increasing the ease of use of the HeTPoM DSS framework (by providing additional legend, HeTPoM DSS framework manual documents, and video manual to use the refined HeTPoM DSS framework).

6 Conclusion

The last chapter of this thesis is the thesis conclusion. This chapter concludes this report in four sections. The first section presents the conclusion of the research questions and the answer from these four research questions (Section 6.1) followed by the answer to the main research question. Then contribution to the research and society are presented in Section 6.2. Then limitation of the research is assessed, and future research recommendation is made (Section 6.3). Lastly, a reflection for both Complex System Engineering and Management (CoSEM) study and this research is presented in Section 6.4.

6.1 Conclusion

In an initiative called heat transition, the municipal government of the Netherlands aims to replace energy sources for heating purposes from the conventional to the renewable ones. Although some guides have been offered by different research entities, municipal heat transition is a wicked problem that the municipal policy-makers struggle to grasp. They require a decision support system to help the municipality to systematically combine the power of data in their policy-making process. However, literature that covers the Netherlands heat transition policy decision support system is scarce. Moreover, the literature that comes in multiple dimensions of complexity: technical, social, and economic are sparse.

This thesis was done to fill in this research gap and satisfy the needs from the policy-makers by answering the main research question, **"what decision support system framework can systematically assist municipalities in the heat transition policy-making process?"** Refined municipal heat transition policy-making (HeTPoM) Decision Support System (DSS) framework is designed in this thesis to answer this question.

This thesis applied a design science research approach that adopted from four common design science research phases namely 1) problem identification, 2) identification of possible solutions, 3) design and development, and lastly, 4) evaluation. In each of these phases, research questions are formed to simplify the design process. These four research questions have been answered in Chapter 2 until Chapter 5.

6.1.1 Recap of research questions and answers

Each research questions employs one method to answer them.

The first question *(RQ1: What aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?)* is answered in Chapter 2 using a systematic literature review (SLR) that is adapted from three SLR guidelines. This adapted SLR method consists of three main activities: 1) Planning phase, 2) Conducting the SLR, and 3) Reporting the result of the SLR. The answer from this question is then used to design the case study that is presented in Chapter 3.

In Chapter 3, we use these aspects from Chapter 2 as a base to conduct a case study research to answer the second research question *(RQ2: What are the needs for a decision support system framework to assist municipal heat-transition policy-making?)*. This case study research was done to derive the needs from the three perspectives (policy-makers, researchers, and practitioners) of policy-making (from the municipality of Zoetermeer) for the development of a decision support system framework to support municipalities in making decisions concerning municipal heat transition policy-making. Then these needs are used in Chapter 4 to answer the third research question.

In Chapter 4, needs that are derived in Chapter 3 to create a DSS framework for municipal heat transition policy-making then transformed into and Requirement Breakdown Structure (RBS) to be used to answer the third research question *(RQ3: What decision support system framework can systematically assist municipalities in making decisions concerning municipal heat-transition policy?)*. The design was developed using an adaptation from functional visual communication design from and the engineering design method. Chapter 4 produces a detailed design of municipal Heat transition Policy-making (HeTPoM) Decision Support System (DSS) framework.

This HeTPoM DSS framework then used to answer the fourth research question *(RQ4: What are the potential positive and negative effects of using the municipal heat-transition policy-making decision support system framework?)* using an evaluated in an artificial (ex-ante) evaluation using a concept discussion that was done in an expert workshop (Chapter 5). This chapter then produces the refined HeTPoM DSS framework that is developed by applying evaluation recommendations into the existing design.

These four research questions and their answers are presented as follows:

6.1.1.1 What aspects need to be considered in a decision support system framework for heat transition policy-making by municipalities?

DSS framework defined as an artefact that envisions a basic structural model of a DSS. DSS frameworks are formed by three main elements: 1) database, 2) decision model, and 3) decision dialogue. Database of the system is represented using heat transition influencing factors while the decision model is represented by the policy-making process and actors who are involved in the policy-making (as shown in Figure 6.1).

	Decision model			Database		
	Process		Actors	Heat transition influencing factors		
	Conceptual	Pragmatic		Social	Economy	Technical
DSS Framework	1) Prediction and problem definition 2) Design and experimentation 3) Implementation and evaluation	1) Defines goals 2) Steer heat transition 3) Lead heat transition 4) Enable heat transition	1. Heat transition policy-makers 2) Energy (service) providers 3) Housing providers 4) Citizens	1) Attitude 2) Individual knowledge 3) Individual perception 4) Behaviour 5) Economic power 6) Individual empowerment 7) Established social network 8) Fairness	1) The organisational affair 2) Ownership 3) Path dependency 4) Profitability 5) Energy demands 6) Negotiation 7) Energy national regulation 8) Data regulation	1) Production 2) Consumption 3) Physical transport infrastructure 4) Energy service 5) Data service

Table 6.1 Summary of the answer of the RQ1

In the process side, we can see the policy-making process based on the policy cycle. The simplest presentation came from van Veenstra and Kotterink, (2017): 1) prediction and problem definition, 2) design and experimentation, and 3) implementation and evaluation.

In this process, four groups of actors are defined as follows: 1) the heat transition policy-makers who coordinate the heat transition through regulation, 2) energy service providers (companies) who provide and transport energy, 3). The housing providers, which can be social housing corporations and private real estate businesses, and 4) the citizens who use this energy (house owners or tenants).

In the data side, to support database creation of the DSS, eight social influencing factors, eight economic influencing factors, and five technical influencing factors (total 21 influencing factors) are derived as presented in Table 2.5. First, social heat transition influencing factors are presented based on behavioural control theory. They are listed as follows: 1) attitude (acceptance), 2) individual knowledge, 3) individual perception, 4) behaviour (participation), 5) household economic power, 6) individual empowerment, 7) established social network, and lastly, 8) fairness. Second, eight economic heat transition influencing factors are presented as follows: 1) organisational affair, 2) ownership, 3) path dependency, 4) profitability, 5) energy demands, 6) negotiation, 7) energy national regulation, and 8) data regulation. Lastly, five technical heat transition influencing factors are presented as follows: 1) production, 2) consumption, 3) physical transport infrastructure, 4) energy service, and 5) data service.

6.1.1.2 What are the needs for a decision support system framework to assist municipal heat transition policy-making?

Based on the three lenses of policy, we found that the five main needs for the municipal heat transition DSS framework.

First is that it shall support an open, transparent, and equal municipal policy-making process. As the policy-makers described as the process in the spiderweb where no hierarchy is present. Therefore everyone is equally important and influential in the policy-making process. In this kind of process, instead of substance, the process is much more essential.

Second, the process needs to be able to support key actors needs management. These actors are currently Energy department of the municipality, Stedin, and the social housing corporations (Vestia, Vidomes, and De Goede Woning). However, this set of actors are planned to be expanded with additions from the social department of the municipal office, private house real estate, citizen, and citizen initiatives.

Then third is to supports modularity. As the municipality consists of diverse neighbourhoods, custom solutions for their unique characteristic (neighbourhood profile, building profile, and customer journey phase) need to be accommodated.

Fourth is to supports turning the policy-making substance into process-based governance. This process can be divided into three phases of policy cycles: 1) prediction and problem definition, 2) design and experimentation and 3) implementation and evaluation. In the problem definition phase, six activities are examined in the case study. These activities are 1) data collection, 2) profiling, 3) target setting, 4) stakeholders capability mapping, and 5) stakeholders needs and needs map, 6) broaden the agenda. The design and experimentation phase has seven areas of designs and experimentations, 1) search of solution space for heat transition 2) search for the right marketing strategy, 3) data collection strategy, 4) involvement of models and scenarios, 5) policy codesign, 6) responsibility division, and if needed 7) cooperation with another municipality. However, not many have been done in the evaluation, some part that can be used are 1) enforcement where possible, 2) advising citizen on decision-making, 3) communicate energy transition implication for end-user, 4) communicate feasible options, 5) create a network to improve social cohesion 6) give the educational process for new needed skill, and 7) informing and reassuring citizen.

And lastly is that it needs to be a data-driven process to keep the municipality policies legitimacy. This data includes 27 influencing factors that need to be considered in the policy-making. This information is presented in Table 3.5, Table 3.6, and Table 3.7 and summarised in Table 3.8. We found ten social influencing factors that required to be included in the municipal heat transition policy-making, 1)

Behaviour, 2) Attitude, 3) Capability, 4 Social cohesion, 5) Stakeholder engagement, 6) Demographic profile, 7) Stakeholders profile, 8) Fairness, 9) Uncertain behaviour, and lastly, 10) Stakeholder motivation. We found nine economic heat transition influencing factors in the municipality of Zoetermeer, 1) Society cost, 2) Path dependency, 3) Financial feasibility, 4) Market proposition, 5) National regulation, 6) Responsibility and power to make a decision, 7) Organisational affair, 8) Data gathering and utilisation regulation, and lastly, 9) Conflict of interest. And lastly, we found eight technical municipal heat transition influencing factors, 1) Building criteria, 2) Data digitalisation and utilisation, 3) Technical operation, 4) Technology maturity, 5) Heat source plan, 6) Maintenance and path dependency, 7) Neighbourhood density, and lastly, 8) Future uncertainty.

6.1.1.3 What decision support system framework can systematically assist municipalities in making decisions concerning municipal heat transition policy?

HeTPoM municipal heat transition DSS framework is made based on a functional visual design method. The needs of HeTPoM DSS framework are derived from the Zoetermeer heat transition policy-making needs based on three lenses of policy perspectives (i.e. practitioners, policy-makers, and researchers). The purpose of heat transition policy-making (HeTPoM) DSS framework creation is to support policy-makers. The heat transition policy-making (HeTPoM) DSS framework provides policy-making with activities that are guided by a profile that is determined in the first step of the activity (prediction and problem definition phase), such as data collection, stakeholders needs and requirement analysis and policy target profiling. Also, the heat transition policy-making (HeTPoM) DSS framework provides suggestions regarding influencing factors, processes, and involved actors in each of these activities. Policy-makers can use this suggestion as a systematic guide for their process in creating municipal heat transition policy as well as communication tools to be used together with stakeholders. Thus, using HeTPoM DSS framework both parties (i.e. policy-makers and municipal heat transition stakeholders) can communicate on how they want to co-design the municipal heat transition policy.

6.1.1.4 What are the potential positive and negative effects of using the municipal heat-transition policy-making decision support system framework?

The functionality of HeTPoM DSS framework was stated to potentially be able to be used in the joint process of co-creation of policy to systematically design, assess, and evaluate heat transition policies. Thus, it was stated that HeTPoM can be used by professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. It was discussed that HeTPoM can be used to make people aware of the policy-making process at the municipal level and can be used by the municipality to support citizen inclusion in their policy-making. However, some limitations were also examined in the evaluation in the case of ease of use, structural modularity, and completeness. A list of recommendation is provided to refine the framework. The most urgent one is the need to provide guidance documents as HeTPoM DSS framework is not self-explanatory.

At the end of the evaluation, a refined HeTPoM DSS framework was derived from the recommendations that are given in the expert workshop. These improvements are listed as follows: 1) a refined customer journey map, 2) expanding the role of the citizens, 3) expanding the policy-making activities, and 4) increasing the ease of use of the HeTPoM DSS framework (by providing additional legend, HeTPoM DSS framework manual documents, and video manual to use the refined HeTPoM DSS framework).

6.1.2 Addressing the main conclusion: what decision support system framework can systematically assist municipalities in the heat transition policy-making process?

The answer from these four research questions lead to the following formulation to answer the main research question, **"what decision support system framework can systematically assist**

municipalities in the heat transition policy-making process?" To support the municipal heat transition policy-making process, a decision support system that is specified to be used in the context of municipal heat transition policy-making is imperative. The usage of the context of *municipal heat transition policy-making in the Netherlands* implies that four criteria need to be addressed in this context (i.e. the phenomena of heat transition, municipal level actors, policy-making system, and geographic area of the Netherlands). Considering these criteria and the DSS system components (i.e. database and decision model), a refined HeTPoM DSS framework is proposed to answer the needs of municipalities in the Netherlands to systematically assist them in the policy (co-)creation process.

The refined HeTPoM DSS framework is made based on a functional visual design method to cater to the needs of DSS creation in the context of *municipal heat transition policy-making in the Netherlands*. The requirements of HeTPoM DSS framework needs are derived from a Zoetermeer heat transition policy-making case study analysis with thirteen interviews as the main data collection method. These needs then translated into requirements. These DSS requirements were framed under two main subjects: influencing factors and the policy-making process.

The refined HeTPoM DSS framework serves its function by integrating five main components. First is three dimensions profiling of policy-target. These three dimensions are 1) neighbourhood profile (presented as a social influencing factor), 2) building ownership profile (presented as an economic influencing factor), and policy target behaviour (presented as a branch in the policy-cycle). The second component is a four policy cycle (based on the policy-target behaviour stage) with shared "prediction and problem definition" phase. The third component is the data-driven decision support system framework that is needed in each phase of the policy. This decision support system framework is replicated to make the decision support system framework for the whole cycle of the policy. The fourth component is the main actors in each phase of the policy cycle. Both existing and future actors are mapped here. The last component is municipal heat transition (social, economic, and technical) influencing factors that filling in the data and model input of the meta decision support system inside heat transition policy-making (HeTPoM) DSS framework.

The primary purpose of the refined HeTPoM DSS framework creation is to support policy-makers policy to design, assess, and evaluate the policy in the municipal heat transition. Policy-makers can use this suggestion as a systematic guide for their process in creating municipal heat transition policy as well as communication tools to be used together with stakeholders. That way, both (policy-makers as well as municipal heat-transition stakeholders) can communicate on how they want to co-design the municipal heat transition policy. To serve its purpose, the refined HeTPoM DSS framework is equipped with users manual and video tutorial to use the framework.

As currently the refined HeTPoM DSS framework was made based on the needs taken from the case of the municipality of Zoetermeer, a generalisation will be needed before HeTPoM can be used further for more municipalities in the Netherlands. However, municipalities in the Netherlands might also be able to use the refined HeTPoM DSS framework when they carry these characteristic as follow: 1) located within the area of the Netherlands, 2) each neighbourhood in the municipality is occupied by a diverse population, 3) in the municipality, exist communities that are extremely active in the energy transition as well as communities who are apathetic to the heat transition, 4) in the municipality, exist, people, who are too occupied by their problem to start to think about heat-transition, 5) have not decided on any district heating system in their area.

6.2 Contribution to the research and society

6.2.1 Social contribution

This research contributed to the society by providing an artefact that can potentially be used to assist a systematic municipal heat transition policy-making process. As the step by step of policy-making that is based on policy-target profiling is explicit in the refined HeTPoM DSS framework, a systematic guide for policy-making in the municipal heat transition can be potentially assisted. HeTPoM DSS framework provides policy-making with activities that are guided by a profile that is determined in the first step of the activity (prediction and problem definition phase), such as data collection, stakeholders needs and requirement analysis and policy target profiling. Also, the HeTPoM DSS framework provides suggestions regarding influencing factors, processes, and involved actors in each of these activities. Policy-makers can use this suggestion as a systematic guide for their process in creating municipal heat transition policy as well as communication tools to be used together with stakeholders. An evaluation of Zoetermeer policy-making process by experts was demonstrated in this thesis and reported in Section 5.2.2.

Moreover, the HeTPoM DSS framework can also potentially be used in the process of policy design co-creation for the municipality policy-makers, researchers, and municipal heat transition stakeholder (e.g. citizen initiatives, housing corporations) by providing a common framework to communicate the policy. This can be done because the HeTPoM DSS framework can be used to ease communication of the municipal heat transition policy-making for professionals, people from the municipality (policy-makers), university (research and education), or by energy community initiatives. With the same communication tools, we can argue that with the right communication means, more participant in the policy co-creation can be involved.

Which also means that the refined HeTPoM DSS framework can potentially be used to help to share municipal policy-making in heat transition for education purpose. This framework can be used by teachers or policy-makers to share their knowledge for students or other stakeholders of the municipal heat transition policy-making. Therefore, increase awareness of the municipal heat transition policy-making. With higher awareness of the municipal policy-making process, more input can be given to the government.

Finally, the refined HeTPoM DSS framework can potentially be used as a base to create a computerised municipal heat transition policymaking DSS. In the development of municipal heat transition policy-making DSS, the refined HeTPoM DSS framework can be used as a communication tool between system developers, policy-makers, and researchers. However, some additional works still need to be done to develop the DSS from the refined HeTPoM DSS framework (see Section 6.3.1).

6.2.2 Scientific contribution

This research enriched the body of knowledge on the evidence-based policy research as well as policy lab research by providing an evaluated empirical municipal heat transition DSS framework of municipal heat transition policy-making (HeTPoM). Gachet and Sprague (2005) mentioned that it is important that a DSS framework is made within a context. However, literature in the DSS framework on the heat transition is still scarce, mostly ones that also provide the geographical context in the Netherlands. For example, Hettinga et al. (2018) provide the design of a DSS for a multi-stakeholder local neighbourhood energy planning. However, this literature has not integrated the DSS system with either heat-transition influencing factors, policy profiling, or the concept of policy-cycles. Therefore, there is a knowledge gap of an integrated DSS framework with the policy system (policy cycle) that is context-specific on the municipal heat transition. This thesis enriched the knowledge of the context-based DSS framework with policy cycle and policy profiling integrations for a municipal heat transition in the Netherlands. In the process of creating an empirical context-based DSS for a municipal heat transition in the Netherlands, we derived five additional scientific contributions.

First, we derived twenty-four municipal heat transition influencing factors that need to be taken into consideration when making a municipal heat transition policy as well as their classifications. Also, we have empirically assessed and expanded these 24 municipal heat transitions influencing factor using a study case. Which then resulted in a twenty-seven municipal heat transition influencing factors. These influencing factors have also been evaluated using an ex-ante evaluation method in an expert interview. Understanding of these influencing factors is related to the database that will be needed in a decision support system of municipal heat transition policy-making.

Literature mentioned these influencing factors (e.g. El Geneidy & Howard, 2020; Paiho & Saastamoinen, 2018; Späth & Rohracher, 2015). However, their research either lacks geographical context (e.g. El Geneidy & Howard (2020)) or was conducted from other countries which might experience different influencing factors (e.g. Paiho & Saastamoinen (2018) research in Sweden or Späth and Rohracher (2015) research in Germany). Localisation is critical for social influencing factors because they are dependent highly to the government strategy as well as local culture. In this research, we derived heat transition influencing factors from the SLR from 57 articles and assess these influencing factors using a case study. In the process, we clarify a more suitable heat transition influencing factors by 1) disposal of unrelated heat transition influencing factors, 2) modification of heat transition influencing factors category, and 3) addition of new heat transition influencing factors category.

Second, we enriched the body of knowledge in the municipality policy-making by mapping municipality activities to define, assess, and communicate a municipal heat transition policy-making into policy cycles. Current literature (Bush et al., 2016; Bush & Bale, 2019; van Veenstra & Kotterink, 2017)usually more focus on either the policy cycle to assess a policy or pragmatic activities (e.g. data collection, build simulation, policy co-design). However, in this case, we add to the body of knowledge the relation between a context-based (context: municipal heat transition) policy-making that explicitly provides empirical information on the policy-making activities based on the policy cycle.

Third, we provide a localised actor's dynamic in the municipality of Zoetermeer. These actors can be actors who have been working in the heat transition system in the Netherlands as well as the municipality plan in the future. Paiho and Saastamoinen (2018), Bickel (2017), Busch et al. (2017), Bush and Bale (2019), Büttner and Rink (2019), Lygnerud (2018), and Viétor et al. (2015) provides information about the potential actor in the heat transition. Differently, this thesis contributes by enriching the body of knowledge with specific local information. As actors' dynamics is quite local and specific, the contribution is to confirm these dynamics and narrate them explicitly in the specific case of Zoetermeer municipal heat transition policy-making 2020. In addition, these dynamics have also been mapped into a combination of the policy cycle and customer journey phases, which has not been done in the evaluated literature.

Fourth, this study has allowed us to assess a municipal heat transition policy-making process as well as influencing factors inside them based on the three perspectives, 1) decision support system study, 2) business (customer journey phase) study, and 3) policy study. These new combined perspectives can support the multidisciplinary researcher to recognise their part of the case. In the case of Paiho and Saastamoinen (2018) research on the heat transition actors dynamic with the policy, their analysis has not discussed the connection between these factors in the heat transition.

And lastly, this study provides the refined HeTPoM DSS framework that can be used as a base for a computerised municipal heat transition DSS. As the refined HeTPoM DSS framework has been made in the context of municipal heat transition policy-making, after generalisation process, further research on the heat transition mechanism (such as the correlation between heat-transition factors), and technological needs of the DSS system, a heat transition policy-making DSS can be potentially developed. This work is complementing Hettinga et al. (2018) DSS work (who has also designed the technological needs in DSS) by introducing the integration of DSS with a policy cycle and policy profiling model.

Although these contributions are designed from local needs of the municipality of Zoetermeer, municipalities in the Netherlands might also be able to use the same system when they carry these characteristic as follow: 1) located within the area of the Netherlands, 2) each neighbourhood in the municipality is occupied by a diverse population, 3) in the municipality, exist communities that are extremely active in the energy transition as well as communities who are apathetic to the heat transition, 4) in the municipality, exist, people, who are too occupied by their problem to start to think about heat-transition, 5) have not decided on any district heating system in their area. **However, further research to confirm generality needs to be conducted before a further conclusion is made.**

6.3 Reflection on the thesis limitation and recommendation for future research

The thesis research has been done in approximately five months with a single available researcher. Although incredible support was gained from several essential groups of stakeholders (i.e. TNO, municipality of Zoetermeer policy-makers, citizen initiatives, energy transportation companies, and research institutes), the limitation of the available resources (i.e. human power and time) has limited this research scope. In this section, the reflection of the thesis limitation that is formed due to the scoping choices is presented together with the future research recommendation. Four limitations are discussed as follows with recommendations to follow up on the thesis research.

6.3.1 Bigger scope cr*eates more holistic research instead of deeper research*

The first limitation comes from the thesis scoping. This research scope is quite wide that we need to sacrifice deeper detail of the DSS framework components (e.g. to what extent does behaviour influencing factors helps policy-making?). Going with a bigger scope allows a holistic analysis of the concept. But going in a smaller scope might increase the detail of the research. Thus, although this DSS framework is helpful is supporting municipal policy-makers, researchers, and heat transition stakeholders to design, assess, and evaluate the policy-making process in municipalities, this HeTPoM DSS framework cannot be used directly to be the base of a digitised DSS system.

To go to further research in the digitised DSS system for municipal heat transition policy-making, deeper analysis on the mechanism and complexity of each component of HeTPoM DSS framework are required. Thus, it is recommended to research further on a much smaller scope. These details will be needed in a logic machine such as a computer (that will be used in a DSS). Example of this focus can be the social influencing factors or the role of citizen initiatives in the municipal heat transition policy-making. By taking a much smaller subject in emerging phenomena like citizen initiatives, can help this entity to be recognised and help them to also position themselves in the established heat transition system. Therefore, give the mechanism that is needed to be embedded into the computerised municipal heat transition DSS.

This then leads into two types of future research recommendations that need to be done in series. First is the HeTPoM DSS framework components mechanism study (i.e. the interaction between municipal heat transition influencing factors and the policy-making process). Which then can be followed by digital architecture of the DSS system to support the development of municipal heat transition DSS.

6.3.2 SLR limitation on the derived conceptualised model

The systematic literature review was done with limited resources (i.e. human power and time). Therefore, there was no time to explore more research to create a more detail conceptual model. Moreover, there is also limitation from the tools that are used to do the SLR/ I used SLR using tables (e.g. Microsoft Excel tables) as a note's device, which is a powerful tool for a limited number of articles. However, if more articles are included, SLR will be easier to be done using qualitative data analysis tools (e.g. Atlas.ti, NVivo) instead of tables. Classification and coding can be done to ease the process of analysis with a more systematic analysis approach. That way, more information can be included as the source of the conceptual model.

Then, as the growing number of articles after an extensive exploration of literature, categorisation and conceptualisation of the heat transition DSS framework components can be done more comprehensively. The categorisation (on both the result of SLR and case study) can be made more specific with causation. If more time is available, this causation can also be searched to see how these data influence each other.

6.3.3 Case study selection and the limitation of the single case study

As a single case study allow more focusing resources on a specific subject which allows a deeper understanding of the specific case. This limitation is the reason for this single case study choice. However, a single case study is also limited to their capability to use several cases to explore either comparative or generalisation of the derived theory (Yin & Davis, 2007). A single case study is limited in its ability to be replicated.

Moreover, the municipalities of the Netherlands are quite diverse. Therefore, the theory that is derived (on the needs of the municipal heat transition policy-making DSS framework) is not proven to be valid for other municipalities than Zoetermeer municipality. To answer this limitation, replicated research for a multiple-case study is recommended. Therefore, generalisation and replication of the theory can be evaluated.

Furthermore, this case study has only used qualitative analysis method to derive the conclusion. This case study analysis was deemed sufficient as this thesis was done without the perspective of the citizen in general. Perspectives from the heat-transition policy-makers and companies are more uniform than ones from citizens. However, this qualitative analysis might not be proper to address the view of the citizen who lives in the municipalities that are quite diverse. Therefore, to improve the reliability of the case study, quantitative (or mixed) method to gather citizen perspectives might be necessary.

6.3.4 Evaluation method of the framework does not include the complexity factors that can happen in the real world

The evaluation method used in this research is an ex-ante artificial evaluation. Thus, the result of this research has not been tested with the complexity of the real world. This caused limitation on the evaluation of the framework that might be shown during the real case use of the artefact by policy-makers. Moreover, the number of the respondent in the evaluation that is quite limited (three experts) with only academic perspectives This evaluation method choice then also gives a limited view of the functionality and usage of the HeTPoM DSS framework.

Thus, more evaluation and validation of the study is also recommended as an interesting subject that can be explored. This validation can be done by a different method than the ones that already done, ex-ante artificial evaluation. Or the validation can be done with bigger evaluator so either mixed or quantitative analysis. Evaluation workshop needs to be made with the policy-makers involvement as well as municipal heat transition stakeholders. It would be better to use a real case of a certain area in the neighbourhood (ex-ante naturalistic evaluation). This will give feedback on HeTPoM on the complexity of the real world. Also, evaluation to a wider audience using a video tutorial and questionnaire.

6.4 Thesis Reflection on the Complex System Engineering and Management (CoSEM) program study

In these five and a half months, I have been using the material that I have learned from the CoSEM Master program into my thesis. I am using both process management approaches as well as system engineering approaches in the design of HeTPoM. I recognised design components (e.g. functional requirements, non-functional requirements) as well as process management components (e.g. analogy, broaden the agenda strategies, and turning content into process-based activities) when I am working on my design of HeTPoM DSS framework. In this thesis, I learned how to create a tool that is used to address technological issues (heat transition) based on the stakeholders' (both from private and public domains) needs.

Besides, in this thesis, I also learned how to systematically design a complex system. I started by using systematic approaches (e.g. design engineering approach, SLR approach, case study approach, and evaluation) and ended with a creative analysis on how municipal heat transition policy-making is working. In other words, in each phase of the research, CoSEM tools and techniques were used to guide both systematic methodology and creative thinking.

Moreover, my classes on the energy institution were especially useful in my thesis, as well as the subjects of complexity, network design, and multi-actor decision-making. Particularly the courses that covered institutions, governance as well as multi-actor decision-making problems were truly relevant. Learning from this subject, I was able to see how the municipality is trying to do an activity called "broadening the agenda" and "turning a substance based on a process-based activity." From the alignment framework, I also got trained to think about the institution of technology and vice versa. My study has prepared me to do my thesis well.

In February, I saw that this thesis is a challenging subject with methods that can improve my research skill as well as the understanding of the energy system. I think that in CoSEM, we are more trained to make quantitative experimentation that will be turned to qualitative analysis. Therefore, a full qualitative method was quite challenging. However, I gladly took on this challenge because I wanted to learn how to conduct a qualitative study.

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Appendixes

Appendix I. Literature research

Appendix I.1. Literature used in the SLR publisher index and summary

Index	Publisher	#Papers
a	A+BE Architecture and the Built Environment	1
b	Applied Energy	9
c	California Management Review	1
d	Decision Support Systems	4
e	Energies	3
f	Energy	2
g	Energy Efficiency	1
h	Energy Policy	6
i	Energy Research and Social Science	2
j	Energy, Sustainability and Society	2
k	Environment and Planning A	1
l	Erde	1
m	Government Information Quarterly	1
n	Journal of Cleaner Production	3
o	Journal of Environmental Planning and Management	1
p	MIS Quarterly: Management Information Systems	1
q	Proceedings of the Institution of Mechanical Engineers	1
r	Public Management Review	1
s	Renewable and Sustainable Energy Reviews	2
t	Renewable Energy	2
u	Resources, Conservation and Recycling	1
v	Solar Energy	3
w	Sustainability (Switzerland)	2
x	Sustainable Cities and Society	1
y	Sustainable Production and Consumption	1
	Total journals	**53**
c1	Energy Procedia	1
c2	IEEE International Conference on Systems, Man and Cybernetics	1
c3	CEUR Workshop Proceedings	1
c4	Lecture Notes in Computer Science	1
	Total conferences	**4**

Appendix I.2. Scientific articles used in the SLR publisher detail

(please refer to the index in Appendix I.1.)

Author, year	a	b	c	c1	d	e	f	g	h	c2	i	j	k	l	m	c3	n	o	c4	p	q	r	s	t	u	v	w	x	y	
Sprague & Watson (1979)			X																											
Sprague (1980)																				X										
Konsynski & Sparague (1986)					X																									
Sprague (1987)					X																									
Sage (1991)																X														
Barron et.al. (1999)					X																									
Shim et.al (2002)					X																									
Gachet & Sprague (2005)				X																										
Debizet et al. (2015)																	X													
Jensen et al. (2015)													X																	
K. O. Lee et al. 2015)		X																												
Li et al. (2015)																							X							
Späth & Rohracher 2015)									X																					
Viétor et al. (2015)												X																		
Bush et al. (2016)									X																					
Chwieduk 2016)																										X				
Long et al. 2016)		X																												
Paiho & Reda (2016)																							X							
Sager-Klauß (2016)	X																													
Zdankus et al. 2016)																											X	X		
Abdurafikov et al. (2017)																													X	
Astudillo et al. 2017)		X																												
Bickel (2017)												X																		
Busch et al. (2017)									X																					

Calise et al. (2017)																													
Darby (2017)																													
Leurent et al. (2017)																													
Nciri & Miller (2017)																													
Pearson & Arapostathis (2017)																													
van Veenstra (& Kotterink,2017)																													
Wahlroos et al (2017)																													
Bloemendal et al. 2018)																													
Finck et al. 2018)																													
Han et al. 2018)																													
Hondula et al. (2018)																													
Kerimray et al. (2018)																													
Janssen & Helbig 2018)																													
Paiho & Saastamoinen 2018)																													
Sernhed et al. (2018)																													
Shaffer et al. (2018)																													
Upham et al. (2018)																													
Wijesuriya et al. 2018)																													
Bush & Bale (2019)																													
Büttner & Rink (2019)																													
Domenech et al. (2019)																													
Fabiani et al. 2019)																													
Gillich et al. (2019)																													
Knobloch et al. 2019)																													
Stropnik et al. 2019)																													
Aberilla et al. (2020)																													

Artur et al. (2020)																	■												
Diran et al. (2020)						■																							
El Geneidy & Howard 2020)		■																											
Gan & Xiang (2020)																								■					
Gorroño-Albizu (2020)						■																							
Qu et al. (2019)																								■					
Rissman et al. (2020)		■																											
Sum	1	9	1	1	4	3	2	1	6	1	2	2	1	1	1	1	3	1	1	1	1	1	2	2	1	3	2	1	1

Appendix I.3. Literature used in the SLR list

No	Author	Year	Source	Title
1	Sprague, R.H., Watson, H.J.	1979	California Management Review 22(1), pp. 60-68	Bit by Bit: Toward Decision Support Systems
2	Sprague Jr., R.H.	1980	MIS Quarterly: Management Information Systems 4(4), pp. 1-26	A framework for the development of decision support systems
3	Konsynski, B., Sprague Jr., R.H.	1986	Decision Support Systems 2(1), pp. 103-109	Future research directions in model management
4	Sprague Jr., R.H.	1987	Decision Support Systems 3(3), pp. 197-202	DSS in context
5	Sage, Andrew P.	1991	Proceedings of the IEEE International Conference on Systems, Man and Cybernetics 3, pp. 1978-1983	A dialogue generation and management system for conflict analysis
6	Barron, T.M., Chiang, R.H.L., Storey, V.C.	1999	Decision Support Systems 25(1), pp. 1-17	A semiotics framework for information systems classification and development
7	Shim, J.P., Warkentin, M., Courtney, J.F., Power, D.J., Sharda, R., Carlsson, C.	2002	Decision Support Systems 33(2), pp. 111-126	Past, present, and future of decision support technology
8	Gachet, A., Sprague, R.	2005	CEUR Workshop Proceedings 144	A context-based approach to the development of decision support systems
9	Debizet, G., Tabourdeau, A., Gauthier, C., Menanteau, P.	2015	Journal of Cleaner Production 134, pp. 330-341	Spatial processes in urban energy transitions: considering an assemblage of Socio-Energetic Nodes
10	Jensen, J.S., Lauridsen, E.H., Fratini, C.F., Hoffmann, B.	2015	Environment and Planning A 47(3), pp. 554-570	Harbour Bathing and the Urban Transition of Water in Copenhagen: Junctions, Mediators, and Urban Navigations
11	Lee, K.O., Medina, M.A., Raith, E., Sun, X.	2015	Applied Energy 137, pp. 699-706	Assessing the integration of a thin phase change material (PCM) layer in a residential building wall for heat transfer reduction and management

12	Li, H., Sun, Q., Zhang, Q., Wallin, F.	2015	Renewable and Sustainable Energy Reviews42, pp. 56-65	A review of the pricing mechanisms for district heating systems
13	Späth, P., Rohracher, H.	2015	Energy Policy 78, pp. 273-280	Conflicting strategies towards sustainable heating at an urban junction of heat infrastructure and building standards
14	Viétor, B., Hoppe, T., Clancy, J.	2015	Energy, Sustainability and Society 5(1)	Decentralised combined heat and power in the German Ruhr Valley; assessment of factors blocking uptake and integration
15	Bush, R.E., Bale, C.S.E., Taylor, P.G.	2016	Energy Policy 98, pp. 84-96	Realising local government visions for developing district heating: Experiences from a learning country
16	Chwieduk, D.A.	2016	Solar Energy 133, pp. 194-206	Some aspects of the energy-efficient building envelope in high latitude countries
17	Long, L., Ye, H., Liu, M.	2016	Applied Energy 183, pp. 685-699	A new insight into opaque envelopes in a passive solar house: Properties and roles
18	Paiho, S., Reda, F.	2016	Renewable and Sustainable Energy Reviews 65, pp. 915-924	Towards next generation district heating in Finland
19	Sager-Klauß, C.V.	2016	A+BE Architecture and the Built Environment 5, pp. 1-374	Energetic communities: Planning support for the sustainable energy transition in small- and medium-sized communities
20	Zdankus, T., Cerneckiene, J., Jurelionis, A., Vaiciunas, J.	2016	Sustainability (Switzerland) 8(7),637	Experimental study of a small scale hydraulic system for mechanical wind energy conversion into heat
21	Abdurafikov, R., Grahn, E., Kannari, L., (...), Heimonen, I., Paiho, S.	2017	Sustainable Cities and Society 32, pp. 56-66	An analysis of heating energy scenarios of a Finnish case district
22	Astudillo, M.F., Vaillancourt, K., Pineau, P.-O., Amor, B.	2017	Applied Energy 205, pp. 486-498	Can the household sector reduce global warming mitigation costs? sensitivity to key parameters in a TIMES techno-economic energy model
23	Bickel, M.W.	2017	Energy, Sustainability and Society 7(1),22	A new approach to semantic sustainability assessment: text mining via network analysis revealing transition patterns in German municipal climate action plans
24	Busch, J., Roelich, K., Bale, C.S.E., Knoeri, C.	2017	Energy Policy 100, pp. 170-180	Scaling up local energy infrastructure; An agent-based model of the emergence of district heating networks

25	Calise, F., D'Accadia, M.D., Barletta, C., (...), Pfeifer, A., Duic, N.	2017	Energies10(10),1535	Detailed modelling of the deep decarbonisation scenarios with demand response technologies in the heating and cooling sector: A case study for Italy
26	Darby, S.J.	2017	Energy Research and Social Science 31, pp. 120-127	Coal fires, steel houses and the man in the moon: Local experiences of the energy transition
27	Leurent, M., Jasserand, F., Locatelli, G., (...), Rämä, M., Trianni, A.	2017	Energy Policy 107, pp. 138-150	Driving forces and obstacles to nuclear cogeneration in Europe: Lessons learnt from Finland
28	Nciri, A., Miller, B.	2017	Erde 148(4), pp. 212-228	Energy systems, socio-spatial relations, and power: The contested adoption of district heating with combined heat and power in Sweden, 1945-2011
29	Pearson, P.J.G., Arapostathis, S.	2017	Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 231(6), pp. 478-497	Two centuries of innovation, transformation and transition in the UK gas industry: Where next?
30	van Veenstra, A.F., Kotterink, B.	2017	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 10429 LNCS, pp. 100-111	Data-Driven Policy Making: The Policy Lab Approach
31	Wahlroos, M., Pärssinen, M., Manner, J., Syri, S.	2017	Energy 140, pp. 1228-1238	Utilizing data centre waste heat in district heating – Impacts on energy efficiency and prospects for low-temperature district heating networks
32	Bloemendal, M., Jaxa-Rozen, M., Olsthoorn, T.	2018	Applied Energy 216, pp. 534-557	Methods for the planning of ATES systems
33	Finck, C., Li, R., Kramer, R., Zeiler, W.	2018	Applied Energy 209, pp. 409-425	Quantifying demand flexibility of power-to-heat and thermal energy storage in the control of building heating systems
34	Han, Z., Bai, C., Ma, X., Li, B., Hu, H.	2018	Solar Energy 174, pp. 45-54	Study on the performance of solar-assisted transcritical CO2 heat pump system with phase change energy storage suitable for rural houses
35	Hondula, D.M., Kuras, E.R., Longo, J., Johnston, E.W.	2018	Public Management Review20(5), pp. 746-765	Toward precision governance: infusing data into public management of environmental hazards

36	Kerimray, A., Suleimenov, B., De Miglio, R., (...), Amouei Torkmahalleh, M., Ó Gallachóir, B.P.	2018	Journal of Cleaner Production 196, pp. 1532-1548	Investigating the energy transition to a coal-free residential sector in Kazakhstan using a regionally disaggregated energy systems model
37	Marijn Janssen, Natalie Helbig	2018	Government Information Quarterly 35(4), pp. S99-S105	Innovating and changing the policy-cycle: Policy-makers be prepared!
38	Paiho, S., Saastamoinen, H.	2018	Energy Policy 122, pp. 668-676	How to develop district heating in Finland?
39	Sernhed, K., Lygnerud, K., Werner, S.	2018	Energy 151, pp. 126-132	Synthesis of recent Swedish district heating research
40	Shaffer, B., Flores, R., Samuelsen, S., (...), Mizzi, R., Kuitunen, E.	2018	Energy Procedia 149, pp. 25-38	Urban Energy Systems and the Transition to Zero Carbon - Research and Case Studies from the USA and Europe
41	Upham, P., Dütschke, E., Schneider, U., (...), Klapper, R., Bögel, P.	2018	Energy Research and Social Science 37, pp. 163-174	Agency and structure in a sociotechnical transition: Hydrogen fuel cells, conjectural knowledge and structuration in Europe
42	Wijesuriya, S., Brandt, M., Tabares-Velasco, P.C.	2018	Applied Energy 222, pp. 497-514	Parametric analysis of a residential building with phase change material (PCM)-enhanced drywall, precooling, and variable electric rates in a hot and dry climate
43	Bush, R.E., Bale, C.S.E.	2019	Journal of Environmental Planning and Management 62(12), pp. 2186-2209	Energy planning tools for low carbon transitions: an example of a multicriteria spatial planning tool for district heating
44	Büttner, L., Rink, D.	2019	Sustainability (Switzerland) 11(21),6065	The urban transition of the heat sector in Leipzig toward a post-fossil city?
45	Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., Roman, L.	2019	Resources, Conservation and Recycling 141, pp. 76-98	Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy
46	Fabiani, C., Pisello, A.L., Bou-Zeid, E., Yang, J., Cotana, F.	2019	Applied Energy 247, pp. 155-170	Adaptive measures for mitigating urban heat islands: The potential of thermochromic materials to control roofing energy balance

47	Gillich, A., Saber, E.M., Mohareb, E.	2019	Energy Policy 133,110889	Limits and uncertainty for energy efficiency in the UK housing stock
48	Knobloch, F., Pollitt, H., Chewpreecha, U., Daioglou, V., Mercure, J.-F.	2019	Energy Efficiency 12(2), pp.521-550	Simulating the deep decarbonisation of residential heating for limiting global warming to 1.5 °C
49	Stropnik, R., Koželj, R., Zavrl, E., Stritih, U.	2019	Solar Energy 190, pp. 420-426	Improved thermal energy storage for nearly zero energy buildings with PCM integration
50	Aberilla, J.M., Gallego-Schmid, A., Stamford, L., Azapagic, A.	2020	Sustainable Production and Consumption 22, pp. 1-23	An integrated sustainability assessment of a synergistic supply of energy and water in remote communities
51	Artur, C., Neves, D., Cuamba, B.C., Leão, A.J.	2020	Journal of Cleaner Production 260,121043	Domestic hot water technology transition for solar thermal systems: An assessment for the urban areas of Maputo city, Mozambique
52	Diran, D., Hoppe, T., Ubacht, J., Slob, A., Blok, K.	2020	Energies 13(2),444	A data ecosystem a data-driven thermal energy transition: Reflection on current practice and suggestions for re-design
53	El Geneidy, R., Howard, B.	2020	Applied Energy 263,114600	Contracted energy flexibility characteristics of communities: Analysis of a control strategy for demand response
54	Gan, G., Xiang, Y.	2020	Renewable Energy 150, pp. 12-22	Experimental investigation of a photovoltaic thermal collector with energy storage for power generation, building heating and natural ventilation
55	Gorroño-Albizu, L.	2020	Energies 13(6),1508	The benefits of local cross-sector consumer ownership models for the transition to a renewable smart energy system in Denmark. An exploratory study
56	Qu, Y., Chen, J., Liu, L., (...), Wu, H., Zhou, X.	2020	Renewable Energy 150, pp. 1127-1135	Study on properties of phase change foam concrete block mixed with paraffin / fumed silica composite phase change material
57	Rissman, J., Bataille, C., Masanet, E., (...), Dinkel, J., Helseth, J.	2020	Applied Energy 266,114848	Technologies and policies to decarbonize global industry: Review and assessment of mitigation drivers through 2070

Appendix I.4. Overview of influencing factors mentioned in the literature

Author and year	Technical factors	Economic factors	Social factors
Han et al., 2018	Solar assisted heat pump	-	-
Späth & Rohracher, 2015	Passive house standard	Decision-making institution on policy priorities	-
	Co-generation of heat and power CHP combined with district heating systems DHS		
Fabiani et al., 2019	Advanced urban roofing material	-	-
K. O. Lee et al., 2015	PCMTS	-	-
Astudillo et al., 2017	Heat pump	-	-
	Biomass boiler		
Stropnik et al., 2019	PCM thermal storage	-	-
Wijesuriya et al., 2018	PCM peak demand shaving	-	-
Long et al., 2016	Opaque envelopes	-	-
Knobloch et al., 2019	-	Carbon tax	Behavioural decision-making
El Geneidy & Howard, 2020	Heat pump	Demands side management: notice, penalties, incentive	Behaviour and preferences
Finck et al., 2018	A heat pump or electric heater with water, PCM, thermochemical material tanks building flexibility	-	-
Chwieduk, 2016	Multilayer structures of external walls	-	-
Bloemendal et al., 2018	ATES for seasonal heating	-	-
Zdankus et al., 2016	Mechanical wind energy conversion into heat	-	-
Paiho & Saastamoinen, 2018	Focusing on new productions alternatives	Data utilization to connect with end-users	-
Gan & Xiang, 2020	PCM thermal storage also as PV heat regulator	-	-
Qu et al., 2019	Foam concrete blocks composite PCM	-	-
Rissman et al., 2020	-	Policy evaluation	-
Artur et al., 2020	Building type	Energy demands	New technology adoption attitude
		Load management policy	
		Peak demands	
		Household income	
Gillich et al., 2019	-	-	-
Domenech et al., 2019	-	-	-
Kerimray et al., 2018	Infrastructure age	Annual cost	Poverty
	Passive house choices	Net present value	
	Geolocation	Discount rate	

		Occupancy rate Energy demands	
Hondula et al., 2018	-	-	-
Upham et al., 2018	Niche, regime, and landscape feature	Niche, regime, and landscape feature	Attitude Norm Values Habit Cognitive frames
Calise et al., 2017	Energy demands Energy exchange Energy production Industrial energy demands	-	-
Heinisch et al., 2019	Availability of electricity from local solar PV and thermal storage	Uncertain biomass prices Local pricing Actors collaborations	-
Seidl et al., 2019		Ownership and responsibilities	Acceptance
Lygnerud, 2018	Digitalization	Business model	Trust Loyalty Long term interaction Customer value
von Wirth et al., 2018	Technical and financial feasibility	Local co-ownership	Acceptance Awareness of local benefit
Aberilla et al., 2020	Human health Security of supply Use of local resources Safety	Job creation	Social acceptability
Büttner & Rink, 2019	-	-	-
Bush & Bale, 2019	-	Poverty Building ownership	Lifestyle
Darby, 2017	Location	Income	Knowledge Story
Pearson & Arapostathis, 2017	-	-	-
Busch et al., 2017	-	Local authorities involvement Capital financing	Support for community organization
Nciri & Miller, 2017	Territory, place, scale, and networks		-
Sager-Klauß, 2016	Built environment Energy demands	-	Interest
Gorroño-Albizu, 2020	Local cross-sector integration	Local ownership Infrastructure investment	Acceptance
Musall & Kuik, 2011	-	Community ownership	Acceptance
Li et al., 2015	-	Pricing mechanisms for district heating systems	-

Appendix II Case Study Interview process and list of questions

1. Introduction (5 min)

I am Mustika Siti Hajarini, a last year master student at *Delft University of Technology*. I am doing this interview my graduation project, *"A Case Study into Municipal Heat transition: Data-Driven Policy-making Tool."* The purpose of this research study is to understand the stakeholder requirements on a DSS framework that can be used to support municipal heat transition policy-making. This interview will be recorded in audio and then transcribed. The transcript then will be sent back to you for your approval.

After the project is finished, the audio recording will be destroyed six months after the end of the project. The approved written transcript derived from this activity will be securely archived in the local computers at TU Delft in the. Aggregated data (anonymous) will be shared openly in the 4TU data repository. The summary of the interview (anonymous) will be documented in the graduation thesis appendix. The graduation thesis that contains the analysis from the data obtained through interviews will be stored permanently at https://repository.tudelft.nl/ and is openly available for the public.

In this interview, I will need your perspectives as [ROLE] about heat transition policy-making. I am very honoured to have you in this interview, and I also appreciate that you are willing to spare your time today. In this interview, I will also collect some personal data: your name, email address, and your signature. Therefore, I kindly ask you to sign a signature form.

Since this participation is voluntary, you may withdraw your participation anytime they need to without giving any reason. You may also not answer a question if you are not comfortable with answering it.

2. Read consent informed form (5min)
3. Explain the framework resulted from the literature study (10min)
4. Questions (60min)

For policy-makers

1. Can you please tell me about your position and experience in the municipality of Zoetermeer? (e.g. what is your goal, how your you have been working here) (C1, A1, A2, B1)
2. How are you involved in decision-making about the heat transition in Zoetermeer?
3. How do you think heat transition can be successfully executed at the municipal level? (A1, A3, A4, C1))
4. In my research, I analyse several classes of factors that influence heat transition. To what extent do you think [factors mentioned bellow] plays a role in the heat transition in the municipality of Zoetermeer

5. Who do you think are the most important actors in the heat transition?
6. How do you think these actors want to be involved in the heat transition in Zoetermeer? (B1, B2, B3)
7. What do you think is the essential information that policy-makers need to have to develop a policy for heat transition? (C2, C3) (Check with the stakeholder interest)
8. To what extent have you been involved in collecting this essential information in the past?
9. What do you do if you don't have this essential information? (B3, B4, B5)

10. What threat in the heat transition transformation in Zoetermeer municipality the heat transition you have considered in the policy-making process? (A4)
11. What opportunities in the heat transition transformation in Zoetermeer municipality the heat transition you think is essential but have not considered yet formally? (A4)

For practitioner

1. Can you please tell me about yourself and your research in the heat transition in the Zoetermeer area? (e.g. how long was that and how relevant this to the situation now) (e.g. what is your goal, how your you have been working in the research) (C1, A1, A2, B1)
2. How is your research (can be) used in decision-making about the heat transition in Zoetermeer?
3. How do you think heat transition can be successfully executed at the municipal level? (A1, A3, A4, C1))
4. In my research, I analyse several classes of factors that influence heat transition. To what extent do you think [factors mentioned bellow] plays a role in the heat transition in the municipality of Zoetermeer
    a. Data digitalisation and utilisation
    b. Sustainability factors
    c. Load management
    d. System constraints
    e. Energy demands
    f. Investment decision
    g. Ownership of the building
    h. Negotiation
    i. Regulation
    j. Attitude (acceptance)
    k. Behaviour
    l. Established social network
    m. Fairness
    n. Community empowerment

5. Who do you think are the most important actors in the heat transition?
6. How do you think these actors want to be involved in the heat transition in Zoetermeer? (B1, B2, B3)
7. What do you think is the essential information that policy-makers need to have to develop a policy for heat transition? (C2, C3) (Check with the stakeholder interest)
8. To what extent have you been involved in collecting this essential information in the past?
9. What do you do if you don't have this essential information? (B3, B4, B5)
10. What threat in the heat transition transformation in Zoetermeer municipality the heat transition you have found in the policy-making process? (A4)
11. What threat in the heat transition transformation in Zoetermeer municipality the heat transition you think is essential but have not considered yet formally by policy-makers?
12. What opportunities in the heat transition transformation in Zoetermeer municipality the heat transition you have found in the policy-making process? (A4)
13. What opportunities in the heat transition transformation in Zoetermeer municipality the heat transition you think is essential but have not considered yet formally by policy-makers?

For Researchers

A. About research

1. Can you please tell me about yourself and your research in the heat transition in the Zoetermeer area? (e.g. how long was that and how relevant this to the situation now)

Show the 3 pages of influencing factors from literature

B. Heat transition system

1. What are the main factors that influence heat transition success for the municipality of Zoetermeer? (notes for the interviewer: read from the figure, mark ones that he/she answer important, and unmark ones that are not important)
2. What opportunities (can be) emerge(d) from heat transition?
3. What threats (can be) emerge(d) from heat transition?

C. Data gathering system

1. How can we correlate these influencing factors that decide heat transition success as mentioned by you with heat transition stakeholders? (notes for the interviewer: see notes on the figure that you just made)
2. How do you want to be involved in the heat transition?
3. How do you think data should be gathered to support decision making about the heat transition?
4. Do you think policy-maker sure about the needed data to decide on the heat transition policy?
5. What do you do when essential data is missing to support their decisions concerning heat transition?

D. Decision-making system

1. How do you make decisions concerning the heat transition?
2. What information do you think should be made explicit to support decision making concerning heat transition?
3. Do you think all stakeholders interest is currently included in the heat transition policy-making process?

5. Closing (10min)

Thank you very much for your participation and insight into the topic. I will send you a transcript of this interview to be checked. In case you do not agree with what I have written in the transcript, please let me know. If I do not receive a response, I will assume the transcript is correct. If you inform me that the transcript requires modification, I will edit it and send it back to you for approval.

Is there anyone working on the topic of Zoetermeer heat transition you could recommend for a follow-up interview? This person can be either a researcher, policy-maker, executioner, or citizen representative?

Thank you for your time, and I wish you a good day.

Appendix III Evaluation

Appendix III.1. Evaluation questions

https://docs.google.com/forms/d/13RpJwjOYiIZAuKvqJ3GJW9gVUJZxPiuzpTgItrN7Qss/edit

HeTPoM DSS framework Evaluation Group Interview

I am Mustika, a master student from CoSEM, TU Delft, and also is a graduate intern at TNO for the Policy Lab project for the municipality of Zoetermeer.

I am currently doing my graduation project, the municipal data-driven heat transition decision-making tools, a case study of heat transition in the Zoetermeer area. These questions are based on the attached empirical model called HeTPoM (Heat Transition Policy Making) DSS framework.

The purpose of the evaluation is to see the usefulness, structure, coherence, modularity, conciseness, and facilitating conditions. Your answer will be recorded and be used for a group interview that will be recorded.

Once again, I want to tell you that I am honoured to have your willingness to evaluate this empirical model. Thank you for your kind attention and time.

[HeTPoM Picture]

Legend:
Coloured boxes: Heat transition influencing factors
- Orange: Social factors
- Blue: Technical factors
-Yellow: Economic, regulation, and political factors
White boxes: Process

Made based on the policy cycle and customer journey map of heat transition model and 13 interviews with heat transition stakeholders in the municipality of Zoetermeer.

A. Please rate the following statements about HeTPOM DSS framework structural quality on a scale from 1 -10, with 1 being strongly disagree and 10 being strongly agree

1. Coherence
   · The components of the HeTPOM DSS framework are logically related
   · The components of the HeTPOM DSS framework are in order
   · The components of the HeTPOM DSS framework are consistent
2. Modularity
   · The components of the HeTPOM DSS framework are not overly related to each other
   · The components of the HeTPOM DSS framework can easily be replaced and recombined
3. Conciseness
   · The HeTPOM DSS framework does not contain unnecessary components
4. Completeness
   · Component in the HeTPOM DSS framework contains sufficient elements to create a viable policy cycle design

B. Please rate the following statements about HeTPOM DSS framework functionality on a scale from 1 - 10, with 1 being strongly disagree and 10 strongly agree.

1. For Research

- The HeTPOM DSS framework gives an added value to the evidence-based policy research by providing an empirical model of Zoetermeer data-driven heat transition municipal policy-making
- The HeTPOM DSS framework gives an added value to the policy-lab research by providing an empirical model of Zoetermeer data-driven heat transition municipal policy-making

2. For policy-maker

- The HeTPOM DSS framework supports policy-maker to create a policy systematically.
- The HeTPOM DSS framework supports policy-maker to explain their policy-making process to the heat transition stakeholders.
- The HeTPOM DSS framework supports policy-maker to explore their data needs to create a good municipal heat transition policy-making.

3. For heat transition stakeholders

- The HeTPOM DSS framework supports stakeholders to communicate participation position capability in the Zoetermeer municipal data-driven policy-making.

C. Please rate the following statements about HeTPOM DSS framework usage belief scale from 1 - 10, with 1 being strongly disagree and 10 being strongly agree.

1. Perceived usefulness

- Using *HeTPoM DSS framework* would help policy-makers to design heat transition data-driven policy **quicker**.
- Using *HeTPoM DSS framework* would help policy-makers make it **easier** to design heat transition data-driven policy.
- Using *HeTPoM DSS framework* would help policy-makers enable heat transition data-driven policy design more **effectively**.

2. Ease of use

- I would **find it easy to use** *HeTPoM DSS framework* to analyse heat transition data-driven policy

3. Social influence

- **Colleagues who are in my social circle** would think that I should use the *DSS framework* to analyse heat transition data-driven policy

D. Please rate the following statements about HeTPOM DSS framework usage belief scale from 1 - 10, with 1 being strongly disagree and 10 being strongly agree.

1. Willingness to use

- All things considered, using *HeTPOM DSS framework* to assess a heat transition policy in Zoetermeer would be a good idea
- All things considered, using *HeTPOM DSS framework* to create a heat transition policy in Zoetermeer would be a good idea

Appendix III.2 Evaluation summary

Improvement feedback:

Overall impression:

- A good and comprehensive model
- Can be used with another research that is happening

Presentation:

1. Need to make a better presentation on the dimension of policy-making (customer journey, demographic profile)
2. Need to clarify that data in the problem definition will also be used in the next phase of the cycle
3. Need to pop out the presence of four policy cycles that is using one problem definition phase process over and over.
4. Need to explain that this model is more general and cover not only one type of technology decision-making process but more into the process on how a decision can be made.
5. Need to change act phase into adopting phase for easier understanding

Content:

6. Need to differentiate between the adoption target (adopting agents) citizen and citizen cooperative who are more active to drive heat transition
7. Need to include how citizen initiatives want to be included in the decision-making
8. Need to differentiate financial capability in the problem definition and subsidy needs mechanism in the implementation.
9. Need to add co-creation process with the citizen to increase acceptance and political legitimacy
10. In Zoetermeer, language diversity is also needed to be included because it will affect the communication method that the municipality needs to organize.
11. Need to include cultural bias in the model
12. Need to shows the area where citizen inclusion is processed in the model.
13. Need for policy-maker to make an exit strategy in case citizen are not happy with the result to keep the good relationship between citizen and the government.
14. Need to add the coverage of energy cooperative (citizen initiatives) in the problem definition.
15. Need to add the presence of social structure (e.g. church) that can be used to smoothen the communication with the citizen.
16. Need to separate private and total societal cost

Comment on usefulness:

1. Used in the joint-process (co-creation) of policy
2. Can be used by ...., both in the result of the model to support policy assessment and evaluation
    a. Professional
    b. Some people in the municipality
    c. University
    d. Energy community (cooperation)
3. Can be used to help make people aware of the policy-making process in the municipal level
4. Can be used by municipal to support citizen inclusion in their policy-making
5. Can be introduced to the SHIFTS project, https://energy-shifts.eu/