Data-Driven Support of a Sustainable and Inclusive Urban Heat Transition in the Netherlands

The Data Ecosystem Approach

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Challenge the future

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by

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Preface

The research presented in this thesis is conducted in the context of the Master program in Complex Systems Engineering & Management at the Faculty of Technology Policy & Management of the Delft University of Technology. The thesis is the result of a graduation project, which was carried out in cooperation between the TU Delft and the Netherlands Organisation for Applied Scientific Research (TNO). The research addresses the data-driven support of public and private decision making to accelerate the heat transition in the Netherlands. Essentially this heat transition entails the transition towards a natural-gas free and low-carbon urban thermal energy system which is innovative, affordable and supported by the citizens and stakeholders. Hereby the Data Ecosystem approach is utilised.

In full honesty, I could not have achieved any of my success without a strong support group. First of all, I express great gratitude to my committee members, each of whom has provided expert advice, guidance, flexibility and understanding throughout the research process. A special thanks goes out to Dr. Thomas Hoppe, whom put a lot of effort in supporting me throughout the process and provided me with inspiration and sound academic support during the numerous meetings. I also thank Drs. Jolien Ubacht for the support to guide the thesis towards the end result and consulted me with the decisions, especially in the early stages of shaping the research and choosing a suitable methodology. A special thanks goes to Drs. Adriaan Slob, my external supervisor from TNO, for always ensuring that I possessed over all means to get the work done. Drs. Adriaan Slob showed great interest in the project and was always available for validation questions and the pressing issues in the energy transition. A special thanks also goes out to the chair of the committee, Prof. dr. Kornelis Blok, whom always provided me with critical comments to sharpen my work. Moreover, Prof. Blok provided me with the opportunity and honour of being his student-assistant and closely involved me in his ambitions regarding energy education and research at the TU Delft. This opportunity opened up many doors in the energy sector and kept on inspiring me to contribute in the energy transition, hence the motivation to conduct this research. Also, I would like to thank Dr. Anneke Zuiderwijk for the inspiration and productive talks on the validation of the work. Finally, I would like to thank my colleagues at TNO for taking the role as valuable sparring partner, provide data, validate assumptions, and create the perfect atmosphere to conduct this research.

Last, but not least, I want to express great gratitude to my parents and sister, who supported me with love and understanding. Moreover, they have always set the right example to show that results can only be achieved with hard work, perseverance, tolerance and dedication. Finally, special thanks go out to my friends for their unconditional support and positive distraction during stressful times.

Thank you all for your unconditional support, Grantangi.

Devin D.D. Diran
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Executive Summary

Research definition

The challenge posed by climate change upon humanity can only be adequately addressed by drastically reducing human-induced greenhouse gas (GHG) emissions to the point of zero-emissions. The Netherlands is on the verge of implementing a new framework which aims to accelerate the energy transition, namely the Klimaatakkoord or Climate Agreement. The goal of the Climate Agreement is to propose and enable the realisation of measures to reduce GHG emission by 49% in 2030, relative to 1990, among the built environment, the electricity sector, industry, agriculture and land-use, and mobility (Klimaatberaad, 2018).

Within the built environment, the generation of heat for purposes such as space heating, warm water and cooking, contributes for over 82% in the final energy consumption (Energie Beheer Nederland, 2016). This provision of heat in the Netherlands is dominated, over 87% in 2015, by natural-gas, a fossil fuel and GHG itself, where CO_2 is emitted when combusted (Menkveld et al., 2017). The dominant role of natural-gas for the provision of heat is unique, since other countries have more diverse thermal energy systems in terms of the energy carrier, technology for energy conversion and the central or decentral nature (Niessink and Rösler, 2015). In order to achieve the reduction in GHG emissions in the built environment, the transition towards a sustainable building stock entails the disconnection from natural-gas. In order to do so the municipalities are expected to have a pivotal role together with the building owners and citizens all over the Netherlands. In the Climate Agreement it is proposed that the energy transition will now take a local approach, the so called district approach, and that in the built environment, the total building stock should be transformed to a sustainable building stock at a pace of 50,000 dwellings/year in 2021, increasing to 200,000 dwellings/year before 2030 in order to reach a reduction in the CO_2 emissions of 3.4 MT. The transformation to a sustainable building stock entails the change in energy carrier for the heat provision, but also dwelling retrofit such that energy efficiency measures are implemented and the dwelling is compatible with the more modern and sustainable low temperature heating solutions in an increasingly decentral and diverse urban thermal energy system (Klimaatberaad, 2018).

The necessary interventions in the building envelope and heating installation for the desired energy efficiency and sustainable heat generation, and the collective infrastructure such as District Heating Networks, are tied to high investments. The uncertainty in the initial investment and the payback period is causing citizens and social housing corporations to be hesitant on taking the decision to invest in the dwelling to be disconnected from natural gas (NVDE, 2018). This calls for the governments, both national and local, to establish natural gas-free policies which encompass instruments to 1) incentivise natural-gas free alternatives for the end-user (Rooijers and Kruit, 2018), 2) organise collective infrastructure and retrofits, this includes the prioritisation and alignment of decisions, such as the sequence of districts to be disconnected from natural-gas and what solutions for natural-gas to be adopted by the districts, 3) involve citizens and stakeholders in the decision-making for a supported transition, 4) allocate the high and uncertain costs, and 5) support and inform citizens and stakeholders on the potential of the solutions and financing opportunities (NVDE, 2018). To reach this end, municipalities, citizens and stakeholders are lacking the specific, accurate and objective knowledge and capacities to effectively execute the complex decision-making on policy and investments in an effective and inclusive heat transition.

Big and Open Data, and the related technology and infrastructure, carries the potential to provide that information and support. However, energy policy research is lacking in opening up data and methods for a greater role of data-driven policy and decision-making. Data users and providers operate in a landscape where it is challenging to navigate towards finding the right place to release or acquire data. Moreover, these parties encounter challenges and barriers when working with data that is related to data aspects such as the quality, completeness, integrity and level of detail. These challenges and the complex landscape lead to a gap between the potential of Big and Open Data and the actual application of Big and Open Data to support decision making for policy makers, citizens and stakeholders in the heat transition. Zuiderwijk et al. (2014) and Demchenko et al. (2014) propose the Data Ecosystem (DE) approach, where these complexities between entities involved in data generation, sharing, and use, can be viewed as part of a wider ecosystem in which each instrument or tool can add value as part of the puzzle. Accordingly, the Data Ecosystem (DE) approach is applied to this research. However, little to no research is found on the DE for the energy transitions, which enables the use of Big and Open Data to support decision-making on the local heat transition by the relevant actors. This can be further specified in the identified knowledge gap:

> *There is little to no scientific research on the DE with the application of Open Data and Big Data, public or private, real-time or historic and machine- or human generated, in supporting the realisation of the heat transition through local climate policy and stakeholder decision-making.*

To improve the information provision to the heat transition and thereby accelerate the transition, but also towards the successful development, implementation and functioning of data-driven methods and tools to contribute in the transition, such as the EPL, there is a need to overcome this knowledge gap and work towards a suitable DE. Based on the knowledge gap presented in this section, the research question is as follows:

> *How and under which Data Ecosystem can Open and Big Data be utilised to improve the information provision and support decision-making in the transition towards a sustainable urban thermal energy system,in the Netherlands, given the perceptions and resources of stakeholders?*

Research design

This research is conducted by means of an embedded single-case study (Yin, 2017). The case study design encompasses the Netherlands as the main case, and the municipality of Utrecht as the embedded case. Where on the national level the heat transition will be executed along the framework of national climate policy, for more detail and to capture the local challenges and dynamics in the heat transition, the municipality of Utrecht is the embedded case within the main case of the Netherlands.

For this study, both open and semi-structured interviews are utilised over two phases of the study. In the first phase of problem orientation, open interviews are conducted, to gather empirical information on the perception of the problem and the possible solutions. These interviews yield the information to further specify the research. In the phase of the problem analysis and the DE design, semi-structured interviews were conducted to derive the information necessary to answer the research questions. This information builds upon the knowledge derived from the literature and functions as in-depth knowledge on e.g. the local situation, existing or potential data sources or other specific case related aspects which cannot be found in literature.

Main Findings

DE framework

The DE framework, as derived from literature, consists of five elements related to the Data Life-Cycle: 1) Data capturing and pre-processing, 2) Data release, 3) Data and license search, view and assessment, 4) Data cleaning, linking, analysis and visualisation, and 5) Data discussion and feedback. Moreover, three elements are related to the organisation of the DE: 6) Quality assessment system, 7) Meta-data to link elements , and 8) Use-case promotion. Furthermore these elements are surrounded by the technological context, the regulatory context and the data-stakeholder context consisting of data suppliers, data users, and data intermediates. This DE framework is utilised to assess the current DE in Utrecht, where the study considered 1) the process of declaring Overvecht-Noord as the first district to be disconnected from natural gas, and 2) the regional study with the national Vesta MAIS model for the impact assessment of dwelling and spatial measures. Of the eight elements, the current DE is particularly falling short in the Data feedback, Meta-data, Use-case promotion and Quality management system. In addition, the data feed is sub-optimal whereby, in particular, little to no data is included on the citizens.

The Socio-technical system

The socio-technical system around the heat transition can be described as very extensive, actors and stakeholders can be divided over roughly seven categories: citizens, government, government authorities, market (construction, technical installation, energy utility and service, etc.), Intelligence (research and advisory), Real-Estate (developers, intermediates, and housing corporations), and Other (from network operators to financial institutions and local citizen initiatives). This extensive field of actors and stakeholders evolves around an equally extensive field of technologies at different states of maturity, sustainability and affordability, and with different characteristics on the energy source, temperature, and being an individual or collective system. The actor and stakeholder field converges with the technological field to make decisions, invest and adopt alternatives for natural gas in the heat supply. This is met with challenges on the uncertainty in the performance of technology and the allocation of cost among public and private parties.

In the actor and stakeholder field, one of the most interesting findings is that many of the actors and stakeholders are still in the process of comprehending the problem of natural-gas in the built environment and searching for their role in the envisioned transition. Given that these stakeholders are not yet aware of their role, it is also unclear what resources they have available for the heat transition, while their attitude towards the transition is widely varying and unstable over the field. It is commonly mentioned that the government should be establishing the facilitating conditions, this should provide the stakeholders of clarity on their role, after which they can proceed to decision-making in the heat transition.

From the Data Ecosystem perspective some clear roles can be distinguished, for instance Stedin as network operator is taking the role as data supplier because their legal status forbids them to add value to the data. The municipality with the heat transition vision, and utility companies are taking the role as data user to support the planning and development activities in the heat transition. Kadaster and CBS are establishing themselves as true Data intermediates, a role which entails, on the one hand, DE organisational aspects regarding the establishment and maintenance of databases and the facilitation of the stakeholders involved in that process. On the other hand, there are the data activities where they add value to data and release data to the data-users. The role of standards organisations is an important one in DE to ensure data quality and interoperability, however such an authority only exists for government geo-data. For other data types this role is still vacant, yet badly needed.

Knowledge gaps among actors and stakeholders

From the empirical data it can be concluded that the stakeholders often address challenges in co-occurrence with knowledge gaps. In other words, many of the challenges in the heat transition are a consequence of lacking or sub-optimal knowledge, entailing inadequate information provision to the decision-makers responsible and accountable for decision-making in the heat transition, and stakeholders affected by these decisions. The identified knowledge gaps can be defined over five main themes: 1) the energy system and environment, 2) the data ecosystem, 3) dwellings and end-users, 4) market and economic aspects, and 5) the decision-making process.

Of these categories, the most knowledge gaps, measured by the variety that can be derived from the empirical data, fall under the themes of 1) the energy system and environment, and 2) the dwellings and end-users. In particular, very little is known about 1) the detailed characteristics of dwellings that impact the potential and costs of retrofit and thermal installation upgrades, 2) the perceptions and attitude, leading to the willingness to participate by the citizens and building owners, and 3) the preferences of stakeholders for natural-gas alternatives and their role in the heat transition.

Data-base and Data platform inventory

This study produced an extensive, but not exhaustive, inventory of data-bases currently available, with relevance for heat transition decision making. A total of 24 data-bases are presented in this inventory, categorised over: supply side data, demand side data, building stock data and energy statistics data. It can be concluded that the majority of the data openly available nowadays is on the supply side. The infrastructure data for distribution and storage is also openly available. However, on the demand side, including the dwelling characteristics and the end-user characteristics and behaviour, there is little data captured and released as open data. A significant share of the demand data thus remains to be released, while there also is data with great potential which remains to be captured, namely: 1) citizen preferences and attitudes towards the alternatives for natural-gas and retrofit measures, and 2) data on dwelling envelope retrofit and thermal installation measures already conducted in dwellings.

Besides the data-bases, an inventory is produced on the data platforms or portals targeting energy, and in particular heat. This inventory yielded 9 platforms with varying functionality and data feed. It could be concluded that when placing these platforms and data-bases in the context of an ecosystem, there already is a very rich ecosystem. However there is very little known on the links and interaction between the platforms and data-bases. This means that several platforms have redundant functionality, while other platforms complement each other with their functionality. However, because the overview of the ecosystem is poor, opportunities to jointly utilise platforms are left unexploited.

Data-driven strategies have the potential to address these knowledge gaps, however significant barriers are experienced by the stakeholders in the development and execution of effective data-driven strategies in the current DE. The design of the DE2.0, needs to take into account barriers regarding: 1) restricting (privacy) legislation, 2) data ecosystem barriers e.g. difficult and cumbersome data search and acquisition and poor data quality and detail level, 3) stakeholder barriers, e.g. lacking willingness to share data, and 4) high perceived costs.

Technological innovation in the DE

The case study yielded three technologies or methods to obtain the missing data or improve the insights from the current data. First, *Blockchain* provides opportunities to store, organise and exchange data, while effectively addressing challenges regarding transparency, trust, data quality and integrity, security, and data access. Second, *Big and Open Linked Data or BOLD*, offers attractive opportunities for enhanced insights from distributed and diverse data in the context of the heat transition and the current DE, with heterogeneous data formats, scattered distribution of data, and missing data. And, third, *CrowdSensing or CS*, is a possible means to include the citizen participation and gather citizen data to embed the stakeholder and citizen engagement in the evidence-informed approach. CS can be described as a new paradigm to efficiently acquire data by means of the sensors embedded in, among others, the wide-spread modern-day mobile devices.

Where these technologies offer endless possibilities, and pilots are run by the more progressive actors in the DE, such as Kadaster, many challenges and barriers are encountered on both the technical side, e.g. the scalability of the system and to control and guarantee the quality and integrity of the data transferred over BC, but also on the social side, e.g. how to embed these technologies in society and how should decision-making processes and structures need to change to benefit from these technologies. These challenges and barriers require further research, for the technologies to play a significant role in the future DE.

The DE 2.0 design

After addressing the sub research questions, and gathering all necessary knowledge, the main research question, presented earlier in this section, can now be answered. On the question how and under which Data Ecosystem Open and Big Data can be utilised to effectively improve the information provision and hence accelerate the heat transition, the Data Ecosystem 2.0 is presented below in figure 1.

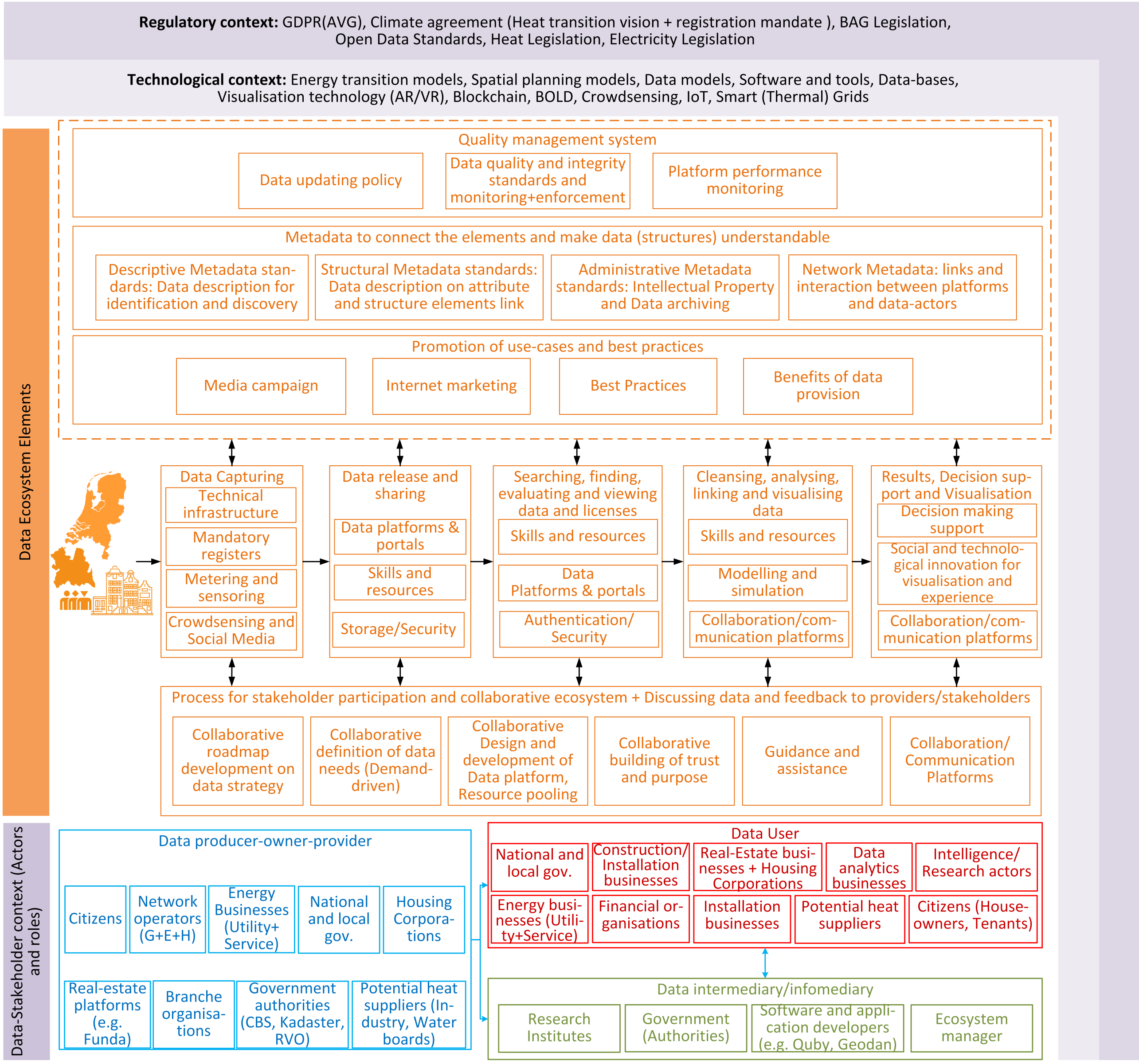

Figure 1: The new Data Ecosystem 2.0 proposed for the Heat transition in the Netherlands, own figure

DE 2.0 takes into account the shortcomings of the current DE, the data needs derived from the knowledge gaps identified among the stakeholders in the heat transition, the inventory of available data-bases and platforms, potential technologies, but also the challenges and barriers experienced.

The DE for the heat transition is in its infancy phase at this point with challenges, barriers and shortcomings in all elements as proposed by the DE framework derived from literature and presented in sub-section 3.2.6. Of the eight elements, the current DE is particularly falling short in 1) the Data discussion and feedback, 2) Meta-data, 3) Use-case promotion and 4) Quality management system. In addition, the data feed is sub-optimal whereby, in particular, little to no data is included for the demand side on the citizens. Currently, energy transition models such as Vesta MAIS utilise available data-bases and the available platforms are casually used by stakeholders in an attempt to visualise and comprehend the challenges in the heat transition. To this point, actual decision-making has not been supported adequately in a data-driven way from the technological context. This can be assigned to the technology being in its infancy, governance and decision-making processes not completely embracing data-driven support, but also the lack of critical data, mainly on the demand side. Where the technology is steadily improving, these technologies in the field of data analysis and visualisation are not relevant without that adequate data supply. In order to establish a DE which effectively supports the decision-making for the heat transition, the lacking data supply on heat demand, dwelling characteristics, and citizen attitude and perceptions requires the main focus. This will require, not only stable and adequate data infrastructure and technologies such as BC, CS and BOLD, but also an adequate quality management system, new roles such as the DE Manager, and a process for stakeholder participation and DE collaboration.

In the DE 2.0 a new element is thus proposed, namely the process for *stakeholder participation and DE collaboration with data discussion and feedback*. This process aims to contribute in increased involvement of the stakeholders, leading to a better familiarity with the ecosystem, but also fosters trust among data suppliers for an improved willingness to share data. Moreover, this element also inherits data discussion and feedback. By doing this along the DE, first, the quality of the data and infrastructure is continuously assessed and ideally improved, and second, continuous interaction enables a DE which is aware of the specific data needs, and targets those data needs effectively and efficiently.

Finally, new roles are proposed, among others, that of the Data Ecosystem Manager. Not only is that entity responsible for data standards and quality assurance, but also to coordinate the previously mentioned process of stakeholder participation and DE collaboration.

Energy Policy Lab functionality and requirements

TNO is looking into the development of the Energy Policy Lab (EPL) to facilitate the energy transition, and incorporate design science and ICT with the aim to research how local government, companies, citizens and other stakeholders can co-create policy to shape the energy landscape in their neighbourhood/municipality.

The following functionality of the EPL could be derived from the interviews: 1) experimenting with (policy) measures, 2) decision-making support and assessment frameworks, 3) capture and release energy system and stakeholders data, 4) means and services to find and acquire the relevant data, 5) guide the utilisation of existing tools and platforms, 6) progress monitoring, 7) facilitate co-creation and knowledge exchange, 8) support the definition of knowledge questions, 9) linking or connecting parties, 10) transition models and tools, and 11) data visualisation and analysis means.

How well the EPL performs in providing these functions is stated to be the main criteria to assess the efficacy of the EPL, furthermore, the following requirements are derived from the qualitative data: 1) findability and accessibility, 2) utilisation rate, 3) convenient and interactive user interface, 4) data and service quality and detail level, 5) standardised data formatting, and 6) embeddedness in process of decision making and transition.

Finally, it could be concluded that much of what the interviewees require in terms of functionality can already, or partially so, be provided by certain platforms or the open source model Vesta MAIS. However, the interviewees are not sufficiently aware of these possibilities. It is proposed for the first step of the EPL, to link and optimise the utilisation of existing platforms and models in an coherent and inclusive approach for the EPL.

From the main findings of this research, recommendations can be made towards the policy makers in the Heat transition. These recommendation address how the proposed DE 2.0 can become reality.

Main recommendations for policy makers

Target social innovation with data-driven methods and tools: In the context of the heat transition in urban thermal energy systems, the main recommendation is that data-driven support for policy-making should reach further than the generation of facts and statistics on the supply of sustainable heating such as geothermal well capacity and cost factors, or DHN and its connected heat sources. A bigger role should be fostered in an underestimated aspect of the heat transition, namely social innovation. This will equip the policy makers with improved tools to cope with the challenges of varying and contradicting perceptions, levels of awareness and willingness to participate. In situations where it would be desired, but not realistic to directly involve each and every citizen in heat transition decision-making, data-driven methods and tools provide endless possibilities to gain insights on the social transition dynamics and interact with the citizens in an effective and low-threshold manner. Hence, it is recommended to policy makers to partly shift the attention from data on the supply side, towards the demand side and the citizen characteristics. In order to realise this, by means of capturing and utilising the necessary citizen data and enabling the desired interactions, it is recommended to establish the necessary changes in the DE accordingly. These changes target the data infrastructure and technology regarding the data value-chain, but moreover, the regulatory context to establish a regulatory basis for data release mandates for end-users, and extended authorisations towards data-intermediaries such as the network operators.

Foundation of the DE Manager and the Quality Management System: To coordinate the development of an effective DE, with an adequate Quality Management system to cope with issues on data quality and integrity, standards and utilisation, it is plead to enable the role of the DE Manager. In the national program to improve the information provision in the energy transition, these tasks are proposed to be carried out by a Data Commission, consisting of experts from key stakeholders, namely: Ministry of Economic Affairs and Climate, Ministry of Internal Affairs and the Kingdom Relations, CBS, Kadaster, PBL, Rijkswaterstaat and RVO (Dekker et al., 2019). In this proposal, the sole participants in the Data Commission are public parties and Data Intermediates according to the role definition in this research. However, from the DE approach it is recommended to expand the composition of this DE Manager with representatives from: 1) the data suppliers, e.g. the network operators, 2) the data users, e.g. the energy utility and service businesses, and 3) the standards organisations, i.e. Geonovum. With this composition, the relevant interest are represented in the DE Manager, fostering comprehensive DE organisation and management.

Establish the regulatory basis through climate policy: For the DE to evolve with a rich supply of data to increase the role of data-driven methods and tools, a sound regulatory basis is essential. This regulatory basis should target the parties releasing data, such as data release obligations for the citizens, the data-intermediaries, such as extended data-processing authorisations for the network operators, and data-users, such as data security measures for energy utilities. The establishment of the Data Quality System and the DE manager, as proposed in this research, are recommended to be founded via this regulatory basis. To establish this regulatory basis, it is recommended to utilise the momentum which is currently present in climate policy. In particular the Climate Agreement, the Environmental Code, and to a lesser extent the Regional Energy Strategies, can provide the regulatory framework to embed the regulatory basis for data-driven strategies and an advanced DE.

Prioritise the low hanging fruit: Where the regulatory basis will contribute towards the realisation of the advanced DE on the medium- to long term, recommendations can also be made on steps which can improve the state of the DE on the short term with relatively less effort. Given the encountered challenges of dispersed data distribution and the consequent issues related to data quality and interoperability, surfaced by this study, it is recommended that the short-term focus of policy makers should be on the consolidation and improvement of existing data sharing and utilisation platforms and portals. Hereby, on the contrary to the trend of initiating new and specific data initiatives, which only adds to the disperse nature of the DE and the challenges to navigate the DE, adequate efforts should be guided towards the understanding and communication of existing links and relations between data initiatives, and the promotion of the functionality and added value of these platforms. Eventually, these efforts aim to increase the familiarity of the current DE and improve the utilisation of the existing facilities and infrastructure, while interest and momentum is created to engage on the mid- to long term development of the future DE.

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Introduction

1.1. Research Context

1.1.1. Introduction on the heat challenge in the Energy transition

The challenge posed by climate change upon humanity can only be adequately addressed by drastically reducing human-induced greenhouse gas (GHG) emissions to the point of zero-emissions. In the Paris Climate Agreement adopted in 2015, a binding agreement is made to reduce these emissions and limit the rise in temperature as a consequence of climate change to 2 ^oC or ideally 1.5 ^oC relative to pre-industrial levels (United Nations, 2015). In the realisation of this agreement, the European Union (EU) has a pivotal role in determining climate policy for her member states in order to contribute to this Global reduction in GHG emissions. On its turn, the member states such as the Netherlands have to implement the EU policy in national legislation for the concrete materialisation of measures to reduce emissions nationally. The Netherlands is on the verge of implementing a new framework which should accelerate the energy transition, namely the Klimaatakkoord or Climate Agreement. The goal of the Climate Agreement is to propose and enable the realisation of measures to reduce GHG emission by 49% in 2030, relative to 1990, among the built environment, the electricity sector, industry, agriculture and land-use, and mobility (Klimaatberaad, 2018).

The built environment, as depicted in figure 1.1, is responsible for over 36& in the Final Energy Consumption (FEC), which is equivalent to 25% of the GHG emissions in the Netherlands. Within the built environment, the generation of heat for a variety of purposes such as space heating, domestic warm water and cooking, contributes for over 82% in the final energy consumption (Energie Beheer Nederland, 2016). This provision of heat in the Netherlands is dominated, for over 87% in 2015, by natural-gas, a fossil fuel and GHG itself, where CO_2 is emitted when combusted (Menkveld et al., 2017). The dominant role of natural-gas for the provision of heat is unique, since other countries have more diverse heating systems in terms of the energy carrier, technology for energy conversion and the central or decentral distribution of generation (Niessink and Rösler, 2015). In order to achieve the reduction in GHG emissions in the built environment, the transition towards a sustainable building stock entails the disconnection from natural-gas. This shift is included in the Climate Agreement, and moreover, since July 1 2018, changes in the Dutch Gaswet impose that it is no longer obligatory for buildings to be connected to the national gas infrastructure. *The disconnection from natural-gas and the shift towards sustainable sources for the urban thermal energy system, with the necessary changes in the building stock, is defined as the heat transition in the remainder of this thesis.*

To establish the disconnection from natural gas and the transition of the building stock towards a sustainable building stock, the municipalities will have a pivotal role together with the building owners, citizens and stakeholders throughout the Netherlands. In the Climate Agreement it is proposed that the energy transition will adopt a local approach, the so called district approach, and that in the built environment, the total building stock should be transformed to a sustainable building stock at a pace of 50,000 dwellings/year in 2021, increasing to 200,000 dwellings/year before 2030 in order to reach a reduction in the CO_2 emissions of 3.4 MT for the built environment. The transformation to a sustainable building stock entails the change in energy carrier for the heat provision, but also dwelling retrofit such that energy efficiency measures are implemented and the dwelling is compatible with the more modern and sustainable low temperature heating solutions (Klimaatberaad, 2018).

A trend accompanying the decarbonisation of the energy system with the shift from fossil based fuels to renewable energy, is the decentralisation in the generation of energy as more consumers are generating energy locally. Subsequently, the diversity in the energy system will continue to increase and develop to fit the local technical and social conditions (Young and Brans, 2017). Hence, it is necessary for local climate policy to facilitate these dynamics on the local to regional level and guide them in the desired direction of ultimately reaching the national climate goals.

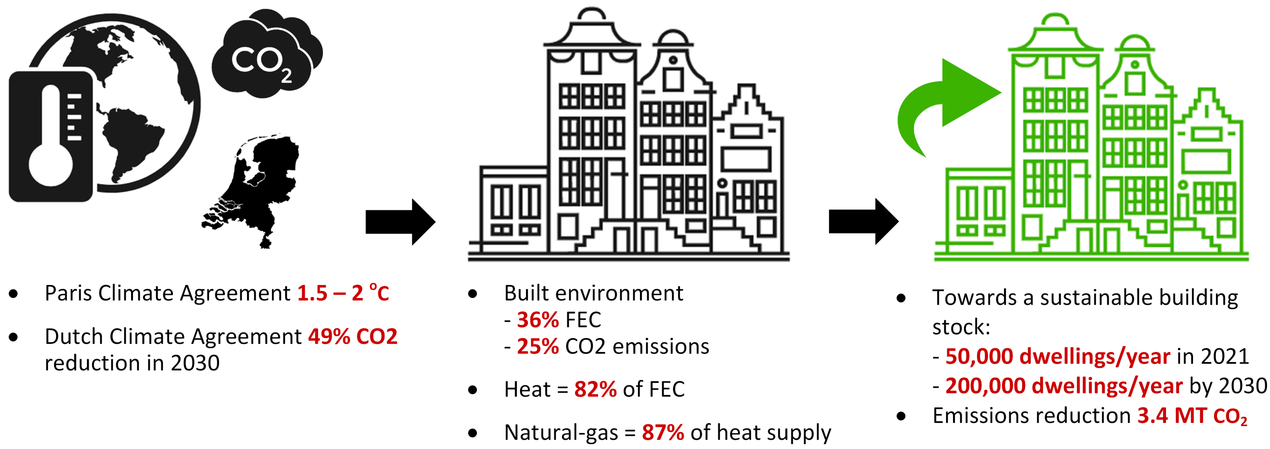


Figure 1.1: An overview of the goals for the built environment

Finally, the necessary interventions in the individual building envelope and heating installation for the desired energy efficiency and sustainable heat generation, and the collective infrastructure such as District Heating Networks, are tied to high investments. These interventions should lead to a sustainable heat supply, but also to a reduced energy bill, which on its turn pays back the investments. However, there is uncertainty on the actual payback period of these investments, via uncertainties in the initial investments and the performance of the interventions (Hers et al., 2018). This uncertainty is leading to hesitant behaviour among building owners and tenants in decision-making regarding investments in the dwelling to be disconnected from natural-gas (NVDE, 2018). This calls for the governments, both national and local, to establish natural-gas-free policies which encompass instruments to: 1) incentivise natural-gas-free alternatives for the end-user (Rooijers and Kruit, 2018), 2) organise collective infrastructure and retrofits, this includes the prioritisation and alignment of decisions, such as the sequence of districts to be disconnected from natural gas and what solutions for natural gas to be adopted by the districts, 3) involve citizens and stakeholders in the decision-making for a supported transition, 4) allocate the high and uncertain costs, and 5) support and inform citizens and stakeholders on the potential of the solutions and with financing opportunities (NVDE, 2018).

1.1.2. Policy Making and the Policy Lab

Over the course of time, policy-making has been heavily determined by factors other than empirical evidence, such as (political) ideology, personal observation or experience, intuition, instinct and hype (Esty and Rushing, 2007). However, this traditional policy-making is commonly understood to be ineffective in establishing sustainable urban heating which provides the households with sustainable, reliable and cost efficient heating. The existing processes are lacking certain knowledge regarding the heating needs and the technological possibilities to supply the heat, and a sound strategy to involve the citizens and stakeholders (Dekker et al., 2019).

The district approach for urban heating, as proposed by the Climate Agreement, can be related to the literature on climate policies and action for small- and medium-sized cities which enjoy significant attention from scholars. The article by Hoppe et al. (2016) presents an analytical framework to assess local climate policy and actions. Furthermore, the review by Broto (2017), among others, conclude that the institutionalisation of climate change governance in urban areas reflects the specific characteristics of that local context. Moreover, according to Broto (2017), the local authorities are gaining ground in their role in climate policy and experimentation is also gaining ground for local climate change governance. Matschoss and Heiskanen (2017) dive into the matter on how this experimentation can be shaped by the local policymakers, financiers and local actors and which role intermediaries have in this process. However, in reality, this increasing role of the local authorities is not yet the standard, and there is a call for research on the implementation of novel policy making means which are suitable for the local context (European Commission, 2017).

To base policy-making on a reliable set of evidence, the link can be made to Evidence-based policy-making (EBPM) where the main goal is to establish improved and innovative policy design, evaluation and implementation for today's challenges such as climate change. The call for evidence-based policy making for governments on all levels to benefit from the availability of ample data is underpinned by the European Commission (European Commission, 2017). The EU's H2020 work program for 2016/17 mentions the need for new methods and tools to realise the new style of EBPM, whereby it is essential for the public policy-makers to thoroughly understand the legal-, technical, economic and social framework and take into account sociological, cultural, political, legal and behavioural aspects when experimenting with the incorporation of Big and Open Data in the policy-making tools and methods (Slob, 2018).

Policy Labs (PLs) form a novel method to meet trends such as EBPM (Fuller and Lochard, 2016) and 'open government' agendas (Acevedo and Dassen, 2016) which aim to build trust and transparency by making government held public data more accessible for all relevant parties (Yu and Robinson, 2011). PLs have the potential to address the shortcoming of aforementioned traditional policy-making and service design (McGann et al., 2018) and coordinate the efforts between public, private and academic parties (Williamson, 2015a). The research on PLs aims to redefine the role of the government by implementing emerging methods and technologies, such as data science, predictive analytics, artificial intelligence, sensors, applied programming interfaces, autonomous machines and (digital) platforms, in government organisations (Maltby, 2015). The research presented in this thesis is conducted in cooperation with the Netherlands Organisation for Applied Scientific Research (TNO) and will, in particular, pay attention to TNO's Policy Lab for the Energy transition, namely the Energy Policy Lab (EPL). The EPL encompasses three pillars, 1) experimentation, 2) data-driven and 3) co-creation, and aims to develop, experiment with, and implement new ways of policy-making among the three phases of 1) Predictive Analysis & Problem definition, 2) Design & Experimentation, and 3) Implementation & Evaluation (van Veenstra and Kotterink, 2017).

For the application in the heat transition, TNO is in the phase of designing the EPL where questions remain on the requirements and functions which makes the EPL of added value to support decision-making in the heat transition by the policymakers, citizens and stakeholders. To this end, this research will propose relevant requirements and functions, based on the knowledge gaps in the heat transition and the current state of policy-making.

1.1.3. BIG AND OPEN DATA IN THE ENERGY TRANSITION

Big Data and Open Data have been carrying great potential to enhance society, affecting all aspects of human activity, by incentivising citizen participation, transparency, economic growth and innovation (Zuiderwijk et al., 2014). For EBPM, the data-driven approach utilises data to recognise problems, set priorities, make policy, implement policy, and finally monitor and assess the efficacy of policy and the need to adjust policy or aspects of it (European Commission, 2017, van Veenstra and Kotterink, 2017). The technological advances achieved in the last decades, in particular the ICT domain, such as the use of social media, smart phones and the Internet of Things (IoT) is driving the exponential increase in the volume of data, leading to the so called Big Data. In the context of the policy and decision-making sphere for urban heating, Big Data can be defined as: "Big Data is a step change in the scale and scope of the sources of materials (and tools for manipulating these sources) available in relation to a given object of interest" (Poel et al., 2018, p. 349). This working definition will be applied for the remainder of the thesis and is more specific than the more common definition of Big Data in industry, where Big Data is defined by means of its five characteristics of Volume (e.g. a large number of objects or time series), Variety (Large variety among data types e.g. statistics, sensors, social media), Velocity (high speed of data generation, e.g. real-time data) and Veracity (the trustworthiness or validity of the data) (Poel et al., 2015). With the increasing application of sensors, wireless network communication, advanced metering, and cloud computing technologies, large amounts of data are continuously being accumulated in the energy sector. These applications have predominantly been utilised in the context of Smart Grid and power systems research, to enable generation and demand side management, asset management and collaboration, and micro-grid and renewable energy generation (Zhou et al., 2016).

In addition to Big Data, this research addresses Open Data as a source of knowledge and decision support. The Open Knowledge Foundation, an international non-profit organisation, promotes Open Data as part of the their Open Knowledge campaign and define Open Data as "a piece of data or content that is free to be used, reused, and redistributed - subject only, at most, to the requirement to attribute and/or share-alike" (Dietrich et al., 2012, p. 6). Other characteristics, included by alternative definitions, include: standard formats, no restrictions from copy rights or patents, interoperable, digital and machine readable format, and public sector information (Visser, 2015).

Big and Open Data can be sourced from both the energy generation and distribution infrastructure (Noussan et al., 2017, Visser, 2015), as from the demand, influenced by end-user behaviour and building characteristics (Di Corso et al., 2017, Mathew et al., 2015). Previously it was stated that in the heat transition, policy has a significant role to enable and guide the transition and that data is a key element in generating the necessary knowledge and facts for EBPM. Moreover, for these policies to be effective, the accurate evaluation and assessment of the policies and its instruments, using openly available data on energy, the environment and the economy is necessary (Wang et al., 2014). Although the relevance and necessity of Open Data of adequate quality, integrity and detail is acknowledged by the sector and studied over a wide field of applications in the energy sector, energy policy research is lacking behind other sectors in promoting open and reproducible data and methods (Pfenninger et al., 2017, Poel et al., 2018).

Energy data is released as open data and visualised via a variety of Data Platforms or Portals. These Platforms or Portals form a collection of data-sets and allow for the data-users to gain access to this data in raw format or for the data to be visualised on maps in Geographic Information System (GIS) platforms (Geonovum, 2017b, Gupta and Gregg, 2017). In the Netherlands examples of these platforms are PDOK, the Klimaatmonitor and the Warmteatlas. However, data users and providers encounter reoccurring challenges and barriers regarding Big and Open Data in the utilisation of these platforms. As a consequence, the utilisation of these platforms is sub-optimal, and much of the potential provided by Big and Open Data is left untapped.

In energy systems, data is being utilised in various ways, whereby dedicated approaches are developed to process and analyse Big Data in the energy sector. An review of these methods is presented by Wei et al. (2018), where in summary, these methods are utilised in energy supply and demand models, and in decision support tools to help urban planners in choosing optimal energy strategies. To this end, models and tools can be used to: 1) simulate and map the local energy potential (Broersma et al., 2013), 2) derive the characteristics and drivers of heat load patterns to predict future heat load patterns (Noussan et al., 2017), and 3) to simulate retrofit measures such as energy efficiency measures like insulation (Wang and Cho, 2015). In this research it will be studied how the various types of methods and tools which are driven by data, are facilitated within the heat transition with the available data and the prevailing challenges.

1.1.4. PROBLEM DEFINITION

Given the context on the heat transition, policy, and the application of Big and Open Data in the previous sub-sections 1.1.1, 1.1.2, and 1.1.3 this sub-section will further define the problem which will be addressed in this study.

For the climate goals to be realised, the energy landscape in the built environment will have to drastically change. In this process, challenged by technological novelty, high costs and social complexity, it is desired for the local governments along with the citizens and stakeholders to jointly work towards prioritising, aligning and executing decisions on how to shape the heat transition from the household level, up to the municipal level (Klimaatberaad, 2018). However, municipalities, citizens and stakeholders are lacking the specific, accurate and objective knowledge and capacities to effectively execute the complex decision-making on policy and investments in an effective and inclusive heat transition (Dekker et al., 2019, Roberts and Geels, 2019).

Big and Open Data, and the related technology and infrastructure, carry the potential to contribute in the provision of that information and support. However, energy policy research is lacking in opening up data and methods for a greater role of data-driven policy and decision-making. Data users and providers operate in a landscape where it is challenging to navigate in, towards finding the right place to release or acquire data. Moreover, these parties are stated to encounter challenges and barriers when working with data, with respect to for instance the quality, completeness, integrity and level of detail. These challenges and the complex landscape lead to a gap between the potential of Big and Open Data and the actual application of Big and Open Data to support decision making for policy makers, citizens and stakeholders. This gap can also be identified in the heat transition, and this calls for research on the challenges and barriers occurring in the heat transition, and how this can be overcome to maximise the role of Big and Open data in the acceleration of the heat transition. Hereby the heat transition can be characterised by a highly dynamic and complex urban thermal energy system, with stakeholders which are searching for their role, and technologies which are new for the Netherlands and subject to uncertainty regarding investments and performance, and complexity for system integration. Zuiderwijk et al. (2014) and Demchenko et al. (2014) propose the Data Ecosystem (DE) Approach, where these complexities between entities involved in data generation, use or infrastructure, can be viewed as part of a wider DE in which each instrument or tool can add value as part of the puzzle. Accordingly, the DE Approach will be applied to this research. However, little to no research is found on the DE for the energy transition in the Netherlands, which enables the use of Big and Open Data to support decision-making on the local heat transition by the relevant actors. This can be further specified in questions such as: which elements can be identified in the DE, what is the behaviour and interaction of stakeholders in the ecosystem and how does this impact data sharing in the DE, which policy instruments and stakeholder decisions can be supported and improved with data, and which stakeholders in the ecosystem are necessary to provide data and add value to the data? The identified knowledge gap can be summarised as follows:

There is little to no scientific research on the Data Ecosystem with the application of public or private, real-time or historic and machine- or human generated Open Data and Big Data, in supporting the realisation of the heat transition through local climate policy and stakeholder decision-making.

To improve the information provision to the heat transition and thereby accelerate the transition, but also towards the successful development, implementation and functioning of data-driven methods and tools to contribute in the transition, such as the EPL by TNO, there is a need to overcome this knowledge gap and work towards an enabling and facilitating DE. Based on the knowledge gap presented in this section, the following section addresses the research definition, starting with the research objective.

1.2. THE RESEARCH DEFINITION

1.2.1. RESEARCH SCOPE

SCOPE WITHIN THE GOVERNMENT HIERARCHY

The proposed research will address energy policy on a local level, this thus entails the further specification and implementation of national climate policy on the local level by e.g. the municipality. Within the governing hierarchy, the research scope encompasses the policy-making means and instruments of the Municipal government on the local level, whereby decision making on the neighbourhood and site level are inherently part of the scope. Cities and municipalities are on the level where technologies and means in the context of the energy transition are actually implemented, and from all levels of governance, municipalities have the best access to local stakeholders, citizens, NGO's and companies which should play a role in the energy transition (Slob, 2018). Policies on the international and national level will be assumed as a given.

SCOPE WITHIN THE FUNCTIONAL ENERGY USE CATEGORIES

This study addresses the heat provision and demand of the built-environment, with a further focus on residential buildings. Based on the measures in the Climate Agreement for the built environment, the functional scoping of the study encompasses the provision of natural-gas-free heating and cooling to dwellings, inhabited by citizens, in neighbourhoods with each their unique characteristics and challenges. In these dwellings, the relevant functions are space heating and cooling, domestic warm water, and cooking (Klimaatberaad, 2018). With the focus on the residential heating and cooling, the study takes into account the building energy efficiency, the decentral generation of renewable energy by buildings, and the necessary retrofit of residential dwellings to enable energy efficiency and compatibility with low temperature solutions, e.g. heat pumps. In addition to the dwellings and the individual installations, the scope encompasses the collective sustainable heating systems for heat generation and storage on a local or regional scale such as District Heating Networks (DHN) supplied with heat from various sources such as solar, geothermal, residual heat and surface water.

1.2.2. RESEARCH OBJECTIVES

The main objective of this research can be described as:

> To research the current Data Ecosystem (DE) in the Dutch heat transition and propose a DE 2.0, taking into account the shortcomings and challenges of the current DE and the data needs of methods and tools to support the stakeholders.

This main objective combines the following sub-objectives:

1. To identify the knowledge gaps which challenge local governments and stakeholders in accelerating the heat transition.
2. To identify current and potential Open and Big data sources to address the knowledge gaps identified in sub-objective 1.
3. To identify the opportunities to engage stakeholders in the development and execution of data-driven local heating policy through Open and Big data.

1.2.3. RESEARCH QUESTIONS

Following the research objective and the knowledge gaps, the research question can be described as follows:

> *How and under which Data Ecosystem can Open and Big Data be utilised to improve the information provision and support decision-making in the transition towards a sustainable urban thermal energy system, in the Netherlands, given the perceptions and resources of stakeholders?*

The corresponding sub-research questions (SQs) with the subsequent deliverables are:

1. *What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?* The aim of the first sub-question is to describe the socio-technical landscape around the urban thermal energy system. The SQ addresses the technologies and related technical aspects, but also the relevant stakeholders. What is their current position in the heat transition, and how might this change with the eye on evolving local climate policy and technology? These insights eventually contribute towards the location and role of the actors and stakeholders in the DE.

2. *Among the decision-making of the actors and stakeholders for the heat transition in urban thermal energy systems, what knowledge is lacking, hence preventing effective decision-making?*
   The second sub-question aims to derive the decision-making which is relevant for the heat transition and the knowledge gaps among the stakeholders which complicates the decision-making. These knowledge gaps are translated into data needs and linked to the DE.

3. *How can a Data Ecosystem be composed and how does the current Data Ecosystem look like for the Dutch heat transition, what are the shortcomings and challenges?*
   This sub-question is twofold, first it is a descriptive question which identifies and describes relevant DE theories through literature research. From the identified DE theories, and the elements, processes, and roles proposed by these theories, the current DE for the heat transition will be derived. The answers from this SQ provide the input towards the DE 2.0.

4. *Which Open and Big data sources are currently, or could potentially, be made available to support evidence-based policy and decision-making by targeting the knowledge gaps derived in SQ 2, and what are the barriers for the utilisation of this data?*
   The fourth SQ results in an overview of the existing and potential data sources which can be relevant for the data needs identified in SQ 2. It will also be presented over which platforms or portals this data can be accessed and acquired, and what the encountered challenges and barriers are for data users, data providers and other stakeholders when utilising the data over the available platforms and portals.

5. *Through which technology and/or methods can the missing data identified in SQ 2 be acquired, and the Data Ecosystem be improved towards the 2.0 proposal?*
   The answer to this question provides the technological opportunities to acquire missing data, this technological input contributes towards the DE 2.0.

6. *What are the requirements and functionality for a data-driven method, such as TNO's Energy Policy Lab, to be of added value in the realisation of a sustainable and inclusive residential heat system, within the proposed DE 2.0?*
   The final SQ targets the EPL by TNO and aims to yield recommendations on the functionality and requirements of an EPL to be of added value in the heat transition. Hereby the aim is for the EPL to fit within the proposed DE 2.0, by exploiting the data potential provided by the DE 2.0. This is input towards the design of the EPL by TNO.

1.2.4. SOCIETAL AND SCIENTIFIC RELEVANCE

SOCIETAL RELEVANCE

The societal relevance lies in the expected contribution of the research in the improved understanding and further development of the DE. On its turn this improved understanding is expected to improve the information provision in the heat transition and support decision-making. The support in decision-making by means of a sound information supply should ultimately lead to a cost effective, inclusive and future-proof transition towards a sustainable urban heating system. This contribution takes place over the DE insights, but also via the contribution of this research to the EPL by TNO, which aims to improve local climate policy to be in line with the current day dynamics and complexity of local energy systems.

SCIENTIFIC RELEVANCE

Where the field of DE is well covered on a conceptual level, e.g. the research by Zuiderwijk et al. (2014) on the essential elements in a general Open DE, there is little research on DEs within the field of energy. A search for the key-words of "Data Ecosystem" and "energy" in several combinations, yielded one result, namely the study by Kontokosta (2013) on energy disclosure regulation to transform the market for energy efficiency. Further searches on the release and utilisation of Open and Big energy data yields more results, for instance in the area of smart electricity grid research, however not through the comprehensive approach like the DE approach to take into account the complexity and dynamics of local thermal energy systems. Hence, this study contributes to the existing literature on DEs with the body of knowledge developed for the specific case of the heat transition in the Netherlands. This specific case application, takes the field of DE research into more depth on for instance the interrelations between the entities involved and how this impacts data disclosure and utilisation.

Furthermore, where previous studies on data-driven approaches in the energy transition mainly accounted for open and geographic data on energy potential and energy assets, this research includes the perspective of the citizens and how data from these citizens with potential insights on their attitude and preferences can enrich the DE in the heat transition. With this, this research contributes in filling the gap on the role of end-user energy data in energy policy research for thermal energy systems.

Finally, the inventory on Big and Open data and data platforms or portals available for application in the heat transition, provides researchers looking to engage on data-driven research with an overview of the available data. In this way the research contributes to kick-start future data-driven heat transition research, with an improved understanding of the DE and the available data.

1.3. Research Methodology

1.3.1. The Data Ecosystem approach

With the research questions and objective presented in the previous section, the focus of this thesis is thus to contribute in the information provision towards decision-making in the heat transition by means of Big and Open Data. Due to the lack of research on the current data landscape and the complexity of this landscape with a large number of stakeholders, an approach is required which embraces the complexity of interrelations between entities from a data perspective. Zuiderwijk et al. (2014) and Demchenko et al. (2014) argue that for the immense growth in the infrastructure and technology to enable Big and Open Data, such as Big data storage and processing facilities, Open data portals and platforms and tools and instruments, a large number and variety of entities are involved in the development and utilisation. Hence, it is proposed to view them as part of a wider ecosystem in which each instrument or tool can add value as part of the puzzle, this is then called the Data Ecosystem (DE) approach. Moreover, the literature review on DE research by Oliveira et al. (2019) derived the following potential benefits of the DE approach: 1) improved political and social understanding, 2) improved economics of data systems, 3) convenient data generation and utilisation, 4) improved communication and interaction between actors, and 5) improved quality of data and services. For these reasons this study will utilise the DE approach for the heat transition.

1.3.2. Case study: The Netherlands and the municipality of Utrecht

This research is conducted by means of an embedded single-case study (Yin, 2017). The case study design encompasses the Netherlands as the main case, and the municipality of Utrecht as the embedded case. The case study meets in the necessity to derive the real-life context on the heat transition with regards to the actors involved, the current and future decision-making processes, the knowledge gaps based on the actual technological, social and economic context and the data available. Where on the national level the heat transition will be executed along the framework of national climate policy, for more detail and to capture the local challenges and dynamics in the heat transition, the municipality of Utrecht is the embedded case within the main case of the Netherlands.

The case of Utrecht is elaborated further in section 4.1.1. Utrecht is among the most ambitious municipalities in the Netherlands with regards to the local climate policy. Moreover, a body of research, both scientific and non-scientific, exists regarding, for instance, the potential heat sources in Utrecht, and the costs of the heat transition for citizens (Eneco, 2018, van den Wijngaart et al., 2018). Within the main case of the Netherlands, an outreach is also made to the municipality of The Hague to determine whether the challenges and knowledge gaps found for Utrecht, also hold for another municipality of comparable scale and urban setting.

Finally, it should be mentioned that the research included conference visits. These visits enabled the research to be placed in the context of state of the art heat transition research, both in the Netherlands and in Europe, it provided a network of stakeholders, and it sharpened the relevance and focus of the study. First, the Sustainable Urban Energy Systems Conference was visited in Delft during November 8 and 9 in 2018. This conference took a multi-disciplinary approach and explored the urban energy systems from a comprehensive engineering perspective with ample attention for urban thermal systems. Second, the CELCIUS Summit in Brussels was visited on November 21 2018. CELCIUS is a European project, functioning as a knowledge sharing hub for integrated and sustainable heating and cooling in Europe. During this summit, various European projects on sustainable urban heating presented best practices and this enabled this study to also be placed in the wider European context.

In the next sub-section it is depicted how the above-mentioned Data Ecosystem approach and the embedded single-case study are operationalised by means of the research flow diagram.

1.3.3. The research flow diagram

This research will follow a research flow as is presented in figure 1.2. In this research flow diagram an overview is provided of the research approach, including the input and output of each phase and which method of data-generation will be applied for each phase. The step-wise approach in the research flow diagram targets the Data Ecosystem approach in the upper section, and the EPL by TNO in the lower section.

In figure 1.2, the DE 2.0 process is framed by the red boxes, and the EPL process by the blue boxes. Both Processes are initiated by a thorough *Problem exploration* on the heat transition in the Netherlands. In this step, the perceived prob-

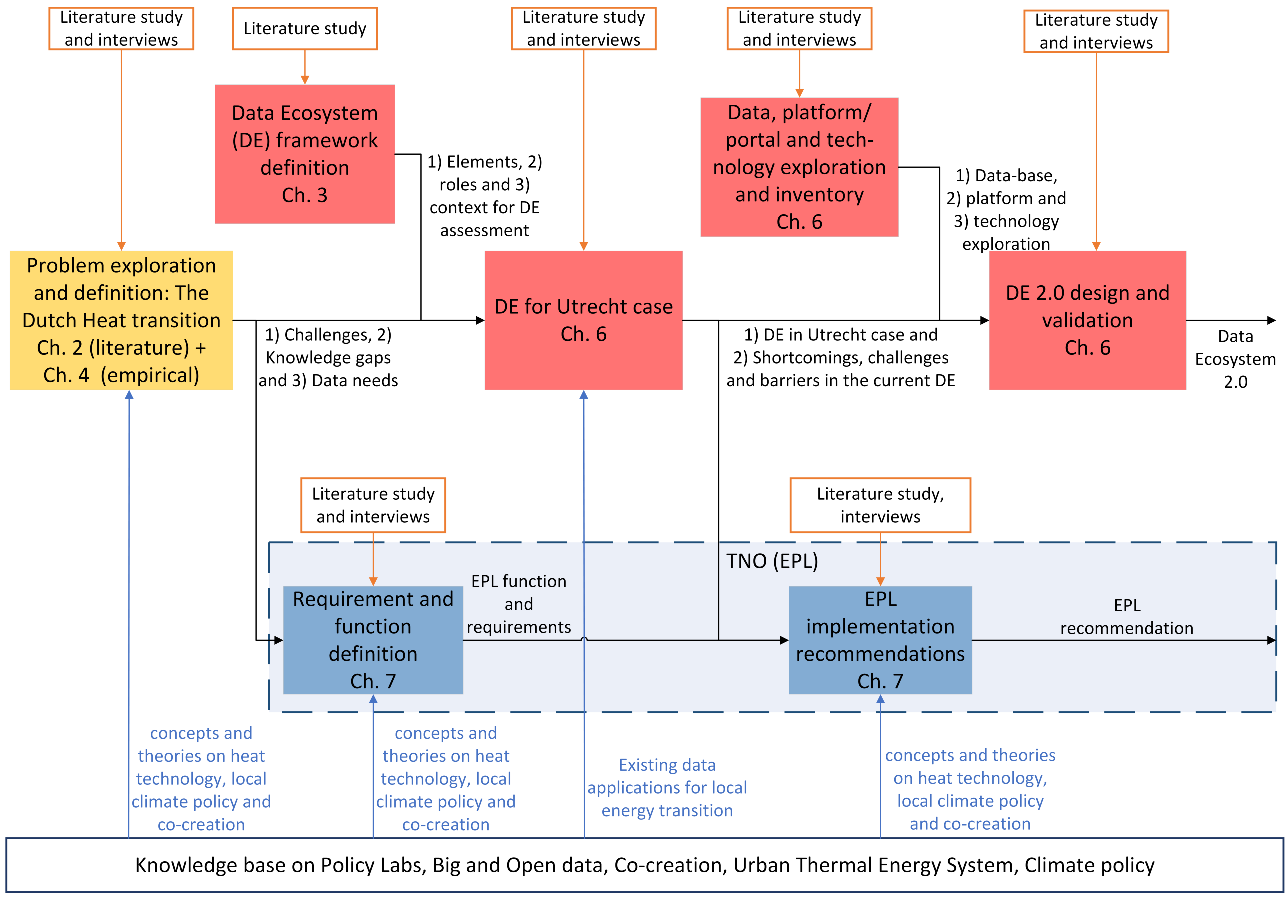


Figure 1.2: The Research Process Flow

lem as the subject of this study, is critically assessed on social, economic, technological and governance aspects. This leads to insights on the socio-technical system behind the heat transition, among others, the overview of stakeholders and their associated characteristics. Moreover, this phase identifies the challenges and barriers encountered in the decision-making for the heat transition, and the knowledge gaps associated to these challenges and barriers. Finally, the knowledge gaps are translated into data needs, to determine to what extent the current DE and the databases available in this DE can provide the necessary knowledge to fill the identified knowledge gaps. After the Problem exploration and definition phase, the DE phase in the red boxes, studies the existing DE within the heat transition, and proceeds towards the design of the DE 2.0, taking into account the challenges and shortcomings from the current DE. The DE phase consists consists of:

- *General DE framework definition*: first, by means of a literature study, a DE framework is derived. This DE framework encompasses the elements, roles and context out of which a DE can be composed, and this DE framework is established to assess the current DE and provide the elements, roles and context towards the design of the DE 2.0.
- *DE definition for the Utrecht case*: with the DE framework established, the DE for the heat transition in the case of Utrecht will be presented. Hereby it will be derived how the elements of the framework are filled in, but also what the shortcomings and barriers are.
- *Data and technology exploration and inventory*:
  - This stage results in the inventory of Open and Private or restricted data sources, which can provide the necessary data to tackle the identified knowledge gaps. From the DE approach, this step also includes the relevant portals or platforms over which this data is or can be released or utilised. Moreover, the stakeholders responsible and/or accountable to generate and release this data are addressed. The identified data-sources can plat a role within the urban thermal energy systems, and the identified municipal policy instruments. Given the identified data-sources and portals or platforms, an analysis is made on which knowledge gaps can readily be addressed with the existing data. As a result, this step will surface which knowledge gaps remain unaddressed by existing data, and thus which data is lacking and needs to be generated and released. Literature research and complementary interviews will be applied to answer these questions on potential data-sources and the ways through which these can be utilised.

  - Finally, this stage includes the exploration of technologies which can contribute in the DE by capturing the missing data, but also in the data exchange, and data analysis. The technology or methods will be presented in a way which provides insights on the opportunities, barriers and readiness of each technology or method, in order to spark further research on the development and implementation.

All-together this input is utilised in the final stage of the DE phase, namely the DE design and validation. After the initial design based on the literature and empirical findings on the heat transition in the Netherlands, an expert validation session is conducted to assess the design on missing elements and usability.

In the EPL phase within the blue frame, the problem definition executed in the first step, results in a recommendation on the requirements and functions for an EPL by TNO in the heat transition. This is based on: 1) the gained knowledge on the state and characteristics of the local thermal energy system and its transition to sustainability, and 2) the DE 2.0, which can feed the EPL by TNO, and heat transition decision-making in general, with Data, Data services and infrastructure. The EPL by TNO phase consists of:

- *Requirement and function definition*: in this stage, it is studied what the necessary and desired functionality is of an EPL by TNO, to be of added value in enabling the local heat transition. In addition, requirements are identified, according to which the added value of the EPL by TNO can be assessed by the stakeholders.

- *EPL implementation recommendations*: based on the derived functions and requirements, recommendations will be made on how these can be operationalised in an EPL by TNO design, utilising the possibilities provided by the DE.

The applied research methodology, consists of methods around literature study and interviews as a means of data collection with decision-makers and stakeholders with a role in the heat transition.

EMPIRICAL DATA COLLECTION

For this study, both open and semi-structured interviews are utilised over two phases of the study. In the first phase of problem orientation, open interviews are conducted with experts in the field of the heat transition at TNO and the Municipality of The Hague, to gather empirical information from these experts on the perception of the problem and the possible solutions (Seidman, 2013). These interviews yielded the information to further specify the research and determine the approach as presented in figure 1.2.

In the phase of the problem analysis and the DE design, semi-structured interviews were conducted to derive the information necessary to answer the research questions. Here, the questions are constructed and categorised according to the research questions, and these interview questions will build upon the knowledge derived from the literature and will function as in-depth knowledge on e.g. the local situation, existing or potential data sources or other specific case related aspects which cannot be found in literature. The design of the interviews, e.g. according to which approach the respondents are selected and how the qualitative data is analysed for the research questions to be answered, is elaborated in detail in chapter 4.

LITERATURE STUDY

Each research phase is initiated by a literature study to establish the state of the art as presented in scientific literature. Literature databases such as Scopus, Web of Science, Google Scholar and IEEE will be searched. In addition, non-scientific or grey literature on local energy transition cases, in particular, but not limited to Utrecht, will be searched. The literature study targets the following aspects, in relation to the SQs:

- SQ1 and SQ2:
  - National, regional and local energy transition goals and policies will be identified for the heat transition
  - Actors and stakeholders in the local energy transition, including their interests, attitude and resources for the heat transition
  - Strategies and technologies for sustainable urban thermal systems, and the digitisation of the modern thermal energy systems
- SQ3: DE theory and DE best-practices for derivation of the DE framework
- SQ4: Big and Open data sources and platforms or portals existing or desired for urban thermal purposes in the Netherlands and abroad
- SQ5: Technologies and methods with the potential to improve the DE and the role of data in the heat transition
- SQ6: PLs as a method to support decision-making by local governments, citizens and stakeholders, including its main aspects of design-for-policy or experimentation, data-drivenness and co-creation

1.4. THESIS STRUCTURE

After introducing the research, and presenting the main research methodology in chapter 1, chapter 2 will provide background information on the technical and policy aspects in urban thermal energy systems. In chapter 3 the theoretical background is discussed on the Policy Labs and the Data Ecosystem approach, where ultimately the Data Ecosystem framework which can be derived from literature is presented. Chapter 4 elaborates further on the research methodology and specifically focuses on the design of the empirical research and the interviews as data collection method. Moreover, the embedded-case of Utrecht is elaborated in chapter 4. Of this empirical research, the findings are presented in chapter 5. Subsequently, chapter 6 presents the current DE based on the Utrecht case, and proceeds with the design of the DE 2.0. Chapter 7 elaborates on the contribution of this thesis to TNO by means of the functions and requirements for the EPL. Finally, the thesis is concluded in chapter 8.

2

Contextual Background: The Dutch heat transition

In this chapter the contextual background of this study is discussed. Background information is provided on the Dutch heat transition as part of the energy transition, where light will be shed on both the technical system and the relevant policy framework. This background contributes in the depiction of the institutional and technical aspects of Urban Thermal Energy Systems as an socio-technical system. The social aspects of the socio-technical system, i.e. the stakeholders and the associated roles and resources, are derived from the empirical data and presented in chapter 5. With the insights on the technical and policy context behind the heat transition, this chapter contributes in answering the following SQ:

> *1. What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?*

2.1. The Policy Framework: from Global to Local

With the Paris Climate Agreement enacted in 2015, the stage was set for the World to take active measures in drastically reducing Greenhouse Gas (GHG) emissions to limit human induced Climate Change to 2 °C or ideally 1.5 °C relative to pre-industrial levels (United Nations, 2015). In figure 2.1 it is displayed how this Global framework can eventually be applied on the local level with the focus on the heat transition, encompassing the disconnection from natural gas. In the realisation of the Paris agreement on the Global scale, the European Union (EU) has a pivotal role to draft European climate policy to reduce human induced GHG emissions. On its turn, the member states, such as the Netherlands, have to implement the EU policy on the national level for the concrete materialisation of measures to reduce emissions nationally among all relevant sectors. The Netherlands, by means of the the National Government, is on the verge of implementing a new framework which should accelerate the energy transition, namely the "Klimaatakkoord" or Climate Agreement. The goal of the Climate Agreement is to initiate and facilitate the realisation of measures to reduce GHG emission by 49% in 2030, relative to 1990. This reduction should take place among the built environment, the electricity sector, industry, agriculture and land-use, and mobility (Klimaatberaad, 2018).

Klimaatberaad (2018) state in the Climate Agreement, that in the built environment on the national level, the total building stock should be transformed to a sustainable building stock at a pace of 50,000 dwellings/year in 2021 and this should increase to 200,000 dwellings/year before 2030 in order to reach a reduction in the CO_2 emissions of 3.4 MT. The transformation to a sustainable building stock entails that energy efficiency measures are implemented, such as adequate insulation, and that heating is provided from sustainable energy sources through collective or individual infrastructure. The disconnection from natural-gas is included in the Climate Agreement, and moreover, since July 1 2018, changes in the Dutch Gaswet impose that it is no longer obligatory for buildings to be connected to the national gas infrastructure.

On the regional level, Provinces, Municipalities and Water Boards cooperate to develop the Regional Energy Strategies (RES) for the 30 energy regions defined in the Netherlands. The RES entail instruments to jointly plan and make decisions on the generation of sustainable energy, including urban heating, and the necessary storage and distribution infrastructure (Het Nationaal Programma Regionale Energie Strategieën, 2019).

To establish the disconnection from natural-gas and the transition of the building stock towards a sustainable building stock, local governments will have a pivotal role together with the citizens and other stakeholders. The planning and realisation of the heat transition for all neighbourhoods does not solemnly rely on the technical aspects of the

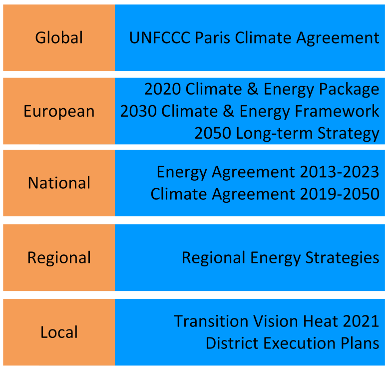


Figure 2.1: An overview of climate policy from the global to the local scale, own image

buildings. In addition, the inclusion of citizens and other stakeholders with regards to their interests and resources can be decisive factors. By 2021, when the operational implementation of the "neighbourhood approach" kicks-off, municipal governments should have the plans ready on how to establish sustainable urban heating systems for each neighbourhood (Klimaatberaad, 2018).

The "neighbourhood or district approach", proposed by the Climate Agreement, emphasises the role of local climate governance. As presented by Hölscher et al. (2019), local climate governance encompasses the policy-making and planning by local governments and public parties, and the decision-making by private parties, such as the citizens and social housing corporations. The municipalities are responsible to establish the Transition-vision Heat for each district. This entails that the municipality needs to draft a plan which is twofold, on the one hand it entails the sequence in which districts will be disconnected from natural-gas, a step where collaboration between local authorities and local actors is key (Hoppe et al., 2011), and on the other hand it has to be determined what alternative will provide the residences with sustainable heat and possibly cooling. The neighbourhood approach for urban heating, can be related to the literature on climate policies and action for small- and medium-sized cities which enjoy significant scholarly attention. In the article by Hoppe et al. (2016) an analytical framework is presented to assess the local climate policy and actions. Furthermore, the review by Broto (2017), among others, conclude that the institutionalisation of climate change governance in urban areas should reflect the specific characteristics of that context. Moreover, the local authorities need to gain in defining and executing their role in local climate policy and governance. To this end, local governments are found to be experimenting on their role and the interaction with the citizens and stakeholders, to cope with the open ended processes in urban governance (Broto, 2017, Hölscher et al., 2019). Matschoss and Heiskanen (2017) dive into the matter on how this experimentation can be shaped by the local policymakers, financiers and local actors and which role intermediaries have in this process. This will be related to the Policy Lab method in chapter 3.

A trend accompanying the decarbonization of the energy system with the shift from fossil based fuels to renewable energy, is the increasing decentralisation in the generation of energy as more consumers are generating their own energy. Subsequently, the diversity in the energy system will continue to increase an develop to fit the local technical and social conditions (Young and Brans, 2017). Hence, it is necessary for local climate policy to facilitate these dynamics on the local/regional level and guide them in the desired direction of ultimately reaching the national climate goals of the Netherlands. Finally, to anticipate the inevitable spatial impact of the Climate Agreement, the Omgevingswet or Environmental code is undergoing changes which should result in energy, and the necessary infrastructure and services, becoming an integral part of the zonal planning and the municipality taking control of the local energy transition by 2021 (Klimaatberaad, 2018, van Oudheusden, 2017).

While the policy framework to enable and facilitate the heat transition is under development, as part of the local climate policy and governance regime, shortcomings and constraints on the current development are identified in literature. It is stated by Measham et al. (2011) that the most recognised constraints encountered by local policy-making and public planning are: 1) a lack of information, 2) institutional limitations, and 3) resource limitations. The existing governance structures are dominated by incremental decision-making, short-term policy cycles, and interests favouring short-term optimality. This model impedes innovation and more disruptive changes (Hölscher et al., 2019).

Moreover, the current regime is lacking adequate understanding of the responses to climate change occurring among the citizens and stakeholders, and outside of formal policy channels. Up to now the focus has mainly been on the processes of policy-making and agenda-setting, the establishment of plans and strategies, and the selection of measures and instruments. The growing role of private actors and the blurring line between public and private parties in climate change policy, entails that the urban response to climate change reaches wider than the municipalities alone and that the knowledge gap requires attention (Broto and Bulkeley, 2013).

Finally, over the course of time, policy-making has been predominantly determined by factors other than empirical evidence, such as (political) ideology, personal observation or experience, intuition, instinct and hype (Esty and Rushing, 2007). However, this traditional policy-making is proven ineffective for the energy transition, lacking the engagement of citizens and stakeholders and a knowledge base based on science. The inclusive policy on the neighbourhood level entails that the strategies and plans to disconnect the households from natural-gas should be established in a transparent way, where decisions are made based on a body of evidence regarding the heating needs and the technological possibilities to supply the heat.

To base policy-making on a reliable set of evidence, the link can be made to Evidence-based policy-making (EBPM) where the main goal is to establish improved and innovative policy design, evaluation and implementation for today's challenges such as climate change. The call for new types of EBPM for governments on all levels, to benefit from the availability of ample data in realising improved policy-making, is underpinned by the European Commission (European Commission, 2017). The EU's H2020 work program for 2016/17 mentions the need for new methods and tools to realise the new style of EBPM, whereby it is essential for the public policy-makers to thoroughly understand the legal-, technical, economic and social framework, and take into account sociological, cultural, political, legal and behavioural aspects when experimenting with the incorporation of Big and Open Data in the policy-making tools and methods (Slob, 2018). Hereby, the data-driven approach behind EBPM can utilise the data on e.g. energy use via smart meters and the movement of people and goods, to recognise problems, set priorities, make policy, implement policy and finally monitor and assess the efficacy of policy and the need to adjust policy or aspects of it (European Commission, 2017, van Veenstra and Kotterink, 2017).

2.2. THE DUTCH URBAN THERMAL ENERGY SYSTEM: THE CURRENT SYSTEM

Over the course of the 20th century the Dutch heat supply for purposes of space heating, warm tap water and cooking, shifted from a dominance by wood, lignite briquettes and coal, towards the mass use of natural-gas with the discovery of the Groningen gas fields 1959. The discovery of the Groningen gas fields was followed by the rapid construction of a Nationwide gas grid from 1963 onward, where in the first two years alone over 1,200 km of pipeline was established (Friedel et al., 2012). In 2012 the national gas grid consisted of over 12,500 km in pipes, while there is an additional 124,000 km of pipelines for the fine-grained regional distribution (Compendium voor de Leefomgeving, 2014).

The conventional Dutch Urban Thermal Energy System for heating is thus a natural-gas based, individual system depending on collective infrastructure. In 2015, around 92% of the households were connected to the natural gas grid and equipped with a gas based boiler, in the individual dwelling or on a block or flat level, to convert the incoming natural gas into the necessary heat (ECN et al., 2016). The heat is then used to warm up domestic or tap water and to warm up water for space heating. Additionally, the combustion of natural gas occurs in gas based kitchen appliances to generate heat for cooking. In figure 2.2 a schematic overview is provided of the individual thermal system which can be found in most Dutch dwellings. Collective heating supply, such as district heating, are not common in the Netherlands. In 2015, 410,000 dwellings, equal to 4.4% of the total housing stock, were connected to District Heating Networks (ECN et al., 2016). The 4.4% connected to DHN equals a total of 4% of the heat supply to the households, with heat predominantly coming from local combined heat and power plants (CHP) and waste incinerators (Menkveld et al., 2017).

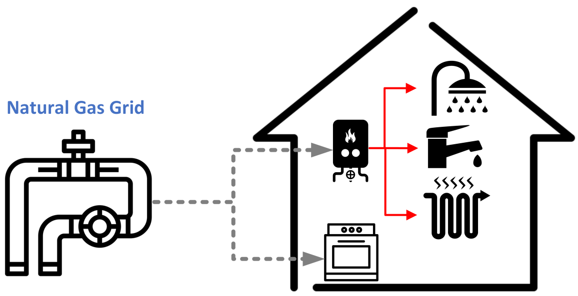


Figure 2.2: The conventional urban heat system of Dutch dwellings, adapted from (Friedel et al., 2012)

2.3. NATURAL-GAS-FREE URBAN THERMAL ENERGY SYSTEMS

In the transition of the Urban Thermal Energy System towards the point of zero GHG emissions and sustainability, the disconnection of natural-gas is one of the main requirements. This entails a de-carbonised Urban Thermal Energy System of which a possible schematic overview is presented in figure 2.3. In addition to the sustainable, non-fossil, sources in green, fossil sources are included in the grey box, however, under the condition that fossil fuel combustion is equipped with Carbon Capture and Storage or Utilisation (CCS or CCU). In this energy system, where no natural-gas enter the dwellings, a distinction can be made in the *individual systems*, which are oriented around the generation of heat and/or cooling for a single dwelling, and the *collective systems*. These systems are schematically presented in figure 2.4 and in the following sub-sections these systems will be further elaborated. From these systems the knowledge gaps will be identified which withhold these systems from gaining foothold in the Dutch heat transition. Note that this section does not provide an in depth and exhaustive state-of-the-art on heating and cooling technologies for residential applications, however, it does sketch the essential elements of a technological landscape within which governance and decision-making is performed by the local policy makers, citizens and other stakeholders.

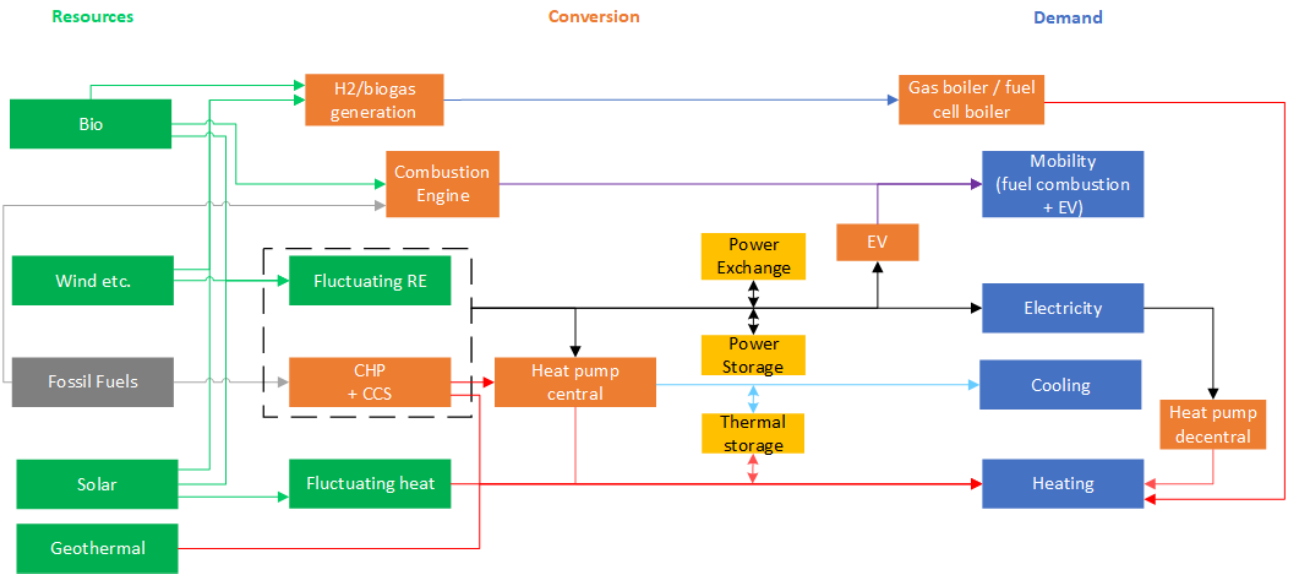


Figure 2.3: A schematic example of a low-carbon and smart Urban Thermal Energy System, adapted from (Paardekooper et al., 2018)

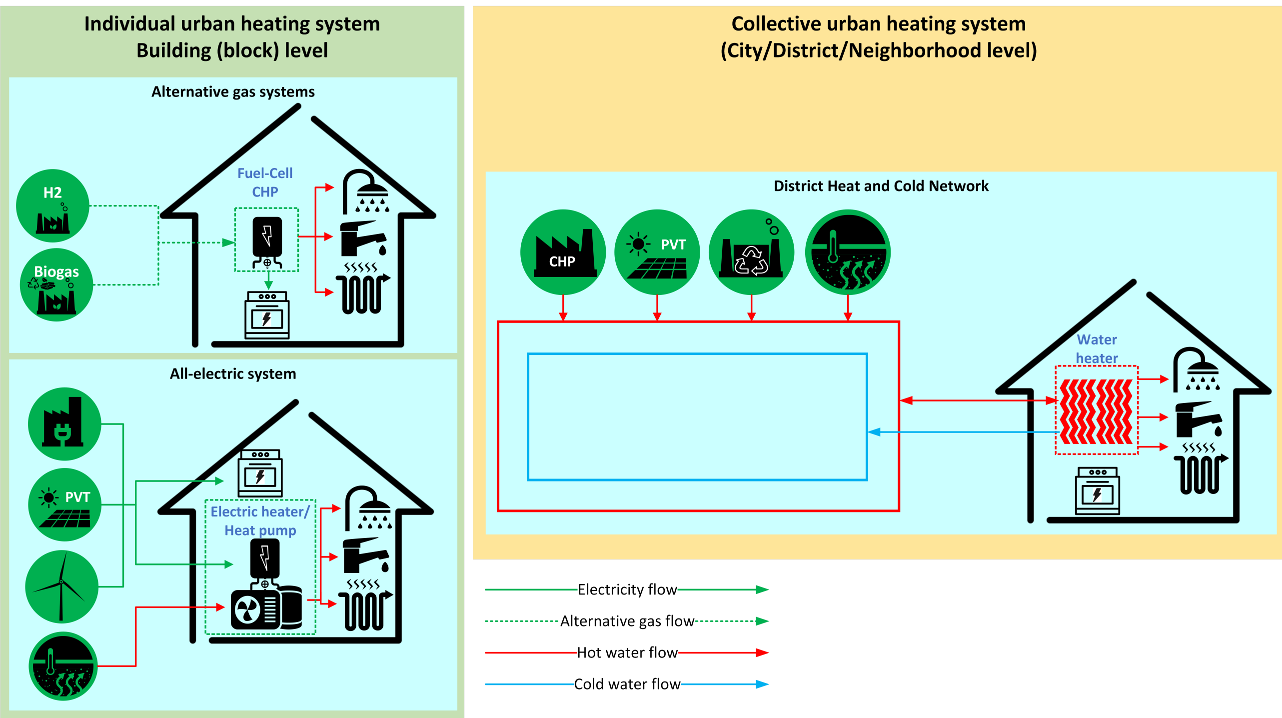


Figure 2.4: Sustainable Urban Thermal Systems, both individual (on the left) and collective (on the right), adapted from (Reda et al., 2015, Schmidt et al., 2017)

2.3.1. INDIVIDUAL THERMAL SYSTEMS

Where the individual systems in the conventional heating provision of Dutch households are based on the combustion of natural-gas, the gas-free solutions are predominantly based on electricity and can be summarised under the all-electric solutions. This electricity is generated from sustainable sources such as solar and wind energy, or from fossil sources in power plants equipped with Carbon Capture and Storage or Utilisation technology. Also heat sourced from geothermal sources via ground source heat pumps and the sun via solar thermal panels (Reda et al., 2015). In the all-electric systems, technologies such as both air and ground source heat pumps and electric heaters utilise electricity to either extract heat from the air or ground, or transfer electricity to heat. The electricity can be generated centrally by power plants or large scale solar or wind farms, but also decentrally by the photovoltaic solar panels on the roofs of households. In addition, solar thermal panels convert solar energy in thermal energy for domestic use (Reda et al., 2015, Willem et al., 2017).

The alternative gas-based solutions encompass bio- or synthetic gasses such as bio-gas or H_2 (Dodds et al., 2015). For sustainable gas based systems, relevant technologies are bio-gas boilers, fuel-cell micro-CHP solutions fuelled by H_2 and hybrid heat pumps. Fuel-cell technology has long been seen as the technology of the future, but products with this technology are not yet widely available in Europe. However, these technologies are gaining ground in Asia (Dodds et al., 2015). Via a exothermal electrochemical process the fuel-cell micro CHP converts gas into electricity with warm water as by-product, which can be utilised in the residential heating system. Through this direct conversion the system can reach an overall efficiency of over 90% (Staffell and Green, 2013).

2.3.2. COLLECTIVE THERMAL SYSTEMS

Collective alternatives in the line of District Heating and Cooling (DHC) are expected to play a significant role in realising a renewable non-fossil heating and cooling supply as part of the transition towards smart and sustainable energy systems throughout Europe (Connolly et al., 2014, Lund et al., 2014, Paardekooper et al., 2018). In addition to the adoption of DHC, these sustainable energy systems entail an integration with the transport and electricity sector and this remains a challenge (Lund et al., 2014). DHC networks are not new and have experienced an evolution of over four generations with the 5th generation of DHC now under development. See table 2.1 which exhibits both the technical and institutional aspects of the DHC networks from the various generations. In figure 2.4 these DHC networks are exhibited on the right-hand side in the collective solutions and it can be seen how such a DHC network is schematically connected to the dwellings for the provision of heat for space heating and domestic hot water. The fundamental idea behind DHC is to use local fuels or resources that would otherwise be wasted, to satisfy the local heat demand by means of conversion plants or facilities to generate the necessary energy, a network of pipe infrastructure for the heat distribution, and a local market place (Werner, 2017). DHC can utilise a variety of sources for the energy supply, such as CHP based on sustainable gasses or biomass, waste-to-energy, excess heat from energy-intensive industries, and geothermal energy (Persson and Werner, 2011).

Although the studies by Connolly et al. (2014), Lund et al. (2014) and Paardekooper et al. (2018) conclude with significant roles for DHC, they stress that these systems need to undergo radical changes towards low-temperature DHC networks. Low temperature district heating operate at a lower temperature than conventional DHC network, typically above 23 °C for space heating and around 50 °C for the provision of domestic hot water to avoid risks related to legionella bacteria. These low-temperature solutions entail benefits on the demand side through energy efficiency, the distribution through reduced heat losses, and the supply side through the connection of sustainable sources (Schmidt et al., 2017). In addition to the shift to low-temperature solutions, requirements for DHC networks encompass, interaction with energy-efficient dwellings, exploitation of synergies to maximise system efficiency, and integration in the smart energy system (Lund et al., 2014, Paardekooper et al., 2018).

The 4th generation DHC networks are the first with the integral intention to be integrated within the smart and sustainable energy systems. This entails that these 4th generation DHC, different from previous generations, include an institutional framework encompassing both the social interaction mechanisms and institutional regulations. This framework targets: 1) heat infrastructure planning by governments and stakeholders on the location, capacity and sources of DHC networks, 2) cost principles and operational incentives to enable an optimal balance between investments and production, and 3) the seamless integration of fluctuating sources of renewable energy in the DHC networks (Lund et al., 2014).

Table 2.1: Overview of the evolution of DHC networks, adapted from (Lake et al., 2017, Lund et al., 2014, Werner, 2017)

	1st generation	**2nd generation**	**3th generation**	**4th generation**
		Technological aspects		
Period	1880-1930	1930-1980	1980-2020	2020-2050
Heat production	Steam boilers	CHP, Heat-only boilers	Large scale CHP, Distributed CHP, Steam-only boilers	low T heat recycling, Heat pumps, Solar thermal panels, Fuel-cells

Table 2.1: Overview of the evolution of DHC networks, adapted from (Lake et al., 2017, Lund et al., 2014, Werner, 2017)

	1st generation	2nd generation	3th generation	4th generation
Resource/fuel	Coal	Coal and oil	Biomass, waste, coal, oil and natural gas	Renewables
Carrier	Steam	Pressurised hot water	Pressurised hot water	Pressurised hot water
Temperature	>100	>100	<100	23 - 70
Metering	Condensate meters measure the steam consumption	Flow meters in sub-stations, replaced by heat meters with monthly or annual reading	Heat meters and flow metering to compensate for high return temperatures. Wireless reading for increased frequency.	Comparable with 3th gen metering, with continuous commissioning of consumer heating system
Dwelling	Apartments, Utility buildings	Apartments, Utility buildings at 200-300 kWh/m2	Apartments, Utility buildings at 100-200 kWh/m2	New buildings <25 kWh/m2 existing buildings 50 -150 kWh/m2
Institutional aspects				
Primary societal motivation	Comfort and reduced risks	Fuel savings and reduced costs	Security of supply	Transition to smart and sustainable energy system
Infrastructure planning	Regulation of competing heating infrastructure	Enabling the cost-efficient use of CHP	Identifying and implementing suitable DHC infrastructure in fossil energy based systems	Identifying and implementing renewable energy infrastructure in sustainable energy systems
Cost principles	Minimise the per unit supply cost	Minimise the per unit supply cost	Dilemma between short- and long-term production costs	Dilemma between short- and long-term production costs with a need for better integration of future investments

After addressing the promise of alternatives to natural-gas in a sustainable urban thermal energy system, the following section addresses challenges for the large scale implementation of these solutions.

2.4. CHALLENGES AND BARRIERS TOWARDS SUSTAINABLE URBAN THERMAL ENERGY SYSTEMS

In general the challenges and barriers encountered by low-carbon solutions for a sustainable urban thermal system can be summarised as: high capital and installation costs for e.g. a heat pump, the perceived low technological maturity, uncertain operational costs for e.g. fuel, house space requirements, and noise pollution (Dodds et al., 2015). In addition, passivity, hassle, and a lack of interest or knowledge on the alternatives are stated as barriers to change by Hoggett et al. (2011). These main barriers presented by Hoggett et al. (2011) in a study to assess the implications on citizens of UK policy on the sources and technologies utilised for the provision of household heat, can be further elaborated as:

- high initial investments and long payback periods, with a risk of not achieving expected cost savings
- unknown and uncertain operational costs
- a lack of awareness, understanding and confidence in the sustainable alternatives by citizens, due to, among others, the limited deployment of sustainable urban heating to date and the subsequent limited visibility
- poor sustainability of dwellings, e.g. the energy performance of dwellings in terms of energy efficiency and renewable energy generation
- lack in market capacity in terms of skilled installers and suppliers
- hassle associated to the necessary interventions in the dwelling technical installation or facade
- concerns regarding the convenience of the new technologies

After previously addressing the more general barriers for the heat transition, the focus is now shifted to the low-temperature solutions. One of the main challenges in the transition towards low-temperature solutions on both the individual and collective level, is related to the building stock, in particular the existing buildings (Østergaard and Svendsen, 2016, Werner, 2017). These buildings are commonly poorly insulated and this requires a high temperature for space heating. For low-temperature solutions to be suitable for these dwellings, while the level of comfort is maintained or improved, it is necessary for these old dwellings to either install equipment to reheat the incoming water, or be retrofitted towards low-temperature dwellings. This entails significant investments in the building envelope, such as insulation and double-glazing (Paardekooper et al., 2018, Schmidt et al., 2017).

Moreover, Werner (2017) state that DHC is experiencing challenges regarding the information provision on the local and specialised character of DHC. Different to the generic conventional heating systems, DHC is associated to local conditions on the urban energy demand and a larger variety in the local heat and cold sources. These local conditions often remain a knowledge gap, and challenge the decision-making on the local heat transition such as the dimensioning and routing of DHC networks.

Finally, challenges are experienced in the institutional context and governance of DHC. Within the institutional context, the legal frameworks governing the market conditions for DHC are different for various countries and this impacts:

- the ownership of DHC networks: are the DHC networks in public or private hands? (Werner, 2017)
- the (third party) access to DHC networks: according to which rules and regulation are DHC concessions tendered and contracted, does this allow one or more parties to supply the DHC network with heat or cold? (Lund et al., 2014, Werner, 2017)
- the pricing of heating and cooling as a utility: is pricing regulated? Is the pricing market-based, compared to the competing alternatives, or cost-oriented, based on the fixed and operational costs of DHC networks? and how is pricing coupled to advanced metering and the smart grid concepts? (Lund et al., 2014, Werner, 2017).

These questions are experienced as challenges in the roll-out of sustainable DHC networks Globally, and to a large extent can also be experienced in the Netherlands. In chapter 5 it will be presented how the interviewees perceive the challenges for the Dutch situation.

2.5. CHAPTER CONCLUSION

This chapter contributed to the following SQ:

> *1. What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?*

For the Dutch heat transition in the Urban Thermal Energy Systems, an extensive field of technologies at different states of maturity, sustainability and affordability, and with different characteristics on the energy source, temperature, and being an individual or collective system can be identified. This technology poses ample opportunities to shift toward a low-carbon urban thermal system, however, the need to invest in, and adapt to these alternatives for natural-gas is met with significant challenges and barriers. The challenges can be summarised in high capital and installation costs and the allocation of cost among public and private parties, the perceived low technological maturity, uncertain operational costs, house space requirements, and noise pollution. In addition, passivity, hassle, and a lack of interest or knowledge on the alternatives are commonly stated as barriers. These challenges will be further studied in chapter 5 on how they are encountered in the Dutch situation.

After addressing the technological and policy context behind the heat transition in the Netherlands, the following chapter will address the theoretical background of this research. The Data Ecosystem approach and the Policy Lab method, which form the two main elements of the methodology behind this study, are presented.

3

Theoretical Background

In this chapter, the theoretical background of this research is presented. The DE (DE) approach and the Policy Lab (PL) method, which form the two main elements of the methodology behind this study, will be presented. In short, this chapter relates to the research questions in the following manner:

Section 3.1 and Section 3.2	⇒	*3. How can a DE be composed and how does the current DE look like for the Dutch heat transition, what are the shortcomings and challenges?*
Section 3.3, 3.4, 3.5, 3.6 and 3.7	⇒	*6. What are the requirements and functionality of a data-driven method, such as TNO's EPL, to be of added value in the realisation of sustainable and inclusive Urban Thermal Energy Systems within the proposed Data Ecosystem 2.0?*

After the literature study on Big and Open Data applications in local energy decision-making, the literature on DEs is addressed. The DE literature study contributes to the derivation of a DE framework consisting of elements and roles. This DE framework thus entails the composition of DE and the answer to the first part of SQ3. This DE framework will be utilised to analyse the DE in Utrecht and subsequently towards the design of the DE 2.0.

Finally, this chapter addresses the relevant literature on PLs and its application in various domains, in relation to Evidence-based policy-making (EBPM), Co-creation in local initiatives, and Design based approaches for decision-making. Insights from this background contribute in the recommendation on the design and implementation of the EPL by TNO.

3.1. Big and Open Data

Big Data and Open Data have been carrying great potential to enhance society, affecting all aspects of human activity, by incentivising citizen participation, transparency, economic growth and innovation (Zuiderwijk et al., 2014). In this section Big and Open data will first be introduced in sub-section 3.1.1, together with the platforms and portals over which the data can be released. Thereafter, in sub-section 3.1.2 it will be discussed what the role of Big and Open data can be in the context of private and public decision-making for climate and energy policy, with the focus on urban thermal energy systems. Finally, sub-section 3.1.3 elaborates on challenges and barriers encountered by Big and Open Data application for private and public decision-making.

3.1.1. The concepts of Big and Open data

Data is increasingly gaining value as an economic asset, however, this is not yet the case for policy-making and public decision-making in general. Data utilisation, among others, offers new insights into behaviours and patterns, with less dependence on surveying. However, it requires major efforts to bring together multiple actors from various disciplines and practices to study the under-explored relationship between data types (Janssen and Kuk, 2016).

Big Data

Big data, the first concept to be discussed in this section, and its role in both public and private decision-making has attracted significant research in the past decade (Androutsopoulou and Charalabidis, 2018, Clarke and Margetts, 2014). The technological advances achieved in the last decades, in particular the ICT domain, such as the use of social media, smart phones and the Internet of Things, is driving the exponential increase in the volume of data, leading to the so called Big Data. Hereby literature is quite diverse in the definition of Big Data, among others, due to the strong developments. A commonly found definition is that big data means *"data-sets that are too large for traditional processing systems and require new technologies."* (Provost and Fawcett, 2013, p. 54). A more comprehensive definition, which also emphasises the increase in scale and scope of data is as follows: *"Big Data is a step change in the scale and scope of the sources of materials (and tools for manipulating these sources) available in relation to a given object of interest"* (Poel et al., 2018, p. 349). This working definition will be applied for the remainder of the thesis, due to its comprehensiveness and it being more specific than the more common definition of Big Data in industry, where Big Data is defined by means of its five characteristics of Volume (e.g. a large number of objects or time series), Variety (Large variety among data types e.g. statistics, metering data, social media data), Velocity (high speed of data generation, e.g. real-time data) and Veracity (the trustworthiness or validity of the data) (Poel et al., 2015).

With the increasing application of sensors, wireless network communication, advanced metering, and cloud computing technologies, large amounts of data are continuously being accumulated in the energy sector. These applications have predominantly been utilised in the context of Smart Grid research and power systems to enable generation side and demand side management, asset management and collaboration, and micro-grid and renewable energy generation (Zhou et al., 2016).

Open Data

In addition to Big Data, this research addresses Open Data as a means or source of knowledge and decision support. The Open Knowledge Foundation, an international non-profit organisation, promotes Open Data as part of the their Open Knowledge campaign and define Open Data as *"a piece of data or content that is free to be used, reused, and redistributed - subject only, at most, to the requirement to attribute and/or share-alike"* (Dietrich et al., 2012, p. 6). Other characteristics, included by alternative definitions, include: standard formats, no restrictions from copy rights or patents, interoperability, digital and machine readable formats, and public sector information (Visser, 2015).

For data to be classified as Open Data, the data should comply to the 10 criteria established in 2010 by the Sunlight Foundation, a NGO aiming to make governments and politics more accountable and transparent by means of, among others, open data, namely: complete, primary, timely, accessible, machine processable, non-discriminatory, non-proprietary, permanent, licence-free, and preferably free of charge (Welle Donker and van Loenen, 2017).

Open Data is being increasingly considered as a major enabler of public service innovation (Toots et al., 2017). The open access to data-sets, without any predefined financial and regulatory restrictions or conditions of use, and advanced analytical methods and tools have opened up endless possibilities to generate new knowledge and drive data-driven solutions. In the next sub-section these applications of Big and Open data for energy and climate policy will be addressed.

Data platforms or portals

In literature the terms Data platform and Data portal are often interchangeably used to refer to some kind of infrastructure which is established to primarily support the production and consumption of easy accessible, machine-processable and possibly real-time data (Ding et al., 2011, Welle Donker and van Loenen, 2017). This main functionality may be extended with functionality regarding data (geo)visualisation, data analysis, and finally the education and support of the data community as one would expect in a platform (Ding et al., 2011). These data portals have been growing immensely over the last decade and large varieties of data-sets are now being offered to data consumers. These platforms are administered by authorised users whom are in charge to release data-sets and fill in meta-data fields to make it clear what the data-set entails and in which format. Hereby it is important to do this in such a way that users can engage on the use of the data to improve society. This entails that there is a need for best practices, instructions and inspiration for the users on how to use the data (Reis et al., 2018, Zuiderwijk et al., 2014).

3.1.2. Big and Open Data in Climate and Energy Policy

Big and Open Data can be sourced from both the energy infrastructure for generation and distribution (Noussan et al., 2017, Visser, 2015), as from the demand, influenced by end-user behaviour and building characteristics (Di Corso et al., 2017, Mathew et al., 2015). In the heat transition, climate policy has a significant role to enable and guide the transition. For EBPM, the data-driven approach may utilise data on energy, the environment and the economy, to establish a knowledge base and subsequently recognise problems, set priorities, establish and implement policy, and finally monitor and assess the efficacy of policy and the need for adaptive response (European Commission, 2017, van Veenstra and Kotterink, 2017, Wang et al., 2014). Although this relevance and necessity for open data of adequate quality, integrity and detail is acknowledged by the sector and studied over a wide field of applications in the energy sector, energy policy research is lacking behind other sectors in promoting open and reproducible data and methods (Pfenninger et al., 2017, Poel et al., 2018).

In the exploration on innovative data-driven approaches for policy-making by Poel et al. (2015), the most common applications of data include pilots where new data sources are utilised for agenda setting and policy implementation. Moreover, open data is stated to be commonly utilised for transparency, accountability and enhancing participation, while administrative data or statistics are applied to track the output and impact of policy.

In the Policy Lab specialist team within the British Cabinet, Data Science plays an important role to identify patterns of policy impact. Due to the novel application of data in policy-making, a key element of data science in policy-making is exploratory data analysis where data scientist get a feel of the available data by applying basic analysis and visualisation. Based on the knowledge gained from the exploratory phase, the data scientist can decide on the most appropriate method to model the data for the purpose at hand (Bakhshi and Mateos-Garcia, 2014).

In literature several scholars have addressed various data-driven approaches to develop and operate heating and cooling on the urban district level. These studies target broader urban thermal planning aspects, for instance, Gulbe et al. (2017) studied both large and small scale data, from regional to building level, derived via remote thermal sensing on thermal distribution patterns. With the large scale data, correlations between vegetation and temperature patterns were studied, while the building data was utilised to assess the roof insulation. After introducing the role of Big and Open Data for Energy Policy, the following paragraphs dive deeper on the role of data in the Urban Thermal setting. Approaches will be addressed for: 1) the potential of heating and cooling supply from various sources, 2) heating and cooling demand mapping, and 3) building retrofit to improve energy efficiency and implement sustainable thermal technology. Finally, it will be presented which data these methods utilise and from which data-bases the data is acquired.

Energy potential estimation

Within the body of literature on data-driven applications for renewable energy purposes, a large share of the research covers the calculation of renewable energy potential such as solar and wind. McIntyre (2012) apply a variety of data sources, namely atlas, meteorological and GIS data, to determine solar potential. Korfiati et al. (2016) used open data to estimate the global solar potential. Schiel et al. (2016) calculated the shallow geothermal potential in a GIS approach, connecting building energy demand with geothermal extraction potential of the corresponding parcel. The study by Sbrana et al. (2018) combined simulation and 3D modelling for the geothermal potential of the larger Pisa Sedimentary Plain, while ThermoGIS by Kramers et al. (2012) determines and maps the geothermal potential for the whole of the Netherlands.

District heating and cooling networks

In the data-driven research on thermal energy systems, district heating and cooling, as elaborated in sub-section 2.3.2, plays a prominent role. The development and operation of these systems is dependant on the deep knowledge on consumer heat and cooling load profiles which is related to users' behaviour, network performances and control logic. Noussan et al. (2017) use real user data to derive the main characteristics of heat load variations and the main drivers for heat load prediction. Dalipi et al. (2015) propose a cloud computing based framework to implement ICT solutions with flexible and distributed data collection and storage in smart heating networks for improved efficiency and reliability. The ICT solutions target the complex monitoring and control of DHC with the varying load patterns and generation units.

Energy demand estimation and mapping

Gupta and Gregg (2017), Ramachandra and Shruthi (2007), van den Dobbelsteen et al. (2018) study the spatial mapping of energy potential and demand via GIS based tools. For instance Gupta and Gregg (2017) addresses how open data on dwellings and energy can be used to map and plan mass retrofit and propose effective and targeted low carbon measures across a city. Notably Gupta and Gregg (2017) propose how to deal with the challenges of having: 1) incomplete data and 2) the inability to optimise and consolidate private sector housing retrofit activities to minimise installation costs.

Dwelling retrofit or renovation

On the end-user side, dwelling retrofit is considered an effective mean to drastically reduce energy use and enable more innovative, sustainable and energy efficient heating and cooling solutions. Karkare et al. (2014) applies data-analytics and energy modelling on the building technical and consumption aspects to determine the efficacy of non-structural retrofit strategies on energy efficiency in a residential building. A more data-driven approach is applied by Miller (2017), where smart meter and retrofit data from 1,600 non-residential buildings is collected and merged with data from previous energy saving retrofit measures to predict the success of energy saving measures based on the type of building and the industry type. No comparable research applied for residential buildings could be found.

Databases for sustainable heating and cooling potential, demand estimation, and dwelling retrofit

In Europe the common ambition is to set up a centralised data-base for sustainable buildings. This ambition is met by the establishment of the data-base for Near Zero Energy Buildings (NZEBs) by the European Energy Efficiency Platform (E3P). From this data-base the E3P aims to establish a comprehensive reference guideline for NZEBs (D'Agostino et al., 2017). In addition to the NZEB retrofit data-base, D'Agostino et al. (2017) report on several other European level data-bases for building data:

- The Building Performance Institute Europe (BPIE) maintains a data-base with data on energy policy, energy use, building envelope and performance, and climatic zones of the building stock in Europe (D'Agostino et al., 2017).
- Enerdata manages the Odysee-Mure database, containing data on the drivers behind energy consumption by end-use, efficiency and CO_2 indicators for various sectors and buildings. The data on energy efficiency measures and policies carried out throughout Europe is hoped to enable the simulation and comparison of measures on the national level (ODYSSEE-Mure, nd).
- The Tabula Intelligent Energy Project on the typological approach for building stock energy assessment maintains a data-base which encompasses data on good practice buildings, construction elements, energy use by energy carrier and energy efficiency measures (Ballarini et al., 2014).
- The Zebra tool is connected to a data-base which contains data on the best practices in Europe regarding energy efficient buildings. Information on most used technologies, materials and strategies towards NZEBs can be derived from this data-base (Zebra2020, 2016). The database established by Rehva and Aircarr contains comparable data, however, in a more detailed format and limited to buildings in Mediterranean countries (Becchio et al., 2015). Finally the IEA established a database on the high energy efficient buildings.

The role of data for energy and climate policy is thus acknowledged by numerous scholars and the potential is well-documented. However, challenges and barriers withhold the potential of data to be optimally exploited. In the following sub-section it is presented what these challenges and barriers are.

3.1.3. Challenges and barriers for Big and Open Data

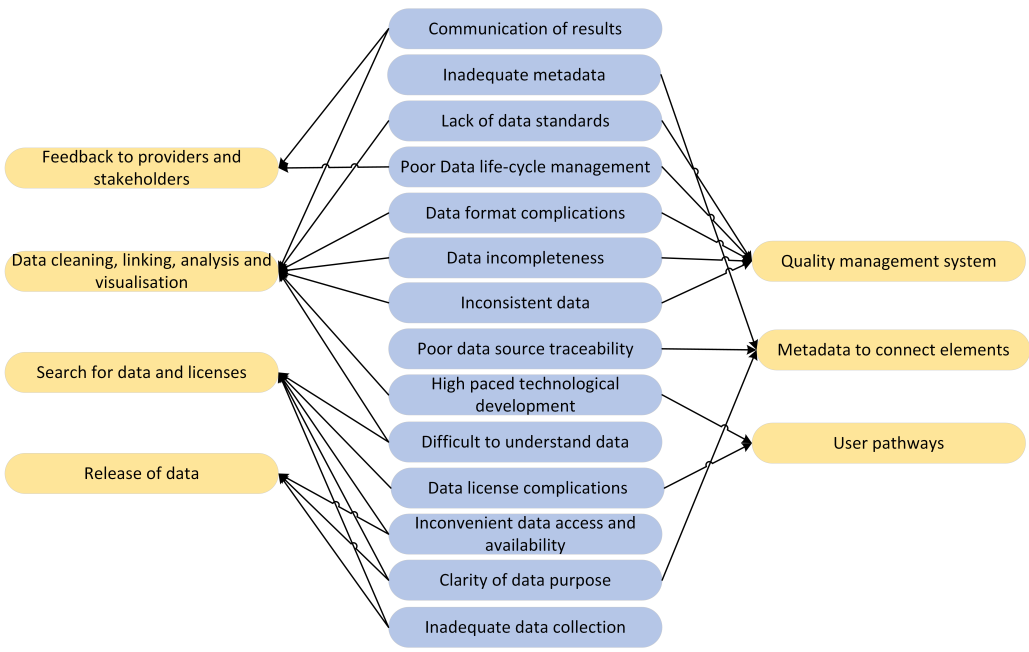


Figure 3.1: Challenges and barriers for the use of Open data and platforms in connection to the DE elements, own figure

The work by Reis et al. (2018) provides an overview of recurring challenges and barriers in the application of open data and open data platforms or portals worldwide. In figure 3.1 these challenges are exhibited, complemented with challenges discussed in work not assessed by (Reis et al., 2018). The challenges are linked to the DE elements as presented in sub-section 3.2.6 and can be described as follows:

- *Inconvenient data access, availability and findability*: users or intermediaries have difficulties to access the portal or platform. This can either be in the identification of the data-sets they need and the pathway to find the portal containing the desired data-set over search engines. Furthermore, broken links and inconvenient user interfaces complicate the navigation to and in the portals and platforms.

- *Clarity of data purpose*: data-sets without actual purpose of use or without users and providers acknowledging the purpose, may lead to these data-sets not being collected and released, while they may be relevant and necessary.
- *Inadequate or poor data collection*: portals and platforms with few data-sets and little variety of data in categories or themes.
- *Data license complications*: missing open data licences, specifying the conditions of the data utilisation and sharing.
- *Difficult to understand the data*: users experience difficulty in the understanding or interpretation of the data-set and what the data represents, and may provide in insights. A high level of skills and expertise is expected from the users, making the data not accessible to all potential users.
- *High paced technological development*: even for the most commonly used technologies in Big DEs, the maintenance is intensive and the learning curve is steep due to the complexity and distribution of the eco-system components over multiple machines. The technology landscape is fast evolving with constant improvements and this is challenging decision making on which technology to utilise in the data landscape. There is a constant trade-off between maintaining a stable system and implementing the latest technologies (Linder et al., 2017).
- *Inconsistent data*: lacking consistency in data, e.g. over the time or areas data is collected, or the data does not reflect reality. This may lead to interoperability issues. There is thus a high variability and dimensionality in data and this complicates the exploitation of algorithms for e.g. cluster analysis and pattern mining (Di Corso et al., 2017).
- *Incomplete data*: Incomplete data-sets, missing data or relevant attributes, erroneous data registered.
- *Lack of data standards*: lacking standardisation of data attributes, units of measure, and other format related aspects. It is stated by Mathew et al. (2015) that the lack of standard data formats, terms and definitions, is a barrier in the realisation of the full potential of building big data. The high variability in data format and data field definition, calls for standardisation of building data. Each project or use-case commonly defines its own requirements and priorities for data collection and this leads to a large variety in the data-bases. This challenge is underpinned by Göçer et al. (2016) and Chen et al. (2017) for the building industry.
- *Inadequate meta-data*: the absence or poor quality of meta-data, with meta-data being the information on the data-sets such as: what data it contains and how the data is collected.
- *Communication of results*: communicating immense amounts of energy data to stakeholders as knowledgeable and actionable information is still a big challenge and falls under the exponentially growing field of big data visualisation and analysis (Reinhart and Davila, 2016).
- *Poor data life-cycle management*: inadequate management of the data over its value adding life-cycle, this entails the lack of data updating policy, warehousing and deletion of data-sets.
- *Poor data traceability*: missing information on the source of the data, e.g. to verify the quality or trustworthiness of the data.

After introducing the concepts of Big and Open Data in this section, and the encountered challenges and barriers, the following section will elaborate on the Data Ecosystem approach and the relevant theories.

3.2. THE DATA ECOSYSTEM APPROACH

After the elaboration on the role of Big and Open Data in energy policy and in particular urban thermal systems, in section 3.1, this section proceeds with the elaboration of the Data Ecosystem (DE) approach and the relevant theories. This contributes to answering SQ 3, particularly, the part on the composition of a DE. The section is concluded with a DE framework consisting of elements which encompass the roles, activities, and environment in DEs. This framework forms the means to analyse the current DE and paves the way towards the DE 2.0 in chapter 6.

3.2.1. DATA ECOSYSTEM THEORY

The technological advances achieved in the last decades, in particular in the ICT domain, such as the use of social media, smart phones and the Internet of Things is driving the exponential increase in the volume of data leading to the so called Big Data which is previously discussed in sub-section 3.1.1, together with Open Data. According to the immense growth in Big and Open Data, the infrastructure and technology to enable these technologies, such as Big data storage and processing facilities, Open data portals and platforms, and tools and instruments, have been introduced and developed at an unprecedented pace to exploit the potential behind Big and Open Data. Zuiderwijk et al. (2014) and Demchenko et al. (2014) argue that these facilities and infrastructure are utilised by many users, and also developed and maintained by many parties. Hence, it is proposed to view them as part of a wider open DE in which each instrument or tool can add value as part of the puzzle. Subsequently, in this research DE theory plays an important role to understand the involved stakeholders and the interaction between them in generating and utilising Big and Open Data for an inclusive heat transition. The heat transition will be addressed from the perspective of its current and future DE, which should form the foundation for the provision of knowledge and support to decision making among all actors and stakeholders involved.

Moreover, the literature review on DEs by Oliveira et al. (2019) derived the following potential benefits of the DE approach: 1) improved political and social aspects, 2) improved economic aspects, 3) convenient data generation and utilisation, 4) improved communication and interaction between actors and 5) improved quality of data and services. These are thus benefits which are in line with the needs of modern day governance of complex challenges, such as the heat transition.

The term ecosystem is derived from its use in biology where an ecosystem represents a natural unit, functioning as a whole, consisting of plants, animals and microorganisms together with the non-living physical resources in the environment (Oliveira et al., 2019). For Open Data, the Ecosystem metaphor is used to refer to the interdependent social system consisting of individuals, organisations, infrastructures, and resources that can be created in technology-enabled, information-intensive social systems (Harrison et al., 2012, Oliveira et al., 2019, Zuiderwijk et al., 2014). In the study with the focus on the architectural elements of Big Data Ecosystems by Demchenko et al. (2014), the ecosystem metaphor is used to state that the Big Data challenge is not only that of its core technological components, but it is rather a complex whole of components to store, process, visualise, and deliver results. This whole of interrelated components is what is defined as the Big Data Ecosystem which deals with the evolving data, models, and supporting infrastructure over the entire Big Data Life-cycle.

3.2.2. DEs: Definitions

The term DEs is commonly used in studies, however there is little agreement on the definition of the term. The literature review by Oliveira et al. (2019) surfaced 15 different definitions of DEs. In that literature review the work by Harrison et al. (2012), Pollock (2011), Ubaldi (2013) and Heimstädt et al. (2014) is presented as the most cited among the selected 29 primary studies published in the period between 2011 and 2016. The first work on DEs, according to the review by Oliveira et al. (2019), is published in 2011 by Ding et al. (2011) and Davies (2011).

Pollock (2011) states that a DE consists of data cycles, and within these, intermediate data consumers, such as app developers and data wranglers process the data and share the cleaned, integrated and packaged data back into the ecosystem to be utilised by the end-consumers.

In the work by Zuiderwijk et al. (2016), DEs are generally defined as *"all activities for releasing and publishing data on the Internet, where data users can conduct activities such as searching, finding, evaluating, and viewing data and their related licences, cleansing, analysing, enriching, combining, linking, and visualising data, and interpreting and discussing data and providing feedback to the data provider and other stakeholders"(Zuiderwijk et al., 2016, p. 3)*.

Alternatively, Ding et al. (2011) look at a DE for linked data and provide the following definition:*"a data-based system where stakeholders of different sizes and roles find, manage, archive, publish, reuse, integrate, mash-up, and consume data in connection with online tools, services, and societies." (Ding et al., 2011, p. 326)*.

Although there is a large variety in definitions for DEs, certain characteristics of these ecosystems are common over the definitions. It can be observed that all mentioned definitions share the following components: 1) stakeholders and roles with relationships and interactions, 2) activities and processed to find, clean and add value to data, and 3) (digital) resources. In the proceeding sub-section these elements will be further elaborated on.

3.2.3. DEs: Characteristics

From the review study on DEs by Oliveira et al. (2019), one of the main findings is that the various views on DEs, commonly identify these ecosystems as socio-technical systems with a large variety of technical and social elements involved and a high degree of inter-dependencies. Hence, the study and design of DEs require thorough contextual understanding of human interactions, in relation to the technological, cultural, political, and economic context.

Moreover, Oliveira et al. (2019) reports on the organisational structure of the DEs as relevant category of characteristics. This entails the actors and the type of role they take in the ecosystem, but also the interest and business models connecting these actors. Hereby the most common organisational structures found in the reviewed work are: 1) *Keystone-centric*, where stakeholders are organised around the Keystone actor responsible to directly or indirectly provide data, 2) *Intermediary-based*, where the data intermediaries are accountable to add value to the data, 3) *Platform-centric*, where a platform shapes the organisation of the DE, and 4) *Marketplace-based*, where the market provides the infrastructure, business-models, rules, and services for the exchange of data between actors.

Van Schalkwyk et al. (2016) argue that the context of DEs can be characterised in at least three different categories. First, the regulatory context entails laws, policies, standards, and agreements, and guides the structure of the DE and the relation between the actors. Second, the institutional context, where the actors operate under certain values, rules, and norms. This context is also called the environmental context by Zuiderwijk et al. (2016). Third, Van Schalkwyk et al. (2016) proposes the technological context, encompassing the IT resources and operators, but also other enabling technologies that contribute in connecting the DE elements.

Finally, the review by Oliveira et al. (2019) reports on characteristics of DEs, proposed by Heimstädt et al. (2014), that relate to: 1) the cyclical nature of processing resources, 2) sustainability to maintain continuity of the ecosystem, 3) user-centricity, 4) demand-drivenness, and 5) self-organisation.

3.2.4. DE: ELEMENTS

After addressing the characteristics of DEs regarding the context and organisation, the elements of DEs can be considered as the next operationalisation of the characteristics in the Ecosystem design. Several studies propose DE elements or components, in order to interact and achieve the desired functionality of the ecosystem. In table 3.1 it is presented which elements for both Open and big DEs are proposed by the work from Demchenko et al. (2014), Mercado-Lara and Gil-Garcia (2014), Zuiderwijk et al. (2014) and Shin and Choi (2015).

Table 3.1: An overview of DE elements derived from literature

Ecosystem type	Element or Component	Source
Open DEs	1) Releasing and publishing open data on the internet 2) Searching, finding, assessing and viewing data and the associated licences 3) Cleansing, analysing, enriching, combining, linking and visualising data 4) Interpreting and discussing the data and providing feedback to stakeholders and the data providers 5) User pathways to inspire users on how data can be used 6) A quality management system 7) Meta-data to connect the elements	(Zuiderwijk et al., 2014)
Open DEs	1) Government policies and practices 2) Innovators as a combination of technology, business and the government 3) Users, civil society, and business	(Mercado-Lara and Gil-Garcia, 2014)
Big DEs	1) Data models, Structures and Types, this concerns Data formats, file systems etc. 2) Big Data Management on e.g. Big Data Life-cycle, Big Data transformation and staging, and sourcing, curating, and archiving 3) Big Data analytics and tools, e.g. Big Data applications, the target use, presentation, and visualisation 4) Big Data Infrastructure for e.g. storage, computation, exchange, and Big Data operational support 5) Big Data Security, on in-rest and in-move data, and through trusted processing environments	(Demchenko et al., 2014)
Big DEs	1) Infrastructure 2) Software and Technology 3) Service and Applications 4) Standards 5) Users 6) Social and Cultural factors 7) Government 8) Industry	(Shin and Choi, 2015)

In the first study to address these elements in this section, Zuiderwijk et al. (2014) propose a set of four core elements and three additional elements for DEs with the focus on Open Government Data (OGD). Next, three categories of ecosystem elements are proposed by Mercado-Lara and Gil-Garcia (2014). Here it can be noticed that Mercado-Lara and Gil-Garcia (2014) is placing more emphasis on the social and regulatory aspects within the ecosystem. On the contrary, the set of elements proposed by Zuiderwijk et al. (2014) encompasses a broader set of aspects and particularly places the emphasis on the activities which are or can be carried out in DEs.

Demchenko et al. (2014) and Shin and Choi (2015) study the Big DEs and propose different sets of elements. Compared to Demchenko et al. (2014), Shin and Choi (2015) take a broader approach in proposing the key elements of a Big DE where also the social aspects are taken into account, in addition to the technological aspects as previously presented by Demchenko et al. (2014).

It should be noted that, among these studies, it can be observed that none address both Big and Open DEs as the focus is on either Big or Open Data. To fill this gap, this study takes an integrated approach for the DE, addressing both Big and Open Data. Given the characteristics and elements of DEs as mentioned above, Davies (2011) proposes a set of steps to facilitate the development of an DE. These steps are as follows:

1. identify the people and organisations that can take a role as essential component of the ecosystem
2. comprehend the nature of the transactions and interactions that occur between those entities
3. identify what resources are needed by each entity to engage with each other in transactions and interactions
4. observe the indicators to measure the health and performance of the ecosystem as a whole

These steps are followed for the derivation of the stakeholder map for the heat transition in the Netherlands from the DE approach. This, to comprehend the current DE, with regards to the actors and stakeholders involved and the resources and (data)interactions between them, and use it as a foundation for the design of a DE 2.0. The following sub-section elaborates further on the theoretical background behind the DE approach.

3.2.5. DES: THEORETICAL FOUNDATION

According to Oliveira et al. (2019) the theoretical basis for the DEs has been slow to develop as there is no common agreement on how theories should look like. When considering the work carried out in the field of DEs and as reviewed by Oliveira et al. (2019) in a final selection of 29 articles, a large variety of theories is applied to study and understand DEs. The main theoretical foundations adopted by DE studies are:

- Socio-technical systems theory - adopted by 6 out of 29 studies
- Resource dependency theory- adopted by 2 out of 29 studies
- Value chain theory - adopted by 4 out of 29 studies
- Business ecosystems - adopted by 4 out of 29 studies
- Software ecosystems - adopted by 2 out of 29 studies

As was presented in sub-section 3.2.3, DEs, among others, include elements such as activities and processes, databases, work-flows, people, market parties, the government, and infrastructure. With these elements, DEs need to combine and integrate components from various ecosystems and domains (Oliveira et al., 2019). It could be derived from the previous list of theoretical foundations, that alternative Ecosystem theories are commonly applied to study the novel DEs. Zuiderwijk et al. (2014) relates the DE to Business Ecosystems, Innovation Ecosystems, Digital Ecosystems, and Open Government Ecosystems.

The body of literature on DEs is thus growing, and applications are wide-spreading over various sectors and stakeholders. However, no application of DE research has been found for the energy sector. As other sectors, the energy sector is ever increasing in digitisation with the introduction of smart metering and control technology to promote energy efficiency and demand side management, but also to cope with the increasing diversity and share of (intermittent) sustainable energy sources which pose challenges to balance the grid. This is one reason why this study on the realisation of an inclusive and sustainable urban heat supply can contribute in the further development of the DE approach. In this DE approach, the system as a whole needs to combine components from different domains in order to be a functioning whole, taking into account the dynamic interaction between the different factors and components.

With the theoretical background on the DE approach presented in the previous sub-sections, the following sub-section establishes a DE framework which will be utilised for the remainder of this research.

3.2.6. THE DE FRAMEWORK: ELEMENTS, ROLES AND CONTEXT

Building forward on the literature reviewed on DEs in the previous sub-sections, this sub-section derives a DE framework to assess the case of the heat transition. This framework is presented in figure 3.2 and consists of the essential DE elements in orange, and the technological, regulatory and data-stakeholder context in purple. The distinction of the DE context is derived from Van Schalkwyk et al. (2016) and Zuiderwijk et al. (2014), whereby the data-stakeholder context encompasses the three main roles which can be distinguished in DEs, according to Susha et al. (2017), van den Homberg and Susha (2018) these three roles are:

- *Data owners, producers and providers*: the organisations or entities which produce and provide the data, whereby the data can be acquired over a myriad of technologies and the produced data can be categorised according to the various data types.
- *Data users or consumers*: the organisations or entities which can use the data and derive valuable insights. Categories of data users are: Academic, Commercial, Governmental or public, Non-profit and Citizens.

- *Data intermediaries*: Organisations or entities which organise and facilitate the exchange of data, and coordinate the participation of users and providers. These are the organisational functions of the intermediary. Additionally, the intermediaries may have data-related functions, e.g. data pre-processing, visualisation and the provision of technology for data sharing.

In the data-stakeholder context in figure 3.2, see the lower part referenced "Data-stakeholder context" in purple, it is depicted how these roles relate to each other and to the DE. For each role it is stated which challenges commonly occur in the DE.

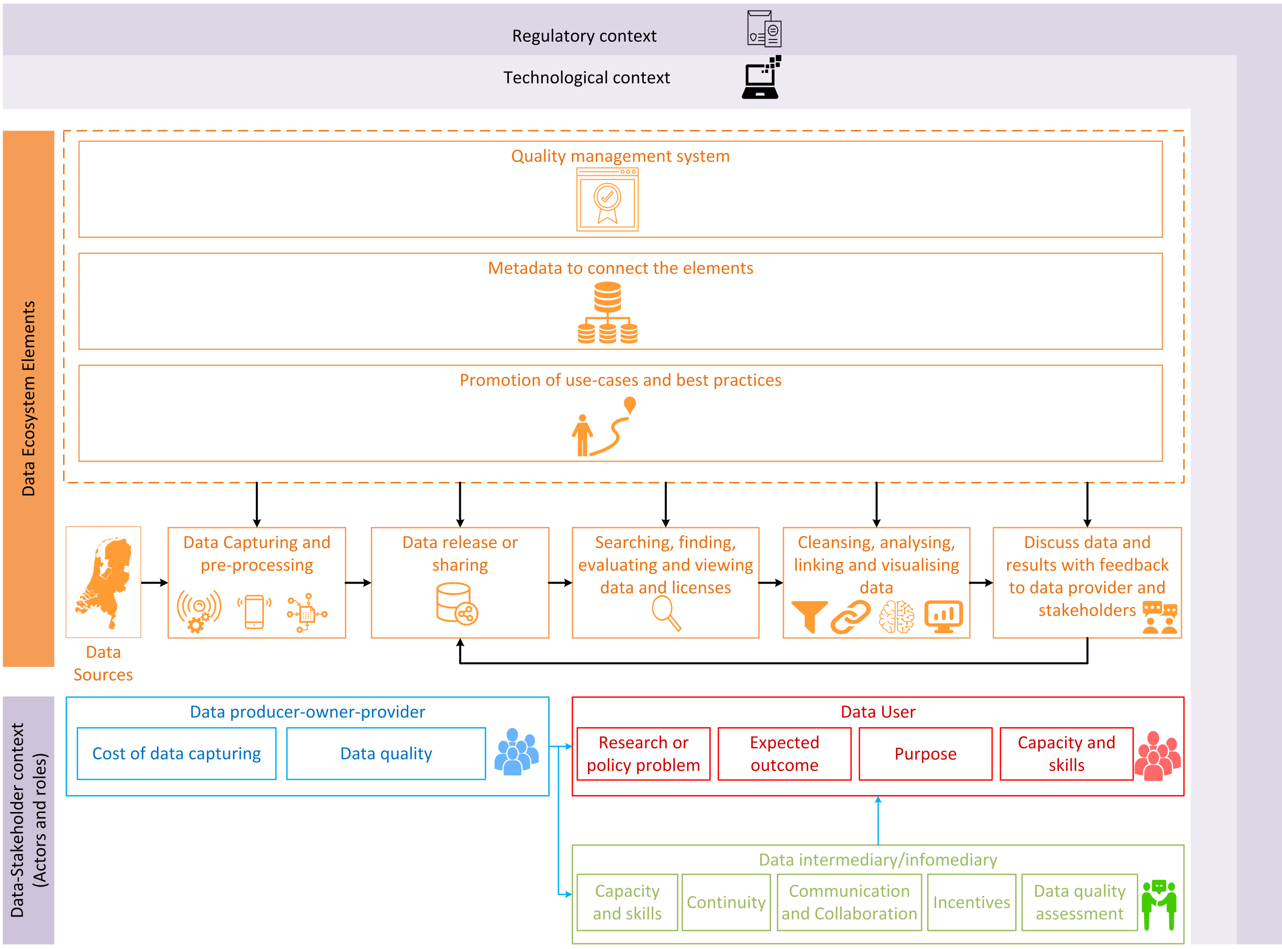


Figure 3.2: The DE framework derived from literature, adapted from (Demchenko et al., 2014, van den Homberg and Susha, 2018, Van Schalkwyk et al., 2016, Zuiderwijk et al., 2014)

The essential elements of the DE are mainly derived from the work by Zuiderwijk et al. (2014), focusing on Open Government Data, and Demchenko et al. (2014), focusing on Big Data, whereby the elements proposed by these studies complement each other to cover the most important characteristics and interactions in DEs. The included elements target both the organisational aspects of data, as well as the data life-cycle, and come down to:

- data life-cycle elements:
  1. Data capturing and pre-processing to desired format
  2. Data release or sharing
  3. Searching, finding, viewing and assessing data and data licences
  4. Cleansing, linking, analysing and visualising data
  5. Discussing data and providing feedback to providers and stakeholders
- data organisation elements:
  6. Meta-data to connect elements
  7. Use-case promotion
  8. Quality management

These elements capture the data life-cycle management or data value chain where various approaches propose steps on how to gather data and add value to the data as it passes through the different steps. Curry (2016) elaborate on the following steps in the data value chain: 1) Data acquisition, 2) Data analysis, 3) Data curation, 4) Data storage, and 5) Data usage. In an approach to support decision making on the enterprise level in a data-driven way, Miller and Mork (2013) make mention of the following steps: 1) Data collection and annotation, 2) Data preparation, 3) Data organisation, 4) Data integration, 5) Data analysis, 6) Data visualisation, and 7) Decision making. In the DE for Big Data Demchenko et al. (2014) propose a Big Data Life-cycle Management model consisting of the following steps: 1) Data Collection and Registration, 2) Data Filtering, 3) Enrichment and Classification, 4) Data Analytics, Modelling and Prediction, 5) Data delivery and Visualisation, and 6) a parallel step of 6a) Data re-purposing, 6b) Analytics re-factoring and 6c) Secondary processing. What these approaches commonly show is that the steps are organised in a linear way, whereby often feedback-loops occur towards earlier steps. The activities proposed as part of the Data Value Chain by the above mentioned scholars are taken into account in the DE elements depicted in figure 3.2.

After addressing the DE approach and concluding with the DE framework, the step will be made towards a different, yet relevant for decision-making in the heat transition, concept in the following section. In the following section, the Policy Lab method will be discussed, as a method providing opportunities to enable public sector innovation, for instance, by means of data and design-science. Via the role of data in Policy Labs, the link to the previously discussed DEs can be made.

3.3. Policy Labs

Policy Labs (PLs) are a novel concept introduced in line with the growing interest in evidence-based policy making or EBPM (Fuller and Lochard, 2016), and in 'open government' agendas (Acevedo and Dassen, 2016). These PLs aim to build trust and transparency, among others, by making government held data more accessible for all stakeholders (Yu and Robinson, 2011). PLs are reported to have the potential to address the shortcomings of traditional policy-making and service design (McGann et al., 2018), and coordinate the efforts between public, private and academic entities to improve the structure of multi-actor networks (Williamson, 2015a). Hereby, research on PLs aim to predict and anticipate how emerging methods and technologies such as data science, predictive analytics, artificial intelligence, sensing and metering, applied programming interfaces, autonomous machines, and (digital) platforms can be embedded in government organisations, and redefine the role of the government to create stronger relationships with the public (Maltby, 2015). Due to the novelty and wide area of application of PLs, the definition and also the name used for the concept, found in literature is largely varying. The next sub-section elaborates on the names and definitions found for PLs in literature.

3.3.1. Policy Labs: names and definitions

Policy Labs are often called PSI labs, where PSI may refer to either 'public sector innovation' (McGann et al., 2018) or 'public and social innovation' (Williamson, 2015a). In addition to the use of the term PSI lab or Policy Lab, other terms for the concept encountered are: government innovation lab, social innovation lab, innovation lab, and public innovation lab (Gryszkiewicz et al., 2016, McGann et al., 2018).

Along with the various names found for the concept of PLs, depending on the particular application of the PL, the definition for the concept also varies largely. In the review of policy labs in EU member states by Fuller and Lochard (2016), a policy lab is defined as *"dedicated teams, structures, or entities focused on designing public policy through innovative methods that involve all stakeholders in the design process"* (Fuller and Lochard, 2016, p. 1). Fuller and Lochard (2016) break down this definition in the following PL pillars:

- PLs approach policy issues through a creative, design, or user-centred perspective
- PLs aim to test proposed policies through experiments
- PLs work for, or, within the government and contribute to the shaping or implementation of public policy

Williamson (2014, 2015a,b, 2016), is one of the more established scholars studying the organisational aspects of Pls and how the labs utilise methods and tools from the field of data science, evidence-based evaluation, and design-for-policy. Hereby, Williamson (2015a, p. 4) defines policy labs as *"an experimental R&D lab for social and public problems, located in the interstitial borderlands between sectors, fields, and disciplinary methodologies"*, or alternatively, *"a new kind of intermediary policy actor that is operating to mediate and translate key governing discourses into policy and practice"* (Williamson, 2014, p. 4).

As stated by Williamson (2015a), PLs embrace the concept of experimenting with new technologies and fostering innovation, hence, to this regard PLs may be compared to living labs. Living Labs can be defined as dynamic environments which are built to test project solutions, such as different novel innovations and technologies, in real-life, where several implementations can be performed by several stakeholders in parallel (Gatta et al., 2017). However, PLs go further than living labs, not only do PLs enable experimenting with novel technological developments, in addition, PLs utilise the data coming from the living labs, together with data on the broader city context to embed the innovations in knowledge-based policies (Gatta et al., 2017).

Moreover, PLs can be placed in the broader context of collaborative governance, and the support provided to the collaborative governance by digital platforms. Collaborative governance is defined by Emerson et al. (2012, p. 2) as: *"the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished".*

Finally, PLs are conceptually similar to think-tanks. However, the main difference is that PLs extend its role into the domain of R&D. This with the particular emphasis on innovative experimental development, design-based approaches, the generation of data, and derived from that data, evidence on best practices per sector (Williamson, 2015a). The following sub-section elaborates further on the development of the PL concept over time, as can be derived from the body of PL literature.

3.3.2. Policy Labs: history and cases

This sub-section will shed light on the development of the Policy Lab concept over time, through the body of literature developed on PLs. An overview is provided on the Real Life practice of PLs, with regards to a set of characteristics such as, the field of application and the geographical scale. From the body of literature and the PL cases, the main PL functionality and design variables will be derived.

Body of Policy Lab Literature

Although the Policy Lab concept really took off in the last decade, the first form of a PL can be derived back to 1967 when the SITRA Lab was founded in Finland to focus on general policy development as an independent fund reporting to the Finnish Parliament (European Public Administration Network, 2018). The study by the European Public Administration Network (EUPAN) (2018), on policy lab innovation in public administration, based on 24 questionnaires from 21 EU Member States, Switzerland, Norway and the European Commission, reports that of the PLs addressed in the study, 13 PLs were established after 2010, and 10 PLs were founded before 2010. In a more comprehensive study by Fuller and Lochard (2016) to map public PLs in EU Member States for the Joint Research Center of the European Commission, a total of 64 PLs could be identified, according to the definition criteria for PLs discussed before.

In addition to the exploratory literature on PLs by EUPAN (2018) and Fuller and Lochard (2016), the working paper by Williamson (2015b) and the journal articles by Williamson (2015a), Gryszkiewicz et al. (2016), Schuurman and Tõnurist (2017), Tõnurist et al. (2017), van Veenstra and Kotterink (2017), and McGann et al. (2018), indicate that scientific publishing on the subject of PLs is something of the last five years. These papers commonly have the aim to fill the missing knowledge on the organisational and operational methods and tools behind the PL concept which are insufficiently documented and understood. Despite the growing body of literature and research interest, many knowledge gaps remain unanswered. In the following section examples are presented of PLs brought into practice and what knowledge gaps still exist based on their organisation and performance.

Policy Labs in practice

The reports by EUPAN (2018) and Fuller and Lochard (2016) provide comprehensive overviews of PLs in the EU Member States. Of the PL mapping by Fuller and Lochard (2016), figure 3.3 presents the statistics on the PL policy focus area or scope, the PL parent entity (or the organisation under which the PL operates or is funded by), the PL geographic level and the PL country.

Regarding the policy scope of the PLs, the study by EUPAN (2018) found that most, 11 out of 24, of the PLs focus on the general policy development and a smaller share, 7 out of 24, on specific thematic policy areas such as taxation and the environment. A few, 3 out of 24, PLs focus on policy areas to which principles of behavioural insights can be applied and another few, 4 out of 24, address other subjects such as the popularisation of the public sector and cooperation with other parties. The PL mapping by Fuller and Lochard (2016) also found that the largest share of PLs focus on general policy, but then mainly linked to public innovation. Whereas for the PLs focusing on a specific policy field, the largest share focuses on Healthy and Inclusive Societies.

Europe has truly become a breading ground for PLs and they can be found all over the EU Member States. In Europe, the UK leads with 20 PLs or comparable concepts active in 2016, with France being the runner-up with 17 PLs. Furthermore, many of the identified PLs, 19 out of 64, operate on the National level, while a total of 45 PLs operate on the Regional, Metropolitan or City level (Fuller and Lochard, 2016).

Fuller and Lochard (2016) also studied the parent entities of these PLs, or the authorities or organisations these PLs report to and/or get funded by. By far, most PLs, 31, are initiated by and operate for a Regional or Municipal Government, while a total of 21 are initiated by, and operate for a National Government. Interestingly, three PLs are initiated and operated by universities and another six by other private or public institutions.

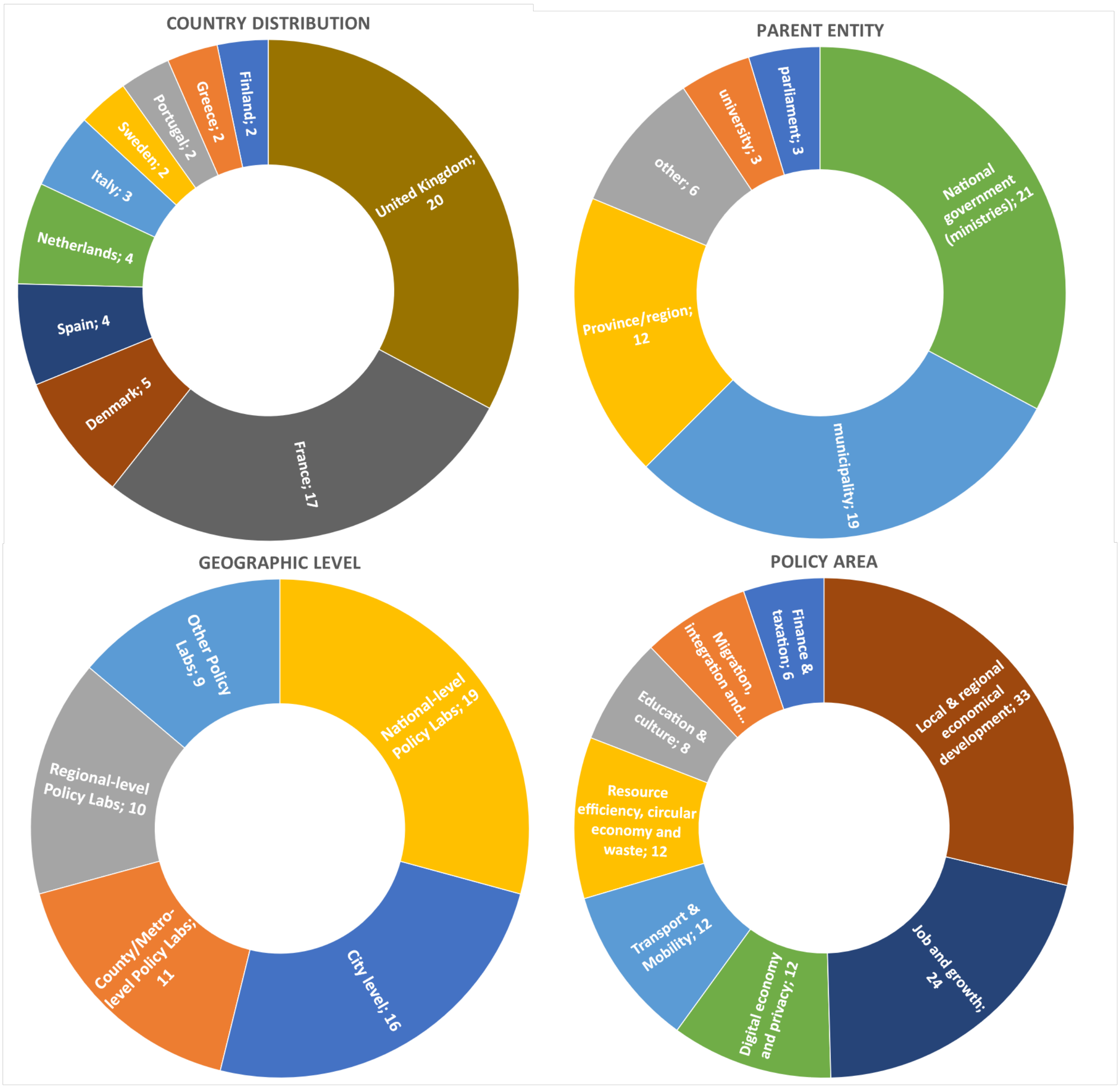


Figure 3.3: PL statistical overview in Europe, adapted from (Fuller and Lochard, 2016)

Bailey and Lloyd (2017) report of the first Policy Lab within the British Government, as a small specialist team in the Cabinet Office, established in 2014. The task of this team is to support the policymakers in the Civil Service reform and the pursuit of the Open Policy Making agenda, by implementing evidence-based policy together with principles, tools and techniques from the field of design science (Bailey and Lloyd, 2017, Kimbell, 2015).

In literature, education is the field within which PLs are published most about. Williamson (2014) report on the role of PL in education governance, e.g. to improve the pedagogical methods applied based on the personal needs of students. Hereby database technologies in education are enabling an emerging form of governing knowledge and governing-through-data, which utilises data on students as a governing resource to derive suitable methods of education (Williamson, 2014).

The realisation of the PL by Gatta et al. (2017) integrates: 1) the desk approach, for data acquisition and evidence-based policy ranking, 2) the living lab approach, for stakeholder engagement in policy co-creation, and 3) the modelling approach, to evaluate policy measures and define effective and coherent policy packages for Urban Freight Transport. They note that in order to generate sustainable and desired effects, the selected policies should be coherently and coordinately evaluated, taking into account the existing city planning framework.

In conclusion, the main benefit of the PL concept, is the ability to enable policy and decision-making which is backed by data-driven evidence and thus well-informed, but also aligned with the interests and resources from the stakeholders in the public-private-citizen network. In the next sub-section it is elaborated how this main benefit can be translated into PL functionality, as found in literature.

3.3.3. POLICY LAB FUNCTIONALITY

Based on the literature found on real-life PL realisations discussed in sub-section 3.3.2, this sub-section will present the functionality of the PL. The functionality of PLs, or how PLs meet in the needs and demands of governance, is described in various ways in literature, and is commonly related to the concepts of Evidence-Based Policy-making, data science and open governance. Among others, the functionality through which PLs may have the greatest impact, lies in the harvesting of knowledge from diverse sources and translating this in usable forms of policy knowledge for the policy makers and stakeholders (McGann et al., 2018).

Both the PL applications for education williamson2015testing,williamson2016boundary, and urban logistics (Gatta et al., 2017), specifically report on the important role of data, both Big and Open Data, in PLs. van Veenstra and Kotterink (2017) specifically propose a data-driven approach for the PL with data being at the center point of all organisational and operational aspects of the PL.

In the context of social cohesion policy, Olejniczak et al. (2016) identify three elements embedded in the PL approach to assist policy practitioners, namely:

1. a novel framework for designing policy interventions
2. a platform for safe and collaborative learning from implementing experimental solutions within existing programs
3. a diverse research method to establish credible knowledge

Given the PL functionality presented above, the following sub-section 3.3.4 address the design variables for PL design which can be derived from the literature.

3.3.4. PL DESIGN VARIABLES DERIVED FROM LITERATURE

From the literature on PLs brought into practice as either pilot project or long-term project, lessons can be learned on the organisational and operational aspects. Subsequently, from these cases, design variables can be derived. The design variables can be considered as the degrees of freedom for PL designers and practitioners, in order for the PL to provide in the desired functionality which meets the governance needs. The design variables which could be derived from EUPAN 2018, McGann et al. (2018), Schuurman and Tõnurist (2017), Tõnurist et al. (2017), Williamson (2014) and Kimbell (2015) are as follows:

- PL owner and operator
  - *Parent Entity*: which actor(s) takes accountability and responsibility for the PL during its establishment and operation?
    - Possible parent entities are: Private/commercial entity; Regional/local administration; Independent public body (not under the direct supervision of a government executive body); Ministry/Department (under the direct supervision of an executive body); Centre of the government (within the (equivalent of the) secretariat-general or central coordinating body); Other (universities, non-profit organisations etc.).
  - *Governmental link*: controlled by the government or not (independent)? What is the proximity to the executive government branches?
    - Owned by government ministry, but administratively separate.
    - Completely independent from the government, e.g. part of a non-profit organisation or an independent unit and reporting directly to the parliament.
  - Funding Entity: where do the funds to operate the PL originate from?
    - NGO; Private/Commercial party; Self: by providing paid services; Governmental executive body; Centre of the government (within the (equivalent of the) secretariat-general or central coordinating body); Mixed (e.g. government + EU funding).
- Geographic reach: on which geographic level should the PL operate?
  - National/Regional/Municipal/Local.
- Policy scope: Is the PL addressing general policy or specific policy fields?
  - Generalist lab: public administration reform; Administrative service design and service delivery; Policy development or coordination with stakeholders (co-creation).
  - Specialist lab: Tax and revenue; Healthy and inclusive societies; Local or regional economy; Energy, climate, and/or environmental issues; Migration, integration, and humanitarian aid programs; Infrastructure, transport and/or mobility; Social policy and inclusion; Jobs and wealth; Education and culture; ICT systems and e-Governance.
- Policy cycle scope: which functions or processes of the policy cycle are addressed by the PL?

    - problem definition
    - policy design
    - policy implementation and evaluation.
- PL staffing
    - Size of the PL: what is the number of staff necessary for the tasks at hand?
    - PL expertise: what skills are necessary to be covered by the staffing of the PL?
- *Design science*: which tools and methods from the field of Design Science are to be embedded in the PL to enable the necessary functionality?
    - Examples mentioned are: Road mapping, Ideation, Co-design, Prototyping, Customer Journey Mapping, Design Ethnography etc.
- *Data Science and ICT*: which data, technologies, tools and methods from the field of Data Science are to be embedded in the PL to enable the necessary functionality?
    - Examples mentioned are: Data analysis models, e.g. for data mining and exploratory analysis; Data visualisation techniques; Data acquisition, storage, processing and analysis procedures etc.

In the following sections, light will be shed on the concepts and theories which are found to be relevant for the PL and its design variables, namely Evidence-based Policy-making (EBPM), Co-creation of local solutions and the Design Approach in Policy-making. Big and Open data also belongs in this row of concepts, however, Big and Open Data for policy making is discussed earlier in sub-section 3.1.1.

3.4. EVIDENCE-BASED POLICY-MAKING

The notion on the application of data of any kind for policy-making purposes can be directly associated to the specific school of policy making called Evidence-based policy-making or EBPM. The aim of EBPM is ultimately to establish efficient and effective policies. EBPM finds its origin in the early 1990's and was first applied in health-care (Davies and Nutley, 2000). Hereby the premise was that if doctors make their decisions based on the results of research, policy-makers should also do so (Black and Donald, 2001). The evidence to base policy making on, can be defined as *"The available body of facts and other information indicating whether a belief or proposition is true or valid, in this case regarding the impacts of programs"* (Evidence-based Policymaking Collaborative, 2016, p. 4).

Of the literature published on EBPM, the most cited work subsequently also addresses health care. The systematic review by Oliver et al. (2014) included 145 papers, and reported that over 78% of research assessed health-care policy. These findings are in line with the findings of the earlier review by Mays et al. (2005). Older work by for instance Tunis et al. (2003), Flay et al. (2005) and Innvaer et al. (2002), all presented methods and frameworks for health-care EBPM. Reaching further than the previous studies targeting health-care as more or less an isolated field, Young et al. (2014) studies the attitude toward EBPM on the cross-section between agri-food and health-care.

More recently, EBPM is being applied in education, whereby policy measures for the education system on a higher level or on the level of individual schools are shaped by data or evidence gathered on student performance (Marsh et al., 2006, Wohlstetter et al., 2008). The review by Oliver et al. (2014) also report advances of EBPM in Transport, Environmental and conservation management, and Social care/social work.

For EBPM specifically in the field of energy or climate policy, the body of literature is currently limited, but growing. For instance the work by Sébastien et al. (2014), Chapman et al. (2016), Sorrell (2007), Kocsis and Hof (2016) and Basher et al. (2015) all address either a framework to enable energy and climate EBPM, or the necessary indicators and sources for evidence. On the other hand, Curry and Maguire (2011) and Sakellaris et al. (2018) chose to study quantitative models which can support energy and climate EBPM.

With the perceived potential and opportunities of EBPM to realise efficient and effective policies, many are advocating an evidence-based policy agenda. In particular the Australian and British government are front-runners in the adoption of EBPM (Oliver et al., 2014), while the EU keeps on seeking for improved policy-making within the EU governing bodies, but also for its member States, by pushing for EBPM (European Commission, 2017).

On the contrary to the potential, literature surfaces many barriers or challenges in the way of the further adoption of EBPM. A non-exhaustive list of barriers from the literature is presented below:

- The access to quality and accurate scientific evidence (Oliver et al., 2014, Young et al., 2014)
- The translation of quantitative and qualitative evidence to policy guidelines (Head, 2010)
- The increasing diversity and complexity of problems and the associated evidence (Head, 2010, Hunter, 2015, Young et al., 2014)
- The skills of policy-makers itself, or the recruitment of specialised analytical staff to derive the significance from the evidence (Head, 2010, Oliver et al., 2014)

- The often fixed agenda-setting with a strong political influence, realised through inflexible and non-transparent policy processes (Oliver et al., 2014)
- Higher costs of the evidence-based approach (Oliver et al., 2014)
- The cultural and institutional difference between research, policy and practice, forms a long standing barrier (Head, 2015)

On a note related to the barrier on the access to quality and accurate scientific evidence mentioned by Oliver et al. (2014) and Young et al. (2014), it is suggested by Tunis et al. (2003) that the presence of gaps in the knowledge signifies the systematic flaws in the generation of evidence. This is, among others, caused by the lack of consistent experimentation with policies to generate the necessary evidence base. Recall that the study presented in this thesis has the main aim to improve the information provision and decision support for the local heat transition governance, hence this barrier will be addressed in more detail, while the other barriers are taken into account for a comprehensive approach. How Big and Open Data can play a role in policy making in general, but also for the derivation of evidence for EBPM is elaborated in 3.1.1. In the following section, the step is made to the literature on the co-creation of policy governance on the local scale.

3.5. CO-CREATION OF LOCAL SOLUTIONS

PL initiatives are commonly utilised as a means to practice open governance in a co-creative style (Acevedo and Dassen, 2016, Maltby, 2015). In published studies on co-creation, the majority of studies claim to seek an outcome or objective of the co-creation process which is related to improve the efficacy of products or services and to increase the citizen involvement (Voorberg et al., 2015). Co-creation is often used to name similar ideas like co-production and collaborative governance, however, it has its specific characteristics. The following definition can be quoted from (Torfing et al., 2016, p. 8): *"co-creation in the public sector is a process through which two or more public and private actors attempt to solve a shared problem, challenge, or task through a constructive exchange of different kinds of knowledge, resources, competencies, and ideas that enhance the production of public value in terms of visions, plans, policies, strategies, regulatory frameworks, or services, either through a continuous improvement of outputs or outcomes or through innovative step-changes that transform the understanding of the problem or task at hand and lead to new ways of solving it."*

The Urban Transition Labs (UTL), as a form of a policy lab, deploy real-life trajectories of sustainable city development in a co-creative collaboration between actors and researchers (Nevens et al., 2013). Hereby co-creation entails not only involving citizens as observed subjects or stakeholders with a say in the matter, but also as a source of creation inspired by the Living Lab concept as a user-centred ecosystem for open-innovation (Pallot et al., 2010). For co-creation in the UTL, actor-analysis is considered important to identify actors that should be included in the co-creation and to understand their interrelationships according to their backgrounds, competencies, interests, and power (Nevens et al., 2013).

Torfing et al. (2016) distinguish three types of co-creation which differ in the degree of citizen involvement, namely:

- citizens as co-implementer where the citizen only has implementation tasks
- citizens as co-designer where the citizen is actively involved in the design of solutions and policy instruments
- citizens as initiator, where the government is an actor in a broader field of policy-making and where citizens contribute in the definition and prioritisation of policy problems.

Finally, general influential factors on the implementation of co-creation and the subsequent level and quality of co-creation, from the perspective of the citizen, are: the willingness to co-create, awareness and feeling of ownership, risk-averse behaviour, and the presence of social capital. From the organisational side, the influential factors are: risk-averse administrative culture, the attitude of public officials towards co-creation, clear incentives for co-creation, and compatibility of the public organisation for citizen participation (Voorberg et al., 2014, 2015). In the next section, light will be shed on the Design based approaches for policy-making, and for instance, how co-creation can be taken into account for policy-making through Design based approaches. For this research the input on the conditions and influential factors for co-creation are relevant in the context of the DE study and design. Not only is co-creation important due to the intrusive and economic consequences of the heat transition for citizens, but also to engage citizens in the establishment of a knowledge base for heat transition governance by supplying data and utilising data products and services.

3.6. DESIGN BASED APPROACHES FOR POLICY MAKING

In general, policy design entails the systematic approach to develop efficient and effective policies through the knowledge gained from experience and actions which are likely to succeed in realising the desired policy goals (Head, 2008, Howlett, 2014). In recent times, inspired by design-centric corporations like Apple and Samsung, non-traditional design aspects such as user-centric design, user experience, service design and design thinking have been taken up by various levels of government (Kimbell, 2015). This section on the Design Approach is included in the research background, since the Design Approach is mentioned in several sources as suitable methodology to be applied in Policy Labs and improve the efficacy and efficiency of policy and governance. McGann et al. (2018) even state that the emphasis on the design approach is the main distinguishing factor between the PL and other policy-making methodologies. The Design Approach invites a more diverse range of voices and ideas in the policy process, which can be related to the principles of network governance.

One of the main differences between conventional problem-solving in the context of policy-making, and the design approach, is that the basic procedures generate and asses a limited list of possible solutions, or, in other words a countable set. On the contrary, the design approach works with an non-countable set (Hatchuel, 2001).

According to Williamson (2015a) many of the PL initiatives have implemented the policy-for-design approach. This specialisation of the Design Approach for policy is developed by Bason (2016) and addressed in his book titled "Design for Policy". The Design-for-Policy methodology consists of two types of experimentation. First, experiments are designed to apply and assess the latest developments in collaboration and decision-making, hence targeting the improvement of the overall policy making cycle for public interest (Williamson, 2015a). On the other hand, experiments are designed to implement and assess novel policy measures on e.g. new technologies in specific policy fields in small living-lab situations, where the next step is to adjust and further develop the policy measures for the large scale implementation of the technology (Bason, 2016).

Kimbell (2015) studied the Policy Lab specialist team within the British Cabinet and in her work titled “Applying Design Approaches to Policy Making: Discovering Policy Lab” she elaborates on the experiments run with design based approaches for policy-making within the Policy Lab. Bringing this design approach into policy making would entail, among others:

- Steps and processes around building understanding on the experiences of people whose life will be impacted by the policy to be designed.
- An approach where iterative prototyping is utilised to explore and develop novel ideas.
- Methods to involve stakeholders in the process of research, idea generation, and policy development.

In the British Government, the simple framework for policy skills for efficient and effective policy consists of three main elements (Kimbell, 2015):

1. Politics: understanding and managing the political context
2. Evidence: developing and using a sound evidence base
3. Delivery: planning how the policy will be delivered or implemented

Hereby the design question is how to bring together these three elements of efficient and effective policy making (Hallsworth, 2011, Kimbell, 2015). Furthermore, changes are required in the way of thinking at the basis of policy-making, to embed the design approach in policy-making (Kimbell, 2015). These changes can be summarised as:

- From resisting complexity, to embracing complexity
- From problem-solving, to envisioning alternative futures
- From a system focus, to citizen-centricity
- From unilateral actions, to the shaping of alliances
- Form facilitation, to stewardship
- From policy-as-strategy, to policy-as-impact

Given these reforms in the way of thinking and the envisioned elements of the PL, the PL will open up issues for exploration, enable problems and solutions to co-evolve, create potential solutions to explore the problems, position participants (citizens and private stakeholders) as co-researchers, and position policy making as collective learning, through the application of the Design Approach (Kimbell, 2015). In the next section, an envisioned Energy Policy Lab (EPL) by TNO will be highlighted as this PL is subject to this study.

3.7. THE ENERGY POLICY SUPPORT LAB BY TNO

TNO, the Netherlands Organisation for applied scientific research, is active within the field of PLs and in early 2018 the process was initiated for the first PL in the field of education in Rotterdam (Timan. T, pers.comm., 2018). In the pilot, indicators were established to measure the performance of the educational system, and these indicators are visualised by means of the various data flows identified and utilised in Rotterdam. Relevant data in education are for instance, student dropout numbers and grades. How the PL will eventually be implemented in the user interface with the policymakers and stakeholders, is yet to be determined, whereby the options range from a visual dashboard for the policymakers, to interactive policy simulators for all stakeholders (Timan. T, pers. comm., 2018). Moreover, TNO is looking into the development of Energy Policy Labs (EPL), these are PLs to facilitate the energy transition, and incorporate design science and ICT with the aim to research how stakeholders (local government, companies, citizens and other interest groups) can co-create policy to shape the local energy landscape. The term EPL particularly targets the methods used to gather data, link the data to knowledge gaps, and in that process involve the stakeholders to gain support for the policy cycle. From the PL application in the education sector, lessons can be learned for an eventual EPL design.

In the EPL, data from the energy system on the local level will be collected and should function as part of the foundation for the decisions and actions to be taken in shaping the energy landscape locally (Slob, 2018). The specific data to be gathered, depends on the application. The text-box below illustrates a possible application:

> The municipality needs to determine a heating plan for each particular district, as part of the heat transition vision on the municipality. This entails the determination when the districts will be disconnected from natural-gas and what the alternative will be. To this end, data on the technical aspects of the buildings is relevant, but also data on the heating behaviour of the inhabitants such as gas use, and the preferences of the citizens for heating technologies, together with performance data on the available technologies and data on the assets, such as the electricty and gas grid, already in place.

Given the potential of the EPL to provide in the needs of public and private decision-making in the energy transition on a local scale, there is ample reason to pursue the implementation of the EPL for the acceleration of the energy transition on the local level. However, as stated by McGann et al. (2018), PLs have thus far received little attention in the literature on policy sciences and public management regarding the organisation and structure. This means that methodological knowledge gaps exist on the organisational establishment and functioning of policy labs and its implementation in a particular policy field.

The PL approach to support EBPM as presented by van Veenstra and Kotterink (2017), targets a policy-making cycle which is fundamentally comparable to what Lasswell et al. (1951) present, and updated based on the inspiration from Janssen and Helbig (2016). This policy cycle, presented in figure 3.4, encompasses the following phases: Predictive analysis & problem definition, Design & experimentation, and Implementation & Evaluation. The policy lab approach encompasses three pillars. First, the PL should enable the policy-making process to utilise data sources and technologies to collect, process, and analyse the data for the identification, definition of and solutions to, current and future issues.

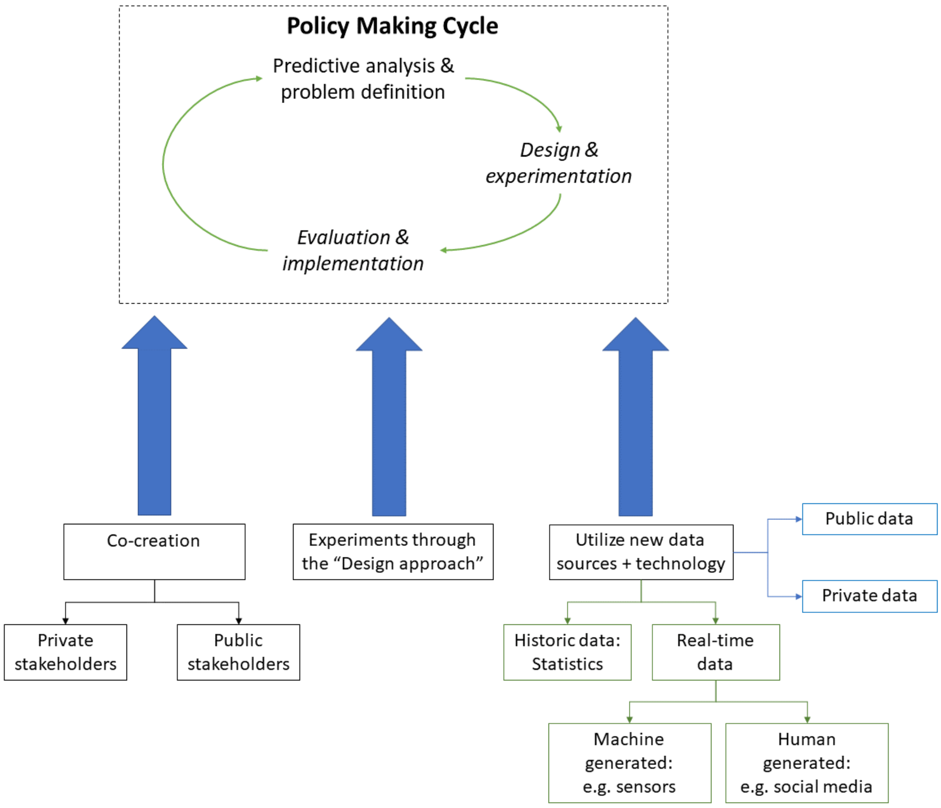


Figure 3.4: The PL method according to TNO, adapted from (van Veenstra and Kotterink, 2017)

Second, the PL allows for experiments to be executed with different versions of policy cycles and policy designs. For instance, to determine which policy instruments or cycle perform best under the specific social, economic and technical local conditions derived from the data collected in that area. This allows for varying policy implementations to be possible over different areas if the data provides insights into which policy measure(s) is most suitable per area. Matschoss and Heiskanen (2017) stated that experiments are gaining ground in public innovation and the PL method thus provides a platform to implement and facilitate this experimentation for policy.

Third, the PL facilitates co-creation of policy and decisions to engage citizens and local private stakeholders. The use of ICT in the PL enables local governments to not only cooperate within the institution, but to cross institution borders, and co-create with the stakeholders. Co-creation enables a better understanding of policy by citizens and more trust in the policy. This is especially relevant in an evidence-based approach where the use of public data and statistics is increasingly met by the citizen's distrust (Davies, 2017).

3.8. CHAPTER CONCLUSION

This chapter contributed to the following SQs:

Section 3.1 and Section 3.2	⇒	*3. How can a DE be composed and how does the current DE look like for the Dutch heat transition, what are the shortcomings and challenges?*
Section 3.3, 3.4, 3.5, 3.6 and 3.7	⇒	*6. What are the requirements and functionality of a data-driven method, such as TNO's EPL, to be of added value in the realisation of sustainable and inclusive Urban Thermal Energy Systems within the proposed Data Ecosystem 2.0?*

This chapter aimed to provide the theoretical background on this research, and in this context light was shed on the Data Ecosystem approach, and the Policy Lab as a method supported by Evidence-Based Policy-making, the Design approach for policy and co-creation.

THE DE FRAMEWORK

Regarding the Data Ecosystem, section 3.1 surfaced several versions of elements to compose the Ecosystem. Based on its comprehensiveness and fit with the energy landscape, the set of elements, roles and the context is mainly inspired by Zuiderwijk et al. (2014), and complemented with role and context related aspects by Mercado-Lara and Gil-Garcia (2014), and DE technical aspects by Demchenko et al. (2014). This results in five elements related to the Data Life-Cycle: 1) Data capturing and pre-processing, 2) Data release, 3) Data and license search, view and assessment, 4) Data cleaning, linking, analysis and visualisation, and 5) Data discussion and feedback. Moreover three elements related to the organisation of the DE: 6) Quality assessment system, 7) Meta-data to link elements , and 8) Use-case promotion. Furthermore these elements are surrounded by the technological context, the regulatory context and the data-stakeholder context consisting of data suppliers, data users, and data intermediates. Finally, challenges and barriers are derived on the elements in the DE related to the life-cycle of Big and Open Data for local policy and decision-making.

POLICY LABS

PLs, being brought into practice under a wide field of names, are reported to have the ability to address the shortcomings of traditional policy making and service design (McGann et al., 2018), and align the efforts between public, private and academic parties to improve the structure of multi-actor networks (Williamson, 2015a). PLs address how emerging methods and technologies such as data science, predictive analytics, artificial intelligence, sensing and metering, applied programming interfaces, autonomous machines, and (digital) platforms can be incorporated in government organisations, and redefine the role of the government to create stronger relationships with the public (Maltby, 2015). Among others, the functionality through which PLs may have the greatest impact, lies in the harvesting of knowledge from diverse sources and translating this in usable forms of policy knowledge for the policy makers and stakeholders (McGann et al., 2018). With this premise, PLs can play a significant role in the heat transition and its DE.

Given this background information and the improved understanding on the DE approach and its elements, together with the challenges and barriers on releasing and utilising data within the context of urban thermal energy systems, the following chapter will address the research design for the empirical data gathering on the Dutch heat transition.

4

Research Design and Methodology

In chapter 1 an overall picture was provided on the Research methodology behind this thesis, and consisting of Literature Research and Qualitative Research based on interview data, see figure 1.2. The latter method is utilised for the empirical analysis of the heat transition to derive the knowledge gaps, challenges, and data needs for actors in the heat transition. In this chapter it will be presented how the Empirical research is designed to answer the research questions. The Empirical research utilises a case study, and this case is finally elaborated on in this chapter.

4.1. Case-study Research

This research uses a case study method, in particular an embedded single-case study design in applied according to the case-study design definition by Yin (2017). The case study design encompasses the Netherlands as the main case, the stage where the heat transition has to be realised on a national level, and the municipality of Utrecht as the embedded case. The case study is executed as a qualitative case study, where the main mean of data collection are interviews. How these interviews are designed in discussed in 4.2. The benefit of the qualitative case study is that rich information can be derived from the interviews on the local issues regarding the heat transition, and the associated DE, via the critical interactions of complex social phenomena (Miles and Huberman, 1994). Hence, the case study meets in the necessity to derive the real-life context on the heat transition with regards to the actors involved, the current and future decision-making processes, the knowledge gaps based on the actual technological, social and economic context, and the data available. In addition, the case study enables the derivation and assessment of the Data Ecosystem as can be found in Utrecht.

The case of Utrecht is elaborated further in sub-section 4.1.1. Within the main case of the Netherlands, an outreach is also made to the municipality of The Hague to determine whether the challenges and knowledge gaps found for Utrecht, also hold for another municipality of comparable scale and urban setting.

4.1.1. The embedded case: The Municipality of Utrecht

In order to derive the real-life context on the heat transition with regards to the actors involved, the current and future decision-making processes, the knowledge gaps based on the actual technological, social and economic context and the data available, this study applies a case study for the municipality of Utrecht. Utrecht is among the most ambitious municipalities in the Netherlands with regards to the local climate policy, and is experimenting with decision-making processes on the sequence of districts to be disconnected from natural gas. Furthermore a body of research, both scientific and non-scientific, exists regarding, for instance, the potential heat sources in Utrecht (Eneco, 2018), and the estimation of costs of the heat transition for citizens (van den Wijngaart et al., 2018).

The municipality of Utrecht is located in the Utrecht province in the Netherlands and covers a surface area of 99.21 km^2. With the ambition to be climate neutral by 2030, Utrecht has its work cut out to make drastic changes to its energy landscape in the coming years (Utrecht, 2018a). In 2018, Utrecht counted 347,483 inhabitants, divided over 178,186 households, in 150,831 dwellings (Waarstaatjegemeente.nl, 2019). The majority of these households are single-households, 52%, while the households with children and one or more parent, and without children, but with two ore more inhabitants make up for respectively 26% and 22%. Furthermore, 55% of the dwellings are being rented, with 60% rented out in the social housing sector and 40% in the private renting sector. The remaining 45% is being inhabited by the private homeowners (Waarstaatjegemeente.nl, 2019).

In figure 4.1 it is depicted what building types can be found in Utrecht, the data is derived from the Basis Registration

Addresses and Buildings (BAG) (van den Wijngaart et al., 2018). This picture is dominated by the flat buildings and row houses with a total share of around 96%. When looking at the built period of the residential building stock in Utrecht, depicted in figure 4.2, there is more or less an even representation among the different categories. However, within the distribution there is a relative over representation of dwellings originating before 1945, also known as the pre-war dwellings.

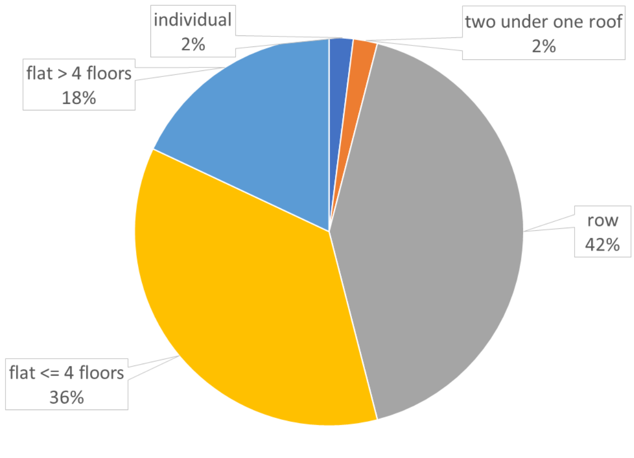


Figure 4.1: Building types in Utrecht in 2017, based on the BAG and adapted from (van den Wijngaart et al., 2018)

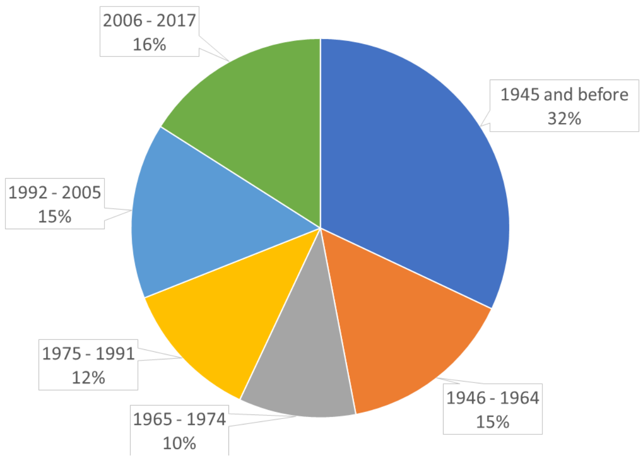


Figure 4.2: Built year distribution in Utrecht in 2017, based on the BAG and adapted from (van den Wijngaart et al., 2018)

In 2017, the residential dwellings in Utrecht consumed a total of 6.39 PJ, of which around 80% of the energy is used as heat for space heating, cooking and domestic warm water. The remaining 20% of the energy use entails the electricity to power appliances and lighting. The heat supply is predominantly provided by natural gas, 3.6 PJ equal to 71%, while District heating accounts for the remaining 1.4 PJ or 29% (Klimaatmonitor, nd). In figure 4.3 it is displayed what energy labels can be associated to the building stock in Utrecht, here it can be observed that nearly 58% of the dwellings has energy label C or better.

In the Netherlands, after Rotterdam, Utrecht is the leader in terms of the installed district heating capacity. In 2015 this amounted to 52,800 dwellings connected to DHN developed and exploited by Eneco, and this is expected to increase to 58,000 connected dwellings in 2020 (Menkveld et al., 2017). In figure 4.4 the DHN is depicted with the connected areas coloured purple. The most important source of heat for this DHN in Utrecht are the gas fired CHP plants in Lage Weide and Merwedekanaal (Menkveld et al., 2017).

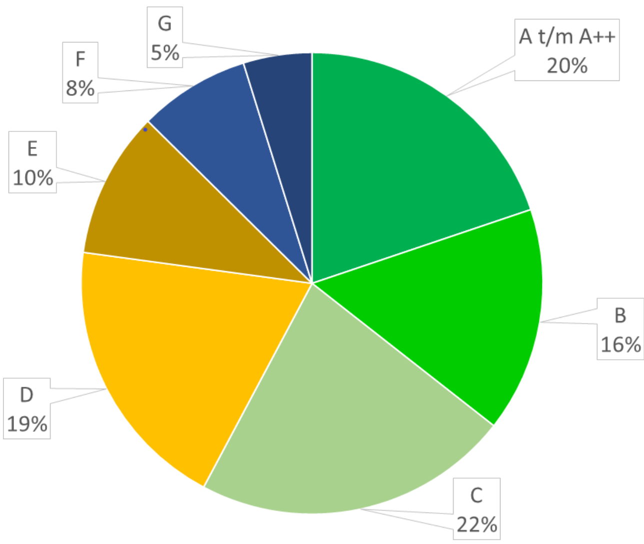


Figure 4.3: The energy labels in Utrecht in 2018, adapted from (Klimaatmonitor, nd)

Figure 4.4: The DHN network in Utrecht in 2018, coloured are the connected areas, adapted from (Utrecht, 2018b)

Regarding the citizens of Utrecht and their motivation to have a positive contribution in the sustainability of the municipality, a survey in 2016 yielded that, when looking at the measures related to the heat demand, 85% of the respondents have some sort of window insulation method implemented such as double glass. Furthermore, 47% have their walls (partially) insulated, 43% have their roof (partially) insulated, 36% have their floor (partially) insulated, 33% have a water saving shower head and/or tap, 9% have an energy-manager e.g. TOON, 35% have a smart-meter, 4% have a heat pump installed, and 1% have PVT panels installed for heating water (Utrecht, 2018d).

Within the Utrecht case, particular focus is placed on the decision-making process around Overvecht-Noord, a district in Utrecht appointed to be the first one to be disconnected from natural-gas. Moreover, the study with the Vesta MAIS model on the local heat transition in Utrecht is studied in more detail. These two sources will provide the case data to draw the current Data Ecosystem for Utrecht.

4.1.2. THE OVERVECHT-NOORD CASE

The first decision making process taken into account is the decision making process as part of the heat transition vision in Utrecht for the first district to be disconnected from natural-gas. This process resulted in the decision to start with Overvecht-Noord as the first districts to be disconnected. According to the interviewed Strategic Adviser from the Municipality of Utrecht (2018) this decision was made along a process which is very much in line with the conventional way of decision making in the municipality where, together with some stakeholders, the municipality looked at a map to determine, what is known, what is already happening and where a start could be made with the transition. The decision for Overvecht-Noord was made based on the following foundation: 1) it is a district built in the 1960's where it is likely that both the dwellings and public space will undergo significant retrofits, 2) there is a high level of uniformity among the building stock with a large share of social housing, and 3) a District Heating Network is already present in the district providing heat to the majority of the 8,000 dwellings. Based on these presumptions, the choice for Overvecht-Noord seemed like a logic one, however, when communicated to the citizens the decision experienced immense opposition. This was among others, due to: 1) the lack of communication and inclusion of the citizens in decision-making, and 2) the high costs this transitions brings along with many questions and uncertainty on who will have to be accountable to finance the transition. It is stated that this situation could likely be prevented by including the citizens in the decision making process at certain points, or in general by being better informed on how the citizens stand in the transition regarding: 1) the sustainability awareness, 2) preferences for heating technologies, and 3) the knowledge and financial competence of the citizens. This knowledge could have improved the communication of the decision and its consequences to the citizens (Strategic Adviser, Municipality of Utrecht, 2018; Senior Adviser, Mitros, 2019).

It was clear that this approach does not work, and the response was to adopt a data-driven process where data should contribute in the richer mapping of the areas and their energy household, in order to shape the energy transition in an inclusive way with support from the citizens and other stakeholders. With the lessons learned in Overvecht-Noord and the envisioned data-driven approach, the municipality will proceed in generating the heat transition vision for other Districts and guide the transition in those Districts. During this decision making process, data-driven support is provided in the form of a knowledge base which is established on data regarding: 1)*assets*: state and replacement plans for both natural gas network and district heating network, 2) *dwellings*: energy labels, age, building type, gas and electricity connection, district heating connection, and from roadside-scans the energy leakage, and 3) *ownership situation*: dwellings owned and inhabited by private owners and dwellings in the social housing sector (Strategic Adviser, Municipality of Utrecht, 2018).

4.1.3. THE VESTA MAIS REGIONAL STUDY IN UTRECHT

The second source is the study on the potential and costs of a climate neutral urban environment in Utrecht by PBL, with a clear focus on the heat supply (van den Wijngaart et al., 2018). This study utilises the Vesta MAIS (Multi Actor Impact Simulation) model, a model used since 2011 for the impact assessment of (national) scenario's in the energy transition, encompassing building and spatial measures. This study also has the aim to test whether the model, initially developed on the national level, is suitable for regional and local utilisation and what data is necessary for those applications. This study provides insights on the data ecosystem currently in place for the application of a prominent model, such as Vesta MAIS in the local situation, and what data and interactions are lacking in the current ecosystem. After gathering data on the local situation in Utrecht, this study simulates the performance and payback-period of measures regarding, on the one hand, the building heat installation and building envelope insulation performance, and on the other hand, the spatial measures regarding the heat source. Increased taxes on natural gas are also included in the simulations (van den Wijngaart et al., 2018).

After addressing the case study design in this section, the following section will elaborate on the design of the data collection phase, where interviews are the main means of data collection.

4.2. INTERVIEWS FOR DATA COLLECTION

For the data collection phase of this study, both open and semi-structured interviews are utilised over two phases of the study. The data retrieved over interviews, provide in-depth and rich knowledge on specific case related aspects e.g. the attitudes and perceptions of actors and stakeholders, which cannot be found in literature for a subject such as the heat transition (Miles and Huberman, 1994). Due to the lack of reported information on the challenges and barriers experienced by the actors and stakeholders in the field, interviews are selected as the method to attain this empirical information directly from the source.

In the first phase of the problem orientation, open interviews are taken with experts in the field of the heat transition at TNO and the Municipality of The Hague. The aim is to gather empirical information from these experts on how the problem and the possible solutions are perceived (Seidman, 2013). These interviews yielded the information to further specify the research and determine the approach as presented in figure 1.2.

In the second phase of the research, semi-structured interviews are conducted to derive the information necessary to answer the research questions. Here, the questions are constructed and categorised according to the research questions. Subsequently the derived knowledge directly contributes in answering the research questions, in combination with the knowledge derived from literature. In the following sub-sections it will be elaborated according to which approach the respondents are selected and how the qualitative data is analysed for the research questions to be answered.

4.2.1. INTERVIEW APPROACH AND RESPONDENT SELECTION

Stakeholder and expert interviews take place in two phases, in the first phase of pre-problem analysis, interviews are conducted with expert interviewees to gain a better understanding on the subject and the challenge at hand, these interviewees are presented in table 4.1. These interviewees are approached via the TNO network in ongoing projects regarding the energy transition. After the first round of interviews with a stakeholder and experts, the understanding of the challenge was improved. The first round of interviews also yielded a set of actors and stakeholders which are stated as important and necessary for the heat transition by the round one interviewees. This set of actors and stakeholders represent the various elements in an urban thermal energy system and form the pool of entities to be interviewed in the second round. Based on the proposed field, an interview strategy was set up containing the interview protocol, with the questions to attain the necessary data, and the criteria which interviewees should comply with. This selection method required significant resources to find and approach the desired interviewees. This approach was continued until most sectors in the urban thermal energy system could be covered. These respondents, selected according to a structured manner, are presented in table 4.2. These tables, 4.1 and 4.2, include the role of the interviewee, the subject on which the interviewee is interviewed, the organisation to which the interviewee is associated and how the interview is conducted. In appendix A the questions for the semi-structured interviews are presented.

Table 4.1: Interviews in the context of the pre-problem analysis

#	**Role and Subject**	**Organisation**	**Stakeholder type**	**Interview type**
1	Researcher - The Policy Lab at TNO	TNO	Research Institute	face to face
2	Professor and Researcher - Regulating Energy Markets	TNO and University of Amsterdam	Research Institute	face to face
3	Policy Officer - The energy transition in The Hague	Municipality of The Hague	Municipality	face to face

Table 4.2: Interviews for the problem analysis and ecosystem definition

#	**Role and subject**	**Organisation**	**Stakeholder type**	**Interview type**
1	Chairman - Coordinating and stimulating sustainable initiatives in the Hoograven district	HoogravenDuurzaam	Local citizen initiatives	Face to face
2	Initiator and Chairman - Coordinating and stimulating sustainable initiatives in the Scheveningen district	Gasvrij Scheveningen and VNG	Local citizen initiatives	Face to face
3	Energy Ambassador - Gathering and answering questions from citizens and providing technical support	EnergieU	Energy corporation	(Video)call
4	Business Developer - Developing Heating solutions for residential purposes such as District heating networks and Heat pumps	Eneco	Energy utility company	Face to face
5	Director - Leading the development of integrated sustainable concepts for e.g the residential sector	HOMIJ DEC	Installation company	(Video)call
6	Head of Energy and Project Director - Establishing the new Energy department and leading the Hart van Zuid project	Heijmans	Construction company	Face to face

Table 4.2: Interviews for the problem analysis and ecosystem definition

#	Role and subject	Organisation	Stakeholder type	Interview type
7	Senior Advisor and Coordinator Technology - Organisation of the sustainability of the building stock	Mitros	Housing corporation	Face to face
8	Product Developer - Developing data-driven products and services within the network company and towards clients	Stedin	Network company	Face to face
9	Consultant and Product Owner - Developing the Geomagine product for VR and AR for urban spatial applications	Geodan	Data product and service provider	(Video)call
10	Innovation-manager Sustainability - Developing new financial products and services around sustainability	Volksbank	Financial sector	(Video)call
11	Strategic Advisor - Developing new and data-driven approaches for the heat transition in Utrecht	Municipality of Utrecht	Municipality	(Video)call
12	Geo-architect RVO and adviser PDOK - Data management at RVO and technical advise on the PDOK development	RVO and Geonovum	Government Authority	Face to face
13	Statistical Officer - Producing statistics on the energy system	CBS	Government Authority	Face to face
14	Product Developer - Innovative data applications for data-driven statistics	CBS (Center for Big Data Statistics)	Government Authority	Face to face
15	Strategic Adviser - Development of the public data release by Kadaster and advising on the role of energy	Kadaster	Government Authority	(Video)call
16	Product owner PDOK - Development of the public data release by Kadaster	Kadaster	Government Authority	(Video)call
17	Consultant - Advising public and private parties on the natural-gas-free heat transition in a data-driven style	Overmorgen	Consultancy or Advisory firm	(Video)call
18	Researcher - Research on deriving and coping with the preferences of citizens in the heat transition	TU Delft	Research & Education Institute	Face to face

4.2.2. METHOD OF CODING AND DATA ANALYSIS

In figure 4.5 it is depicted how the qualitative data is processed and analysed. It should be noted that the processing and analysis is aided by the NVivo software package by QSR International (2019). The NVivo software package provides an environment to code, process, structure, analyse, and visualise the qualitative data in a convenient way.

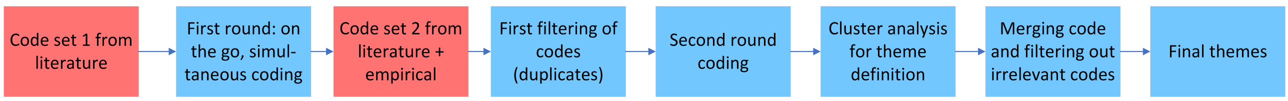


Figure 4.5: The method of qualitative data coding and analysis

FIRST CODING ROUND: ON THE GO AND SIMULTANEOUS CODING

After gathering the interview sources in the NVivo environment, an initial "on the go" coding iteration is run according to the simultaneous coding method to derive the initial set of codes for the content analysis. Simultaneous coding, or co-occurrence coding, entails that each passage of text can be coded with multiple codes relating to several themes or patterns (Saldaña, 2015). For this particular research it is interesting to study, for instance, overlapping knowledge gaps and simultaneously code these knowledge gaps with a corresponding data need. In addition, it is relevant to add a certain direction or extent to a code, for instance whether a citizen willingness is high or low, or, whether a certain attitude is negative or positive. Multiple coding is also applicable to add during which phase of the decision making process or transition a certain code is used, this adds to the context of the coding. Simultaneous coding allows for these desired scenario's (Hsieh and Shannon, 2005).

CODING SETS AND FILTERING

The first round of coding, mentioned above, is conducted with a set of predefined codes derived from the theory and background on data ecosystems and urban thermal energy systems. During the first round of coding, this set is extended with empirically derived codes from the respondents with respect to the attitudes and perceptions in the heat transition regarding knowledge gaps, challenges and barriers, EPL functionality, and the stakeholder landscape. From the first coding iteration a total of 624 codes could be identified in Code set 2. The first iteration was followed by the first filtering iteration to eliminate duplicates. With a set of unique codes a second coding iteration was run over all sources. Since the applied method of "on the go" coding implies that codes are added as the coding proceeds over the interview sources, it may be that sources coded at the beginning of the iteration do not contain all codes in the set at the end of the iteration. Hence, to cover all sources with the total set of codes, the second iteration is executed.

CLUSTER ANALYSIS AND THEME DEFINITION

After the second round of coding, the set of codes is made subject to a hierarchical cluster analysis. The aim of this cluster analysis is to analyse which codes are used in the vicinity of each other and at which frequency this occurs. This analysis provides the first indication towards possible relationships between codes and for themes to surface (Henry et al., 2015, Macia, 2015). Hereby, on the contrary to statistical analysis which requires representative data, cluster analysis does not result in generisable output. It proposes an structuring or organisation of the data, which is commonly extensive and complex, making it useful for smaller qualitative samples (Macia, 2015). This cluster analysis was initially conducted visually by plotting each node, based on the similarity in coding relative to the other nodes. Due to the high number of codes, 436 codes in the final set, this visual representation did not result in a comprehensible overview of the clusters. The alternative was to establish a coding matrix of all codes. From this matrix it could be derived which codes are coded in co-occurrence, and how often this occurs. These co-occurrences, defined as the overlap or common occurrence of two or more codes for a particular segment, are translated into themes such that connections and interrelations can be identified between the data and also between the respondents. These interrelations contribute in the findings to answer the research questions (Eisenhardt, 1989).

After the cluster analysis the resulting final set of codes divided under specific themes, consists of 436 codes. In table B.1, the final coding scheme is presented. During the cluster analysis and, after filtering for duplicates initially, the initial set of 624 codes is reduced to the final set by eliminating irrelevant codes, for instance codes used very rarely, and by merging codes which show significant similarity or a strong correlation.

In addition to the definition of themes, the cluster analysis aids the classification of the data, by grouping data together in classes related to various characteristics of the respondents (Macia, 2015). For each respondent it is namely taken into account what the legal status is, private, semi-public or private, to which company or organisation the respondent is associated, and what role the respondent has within the associated organisation or company. This enables to say something about how respondent characteristics relate to the data, for instance which challenge or knowledge gaps is commonly mentioned by a certain category of respondents. By doing so, the complexity and variation in the perceptions and attitudes of various actors and stakeholders can be better understood when studying the socio-technical system behind the heat transition.

4.3. CHAPTER CONCLUSION

In this chapter the design of the qualitative embedded single-case study is presented, with the aim to derive rich and detailed information on the heat transition and the associated data ecosystem via interviews. The case of Utrecht is elaborated as the embedded case within the main case of the Netherlands, where the heat transition is studied from the national to the local level.

It is presented that interviewees are selected based on criteria to eventually cover the as much as possible of the urban thermal energy system. The data treatment process, consisting of several steps of coding, filtering and cluster analysis is organised in such a manner to derive the answers to the research questions from the qualitative data. The results of this empirical research will be addressed in the following chapter

5

Results of the Empirical Analysis

After elaborating on the technical and policy background of this study in chapter 2, and the theoretical background in chapter 3, this chapter will proceed with the empirical problem analysis regarding the heat transition in the Netherlands. First it will be described how the stakeholder field looks like for the heat transition. Subsequently, the empirical knowledge on the challenges and barriers experienced by the actors and stakeholders is presented, with the focus on the knowledge gaps and the data needs with respect to public and private decision-making in the heat transition. Finally, the stakeholder-data landscape is presented. This takes into account the stakeholder landscape from section 5.1, and the data needs based on the knowledge gaps from sub-section 5.3.2, to present how each stakeholder is envisioned to have a role as data-supplier, intermediate, or data-user. The research design to derive this empirical knowledge is previously presented in chapter 4, and from this research design, the results to the sub-questions are presented in the sections as follows:

Section 5.1, 5.2 and 5.4	⇒	*1. What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?*
Section 5.3	⇒	*2. Among the decision-making of the actors and stakeholders for heating in the built environment, what knowledge is lacking, hence preventing effective decision-making?*

5.1. Stakeholder landscape in the Dutch heat transition

5.1.1. Mapping of the stakeholders

This section draws the actor and stakeholder map within urban thermal energy systems. These actors and stakeholders are first presented in a more generic way, after which it is mentioned how this stakeholder category is filled in for the case of Utrecht. Stakeholders can be defined as *"individuals, groups of individuals, or organisations that affect and/or could be affected by the activities, products or services and associated performance of another organisation"* according to the AA1000 standard for stakeholder engagement by AccountAbility, an international consulting and standards firm on sustainability (ACCOUNTABILITY, 2015). To map the stakeholder field which, the following questions were leading in the document study and in the interviews:

- Interview:
  - How would you describe your role, and the role of your organisation in the heat transition?
  - Which actors or stakeholders would you state as the most important in the heat transition?
- Document study:
  - Who is directly responsible and/or accountable for decisions on the issue(s)?
  - Who can prevent or hinder a decision?
  - Who has relevant interests in the issue, area, community and/or organisation?
  - Who is influential in the area, community and/or organisation?
  - Who will be affected by any decisions on the issue (individuals and organisations) and needs to be consulted or informed on the decisions?
  - Who has been involved in the issue in the past, and who has not been involved and should have been involved?

In table 5.1 the stakeholder map, derived through the above-mentioned questions, is depicted in a manner where for each stakeholder type in the first column, it is presented in which role or way they are involved or affected by the various functions or topics within the urban thermal energy system. For each function among: 1) Energy supply, 2) Energy Distribution, storage and exchange, 3) Energy demand and integration services, 4) Urban planning, and 5) Stakeholder engagement, it is documented whether the stakeholders are Responsible (R) and/or Accountable (A), and whether they should be Informed (I) and/or Consulted (C) in the context of stakeholder engagement and co-creation. With this information, table 5.1 aims to provide a structured overview of the involvement and role of these stakeholders over the functions of the urban thermal energy system, and thereby provide an improved understanding in the stakeholder field. These identified stakeholders are elaborated in the paragraphs after table 5.1.

Table 5.1: Overview of the stakeholders in the heat transition, and the type of involvement over the various functions of urban thermal energy systems, Legend - R: Responsible, A: Accountable, C: Consulted, I: Informed. Derived from literature and interviews

Stakeholder type (General)	In Utrecht case	Energy Supply	Distribution, exchange and storage	Energy demand and integration services	Urban Planning	Stakeholder Engagement
			Citizens			
"The silent majority"	Citizens of Utrecht	A: Prosumer I: Consumer	C, A: Prosumer I, A: Consumer	R,A: Prosumer R,A: Consumer	C: Prosumer I: Consumer	C: Prosumer I: Consumer
Front-runners	Citizens of Utrecht	A: Prosumer I: Consumer	C, A: Prosumer I, A: Consumer	R,A: Prosumer R,A: Consumer	C: Prosumer I: Consumer	C: Prosumer C: Consumer
Private homeowners	Citizens of Utrecht	A: Prosumer I: Consumer	C, A: Prosumer I, A: Consumer	R,A: Prosumer R,A: Consumer	C: Prosumer I: Consumer	C: Prosumer C: Consumer
Tenants	Citizens of Utrecht	A: Prosumer I: Consumer	C, A: Prosumer I, A: Consumer	R,A: Prosumer R,A: Consumer	C: Prosumer I: Consumer	C: Prosumer I: Consumer
			Government			
Local Governments - Municipalities	Municipality of Utrecht	R, A: permit R, A: subsidy R, A: plan, monitor, guide	R, A: permit R, A: subsidy R, A: plan, monitor, guide	R, A: permit R, A: subsidy R, C: plan, monitor, guide	R, A: permit R, A: subsidy R, A: plan, monitor, guide	R, A: facilitate R, A: plan, monitor, guide
Local Governments - Provinces	Province of Utrecht	R, A: facilitate R, A: funding	R, A: facilitate R, A: funding	R, A: facilitate	R, A: facilitate R, A: funding	R, A: facilitate
National Government	National Government	R, A: permit R, A: subsidy R, A: plan, monitor, guide	R, A: subsidy R, A: plan, monitor, guide	R, A: subsidy R, A: plan, monitor, guide	R, A: subsidy R, A: plan, monitor, guide	R, A: facilitate R, A: plan, monitor, guide
			Government authorities			
Statistics Authority	CBS Statistics Netherlands	R, A: Statistics generation and provision	R, A: Statistics generation and provision	R, A: Statistics generation and provision	R, A: Statistics generation and provision	R, A: Statistics generation and provision
Cadaster	Kadaster	R, A: subsurface and object data generation and provision	R, A: subsurface and object data generation and provision	R, A: subsurface and object data generation and provision	R, A: subsurface and object data generation and provision	R, A: subsurface and object data generation and provision
Institutes for strategic policy analysis	PBL The Netherlands Environmental Assessment Agency	A,C: policy research	A,C: policy research	A,C: policy research	A,C: policy research	A,C: policy research
Enterprise Agencies	RVO The Netherlands Enterprise Agency	A,C: subsidy A,C: support and facilitate	A,C: subsidy A,C: support and facilitate	A,C: subsidy A,C: support and facilitate	A,C: subsidy A,C: support and facilitate	A,C: subsidy A,C: support and facilitate
			Market			
Construction businesses	Various parties e.g. Heijmans VolkerWessels	A: develop and provide gas-free solution	A: develop and execute networks	A: develop and execute renovation	C: developer and provider	C: developer and provider
Technology, application and software businesses	Various parties e.g. Quby	A: develop and execute metering and control	A: develop and execute metering and control	A: develop and execute metering and control	A, C: data provision	A, C: data provision
Energy utility and service businesses	Various parties e.g. Eneco, Nuon	A: generate energy	A,C: generate energy	A: generate energy and efficiency services	C: developer and provider	C: developer and provider
Potential heat suppliers	Various parties e.g. Eneco, EnergieU, Industry, Water Boards	A: generate and provide heat	A,C: generate and provide heat	A: generate and provide heat	C: generate and provide heat	C: generate and provide heat
Hardware businesses	Various parties e.g. Gamma, Hornbach	A: provide equipment and hardware	A: provide equipment and hardware	A: provide equipment and hardware	I: provide equipment and hardware	I: provide equipment and hardware

Table 5.1: Overview of the stakeholders in the heat transition, and the type of involvement over the various functions of urban thermal energy systems, Legend - R: Responsible, A: Accountable, C: Consulted, I: Informed. Derived from literature and interviews

Stakeholder type (General)	In Utrecht case	Energy Supply	Distribution, exchange and storage	Energy demand and integration services	Urban Planning	Stakeholder Engagement
Installation businesses	Various parties e.g. HOMIJ DEC	A: develop and execute gas-free solution	A: develop and execute storage metering and control	A: develop and execute efficiency metering and control	C: develop and execute storage and storage metering and control	C: develop and execute efficien-cy metering and control, data
Insulation businesses	Various parties e.g. Kingpanel, Hardware Stores	-	-	A: develop and provide insula-tion solution	A: develop and provide insula-tion solution	A: develop and provide insula-tion solution
			Intelligence & Research			
Energy consultant or advisor	Various parties e.g. Overmorgen	R, A: support and advice	R, A: support and advice	R, A: support and advice	R, A: support and advice	C: support and advice
Research and education institutes	Various parties e.g. TNO, TU Delft	R,A: research and innovation	R,A: research and innovation	R,A: research and innovation	R,A: research and innovation	C: research and innovation
			Real-estate			
Real estate developers and intermediates	Various parties	R,A: realise gas-free building stock	C: realise gas-free building stock	R,A: realise gas-free building stock	R,A: realise gas-free building stock	R,A,C: realise gas-free building stock, data
Housing corporations	Various parties e.g. Mitros	R,A: realise gas-free building stock	C: realise gas-free building stock	R,A: realise gas-free building stock	R,A: realise gas-free building stock	R,A,C: realise gas-free building stock, data
Owner Associations	VvE's Owner associations	R,A: guide gas-free building	C: guide gas-free building	R,A: guide gas-free building	R,A: guide gas-free building	R,A: guide gas-free building, data
			Other			
Local citizen centred initiatives	Various parties e.g. Hoograven Duurzaam (Utrecht)	A,C: stimulate and facilitate local initiatives	C: stimulate and facilitate local initiatives	A,C: stimulate and facilitate local initiatives	C: stimulate and facilitate local initiatives	C: stimulate and facilitate local initiatives
Energy cooperatives	Various parties e.g. EnergieU	A,C: stimulate and offer local sustai-nable heat solutions	A,C: stimulate and offer local sustai-nable storage solutions	A,C: stimulate and offer local sustai-nable heat solutions	C: stimulate and offer local sustai-nable heat solutions	A,C: stimulate and offer local sustai-nable heat solutions
Network operators	Stedin (e+g) Eneco, Nuon (heat)	C: plan and realise network infrastructure and balance	R,A: plan and realise network infrastructure and balance	C: plan and realise network infrastructure and balance	C: plan and realise network infrastructure and balance	R,A,C: plan and realise network infrastructure and balance
Environmental organisations	Various parties e.g. Natuur & Milieu	A: support, educate and inform	C: support, educate and inform	A: support, educate and inform	C: support, educate and inform	C: support, educate and inform
Financial institutions	Banks Credit providers	R,A: provision of support and financing	R,A: provision of support and financing	R,A: provision of support and financing	C,A: provision of support and financing	A,C: provision of support and financing
Standards organisations	Geonovum (data standards)	R,A,C: establish and maintain data standards	R,A,C: establish and maintain data standards	R,A,C: establish and maintain data standards	R,A,C: establish and maintain data standards	A,C: establish and maintain data standards
Market regulator	ACM Authority for Consumers & Markets	R,A: regulate market	R,A: regulate market	R,A: regulate market	C: regulate market	C: regulate market
Branch organisations	Various parties e.g. Bouwend Nederland Netbeheer Nederland	R,A: represent members, guide and protect interests	R,A: represent members, guide and protect interests	R,A: represent members, guide and protect interests	C: represent members, guide and protect interests	A,C: represent members, guide and protect interests

In the following a short description is provided of each stakeholder:

- *Citizens*: citizens are the inhabitants of dwellings and consumers of heating and cooling in the residential sector, subsequently they are accountable to make the changes in behaviour to reduce energy consumption and they are in the lead to make the investment decision and (partially) carry the investment risk of natural-gas-free solutions for heating & cooling in their homes. This large group of stakeholders can be further divided in:
  - *The tenants*, renting dwellings in either the private sector or the social housing sector.
  - *The private homeowners*, owning and inhabiting or renting out a dwelling, and thus accountable for the provision of heat within that dwelling and the use of heat when inhabiting the dwelling.
  - *The front-runners*, these are the citizens taking the lead in behavioural change, implementing measures in the dwelling and their daily life leading to energy efficient behaviour and the use and/or generation of

sustainable energy. This group of citizens is commonly also behind the promotion and establishment of local initiatives (Chairman, HoogravenDuurzaam, 2018; Chairman, Gasvrij Scheveningen, 2018; Product Developer, Geodan, 2018; Energy Ambassador, EnergieU, 2018).
  - *The "stille meerderheid"* or silent majority, form the majority of the citizens which are less enthusiastic about pioneering in behavioural or dwelling facade and installation changes as compared to the front-runners, among others, due to barriers in the field of financial ability and a lack of awareness (Chairman, HoogravenDuurzaam, 2018; Chairman, Gasvrij Scheveningen, 2018; Product Developer, Geodan, 2018; Energy Ambassador, EnergieU, 2018).
- *Government*: The government is responsible and accountable for the establishment of national climate goals and the policy and framework conditions to realise the national goals in the playing-field of public, semi-public and private parties on different geographic and demographic levels. More on the policy framework of the government for the heat transition is elaborated in sub-section 2.1.
  - *the National Government*: on the national level the relevant ministries such as the Ministry of Economic Affairs and Climate, and the Ministry of Internal Affairs and the Kingdom Relations, are setting out policy on how to realise the national climate goals, hereby allocating the resources, both financial and non-financial, deemed necessary to execute the policy. In addition, programs such as the Regional Energy Strategies are established to align the transition efforts on the regional level (Klimaatberaad, 2018).
  - *the Province*: on the regional level of the provinces, the Provincial Government set out their own policy on the development and maintenance of infrastructure, e.g. roads and train-tracks, spatial planning, e.g. the locations for wind-turbines, and nature. Furthermore, they monitor and aim to align the policy and budget of the underlying municipalities (Rijksoverheid, 2019).
  - *the Municipality*: on the local level the municipality is, among others, responsible and accountable for the establishment and execution of policy to realise a carbon neutral municipality in line with the national policy. Hereby the municipality is involved in activities such as the provision of permits, the inclusion of the spatial impact of sustainable energy generation in the spatial plans, providing local subsidies and opt for more ambitious building energy standards, and monitor the progress. For the heat-transition, the role of the municipality as director of the transition has a big impact on how the municipality guides the heat transition among its districts with the heat transition Vision (Strategic Adviser, Municipality of Utrecht, 2018).
- *Government authorities, semi-public organisations*
  - *Statistics Netherlands (CBS)*: responsible and accountable to generate and publish statistics on a high variety of variables among society, industry and public administration (CBS, 2019b).
  - *Netherlands Enterprise Agency (RVO)*: agency responsible and accountable to support entrepreneurs and entrepreneurial activities by citizens with regards to for instance subsidies, expertise and networking activities (RVO, 2019).
  - *Kadaster*: responsible and accountable to register and release data on objects above the ground such as buildings, and under the ground such as pipes and cables. In addition, Kadaster, maintains registers for other authorities such as the Basis-register Addresses and Buildings (Kadaster, 2019b).
  - *Netherlands Environmental Assessment Agency (PBL) and Bureau for Economic Policy Analysis (CPB)*: agencies which are accountable for respectively strategic and economic policy analysis regarding the environment, nature and spatial planning. They contribute in the quality of political decision making by means of reconnaissance, analyses and evaluations via an integral approach which is objective and scientifically sound (PBL, 2019).
- *Market*
  - *Construction Businesses*: Parties with the skills and resources, currently or in the future, to provide products and services to end-users regarding, or related to, the retrofit of existing dwellings and the construction of new dwellings, and the construction of heating infrastructure such as district heating networks. Examples are Heijmans, VolkerWessels and The Royal Bam Group etc (Klimaatberaad, 2018).
  - *Technology, Application and Software Businesses*: Provide the products and services that, for instance, enable the monitoring and control of energy use for consumers, which on its turn enables energy efficiency and the integration of a domestic energy system with intermittent sustainable energy sources, storage and demand side management. These services include technology for data mining, data management and data analysis.
  - *Energy Utility and Energy Service Businesses*: Energy Utilities are the parties in the market which generate and/or retail energy to the consumers. Large market parties are for instance Eneco and Nuon/Vattenfall, which are also active in the development and operation of DHN. On the contrary to the private energy providers, there are also public energy providers such as Stadsverwarming Purmerend, a public entity which established and operates a DHN in Purmerend. The trend within these companies is the shift away from selling energy per unit, to providing energy as a service. Hereby, products which assist consumers in monitoring and controlling the energy-use, and subsequently improve energy efficiency are increasingly offered as part of the service package (Menkveld et al., 2017).

  - *Potential heat suppliers*: Parties with activities, current or future, which can supply heat to the sustainable urban thermal energy system. For instance sewage and waste utilities, the water boards, and the chemical industry.
  - *Hardware Businesses*: Parties with the facilities, such as stores and warehouses, to provide products and services to the end-user for dwelling retrofit and the adoption of a sustainable heating system. Hardware entails, among others, insulation, heat pumps, PV(T) panels and HVAC installations. Examples are the Gamma, Ikea, Praxis and Hornbach.
  - *Installation Businesses*: Parties with the skills and resources, currently or in the future, to provide products and services to end-users regarding, or related to, technical installations for the individual or local heat system, including e.g. heat pumps, PV(T) panels, and HVAC installations. Examples are Engie, SPIE, HOMIJ DEC etc.
  - *Insulation Businesses*: Parties with the skills and resources, currently or in the future, to provide products and services to end-users regarding, or related to, the insulation of the dwelling, an example is Kingspan.
- *Intelligence & Research*
  - *Energy consultants and advisers*: Parties with the skills and resources, currently or in the future, to provide services regarding, or related to, the support of the decision-making on the planning and execution of measures towards a sustainable urban thermal energy system. Hereby, citizens can be supported in investment-decisions, market parties can be supported in the development of new services and products, and governments may be supported in the decision-making on the transition pathway. An example is Overmorgen.
  - *Research and education institutes*: Parties with the skills and resources, currently or in the future, to conduct research and provide factual, objective and up-to-date knowledge and expertise on all aspects of urban thermal energy systems, to all stakeholders involved in the heat transition. Examples are TU Delft, TNO, Deltares etc.
- *Real-Estate*
  - *Real-estate developers and intermediates*, parties in the development and trade of real-estate in the private sector.
  - *Housing Corporations*, develop and offer housing within the social-sector. With a large building stock, the corporations are considered a start-motor in the renovation challenge by the Climate Agreement (Klimaatberaad, 2018).
- *Other*
  - *Local citizen initiatives*: these groups are often initiated and run by the front-runners and operate on the district or neighbourhood level, see for instance HoogravenDuurzaam for the Hoograven District in Utrecht and Gasvrij Scheveningen for the Scheveningen district in The Hague (Gasvrij Scheveningen, 2019, Hoograven Duurzaam, 2019). They aim to stimulate and consolidate sustainability measures within the district or neighbourhood, regarding energy efficiency and the generation of sustainable energy by means of for instance collective purchasing campaigns for PV panels, energy conservation campaigns and the provision of advice and answers to questions and challenges among the citizens. National initiatives aiming to stimulate and consolidate the efforts of the local initiatives, such as Buurtkracht, are also considered in this category of stakeholders (Buurtkracht, 2019).
  - *Energy cooperative*: the Energy cooperatives are a possible next step for the local citizen initiatives to grow towards, in particular, this implies the scaling up of e.g. local energy generation and the operational control thereof, whereby often the legal status changes accordingly. They can become active over the complete chain and take responsibility in the planning, development and operation of a local energy system, such as a DHC network. One example is Cooperative Heat-network East Wageningen, a cooperative of citizens which will develop and exploit a DHN for the Benedenbuurt district (Wageningen Woont Duurzaam, 2018). A second example is Thermo Bello, a local cooperative which operates a local heat network since 2009 in the EVA-Lanxmeer neighbourhood in Culemborg (Vereniging Ontwikkeling Exploitatie Warmtenet, 2008).
  - *Environmental Organisations*: these organisations, with examples being Natuur & Milieu and Milieu Centraal, aim to raise awareness among citizens and support citizens with measures on energy efficiency and sustainable energy generation, cooperate with businesses to develop effective products and services, and lobby at the policy makers on various levels of public administration (Natuur & Milieu, 2019).
  - *Financial Institutions*, this category of stakeholders is accountable for the development and provision of financial services and products to finance the investments necessary to realise the heat-transition, regarding both the building stock and its associated insulation and individual heat installations, and the collective heat and energy infrastructure.
  - *Network Operators*: or the Distribution System Operators (DSO) for Electricity & Gas such as Stedin (for the case area of Utrecht), Alliander and Enexis. These parties maintain the balance on the distribution grid and are responsible and accountable to expand the grid capacity according to the demand in order to guarantee a high availability of the grid. In addition, parties such as Eneco are the network operators for the DHC networks within their portfolio.

– *Standards Organisations*: Here geo-data standards organisation Geonovum is highlighted. Geonovum is developing standards to make geo-data from the government accessible and interchangeable (Geonovum, 2014).
– *Market regulator (ACM)*: regulating the market, e.g. electricity, gas and heat, but also material and equipment, on competition fairness and consumer rights.
– *Branch Organisations*: represent their members in negotiations with the government on e.g. the Climate Agreement. Relevant for the heat transition are among others: Netbeheer Nederland for the network operators, Energie Nederland for the gas, heat and electricity utility sector, Nederlandse Vereniging Duurzame Energie (NVDE) for the sustainable energy sector, Energie Samen for the citizen led local initiatives such as energy cooperatives, Techniek Nederland for the installation and technical retail sector, Dutch Heat Pump Association (DHPA) for the manufacturers and importers of residential and utility heat pumps, Bouwend Nederland for the construction and infrastructure sector, OnderhoudNL for the real-estate maintenance and retrofit sector, Vereniging van Institutionele Beleggers in Vastgoed, Nederland (IVBN) and Vastgoed Belang for respectively institutional real-estate investors and private real-estate investors, Vereniging Eigen Huis for the private homeowners, Woonbond for the tenants, and Aedes for the housing corporations. Regarding the public parties the following associations are relevant: Vereniging van Nederlandse Gemeentes (VNG) for the municipalities, and Interprovinciaal Overleg (IPO) for the provinces.

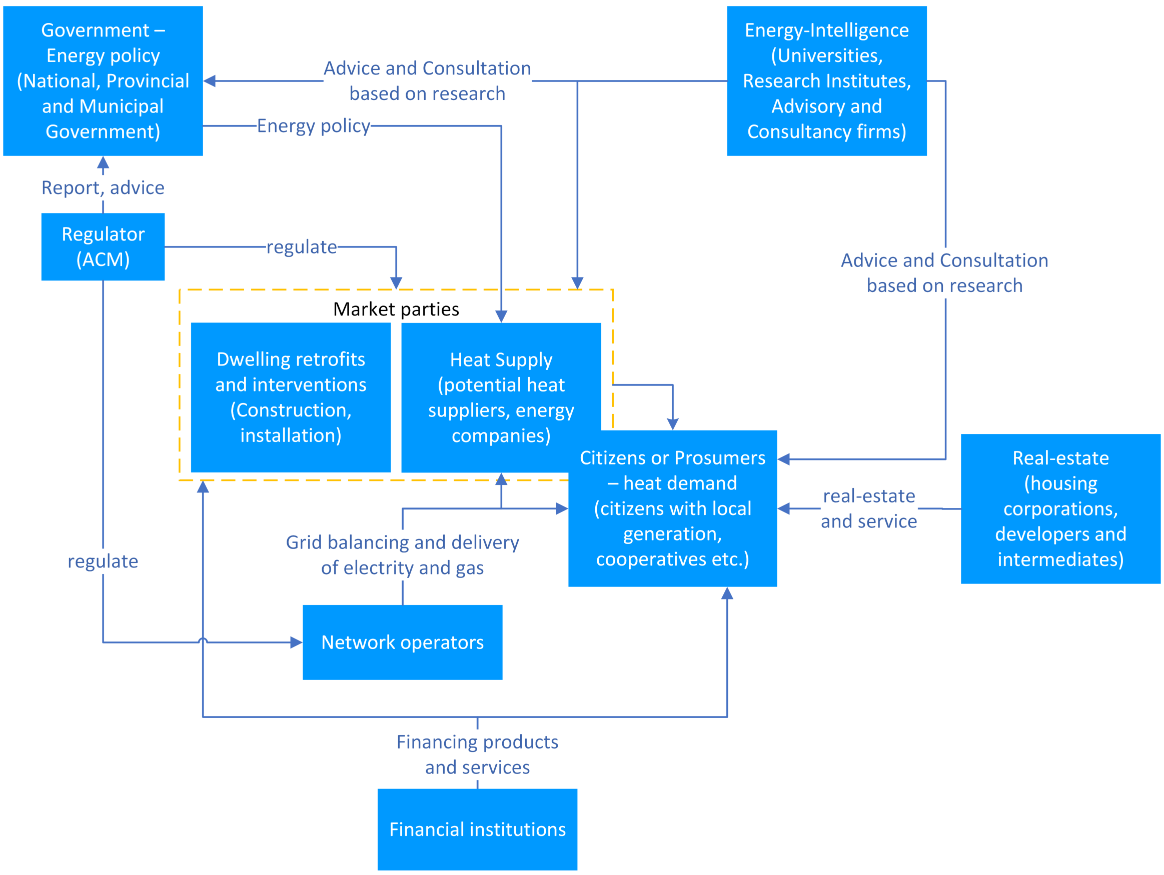


Figure 5.1: The relation between the actors and stakeholders, own image derived from interview data

In Data Ecosystems, actors and stakeholders are connected to each other by means of interests or business models, functioning as either producers or consumers of data, or a combination of both (Oliver et al., 2014). According to Zuiderwijk et al. (2014) the Data Ecosystems are build upon pre-existing networks of interaction with different levels of training and capacity. From the mapping of the stakeholder field in this section, figure 5.1 is a first visualisation of the relations between the actors and stakeholders, and how these may contribute in the data exchange on an aggregated level. Note that the specific data needs and provision per actor are only presented in section 5.3, and after that section, the data-stakeholder context will be presented, where for each stakeholder it is addressed what the possible role is as data supplier, intermediate or consumer. The interrelations on the aggregated level as presented in figure 5.1 are derived from the empirical interview data, whereby the data is derived based on the following questions:

- How would you describe your role, and the role of your organisation in the heat transition?
- Given the stakeholders mentioned by you, how do you interact with these stakeholders in the heat transition?

There are thus many interrelations between the actors and stakeholders in the heat transition and it is stated by several interviewees that these interrelations are not yet well understood. Changes in these interrelation are considered to be likely since the roles of many actors are not yet completely defined. For instance, the municipality and the construction businesses have stated to be searching for the suitable role which maximises their contribution in the heat transition (Project Director, Heijmans, 2019; Strategic Adviser, Municipality of Utrecht, 2018). In the following sub-section it is discussed which stakeholders are perceived as important and necessary in the heat transition by the interviewees.

5.1.2. STAKEHOLDER IMPORTANCE AND ATTITUDE

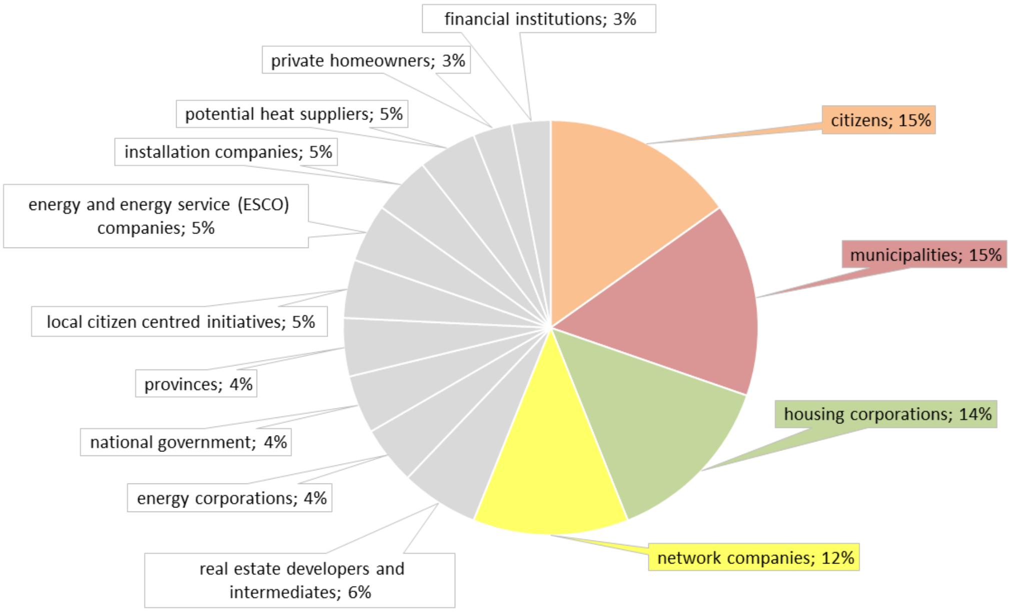


Figure 5.2: The relative importance of actors, % of the total references, derived from interview data

The design of questions for the interviews included questions to derive which stakeholders are perceived as important and necessary, by the interviewee, to take active measures in order to realise a heat transition. In figure 5.2 it is displayed how the importance of actors is perceived by the interviewees. This is based on the percentage a certain stakeholder is labelled as being important and necessary among all references of important and necessary stakeholders. For a total of 48% the respondents consider the stakeholders depicted in the right-half of figure 5.2 as important and necessary. These are the citizens, the municipality, the housing corporations and the network companies.

On the opposite side of the highly referenced stakeholders, there are the stakeholders with little to no explicit references as to being important and necessary. Notably, this spectrum of stakeholders holds the environmental organisations, research and education institutes, and the branch organisations. In addition, market segments such as the construction companies, insulation companies and hardware companies get little references regarding their importance. This raises questions whether awareness regarding the big retrofit challenge and need for resources and skilled labour is acknowledged sufficiently. Furthermore, stakeholders categorised as energy consultant or advisers, market regulators and standardisation organisations, have been mentioned by the interviewees to have a role in the heat transition, however no notion was made on the importance of these stakeholders.

In general it can be concluded that the field of interviewees, representing most sectors of the urban thermal energy system, is aware of the stakeholders involved in the heat transition. However, this can not be said regarding the importance and necessity of stakeholders in the heat transition, where many stakeholders are overlooked, and the importance of other stakeholders is over-estimated.

After discussing the stakeholder map for the heat transition in the Netherlands, and the perceived importance of stakeholders, table 5.2 presents the attitude of the interviewees and their associated organisation in the heat transition, with the options being *Resistant, Neutral*, and *Supportive*. Moreover, it is derived from the interviews what the state of stakeholders is regarding the *awareness* on the extent to which stakeholders are expected to *lead* in the heat transition. This information is relevant for the design of co-creative and inclusive decision-making, recall that this is an aim of a feasible and effective heat transition. In table 5.2, it is depicted for each stakeholder type what the attitude currently is, indicated with a *"c"*, and what the attitude is desired to be, indicated with a *"d"*.

Table 5.2: the stakeholder engagement matrix visualised the current (c) and desired (d) engagement of the stakeholders

	Unaware	Resistant	Neutral	Supportive	Leading
Citizens					
"The silent majority"	c	c		d	
Front-runners				cd	cd
Private homeowners	c	c		d	
Tenants	c		c	d	
Government					
Municipalities				cd	cd
Provinces				cd	d
National Government				cd	cd
Government authorities					
CBS				cd	
Kadaster				cd	
PBL				cd	
RVO				cd	
Market					
Construction Businesses			c	cd	d
Technology, Application and Software Businesses				cd	
Energy Utility and Service Businesses			c	cd	
Potential heat suppliers	c	c		cd	
Hardware businesses	c			d	d
Installation businesses			c	d	d
Insulation businesses			c	d	d
Intelligence					
Energy consultant or advisor				cd	
Research and education institutes				cd	
Real-Estate					
Real estate developers and intermediates		c	c	d	
Housing corporations		c	c	cd	d
Owner Associations		c	c	d	
Other					
Local citizen centred initiatives				cd	d
Energy cooperatives				cd	d
Network operators			c	cd	d
Environmental organisations				cd	
Financial institutions			c	cd	
Standards organisations			c	d	
Market regulator (ACM)			cd		
Branch organisation	c	c	c	cd	

From table 5.2 it can be observed that the majority of the stakeholders can be found as currently supporting the heat transition. However, there is also significant resistance to the transition. Predominantly, this resistance is coming from the citizens and real-estate stakeholders, stakeholders which are expected to be impacted by the changes and of which significant investments are expected in realising sustainable urban thermal energy systems.

Moreover, the last column shows that a leading role is expected from several stakeholders. However, few stakeholders are actually taking that leading role in the current picture, and whether that is according to the expected extent remains to be determined.

Finally, the first column shows that many stakeholders can still be associated with a state of unawareness on the urgency behind the heat transition, but also unawareness regarding the alternatives in the heat transition, and the processes and facilities ongoing to enable these alternatives. This unawareness frequently occurs together with a resistant attitude.

After sketching the stakeholder landscape in this section, together with the attitude, awareness and aspects related to the role of these stakeholders, the following section elaborates on the challenges encountered by the stakeholders in the heat transition.

5.2. CHALLENGES IN THE HEAT TRANSITION AS PERCEIVED BY THE STAKEHOLDERS

The challenges and barriers encountered in the heat transition which are presented in this section, are thus derived from the qualitative interview data. In figure 5.3 it is presented how elaborate the interviewees address challenges in the heat transition. This is considered an indicator that provides insights on the extent to which challenges are encountered by the interviewees, relative to each other. However, it should be mentioned that it has to be taken into account that the data is not generisable to the entire organisation which the interviewee represents. The particular interviewee might not be aware of all challenges encountered by the organisation, or is in a division or department which encounters less challenges compared to other divisions or departments.

It can be observed that (Senior Advisor and Coordinator Technology, Mitros, 2018) relatively elaborated most on the challenges in the interview, over 26%, compared to the other interviewees. (Energie Ambassadeur, EnergieU, 2018) elaborated a comparable amount on challenges, namely 25%, while (Innovation Manager Sustainability, Volksbank, 2019) and (Consultant, Overmorgen, 2018) dedicate the least of the interview to challenges. It is interesting that the Volksbank is on the lower end of this spectrum, while the financing of the significant investments in the heat transition is commonly stated as a, if not the biggest challenge, in the heat transition (Hers et al., 2018, Rooijers and Kruit, 2018).

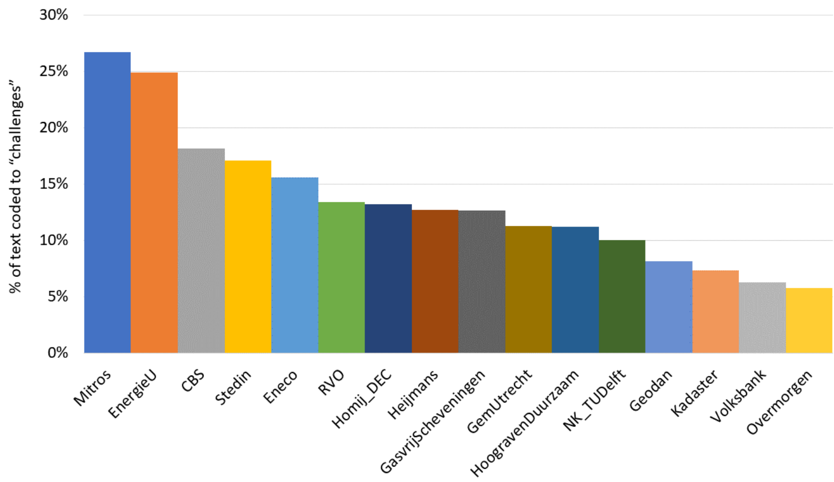


Figure 5.3: The extent to which interviewees elaborate on challenges, in % of the transcript text coded to challenges

The cluster analysis conducted to derive the categorisation of the challenges as presented in figure 5.4, is executed based on the coding similarity of challenges mentioned. The cluster analysis resulted in five main categories of challenges: Transition tempo or pace, Decision making, Energy technology, Economic aspects, Data and intelligence, and the Stakeholders.

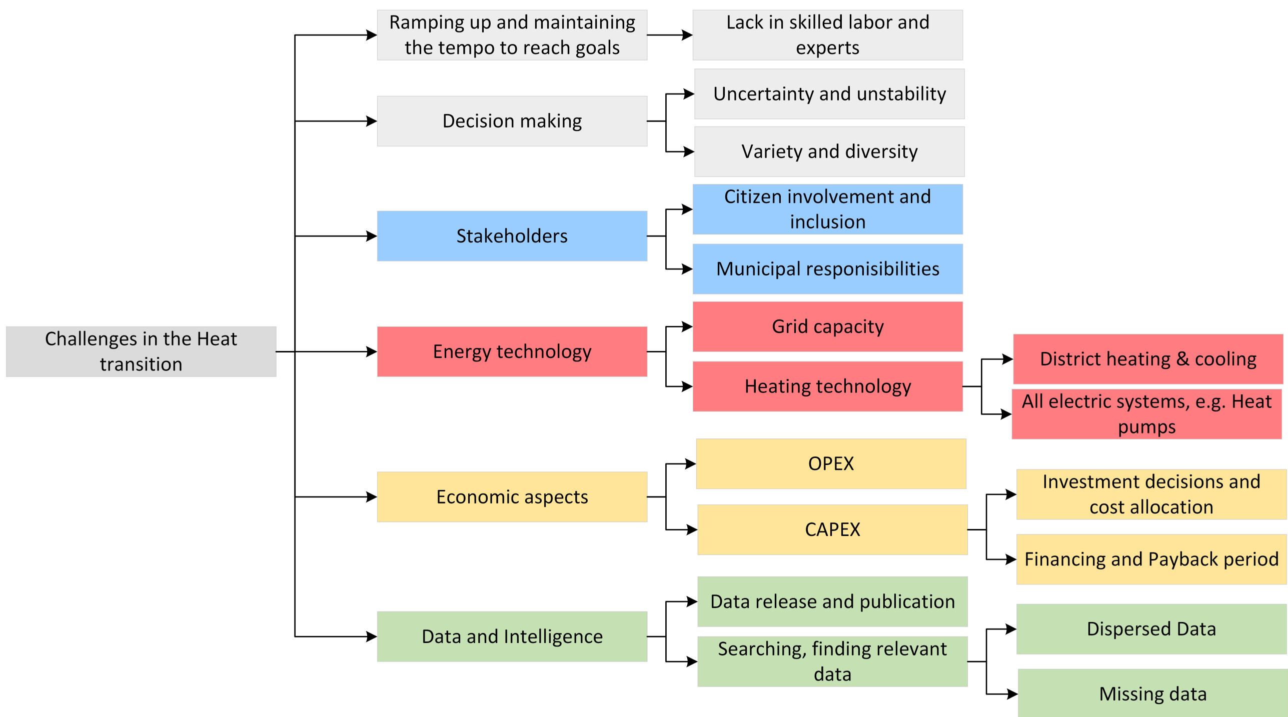


Figure 5.4: The identified challenges among the interviewees

First, a commonly mentioned challenge is the actual realisation of the climate goals, given the current lack of pace and urgency. This is enforced by a lack in skilled labour. For the heat transition, that is labour which is able to expand the grid, but especially execute retrofits in dwelling installations, insulation and facades for gas-free alternatives.

Second, decision-making in the heat transition is met by significant uncertainty and instability, this is mainly with regards to the energy technology and the development of cost curves. Moreover, the high variety among households on the demand side, and technologies on the supply side, is challenging the decision-making (Statistical Officer, CBS, 2018; Product Developer, Stedin, 2018; Strategic Adviser, Municipality of Utrecht, 2018). Besides some municipalities not knowing what they want and need, there is significant variance in the knowledge level between municipalities. This results in varying questions and needs from municipalities towards information providing organisations such as the CBS. On its turn, this diversity has great impact on the subsequent overhead and costs to provide the information (Statistical Officer, CBS, 2018; Product Developer, Stedin, 2018).

Third, decision-makers struggle to find and implement adequate strategies to involve stakeholders in the decision-making at the appropriate moments, and according to the desire of stakeholders to be involved. Regarding the stakeholders, the municipality in particular, is struggling to fill in the novel responsibilities in the heat transition adequately and inclusively. This challenge yields the dilemma that decision-makers, such as the municipality, need to meet goals and deadlines, but at the same time need to think about and implement a strategy of co-creation which consumes significant time and resources (Strategic Adviser, Municipality of Utrecht, 2018; Geo-architect, RVO, 2018).

In the energy system, challenges are significant for network operators on the grid capacity. At the moment, the knowledge is poor on the current electricity loads, the decentral renewable generation in terms of capacity and location, and how this will develop with the roll-out of the natural-gas alternatives. As a consequence the network operators have insufficient insights to plan and execute grid enforcement to cope with the demand which is likely to increase, due to the expected role of all-electric thermal systems and the increasing electrification in general.

Energy technology is an important element of the energy system, the energy technology was already mentioned in the context of the uncertainty it adds to decision-making. The novelty of natural-gas-free alternatives in the Dutch urban thermal energy system is leading to risk-averse decisions by policy-makers on the local level, favouring the collective solutions of District Heating, without collective consent. In addition to the collective level, this uncertainty is also present in technology performance on the individual solutions, e.g. heat pumps or fuel-cell heaters. On the individual level it is translated into uncertainty on the pay-back period, and subsequently this makes building-owners hesitant to invest in the necessary measures (Innovation Manager Sustainability, Volksbank, 2019). The poor information provision towards the decision-makers is contributing in this technological challenge of uncertainty.

The challenges previously mentioned, all touched upon the fact that the information provision between parties is sub-optimal and that stakeholders and decision-makers remain with significant knowledge gaps. The system in place regarding the intelligence, via Research Institutes and Consultancy and Advisory Firms, is thus not sufficiently meeting in the needs of the decision-makers. Moreover, the Data Ecosystem to acquire, release, process, and analyse the necessary data towards relevant insights, poses challenges regarding on the one hand, Data release and publication, where the quality, integrity and completeness of the released data is poor, and on the other hand, searching for and finding relevant data, which is challenged by a strongly dispersed data ecosystem with a low level of convenience to find, access and acquire the necessary data (Statistical Officer, CBS, 2018; Product Developer, CBS, 2018; Geo-architect, RVO, 2018, Business Developer, Eneco, 2018). In the following section, the analysis dives deeper into the knowledge gaps which are challenging decision-makers and stakeholders in the heat transition.

5.3. KNOWLEDGE GAPS AND DATA NEEDS AS PERCEIVED BY THE STAKEHOLDERS

From the empirical data it can be observed that the stakeholders often address challenges in co-occurrence with knowledge gaps, in other words, many of the challenges are a consequence of lacking or sub-optimal knowledge, entailing inadequate information provision to the decision-makers responsible and accountable for decision-making in the heat transition and stakeholders affected by these decisions. In this section it will be discussed what knowledge gaps can be found among the decision-makers and stakeholders, as perceived by the interviewees. Subsequently, the knowledge gaps are linked to data needs which represent the lacking data which could contribute in filling the knowledge gaps. These knowledge gaps and data needs, function as building blocks for the Data Ecosystem 2.0, which should be designed to address these knowledge gaps by means of improved and data-driven information provision and decision support.

5.3.1. KNOWLEDGE GAPS

Resulting from the cluster analysis, the knowledge gaps are organised into categories, see figure 5.5, and presented according to this categorisation. The cluster analysis is based on the coding similarity of knowledge gaps. The knowledge gaps as mentioned by the interviewees are presented in table 5.3 to 5.7, according to the categorisation derived from the cluster analysis. For each knowledge gap an explanation is provided on the context and it is stated by which interviewee the knowledge gap is endorsed.

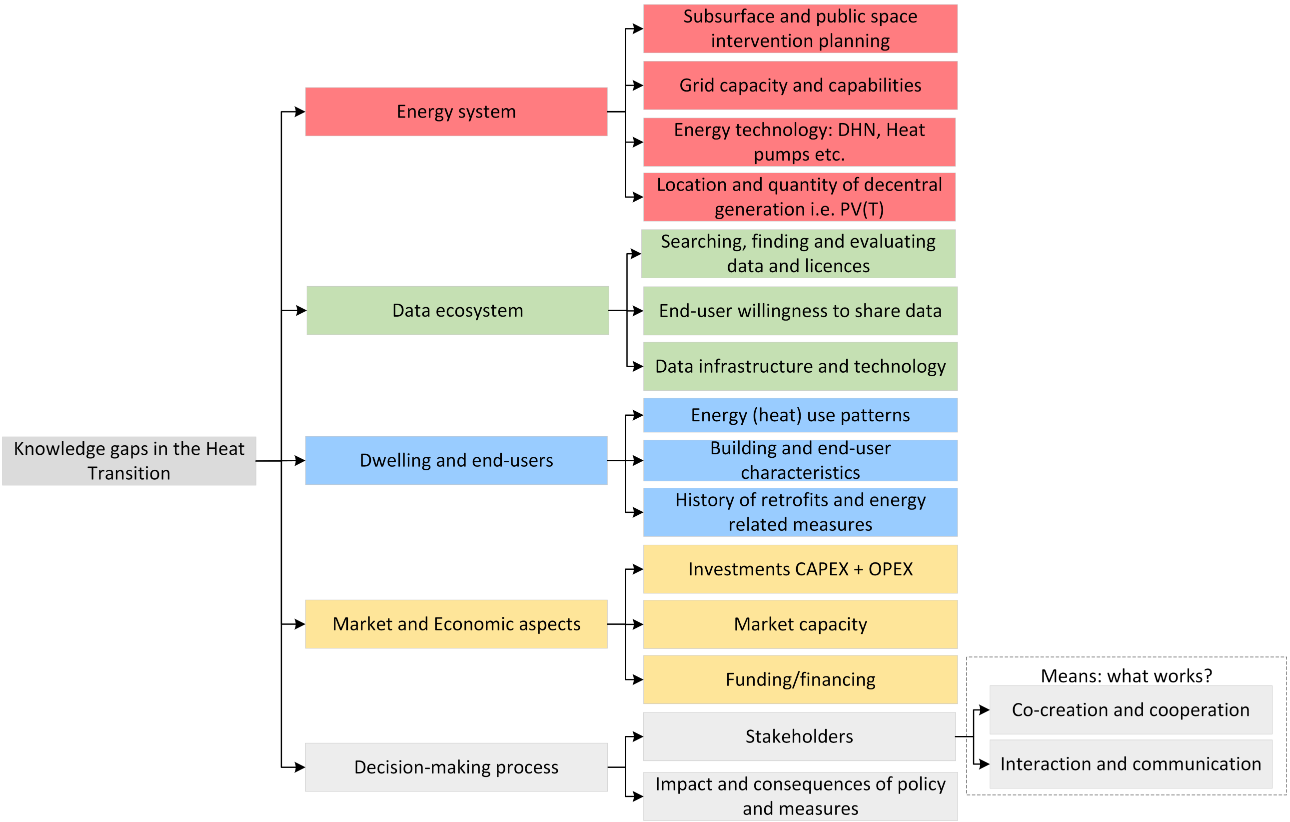


Figure 5.5: Categorisation of the identified knowledge gaps among the interviewees

Table 5.3: Knowledge Gap Theme: The Energy System

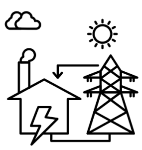
Sub-theme	Knowledge gap	Explanation	Data need
 Sub-surface and public space interventions	What are the plans for maintenance of underground infrastructure and interventions in the public space?	For the minimisation of excavation efforts and costs, a dominant cost factor for DHN, it is necessary to gain information on the plans for maintenance of underground infrastructure by other stakeholders active in the sub-surface and public space. In addition, information on trajectories where excavation is allowed or not, is relevant for DHN planning. Taking an integrated approach and aligning the effort, is expected to lead to a faster transition with lower costs, less opposition and hassle. Endorsed by: Eneco, Municipality of Utrecht	• Asset status for power grid, sewage and other sub-surface infrastructure (age, maintenance needs, etc.) • Data on financial flows towards infrastructural and public space interventions
 Grid capacity and capabilities	Which dwellings are connected to the grids for natural gas, district heating and electricity?	In particular on the current heating networks there is no information on the location and connections due to the commercial nature of these networks. In addition, no information is available on the fuel consumption and emissions of DHN. Endorsed by: Overmorgen, Stedin, Volksbank, CBS	• Data on dwellings connected to DHN and electricity and gas grid • Data on Heat generated and provided over DHN

Table 5.3 continued from previous page

Sub-theme	Knowledge gap	Explanation	Data need
	What is the available and expected capacity expansion of the electricity grid?	This information is relevant to anticipate on what the grid will be able to cope with in terms of peak load, in order to develop and implement thermal system for dwellings. This is particularly relevant for all-electric solutions which are expected to significantly increase the electricity loads.	• Grid enforcement and expansion plans • Current grid load data (E+G+H)
		Endorsed by: CBS, Kadaster, RVO, Heijmans, Stedin	
 Thermal Energy technology	What is the optimal feed in temperature for DHN, and the optimal input temperature for dwellings, that needs to be incorporated as industry standard?	Knowledge is lacking on the factors determining this temperature-standard, and the link to the most suitable heating solution for each temperature level. The optimal standard input temperature for dwellings impacts the need for insulation, and also the sources which can be deployed for DHN.	• Dwelling insulation status and heat consumption • DHN source potential (location + capacity + temperature)
		Endorsed by: Eneco	
	What are optimal strategies to implement sustainable thermal generation technologies in a balanced grid?	In general, a major knowledge gap exists regarding the inclusion of the strong diversity in sustainable heating technologies and sources in an urban thermal energy system which needs to be balanced at all times. This from both technological and organisational perspective.	• Grid capacity (H+E) • Dwelling insulation status and heat consumption • Local heat source potential (location + capacity + temperature)
		Endorsed by: RVO, Municipality of Utrecht	
	How will thermal technology develop in the near future through its performance and cost curves, and how does this affect the investments and estimated payback periods?	There is significant uncertainty regarding the development of technologies, such as heat pumps, and how the costs will decrease. Knowledge on these technologies is necessary to support investment decisions.	• Key performance and economic data for energy technology applied in general and in NL (efficiency, operational costs + maintenance, investments costs)
		Endorsed by: Heijmans, Homij DEC, HoogravenDuurzaam, Mitros, RVO, EnergieU, Gasvrij Scheveningen	
	How will market parties cope with the shortage in skilled labour to implement and maintain the technological advances?	There is a lack of skilled labour to install, and maintain new technologies in the thermal energy systems, and cost curves will only decrease if the labour force is up to date with the technological advances.	• Data on available capacity in labour market according to skill • Key performance data for energy technology applied in NL for automation and data-driven maintenance
		Endorsed by: Heijmans, Homij DEC, HoogravenDuurzaam, Mitros, RVO	

Table 5.3 continued from previous page

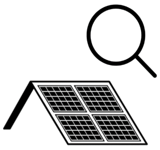
Sub-theme	Knowledge gap	Explanation	Data need
	How should citizen behaviour be adjusted to maximise the potential of new thermal technologies, or, how should the technologies be adjusted to align with consumer behaviour?	After all measures and novel technologies are implemented, citizens lack the understanding of how the house works and consequently miss opportunities to benefit from the efficiency gains. It is necessary for the end-users to gain knowledge on how the house works. Additionally, for the providing parties it is necessary to gain knowledge on how to unburden the end-users. Endorsed by: Mitros, Gasvrij Scheveningen, Homij DEC	• Key performance data for energy technology applied in NL for automation and data-driven maintenance • Data on best-practices for citizens to learn
 Location and capacity of decentral generation (current and potential)	What is the geographic dispersion of heat demand and supply, and how may this change over time, in both capacity and temperature?	An important aspect of planning the heat and cooling provision in the near future without natural-gas, is to take into account the geographically explicit nature of heating. This, as it is not possible to transport heat over long distances without incurring large transmission losses. Hereby, the size of the network, and thus the distances, depends on the availability of heat and the geographic dispersion of heat demand and supply. Endorsed by: Eneco, Municipality of Utrecht	• Heat demand per dwelling, and aggregated to area (municipality, district, neighbourhood, street) distributions. • Local heat source potential (location + capacity + temperature)
	What are the barriers for the large scale, and local generation of sustainable heating?	A lack of knowledge on the barriers for sustainable heat generation on the local scale, is withholding local initiatives from investing in local sustainable heat generation, distribution, and storage. Endorsed by: EnergieU	• Data on performance of implemented sustainable heating projects (demand and supply side) for best-practices and derivation of barriers
	What is the installed operational capacity of renewable energy generation, in particular, where are PV panels installed?	This lack in knowledge complicates the real-time balancing of the grid and the planning of grid reinforcement on the longer term. For example, at this point, the registration of PV panels is poor in the Netherlands due to the lack of registration obligations and the risk of losing financial benefit from the solar delivery to the grid. Endorsed by: Stedin, CBS	• Data on installed decentral renewable energy generation (PV, small-scale wind, small-scale green gas and H_2) • Data on real-time delivery to grid from decentral sources

Table 5.4: Knowledge Gap Theme: Data Ecosystem

Theme	Knowledge gap	Explanation	Data needs
 Data Ecosystem	How and where to find the appropriate data to support the decision-making over all levels in the urban thermal energy system?	Information and guidance on how and where to find the appropriate information in the appropriate level of detail and format. The "how" relates to the inexperienced actors in the sub-optimal data ecosystem regarding the processes to find and acquire the necessary data with the relevant infrastructure, technology, and skills. The where relates to the actual location of the data and the owners of the data. Data, on for instance energy assets, is available, however scattered over multiple parties involved in the energy system. The knowledge on which party owns which data is lacking.	• Meta-data on definition and structure of currently available data and future data • Data on current data utilisation experience
		Endorsed by: Gasvrij Scheveningen, HoogravenDuurzaam, EnergieU, Municipality of Utrecht, CBS, RVO, Kadaster	
	Where, from which actors and stakeholders, will energy data come from regarding supply, demand, and system integration?	Organisations like Kadaster and CBS, which take the role to release open data, lack the insights on where the energy system related data will be coming from, hence it is a challenge to anticipate and put in place the structures and services to facilitate these parties. This hampers proactive operations.	• Overview on current data exchange in urban thermal energy system
		Endorsed by: CBS, Kadaster	
	What is the willingness of end-users to share their energy consumption data and building envelope data to generate a sound knowledge base for the heat transition? What are the factors determining this willingness?	For an effective Data Ecosystem it is commonly mentioned that a comprehensive and extensive population of data-suppliers is important. However, actors organising the Data Ecosystem, lack knowledge on the actual willingness to share data by in particular different groups of citizens and private parties, and on what factors influence this willingness.	• Data on end-user willingness to share data
		Endorsed by: RVO/Geodan, Stedin	
	How should shared data infrastructure and technology, e.g. Data-lakes by the network operators or construction businesses, be organised, secured, and what services should it provide to which users?	For the actors looking to join forces and establish common and shared infrastructure, e.g. Data-lakes for the centralised storage of various data, the knowledge is lacking on how to organise and implement these initiatives in the energy sector, with its unique characteristics, e.g. the legal status of the network operators and the other actors in a liberalised, yet intertwined, energy system.	• Meta-data on definition and structure of currently available data and future data • Data on current data utilisation experience • Overview on current data exchange in urban thermal energy system
		Endorsed by: Stedin, Eneco	

Table 5.5: Knowledge Gap Theme: Dwellings and End-users

Sub-theme	Knowledge gap	Explanation	Data needs


Energy (Heat) Load Patterns
	What is the current and future usage of households regarding natural-gas, electricity or heating from alternative sources such as DHN?
	
	How does this relate to the dwelling characteristics, e.g. building type and the registered energy label?
		During execution of the heat transition the need for highly detailed, e.g. household level data on real-time energy consumption will increase in relevance. For instance, the real-time data is necessary for the real-time grid balancing with increasing variety and intermittency for both supply and demand. On the longer term, this data supports the decision-making regarding the generation capacity to be installed by the energy provider, and the dimensioning and routing of power grids and DHN.
		
		Endorsed by: Eneco, Stedin, CBS, Municipality of Utrecht
			• Real-time dwelling heat demand, heat load patterns, and source data
			• Dwelling characteristics
			  – thermal installation and appliances
			  – dwelling envelope, surface area, value, energy label, ownership

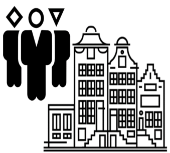
	How and at which rate will energy efficiency measures, on building envelope, installations and controls, develop, penetrate the market, and alter the thermal profile of households?	Where the uncertainty in the development of energy technology is already mentioned in table 5.3, there is also uncertainty regarding the decisions made by citizens and building owners on the energy efficiency technologies to adopt based on its maturity and/or reputation. The energy efficiency measures can significantly reduce the expected energy demand, hence, this lack in knowledge complicates demand forecasting for the subsequent decision-making on investments and technologies by energy providers and network operators. Endorsed by: CBS, Stedin, Eneco, EnergieU, Municipality of Utrecht, Heijmans, RVO	• Real-time dwelling heat demand and source data • Dwelling characteristics (installation + envelope) • Key performance and economic (OPEX + CAPEX) data on energy efficiency measures and technology in NL • Data on citizen willingness to adopt measures and technologies, and change behaviour
 Dwelling and end-user characteristics	What is the composition regarding the dwelling and household type, with the associated ownership, structural, energy and economic profile, for a municipality, district, neighbourhood or street?	Municipalities and stakeholders involved in spatial and environmental planning and heat transition planning need information on the technical and social characteristics of households and dwellings in order to determine effective strategies to support the households in the disconnection from natural gas, for instance what subsidies and information is necessary for each household. Moreover this knowledge is necessary to structurally integrate and plan the heat transition, e.g. to prioritise and align renovation efforts based on suitable pathways for the area composition. Endorsed by: CBS, Municipality of Utrecht, HoogravenDuurzaam, EnergieU, Heijmans	• Dwelling characteristics (installation + envelope + ownership) aggregated on street, neighbourhood, district and municipality level • Household characteristics (social and economic) aggregated on street, neighbourhood, district and municipality level

Table 5.5 continued from previous page

Sub-theme	Knowledge gap	Explanation	Data needs
	How do citizens perceive the disconnection from natural-gas and behave consequently, and how can this information be attained?	Municipalities need information on the social and behavioural characteristics of households in order to determine effective strategies on how to support the households in the disconnection from natural gas. For instance what subsidies and information is necessary for each household to tend towards the desired awareness and motivation, and how and when to involve households in the heat transition decision-making. Endorsed by: TU Delft, HoogravenDuurzaam, Municipality of Utrecht	• Data on citizen perceptions and understanding of the heat transition and the proposed technical alternatives and decision processes • Data on citizen willingness to participate in the heat transition, through e.g. attitudes and awareness
	What are the preferences and requirements of citizens for alternatives in the heat transition, and how can this information be gained?	For instance preferences for collective solutions over individual solutions, or vice versa, but also how the citizens prefer to see their role in the heat transition and what decisions and tasks should be adopted by the municipality. This knowledge is deemed valuable to shape the heat transition Vision by the municipality, and to support the local citizen based initiatives in their activities Endorsed by: TU Delft, Municipality of Utrecht, HoogravenDuurzaam, Volksbank	• Data on Citizen preferences and requirements for the proposed alternatives, both regarding the technical solutions as the processes and roles in decision-making • Citizen attitudes and awareness
	How should the knowledge be gained for the entire population, in a low-threshold and high-frequency manner?	Citizen initiatives have knowledge on the preferences and needs of their members, these members are often the front-runners and the knowledge is gained through the community dynamics in these citizen initiatives. However, it is not known how to gain this knowledge for the rest of the citizens in a district, also known as "The Silent Majority", or the citizens which are not in the front line of the heat transition and need to be engaged and mobilised. Endorsed by: Municipality of Utrecht	• Data on citizen attitude and willingness to share data
 History of retrofit and energy related interventions	What is the retrofit history of the dwelling, which measures are already taken to reduce energy consumption and/or generate energy locally?	During execution of the heat transition the need for highly detailed data will increase in relevance, for instance, to determine which dwellings are suitable to be connected to low temperature heating supply. However, this information is not registered in the Netherlands, and the link between household characteristics, dwelling characteristics and the supply of heating and cooling is not well understood.	Data on dwelling retrofit history: • Dwelling envelope i.e. insulation • Dwelling installation and appliances, e.g. energy efficient HVAC installation and cooking appliances • Measures supporting sustainable behaviour e.g. smart monitoring and control

Table 5.5 continued from previous page

Sub-theme	Knowledge gap	Explanation	Data needs
		Endorsed by: CBS, Municipality of Utrecht, Kadaster, Eneco	

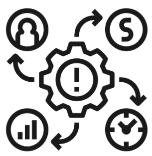
Table 5.6: Knowledge Gap Theme: Market and Economic Aspects

Theme	Knowledge gap	Explanation	Data needs
Market and Economic aspects	How can the supply of the construction and installation sector meet the expected demand from the built environment?	From the perspective of the construction sector knowledge is lacking on how to tackle the large scale retrofit and sustainable heating assignment with limited resources in terms of skilled labour and budget to innovate in technology and processes. In particular this knowledge is lacking for the existing built where the diversity in the retrofit history between the dwellings is large. Endorsed by: Heijmans, Homij DEC	• Data on market capacity (labour and material resources) for retrofit, installation, and collective thermal infrastructural solutions • Data on distribution of retrofit needs and opportunities over street to municipality level. e.g. to cluster comparable needs for organised supply • Performance data of interventions to automate and streamline production
	What is the existing field of subsidies and financing opportunities for retrofits and sustainable energy measures and how will this change in the near future?	Building owners name the significant investments as a major challenge in the heat transition and require adequate financing and/or subsidies. Although it is stated by the Volksbank that sufficient financing is available, this information, in particular on government arranged subsidies, does not land at the building owners and they remain in search of financing. Endorsed by: Heijmans, Overmorgen, HoogravenDuurzaam	• Data on currently available subsidies and financing opportunities • Data on utilisation of subsidies and financing • Data on financing need by citizens and businesses
	How can building owners and tenants cooperate for joint-investments and an improved position relative to commercial parties?	Knowledge on how building owners and tenants can interact with each other towards 1) joint investments, for reduced risks and a stronger market position, and 2) energy exchanges under current and expected legislation is unknown. Endorsed by: Homij DEC, EnergieU	• Data on best practices of previous joint initiatives • Data on real-time system impact of joint initiatives • Data on financial flows in a region purposed towards sustainability initiatives

Table 5.7: Knowledge Gap Theme: Decision-making process

Sub-theme	Knowledge gap	Explanation	Data needs
 Stakeholders: Co-creation, Cooperation, Interaction, and Communication	What drives citizens towards collective change and adoption of innovation in thermal energy systems?	Social psychological knowledge on the adoption behaviour of citizens for technology without direct benefits and without being forced by governments. Addressing this knowledge gap, contributes to the following knowledge gaps stated below. Endorsed by: Geodan	• Data on citizen attitude, awareness and willingness to cooperate • Data on drivers and motivation of citizens to reach climate goals
	What are effective strategies to involve citizens and stakeholders, actively and/or passively, in public and private decision-making in the heat transition? Which stakeholders should be included in the different phases of decision-making? How to turn individual movements of citizens into the collective movement of an entire neighbourhood and district in transition?	Targeting the effective story, means and methods, regarding the alternatives for natural-gas and the transition to those solutions, to create social support and acceptance under the citizens. Hereby relevant factors mentioned by the interviewees are: the associated costs and possibilities for financing, the desire of citizens to be unburdened, and incentivising citizens to be involved both actively and passively. In particular this question is relevant for the situation in which citizens show little interest or do not acknowledge the urgency. This need for information and support is prevalent for the majority of the population which are not the front-runners, but in particular the lower classes without the financial means to undertake action without financial support. Their knowledge needs reach further than financing, and also touches upon the cooperation in homeowner associations, and aspects of the social cohesion and dynamics. Endorsed by: Eneco, Homij DEC, Stedin, Volksbank, RVO, Overmorgen, Geodan, Mitros, TU Delft, HoogravenDuurzaam, Gasvrij Scheveningen, Municipality of Utrecht	• Data on citizen perception and understanding of the heat transition • Data on citizen attitude, awareness, and willingness to cooperate • Data on drivers and motivation of citizens to reach climate goals • Data on efficacy of methods and means tested to enable citizen involvement
	How can the participation of tenants in sustainability campaigns by the housing corporation be improved?	Mitros, one of the major housing corporations in Utrecht, initiated several campaigns over the past decade to incentivise behavioural change among tenants in favour of sustainable and energy efficient behaviour. However, Mitros repeatedly encountered little enthusiasm from the tenants. The same question holds for local citizen initiatives, for their effect to reach further than the front-runner minorities. Endorsed by: Mitros, HoogravenDuurzaam	• Data on tenants demands, drivers and motivation to reach climate goals • Data on efficacy of methods and means tested to enable tenant involvement

Table 5.7 continued from previous page

Sub-theme	Knowledge gap	Explanation	Data needs
	How will decision-making responsibility and accountability be allocated over public and private parties?	Knowledge is lacking on the role of the government and government authorities in the provision of distribution and storage infrastructure and the share of collective versus individual heat supply. Private parties desire freedom in choice on product and service development, and investment decisions. However, there is a need for concrete boundary conditions and facilitation by the government on permits and funding. Endorsed by: Heijmans	• N/A
	How can best-practice methods and approaches for transitions in other sectors, e.g. infrastructure and IT, be adopted for the heat transition? How can the heat transition become part of other transitions with momentum, e.g. IT and Urbanisation?	Knowledge needs to be gained on whether methods and tools applied in other sectors, such as participatory decision making in public space planning and public transportation, can also be applied for the heat transition. Hereby it is also necessary to determine whether and how citizens should be involved in the development of the tools and methods. Endorsed by: TU Delft, RVO	• Data on efficacy of decision-support methods and tools in other sectors • Data on transition progress and development of other sectors, e.g. industry, mobility, agriculture, sewage and waste water systems as potential heat supplier or flexibility provider
 Impact and consequences of policy measures and decisions	What is the impact of policy measures and investments on the progress of the heat transition, measured through indicators such as the emissions per district and the number of dwellings disconnected from natural-gas? How is this impact different when decisions are made and implemented through either, municipal and or government action, or via citizen driven initiatives, and how does co-creation affect the impact?	A common knowledge gap targets the factual impact and effect of measures, on the progress in the heat transition, e.g. CO_2 footprint of residential thermal systems. This impact measurement is complicated by uncertainty regarding the potential of the technology, complexity through system dependencies, and a lack of information on the current adaption of measures by building owners. Knowledge on the progress of the transition is crucial to support adaptive adjustments in decision-making along the pathway towards reaching the transition goals. Endorsed by: Kadaster, CBS, Municipality of Utrecht, Gasvrij Scheveningen	• Accurate, (near) real-time, and factual data, on the transition progress indicators, e.g. % dwellings disconnected from natural-gas, CO_2 emissions, sustainable energy generation • Data covering sufficient areas and applications to enable bench-marking of decision-making efficacy

Following the presentation of the knowledge gaps and the data-needs derived from the knowledge gaps in the fourth column of table 5.3 to 5.7, sub-section 5.3.2 elaborates further on the data-needs.

5.3.2. DATA NEEDS DERIVED FROM THE KNOWLEDGE GAPS

This sub-section elaborates further on how the interviewees perceive the data needs, derived from the knowledge gaps presented in sub-section 5.3.1. These data needs, as perceived by the interviewees, are already presented for each knowledge gap in the last column of table 5.3 to 5.7. These knowledge gaps and data needs, function as building blocks for the Data Ecosystem 2.0, which should be designed to improve the data-driven information provision and decision support. The categorisation of the data needs is presented in figure 5.6, based on the cluster analysis for coding similarity. The cluster analysis resulted in a categorisation of data-needs in five main categories: 1) Dwelling and End-user characteristics, 2) The Energy System and environment, 3) Market and Economic Aspects, and 4) Progress monitoring.

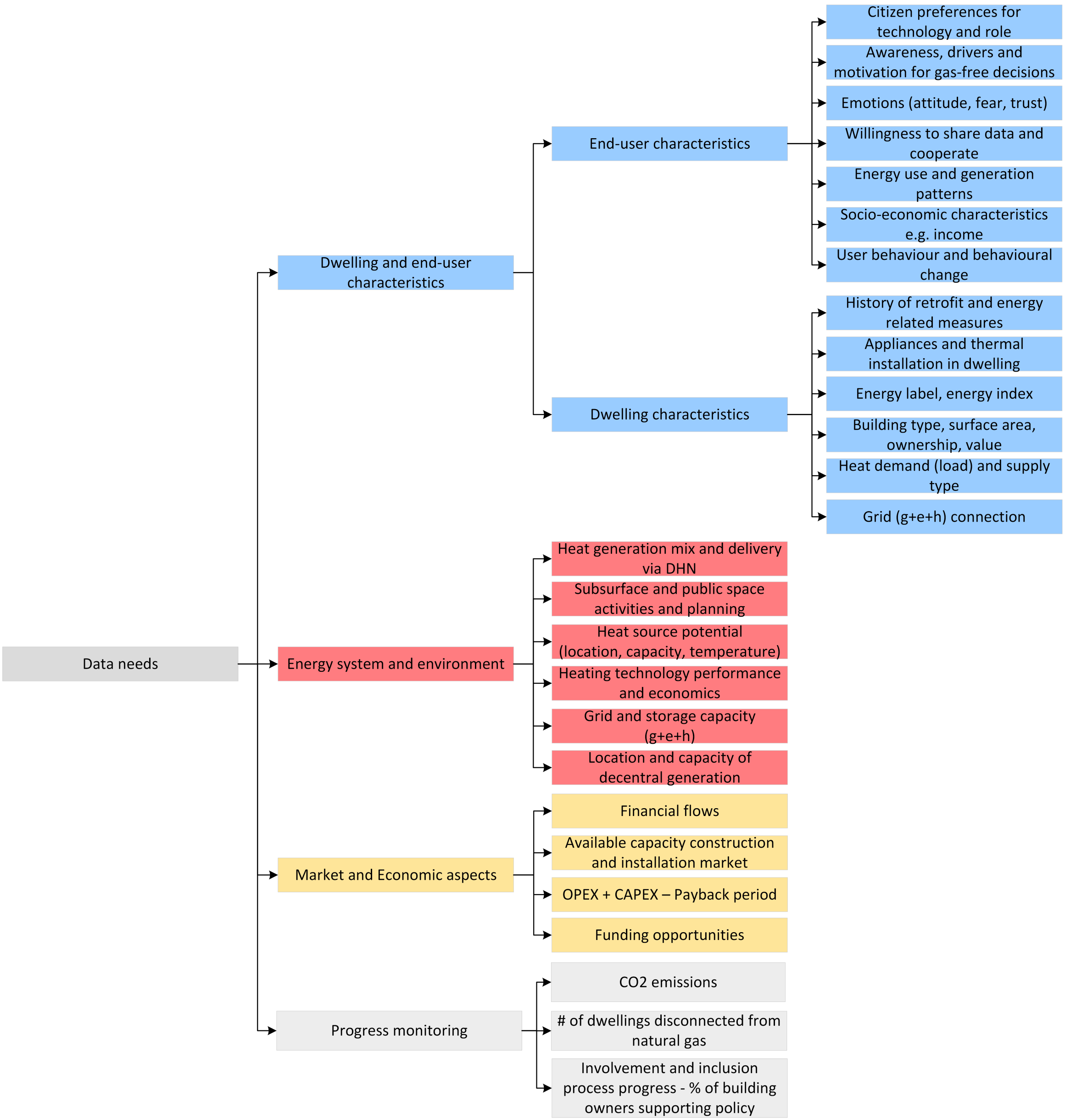


Figure 5.6: Categorisation of the identified data needs among the interviewees

To provide context on how the data-needs are perceived by the interviewees, quotes from the interviewees can be presented.

Local heat source potential (location + capacity + temperature)	*"large industries and sources of geothermal energy and such are important, that data is also recorded somewhere, only we do not know exactly where". (Strategic Adviser, Kadaster, 2019)*
Data on Heat generated and provided over DHN	*"where you cannot get any information at all is on the heat supplied, electricity and gas are registered, but nothing for heat." Energy Ambassador, EnergieU, 2018)*

Heat demand per dwelling aggregated to area (municipality, district, neighbourhood, street) distributions. Real-time dwelling (E+G+H) demand, load patterns, and source data. Data on dwellings connected to DHN and electricity and gas grid.	*"We make a lot of assumptions, we estimate the heat demand based on, for example, the type of building. But time will tell whether these estimates are correct. Of course you do not want to roll out a DHN and the demand is half what you have estimated. ... So we would really need more real heat demand data for real home types to somehow verify the estimates that we now model." (Business Developer, Eneco, 2018)* *"We only get more data requests, the energy transition and heat transition can only take place if it is supported by good data" (Business Developer, Stedin, 2018)*
Accurate, (near) real-time, and factual data, on the transition progress indicators, e.g. % dwellings disconnected from natural-gas, CO_2 emissions, sustainable energy generation	*"municipalities have a strong demand for real-time data, for things that actually happen, and they almost never have them, not even in the simplest form." (Product Developer, Geodan, 2018*
Data on dwelling retrofit history: dwelling envelope interventions i.e. insulation, dwelling installation and appliances interventions, e.g. energy efficient HVAC installation, energy efficient cooking appliances, and interventions supporting sustainable behaviour i.e. smart monitoring and control. Dwelling characteristics: installation and appliances, dwelling envelope, surface area, value, energy-label, ownership. Data on efficacy of methods and means tested to enable citizen involvement	*"I get questions from companies about what the insulation measures are that have already been taken, but you do not have to report that anywhere, so that is not available nowhere. And we generally make many assumptions to map out the current situation and to gain insight into what our strategy should be in that heat transition." (Strategic Adviser, Municipality of Utrecht, 2018)* *"What is not yet included, but what is interesting, is data about the age of homes and how well insulated they are."(Business Developer, Stedin, 2018)* *Towards the implementation of the heat transition, it becomes more important to have data at dwelling level. So really just data about what insulation and what kind of installation is present there. That is very difficult data that is not yet available, so you have to create it in one way or another. If you do not do that, you will end up with very large uncertainties that in turn have an effect on costs. (Consultant, Overmorgen, 2018)*
Data on current data utilisation experience Overview on current data-exchange in urban thermal energy system Data on citizen willingness to share data	*"there are companies that have such ideas ..., but it is very rudimentary and it is very much on the boundary of privacy. Your energy consumption profile, do you want to make that available to a collective to balance the grid? That question is not answered, so you can also see that as a gap, because it is actually necessary. You still have to be able to share confidential data in a secure way to get grid balancing done." (Geo-architect, RVO/Geonovum, 2019).*
Dwelling characteristics (installation + envelope) and distribution over street, neighbourhood, district and municipality level Household characteristics (social and economic) and distribution over street, neighbourhood, district and municipality level Data on citizen drivers and motivation to reach climate goals Data on citizen perceptions and understanding of the heat transition, the proposed technical alternatives and decision processes Data on citizen preferences and requirements for the proposed alternatives, both regarding the technical solutions as the processes and roles in decision-making	*"The heat transition requires more detailed and accurate data, because the measures are more invasive. In the transport sector, people think it is nice to think along about a new bicycle lane or the increased frequency of a tram-line and they believe the information provided to them. However, in the heat transition we see that people need more detailed and accurate data." (Researcher, TU Delft, 2018)* *I think it would really help the municipality if you could provide some good and solid information to the municipality about how people think about it. Now this is of course still a lot from gut-feeling and therefore not data-driven. (Strategic Adviser, Municipality of Utrecht, 2018)* *"We are looking for data about the built environment, data about consumption, data about behaviour, data about the people who live there and the owners and data about what is going to happen so that we can determine whether we should stay far from it or we should get involved in integrated planning." (Strategic Adviser, Municipality of Utrecht, 2018)* *"The difference between neighbourhoods is huge, and so is the difference in neighbourhood approach between neighbourhoods. I would really like to know what the age distribution is like, how ethnicity, income level etc. are distributed. With that data we can manage in a much more targeted way." (Business Developer, Stedin, 2018)*

Data on citizen willingness to adopt measures and technologies and change behaviour, through e.g. attitude and awareness	*"The major technical challenge lies in balancing supply and demand, so I think that all data regarding residents' willingness to adjust their behaviour is very relevant. So how flexible are residents? And then you have to distinguish different groups of residents, and I am very interested in what their willingness is and what the differences are." (Strategic Adviser, Municipality of Utrecht, 2018)* *"Movements of people, when and where do people move to. So real-estate businesses or platforms such as Funda are important for this data. When people are about to move to a new place, I think it is important to motivate and inform those people to take the necessary measures in the new place..., but also to think about what they leave behind so that they can maximise the value of the house that they are selling" (Chairman, Gasvrij Scheveningen, 2018*

From the quotes it can be concluded that a sense of awareness is present among the interviewees, and based on the perceived data needs, strategies are being developed to acquire and utilise the necessary data. Notable organisations with clear strategies are Kadaster, CBS, the municipality of Utrecht, and Eneco. In the next section it is presented how the data strategies of various actors and stakeholders comes together in the data-stakeholder landscape according to the data roles which can be distinguished in DEs.

5.4. Data-Stakeholder Landscape

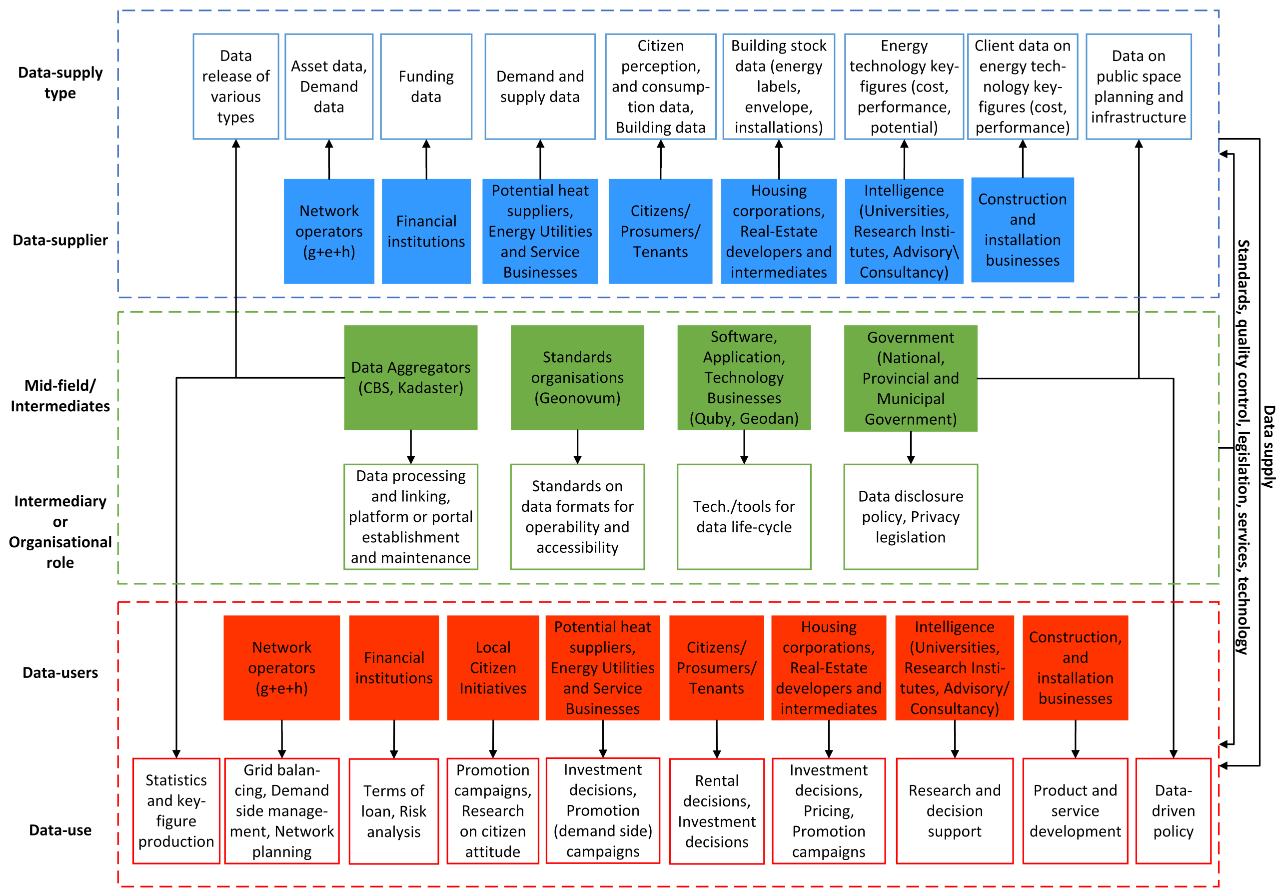


Figure 5.7: The identified data-stakeholder landscape in the heat transition: synthesising stakeholders and data needs

In section 5.1, figure 5.1 it was presented how the identified stakeholders interact with each other in the realisation of the heat transition, while in section 5.3 it was presented what knowledge gaps and subsequent data needs these stakeholders have. This final section in the chapter on the results of the empirical analysis, synthesises the stakeholder landscape from section 3.1 with the data needs from section 5.3, resulting in the data-stakeholder landscape. The data-stakeholder landscape, depicted in figure 5.7, presents the data interaction between the stakeholders according to the roles as defined for the "data-stakeholder context" of the Data Ecosystem in sub-section 3.2.6. For the actors and stakeholders taking the role of *Data-supplier*, coloured blue, it is presented which data-type can be provide by that actor or stakeholder, subsequently, for the actors and stakeholders taking the role of *Data-user*, coloured red, it is depicted for what activities or decision the data is needed. Finally, for the actors and stakeholders in the mid-field, coloured green, taking the role as *intermediary or infomediary*, it is presented which Data Ecosystem organisational activities, possibly complemented by data activities, are being carried out.

5.5. CHAPTER CONCLUSION

In this chapter the following SQs were addressed:

Section 5.1, 5.2 and 5.4	⇒	*1. What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?*
Section 5.3	⇒	*2. Among the decision-making of the actors and stakeholders for heating in the built environment, what knowledge is lacking, hence preventing effective decision-making?*

THE SOCIAL PART OF THE SOCIO-TECHNICAL SYSTEM

For SQ 1 on the socio-technical system, the technical and policy aspects were discussed in chapter 2. In this chapter, section 5.1 and 5.2, addressed the social part of the social-technical system based on the empirical data. The socio-technical system around the heat transition can be described as very extensive, actors and stakeholders can be divided over roughly seven categories: citizens, government, government authorities, market (construction, technical installation, energy utility and service, etc.), Intelligence (research and advisory), Real-Estate (developers, intermediates, and housing corporations), and Other (from network operators to financial institutions and local citizen initiatives). This extensive field of actors and stakeholders operate in an equally extensive field of technologies, to make decisions, invest and adopt alternatives for natural-gas in the heat supply.

In the actor and stakeholder field, one of the most interesting findings is that many of the actors and stakeholders are still in the process of comprehending the problem of natural-gas in the built environment and searching for their role in the envisioned transition. Given that these stakeholders are not yet aware of their role, it is also unclear what resources they have available for the heat transition, while their attitude towards the transition is widely varying and unstable over the field. It is commonly mentioned that the government should be establishing the facilitating conditions, this should provide the stakeholders of clarity on their role, after which they can proceed to decision-making in the heat transition.

From the Data Ecosystem perspective some clear roles can be distinguished, for instance Stedin as network operator is taking the role as data supplier because their legal status forbids them to add value to the data. The municipality with the heat transition Vision, and utility companies are taking the role as data user to support the planning and development activities in the heat transition. Kadaster and CBS are establishing themselves as true Data intermediates, a role which entails, on the one hand, DE organisational aspects regarding the establishment and maintenance of databases and the facilitation of the stakeholders involved in that process. On the other hand, there are the data activities where they add value to data and release data to the data-users. The role of standards organisations is an important one in DE to ensure data quality and interoperability, however such an authority only exists for government geo-data. For other data types this role is still vacant, yet badly needed.

THE KNOWLEDGE GAPS AND DATA NEEDS

From the empirical data it can be concluded that the stakeholders often address challenges in co-occurrence with knowledge gaps. In other words, many of the challenges in the heat transition are a consequence of lacking or sub-optimal knowledge, entailing inadequate information provision to the decision-makers responsible and accountable for decision-making in the heat transition, and stakeholders affected by these decisions. The identified knowledge gaps can be defined over five main themes: 1) the energy system and environment, 2) the data ecosystem, 3) dwellings and end-users, 4) market and economic aspects, and 5) the decision-making process.

Of these categories, the most knowledge gaps, measured by the variety that can be derived from the empirical data, fall under the themes of 1) the energy system and environment, and 2) the dwellings and end-users. In particular, very little is known about 1) the detailed characteristics of dwellings that impact the potential and costs of retrofit and thermal installation upgrades, 2) the perceptions and attitude, leading to the willingness to participate by the citizens and building owners, and 3) the preferences of stakeholders for natural-gas alternatives and their role in the heat transition.

6

Data Ecosystem Design

In this chapter, it will be discussed how the empirical knowledge on the heat transition, with the identified challenges and knowledge gaps, is translated towards the design of a Data Ecosystem (DE) to support the heat transition in the Netherlands. In the first section attention is allocated to the current DE for the heat transition based on the case of Utrecht. Note that for this depiction of the Utrecht DE, the DE framework derived from literature and presented in sub-section 3.2.6 is utilised. The DE is followed by the presentation of an inventory made on data-bases and data platforms and portals in the Netherlands with relevance for the heat transition. These data-bases and platforms are then linked to the current DE and to the identified knowledge gaps and data needs from section 5.3. In short, the first three sections relate to the sub-questions as follows:

Section 6.1	⇒	*3. How can a DE be composed and how does the current DE look like for the Dutch heat transition, what are the shortcomings and challenges?*
Section 6.2	⇒	*4. Which Open and Big data sources are currently, or could potentially, be made available to support evidence-based policy and decision-making by targeting the knowledge gaps derived in SQ 2, and what are the barriers for the utilisation of this data?*
Section 6.3	⇒	*5. Through which technology and/or methods can the missing data identified in SQ 2 be acquired, and the Data Ecosystem be improved towards the 2.0 proposal?*

Ultimately the answers to the above-stated sub-questions, form the building blocks and lead towards the answer to the main research question, or the DE 2.0 in section 6.4. This is an effort to improve on the current DE by taking into account the existing and potential data-bases and platforms, potential technologies to acquire missing data, and the challenges and barriers encountered.

6.1. The current Data Ecosystem for the heat transition in Utrecht

The DE framework, sketched in figure 3.2 of sub-section 3.2.6 and encompassing the elements derived from literature, can be applied to assess the DE for the case of Utrecht. Based on a scenario of the heat transition in Utrecht, the elements which can be recognised in that scenario will be presented in the case specific DE. Starting with this current DE, the knowledge gaps identified in sub-section 5.3, and the inventory of available and potential data in section 6.2, a proposal will be made on how the DE can be shaped for the knowledge gaps to be effectively addressed. The derivation of the DE for the case of Utrecht is based on document study and interviews on the Overvecht-Noord case, as first district to be disconnected from natural-gas, and the local heat transition study with the Vesta MAIS model in Utrecht. These two sources of input, along with the broader heat transition context in Utrecht, are elaborated in the case description in section 4.1.1.

When taking the framework as presented in sub-section 3.2.6, and analysing the Utrecht heat transition, the result is presented in figure 6.1. It can be observed that the Climate Agreement and, among others, the heat transition vision are present in the regulatory context of the DE. Other local climate policies, e.g. related to the local renewable energy generation targets, are also part of the regulatory context, driving the activities in the DE. In the following sub-sections it is addressed which actors take which role, which data-bases are utilised and which shortcomings can be identified in the assessment of the DE.

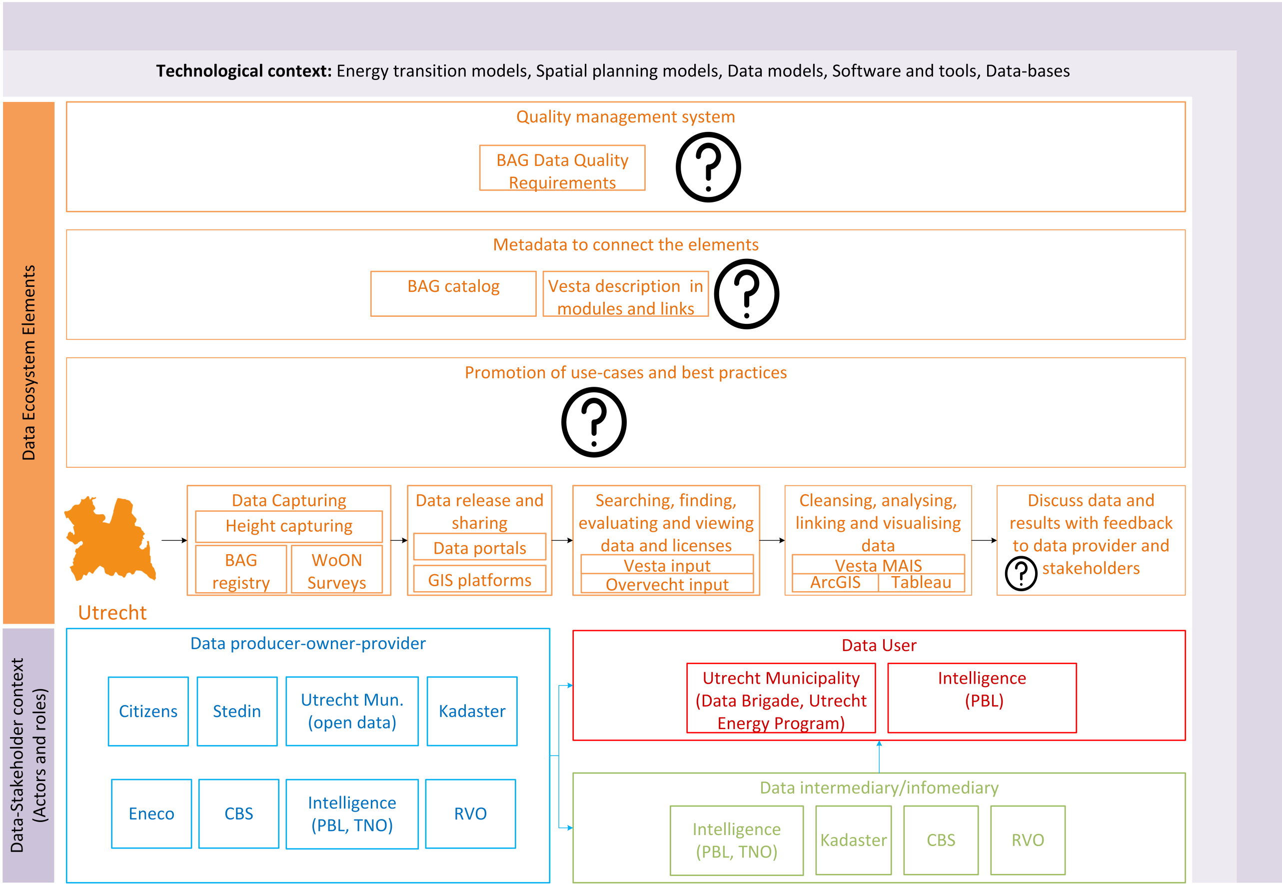


Figure 6.1: The current DE for the heat transition in Utrecht as derived from the case of Overvecht-Noord and the PBL study with the Vesta MAIS model

6.1.1. ACTORS AND ROLES

The data-stakeholder context of the DE, consists of the actors and their roles in the DE. The actors and stakeholders, divided over Data suppliers, Data users, and Data intermediates in figure 6.1, can be derived from the interviews and document sources on the Vesta MAIS study and Overvecht-Noord. When comparing the current DE in figure 6.1 to the stakeholder map as presented in section 5.1, where a complete picture of the stakeholders in the heat transition is presented, many stakeholders are not actively present in the current DE. Hence, there is a significant gap between the actors and stakeholders which are currently involved in the DE for the heat transition, or in other words, significant effort is necessary to involve all relevant parties in the DE. A notable group of actors which are stated to be critical in the heat transition, recall figure 5.2, but are not yet involved in the DE, are the Housing Corporations. Furthermore, real-estate developers and intermediates, the local citizen initiatives, the construction and technical installation sector, potential heat suppliers and the financial institutions are not found as active actors in the current DE.

In section 5.4, figure 5.7, it was illustrated how the stakeholder field ideally fills in the role of Data supplier, Data user, and Data Intermediate in the DE. With many of the actors missing in the current DE, much of the potential in terms of data utilisation, but also data capturing and sharing, is left unexploited. In the following sub-section it is presented, which data-bases are utilised, in the absence of many potential data suppliers.

6.1.2. DATA-BASES UTILISED

DATA-BASES UTILISED: DWELLINGS

In table 6.1, it is presented on what input data the Vesta MAIS model is run for the Utrecht case (van den Wijngaart et al., 2018). From this input data and the interview with the Strategic Adviser of the Municipality of Utrecht (2018), it can be derived that data from the Basis Registry Addresses and Buildings (BAG) plays an important role to provide the necessary insights on the building stock, regarding e.g. the dwelling function, built year and surface area. BAG is maintained by Kadaster, while the municipalities are accountable to feed the register with all objects and addresses in the particular municipality. The municipalities are responsible for the quality of the registered data to be in compliance with the BAG law (Kadaster, 2019a). The data model behind the BAG register is documented in Kooij et al. (2018), this includes the attributes registered for each object type and the relation between objects. In addition to the BAG, the Multi-year Perspective Urban Development plan of Utrecht provides local data on the plans regarding new build and demolition in the municipality (Utrecht, 2018c).

Table 6.1: Input data into the Vest MAIS regional study in Utrecht, adapted from van den Wijngaart et al. (2018)

	Buildings	
Input type	**Source national (initial Vesta input)**	**Source local (additional input)**
Building type and built period on address level	BAG (Kadaster)	Already on the local (address level)
Data on dwelling demolition/ new built plans	Ruimtescanner and WLO (Wealth and Living environment) scenario's (PBL and CPB)	Specific data from 1) Multi-year Perspective Urban Development, 2) performance agreements with the housing corporations, 3) transition potential of dwellings from Utrecht open data
Size and function of utility dwellings	BAG (Kadaster)	Already on the local (address level)
Increase/decrease in the utility dwellings	Ruimtescanner and WLO (Wealth and Living environment) scenario's (PBL and CPB)	Specific data from 1) Multi-year Perspective Urban Development, 2) transition potential of dwellings from Utrecht open data
	Energy Demand	
Input type	**Source national (initial Vesta input)**	**Source local (additional input)**
Heat demand per dwelling for space heating, tap water and cooking	WoON survey (CBS) and National Energy Exploration (NEV)	WoON data for respondents in Utrecht
Electricity demand per dwelling	Nibud: average demand per household	N/A
Potential for insulation measures and sustainable energy installation	WoON survey (CBS) and National Energy Exploration (NEV)	WoON data for respondents in Utrecht
Costs for insulation measures and sustainable energy installation	RVO model houses	N/A
	Energy Supply	
Input type	**Source national (initial Vesta input)**	**Source local (additional input)**
Data on current residual heat: capacity, location, costs and CO_2 emission factor	PBL, CE Delft	CO_2 emission-factor of Utrecht District Heating: 40 kg/GJ heat consumed by the end-user, study by Greenvis
Data on potential heat source capacity and costs: residual heat, biomass, power-to-heat, heat buffers	CE Delft	Provincial mapping of residual heat sources Road-map Sustainable District Heating Utrecht Study by Greenvis
Deep and Ultra deep Geothermal potential and costs	N/A	Provincial mapping of heat sources
Subsurface suitability for geothermal	TNO	Provincial mapping of heat sources
Subsurface suitability for Heat and Cold Storage	Warmteatlas (RVO)	Provincial mapping of heat sources
PV(T) potential and costs	Calculated based on model houses and roof surface area (Zonatlas)	Available for Utrecht by Zonatlas
Heat pump and micro-CHP potential and costs	Calculated based on electricity price and investment costs in installation	Data applicable for Utrecht
Degree-days correction 100x100m grid	KNMI	Data applicable for Utrecht
Cost of energy	WLO scenario's (PBL and CBL)	Data applicable for Utrecht
	Asset Data	
Input type	**Source national (initial Vesta input)**	**Source local (additional input)**
Length and location gas, electricity and heat infrastructure	CE Delft	Specific data on grid and replacement plans by Stedin (Open Data) GIS data on location heat grid from Eneco

DATA-BASES UTILISED: ENERGY DEMAND

On the demand side, it can be observed that the Vesta MAIS model, in its initial state, incorporates energy demand data from the WoON data-base in the Netherlands. The WoON research, by Statistics Netherlands (CBS), entails a sample survey on the housing situation of the Dutch population, their living requirements and needs. The sample includes at least 60,000 respondents in order to also produce reliable statistics on smaller geographic areas. The survey contains variables such as the household composition, the dwelling and living environment, housing costs, living requirements and housing relocations. Moreover, there is a special energy module, however, this module has less respondents, namely 5,000 households. This energy module encompasses energy labels, energy efficiency in the building stock, the influence of inhabitant behaviour, and investments in energy efficiency measures (CBS, 2019a). It was made possible to derive the local data on the WoON respondents in Utrecht and use this for the local instance of the Vesta MAIS model(van den Wijngaart et al., 2018).

The National Energy Exploration by the Energy Research Center Netherlands (ECN) together with CBS and RVO, see Schoots et al. (2018), also provides relevant energy demand data to the Vesta MAIS model. This is enriched by the estimates from the National Institute for Budget Information, while the key figures on costs of measures are derived from the RVO model houses.

Data-bases utilised: Energy Supply

Regarding the energy supply, the majority of the data and key figures on energy potential and costs are derived from research institutes such as TNO, CE Delft, PBL and CPB. Furthermore, advisory firm Greenvis conducted a local exploration on the energy potential in Utrecht and this provides the model with the more detailed local data. Moreover, data is collected from the geographic platform on which the province of Utrecht maps various aspects via Open Data, such as, the energy potential, the subsurface suitability for geothermal energy, and heat and cold storage potential and costs. Finally, solar potential can be estimated based on the RVO model houses, and calculations based on the actual roof area with the Zonatlas for dwellings in Utrecht. It can thus be observed that the supply side carries, by far, the most diversity in utilised data-bases, often provided by respectable research institutes.

Data-bases utilised: Energy Assets and Infrastructure

Finally, regarding the energy assets and infrastructure in place to generate, distribute and eventually store energy, data is provided to the central Vesta MAIS model by CE Delft. This is enriched with local data by the open data platform of the network operator for gas and electricity, Stedin, and the heat network operator Eneco. Note that the data by Eneco on the heat network is not open data. In the Netherlands there is no central registration or obligation to register heat network related data. These networks are owned and operated by private parties, hence the network data is commercial private data (Strategic Adviser, Municipality of Utrecht, 2018; Statistical Officer, CBS, 2018).

6.1.3. The Data Ecosystem elements

Data cleaning, linking, analysis, and visualisation

Given the functionality of the Vesta model, it can be considered as a contributor to the Data cleaning, linking, analysis, and visualisation element in the DE framework. However, the results analysis and visualisation over for instance GIS mapping towards the stakeholders, takes place outside the model. How the results of the study were discussed and further communicated with stakeholders specifically, and what tools and software are utilised for the GIS-analyses, could not be derived from the report on the study by van den Wijngaart et al. (2018). However, it should be noted that this report by van den Wijngaart et al. (2018) is part of the literature used by several citizen initiatives in Utrecht to set out local strategies (Chairman, HoogravenDuurzaam, 2018).

In the early stages of the data-driven strategy in Overvecht-Noord, and now more for Utrecht in general, the municipality utilises software such as Tableau and ArcGIS for data analysis and (geo)visualisation, but no specific or predefined model. Tableau is utilised for the analysis of data and the visualisation in plots and other visual means. ArcGIS is utilised to visualise the data geographically for Utrecht (Strategic Adviser, Municipality of Utrecht, 2018).

Data discussion and feedback

Furthermore, the Vesta study does not discuss the data on for instance quality and integrity. Moreover, no feedback on the data is provided to the data suppliers in order to learn and improve the data. Hence, as far as it is reported, the Data discussion and feedback element is lacking for the Vesta model in the DE.

In Overvecht-Noord, during the presentation of maps on which data was plotted on the dwellings and infrastructure, many citizens commented that the visualisation for their address was incorrect (Strategic Adviser, Municipality of Utrecht, 2018). This step can be considered as part of the Data discussion element, and enforces the statement that for the energy transition, which is intrusive, accurate and correct data is critical (Researcher, TU Delft, 2018).

Quality Management System

In neither of both sources which are studied in detail for Utrecht, could explicit notion of data quality management be encountered. it can be argued that the presentation of data on maps to citizens for feedback, is part of a quality management system with the citizens. However, it came too late, namely when the decision at hand, which Districts to disconnect from natural-gas first, was already made. The faulty data only induced more uncertainty and doubt on the decision for Overvecht-Noord.

In the interviews with the stakeholders, data quality and integrity issues are mentioned repeatedly, this indicates the lack of a data quality management system. Also the role of an organisation accounting for the (open) data standards in the heat transition is insufficiently covered. The only notion of such a standards organisation was made for Geonovum. However, the scope of Geonovum only encompasses standards to make government geo-data accessible and interchangeable (Geonovum, 2014).

META-DATA AND USE-CASE PROMOTION

Other than user manuals on the BAG viewer, (Kadaster, 2019a), and online elaboration on the WoON data-base, (CBS, 2019a), no specific promotion could be found on the education of potential users regarding the use-cases for the (open) data.

The Vesta MAIS model releases meta-data on the link between data input and the model itself on its Github channel as it is an open source model (van den Wijngaart, 2019). For the Data utilisation in the Overvecht case, no meta-data exists to connect elements. This process can be considered an experiment, where the data provision and use took place in an adaptive manner without formal frameworks and meta-data, following the failure of the non data-driven initial approach (Strategic Adviser, Municipality of Utrecht, 2018).

6.1.4. MAIN CHALLENGES AND BARRIERS IN THE DE FOR THE HEAT TRANSITION IN UTRECHT

POOR DATA QUALITY AND LACKING QUALITY MANAGEMENT SYSTEM

The municipality applied a, for them, novel way of working in determining the first districts to be disconnected from natural gas and to guide the process of the transition after that decision. The municipality has a clear set out plan on how to approach the energy transition in a data-driven way, however, the actual execution is in the early stages and encounters many challenges and barriers (Strategic Adviser, Municipality of Utrecht, 2018). This particular process or method for Overvecht-Noord was established in a more or less ad hoc manner and did not apply existing models. The result of the decision for Overvecht-Noord sparked a lot of opposition from the citizens, in particular after the communication to them on how much it will cost them (Senior Adviser Technology, Mitros, 2019). The DE lacked a quality management system and the visualisation of faulty data, made the citizens doubt the decision. It can be stated that the importance of accurate and correct data was underestimated, this while the following was stated in an interview:

> *"The heat transition requires more detailed and accurate data, because the measures are more invasive. In the transport sector, people think it is nice to think along about a new bicycle lane or the increased frequency of a tram-line and they believe the information provided to them. However in the heat transition we see that people need more detailed and accurate data." (Researcher, TU Delft, 2018)*

In addition, in the current state of the DE in Utrecht, although there is much public opposition on the decision for Overvecht-Noord, data on end-user preferences, perceptions and attitude remains unavailable. This can be considered among the most significant blind spots in the current Ecosystem.

DESIRED DETAIL LEVEL OF DATA COMPLICATED AND DIVERSE DATA NEEDS

It is a difficult discussion on the desired detail level and format of the necessary data. There is a need to get structure in the process, and based on the process, determine the data needs to subsequently have a narrowed down and concrete data acquisition phase. Every phase of the heat transition, namely that of planning, execution, and evaluation, has its specific characteristics and knowledge needs and the data acquisition and utilisation need to be aligned with those characteristics. This can be derived from the following quote:

> *"It is a constantly recurring discussion, because in Overvecht we have done that at house level, but then you notice that a lot of the other data is not there at house level, and moreover a planning of a neighbourhood, for example renovation, that is not at house level but that is something that happened in the neighbourhood. So it's a complicated discussion. So preferably as detailed as possible, and you notice that especially with our data scientist who say that they can do the most with the detailed data. But it's just not always possible." (Strategic Adviser, Municipality of Utrecht, 2018)*

It can be concluded that the DE lacks in the coherence and development of certain elements, e.g. quality management and use-case promotion, while the landscape of data-bases utilised, and data-stakeholder involved, is limited. In the next section, before heading to the proposed design, an outreach will be made towards the available data-bases and platforms or portals in the Netherlands. These will form building blocks for the DE 2.0.

6.2. DRIVING THE DUTCH HEAT TRANSITION WITH DATA: DATA SOURCES AND DATA PLATFORMS

Data platforms or portals can be defined as the physical and digital infrastructure established to primarily support the production and consumption of easily accessible, machine-processable and possibly real-time data (Ding et al., 2011, Welle Donker and van Loenen, 2017). These platforms thus form an important element within DE to link data supply with data utilisation. Before presenting the data platforms, sub-section 6.2.1 first presents an inventory of data-bases which are found to have potential in providing insights for the heat transition. These are for instance data-bases which are overlooked in Utrecht for the Vesta MAIS study and the Overvecht-Noord case, and thus not effectively utilised in the DE. Sub-section 6.2.2 then proceeds with the data platforms and portals, which are currently active in the Netherlands with a focus on the urban thermal energy system. Through these platforms and portals, the previously addressed data-bases can be collected, released and visualised.

6.2.1. A DATA-BASE EXPLORATION

Table 6.2: An overview of data-bases with data relevant for the *heat supply*, clicking on the data-base name will direct the reader to the online resource

Data-base	Theme(s)	Data-type	Description	Business/ organisation
Zonatlas	Solar potential	Restricted	Combining LiDAR (AHN) and Kadaster data on roof surface and angle for solar potential mapping	Zonatlas B.V.
WindStats	Wind potential and generation	Open	Data on the installed capacity of wind energy, the, associated real-time production and forecast	Bosch & van Rijn
Energy from surface water	Surface water energy potential	Open	Combining hydraulic data from the Delta-model for potential mapping of sustainable heating and cooling supply from surface water, and with the heating and cooling demand in vicinity of supply	Deltares
ThermoGIS	Geothermal potential	Open	Combining GIS and available subsurface data to map geothermal potential	TNO
Generation Installation Registry	Installed decentral renewable capacity	Closed	All (voluntarily) registered units of decentral renewable energy production <1MW	Energie Data Services Nederland (EDSN)
Cable and pipe network (energy assets)	Infrastructure	Open	Data on the routing of electricity cables and gas pipelines, the associated capacity, status and age	Network Operators (Enexis, Stedin, Liander, Co-gas, Westland-infra, Rendo, Enduris)
SWING	Waste flows	Open	Mapping data on the waste flows in municipalities	Rijkswaterstaat
Various data-bases on GEO-data	Height, Nature and environment, Civil structures, Water, climate and meteorological atmosphere, Transport, Agriculture, Economy, Society	Open	Geographic data-sets, services and maps for the Netherlands	Nationaal Georegister
Actueel Hoogtebestand Nederland (AHN1,2,3)	Height data in the Netherlands	Open	Accurate height information based on LiDAR (laser altimetry), this data is relevant for solar potential mapping	Actueel Hoogtebestand Nederland
Meteorological data for the Netherlands	Daily weather data Annual climate data	Open	The meteorological data is utilised in various solar generation calculations on the Dutch PV Portal 2.0, e.g. the solar generation of the installed capacity. Data from 46 weather stations in the Netherlands and the 12 provincial averages. Daily weather data has a 10-minute time resolution. The annual climate data is determined based on weather data averaged over multiple years, with a one hour time resolution.	Delft University of Technology KNMI

Table 6.3: An overview of data-bases with data relevant for the *heat demand*, clicking on the data-base name will direct the reader to the online resource

Data-base	**Theme(s)**	**Data type**	**Description**	
TOON Smart Thermostat data-base	Gas + electricity consumption, Renewable electricity generation, Boiler/heat pump parameters, Thermostat interaction, Smart plugs	On Demand/ Restricted	Data-base provides anonymised energy data for over 350,000 households in predominantly NL + BE and personal (non-anonymised) data on around 3,000 households for research purposes. Around 140 parameters are collected for a wide range of households over ten years with a granularity of up to 10 seconds for most parameters.	Quby
Energy use (e+g) residential consumer	energy use (gas + electricity)	Open	Data on the energy (gas + electricity) consumption of small-scale consumers based on the metering by the DSOs. Data is aggregated on 6 digit postal code and a minimum of 10 households.	Network Operator (Enexis, Stedin, Liander, Co-gas, Westland-infra, Rendo, Enduris)
E-Common (Energy and Comfort Monitoring)	Household characteristics, Thermostat control, Ventilation dynamics, Shower activity, Temperature, humidity and draught	On Demand	The E-Common data-base on energy use and comfort in residential dwellings is set up under the OPSCHALER project on 35 houses in the period of 2014-2016.	OPSCHALER consortium
Central energy connection register (C-AR)	Energy use	closed	DSOs merged the data on all connection for electricity and gas in this central data-base	Energie Data Services Nederland (EDSN)

Table 6.4: An overview of data-bases with data relevant for the *building stock*, clicking on the data-base name will direct the reader to the online resource

Data-base	**Theme(s)**	**Data type**	**Description**	**Data Provider**
Basic-register Addresses and Buildings or Basisregistratie Adressen en Gebouwen (BAG)	Address location, Building function, Building surface, Building contour, Built year	Open	A data-base consisting of data related to each address in the Netherlands. The data is collected, registered and updated by the municipalities. The data-base is maintained by Kadaster	Kadaster
Housing market statistics	Mortgages, Number of transactions, Financing and economy, Prices existing building stock + new building stock	Open	A dashboard visualising the monitoring of the real-estate market in the Netherlands	CBS + TU Delft OTB
Energy Labels	Energy Label, Energy index, Theoretical energy consumption, Buildings characteristics	Open	The energy label data-base includes the energy label of residential and non-residential buildings from 2003 onward.	Ministry of the Interior and Kingdom Relations
Housing market survey dataWoON	Dwelling characteristics, Household characteristics, Housing costs, Energy consumption, Barriers and drivers to renovation, Type of technologies for energy efficiency and energy use	Restricted	data-base resulting from surveys (with at least 60,000 respondents) every 3 years on the housing market and movement of people in that market with the associated living conditions and needs. Total: 1026 variables	CBS (Statistics Netherlands) + Dutch Ministry of Interior and Kingdom Relations
Energy Performance Survey DataWoON energy	Dwellings characteristics, Households characteristics, Heating and ventilation, Energy and water consumption, Energy saving, Investments in the dwelling	Restricted	data-base resulting from surveys with around 4,500 respondents every 5 years on the energy performance of the Dutch building stock. The survey includes households in the owner-occupied, social housing and private rental sector and is assumed to be representative for the Netherlands. Total: 1119 variables	CBS (Statistics Netherlands) and Dutch Ministry of the Interior and Kingdom Relations

Table 6.4 continued from previous page

Data-base	**Theme(s)**	**Data type**	**Description**	**Data Provider**
WoON verhuis (moving) module	Household characteristics, Changes in the household characteristics, Reason of relocation	Open	The Dutch Ministry of the Interior and Kingdom Relations combines survey and registered data for the data-base on people relocating within the Netherlands. This data includes the moving needs and preferences of residents 18 years and older. The data-base keeps track of these parameters for the same group of respondents.	CBS (Statistics Netherlands) and Dutch Ministry of the Interior and Kingdom Relations
Funda market data	Demand and supply in location and building type, Facilities in dwellings, Consumer needs	Closed	Funda is a platform or digital market place supporting the housing market for both dwellings being rented or sold. As a platform Funda receives and maintains a lot of data on the housing market	Funda
SHAERE (Sociale Huursector Audit en Evaluatie van Resultaten Energiebesparing)-(Social Rental housing Sector Audit and Evaluation of Energy Saving Results)	Energy use, Energy labels, Dwellings geometry + envelope, Expected heating consumption, U-values (thermal transmittance), RC-values (thermal resistance), Heating installation characteristics, Domestic hot water, Ventilation	Restricted	AEDES is collecting data on the dwelling characteristics and the energy saving measures performed on the social housing stock and publishing this data annually. The data is collected for about 50% of the social housing stock (+- 2 million houses). The data is available as aggregated data or statistics	Association of Housing Corporations (AEDES)

Table 6.5: An overview of data-bases with data relevant for s*tatistics on the energy household in the built environment*, clicking on the data-base name will direct the reader to the online resource

Data-base	Theme(s)	Data type	Description	Data supplier
Energy numbers for the built environment	Energy prices, Energy labels, Energy use, Energy efficiency, Energy mix	Open	Annual statistics on energy related aspects for the built environment, presented in a dashboard	RVO
CBS Microdata + Statline	Enriched BAG data, Transactions on existing dwelling, Dwelling characteristics, Value (WOZ) of dwellings, Household composition, Social cohesion, Energy use, Energy and fuel production	Open (StatLine) Closed (Microdata)	The data is available in aggregated form on statline, however for microdata (available per subscription) the data on the individual level is available under specific licenses. e.g. the actual energy consumption per dwelling with encrypted address	Statistics Netherlands (CBS)
Emission-registration	Emissions	Closed	data-base of around 350 polluting emissions	RIVM

Figure 6.2 visualises the previously presented data-bases, in table 6.2, 6.3, 6.4, and 6.5, according to the energy value-chain of Energy supply, Energy distribution and storage, Energy demand and Others, within urban thermal energy systems. Note that the data-sources are categorised in a general term, and not presented with the specific names as in the previous tables. Figure 6.2 also includes data-sources which can be relevant for the heat transition, but which are not yet included during data capturing and release activities, in contrast to the data-bases in the tables which are presently already available. The data-sources are coloured according to their accessibility, first, the openly accessible data-bases are coloured greed. The data-bases which are not yet available as open data, or currently available under restrictions or special licenses are coloured blue, and finally the data which needs to be acquired is coloured grey.

From this overview it becomes clear that most open data is available on the supply side, see the high number of green objects in the supply column of figure 6.2. For the Distribution & Storage column the same holds regarding the availability of open data for the electricity and gas network by the network operators. Open data is also available on the potential for subsurface extraction and storage of heat and cold, predominantly via data-sets released by research institutes such as TNO and Deltares. However, other than the grid and subsurface data, the Distribution & Storage column does not contain a high diversity in data.

On the contrary to the amply available data on the supply and distribution side, the Demand column holds a high number of grey and blue objects, implying that the majority of the data on the demand side is either not openly available or not yet captured. This section thus holds the most missing data, but also the most opportunities to enrich

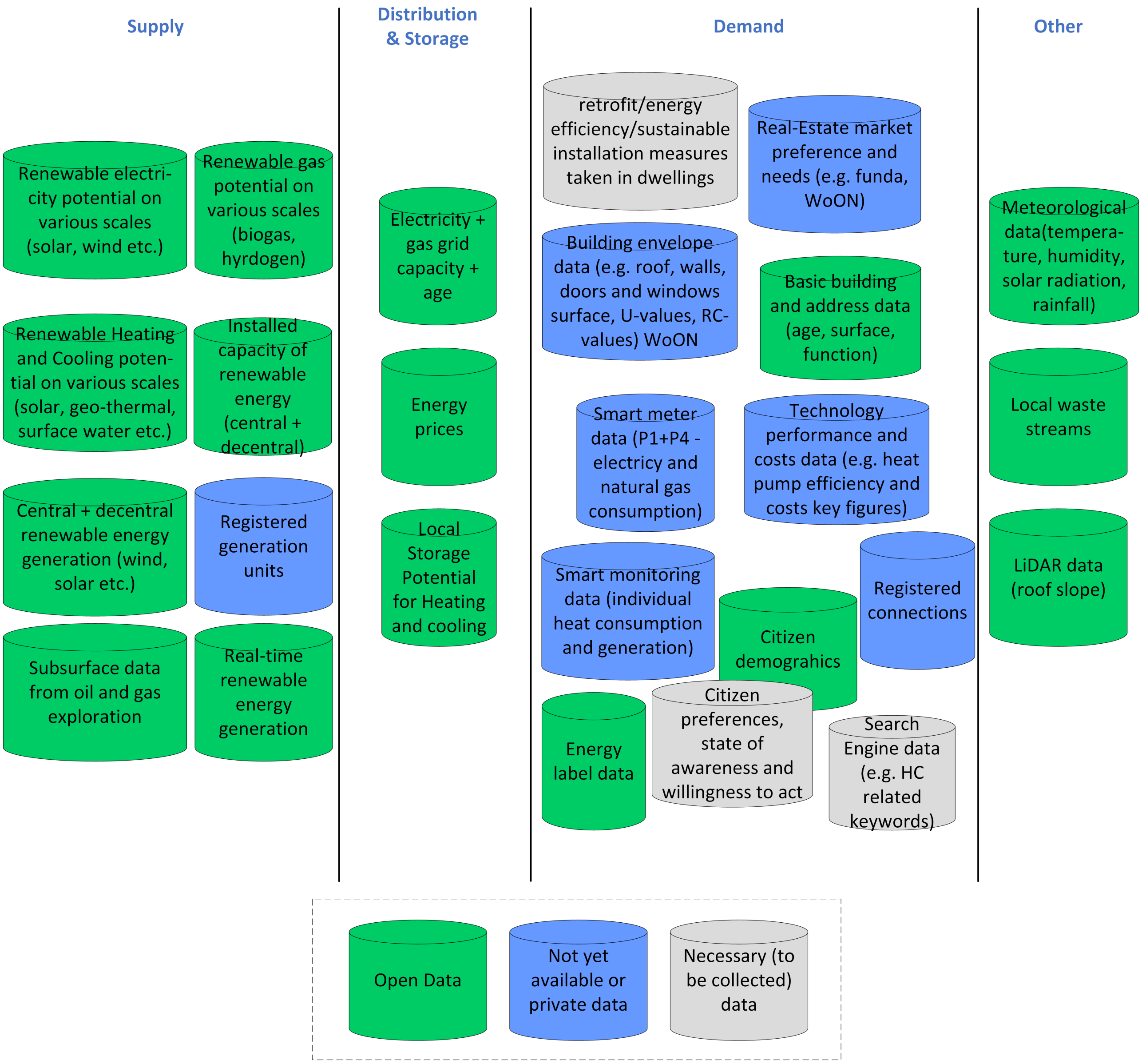


Figure 6.2: The overview of data sources (current and potential) with relevance for the heat transition, own figure

the DE and gain better insights on the social aspects behind the heat transition. Notable missing data on the demand side, and underpinned by (Strategic Adviser, Municipality of Utrecht, 2018) and (Statistical Officer, CBS, 2018), is the absence of real-estate data regarding the ownership of dwellings and the value break-down of dwellings. Factors contributing in the value breakdown are for instance the extent to which the dwelling is designed and built or retrofitted towards the current energy performance. Which measures are taken, or not, by households regarding intrusive or non-intrusive adjustments to the dwelling with an impact on the energy performance of that dwelling. There is no register where households register the state of their dwelling with respect to these measures. This data is relevant for the authorities for policies regarding retrofits, but also for the future owner or renters to gain insights on the future energy performance of the dwelling and the expected energy costs (Project Director, Heijmans, 2019; Consultant, Overmorgen, 2019).

In addition, there is little to no data, structurally acquired and processed, on the social aspects behind the heat transition. This is data on citizen preferences for heating solutions, their awareness on the need and urgency to shift away from natural-gas, and their willingness to have an active role and take actions in this heat transition by means of e.g. investments. Significant relevance is pinned to this data to monitor and guide the social aspects in the heat transition (Strategic Adviser, Municipality of Utrecht, 2018; Product owner, Geodan, 2018; Researcher, TU Delft, 2018; Chairman, HoogravenDuurzaam, 2018; Chairman, Gasvrij Scheveningen, 2018; Energy Ambassador, EnergieU, 2018; Business developer, Eneco, 2018).

6.2.2. DATA PLATFORMS AND PORTALS

DATA PLATFORMS AND PORTALS IN GENERAL

In table 6.6 an overview is provided of the data platforms and portals which could be found to be operational at the time of the study and with a significant inclusion of themes and data regarding the heat demand and supply. In literature the terms Data platform and Data portal are often interchangeably used to refer to some kind of infrastructure which is established to primarily support the production and consumption of easy accessible, machine-processable and possibly real-time data (Ding et al., 2011, Welle Donker and van Loenen, 2017). This main functionality may be extended with functionality regarding data (geo)visualisation, data analysis, and finally the education and support of the data community as one would expect of a platform (Ding et al., 2011). These data portals have been growing immensely over the last decade and large varieties of data-sets are now being offered to data-users. These platforms are administered by authorised organisations whom are in charge to release data-sets and fill in meta-data fields to make it clear what the data-set entails and in which format. Hereby it is important to do this in such a way that users can engage on the use of the data to improve society. This entails that there is a need for best practices, instructions and inspiration for the users on how to use the data (Reis et al., 2018, Zuiderwijk et al., 2014).

The data-sources and associated data-bases presented in the overview in sub-section 6.2.1 can be released online over either an in-house and dedicated portal maintained by the organisation behind the data-set, or the portals or platforms presented in table 6.6. The organisations which release the data over an in-house, dedicated portal are (but not limited to): CBS, Zonatlas, TNO, the network operators, Rijkswaterstaat, RVO, Ministries of the National government, the municipalities and provinces. Due to the high number of dedicated data-portals of the various parties, the consequence is that the data is dispersed and difficult to find for data-users. The aim of the portals and platforms in table 6.6 is thus, among others, to consolidate the various data suppliers in a single platform and address specifically the energy transition. Hereby consolidation entails that the platforms act as an intermediate stage in the Data Ecosystem where various data-sets are collected, visualised and released, to achieve a richer image of the energy system as compared to the individual data-sets separately, in an effective and user-friendly way. In table 6.7 it is presented which main functions are offered by the platforms, the detail level on which data is available and presented, and whether the platform allows for platform output and data to be downloaded for use outside of the platform. The functions can be described as follows:

- (Geo)-visualisation: basic functionality of data or online platforms include the visualisation of data through visual aids such as graphs or charts. Geo-visualisation entails that the platform maps data-layers on geographic maps.
- Monitoring: monitoring of the energy household of a nation or area over time, this entails that the platform includes historic data which is compatible and comparable.
- Bench-marking: the platform provides means to compare an area or entity with other areas or entities, or with national averages or ideally desired and industry norms, e.g. heat consumption of a neighbourhood, compared to the national average.
- Potential: the platforms provides means to translate certain data input towards the potential of measures. For instance the potential savings in the energy bill of a household, due to insulation.

When assessing the online platforms on these functions, not one platform provides all four functions. Among the online energy platforms, the Klimaatmonitor comes forward as most functional, lacking only potential estimation. Of all functions, Geo-visualisation is provided by most platforms, 8 out of 10 platforms, while bench-marking is provided by only one platform, making it the least provided functionality. PICO, the platform developed by Geodan, TNO, Alliander, Ecofys, ESRI Nederland and NRG031, has the unique functionality that the platform embeds energy models such as PBL's Vesta MAIS and the RVO insulation-model. With these models the impact of energy measures in the dwellings and the environment can be calculated and visualised in the PICO maps (Geonovum, 2017a, PICO, 2017).

In table 6.7 it is also provided on which level data and overall functionality is provided by the energy platforms. It can be observed that most platforms include the national to the neighbourhood level. Data release in an open form is limited to an aggregated form on the level of at least 6 digit postal code and that group must include at least 10 objects (Geonovum, 2017a). This restriction is related to the privacy legislation and is elaborated on in sub-section 6.2.4.

Table 6.6: An overview of data-platforms or portals which can be utilised for urban thermal energy system decision making in the Netherlands, clicking on the platform name directs the reader to the online resource

Data-platform/portal	Theme	Description
PICO - Geodan, TNO, Alliander, Ecofys, ESRI Nederland and NRG031	Energy use, Buildings, Spatial area, Energy potential, Sustainable generation, Energy efficiency, Infrastructure, Spatial planning	PICO provides information on the energy use up to the local level and identifies where opportunities and potential lies to best save energy or generate locally

Table 6.6 continued from previous page

Data-platform/portal	Theme	Description
Warmteatlas - RVO	Infrastructure, Emissions, Energy supply, Energy potential, Spatial areas	The Warmteatlas from RVO presents heat demand and supply related information on geographic maps. On the supply side this is: locations potentially suitable for heating- and cooling storage, deep geothermal, biomass and waste heat. The demand side presents e.g, gas consumption
Nationale EnergieAtlas - National Institute for Public Health and the Environment	Energy use, Sustainable generation, Infrastructure, Energy potential, Spatial area mapping, Spatial planning	The National EnergieAtlas is the information portal from the national government which maps current non-renewable and renewable energy generation. In addition, insights are provided on the potential of an area to become sustainable. Kadaster data on property ownership, potential NOM dwellings and governmental buildings, is included.
Klimaatmonitor-Rijkswaterstaat	Emissions, Energy use, Renewable energy, Labour and investments, Residential buildings, Service and utility buildings, Mobility, Industry and agriculture, Infrastructure, Social characteristics	The Klimaatmonitor by Rijkswaterstaat is an extensive platform with dashboards on mainly energy related aspects, but in addition it is enriched with a variety of underlying data on the environmental, societal and economic aspects of areas
CBS in uw buurt - CBS	Fossil energy (natural gas, coal and oil) delivery, Electricity and Heat use, Renewable energy generation	CBS in uw buurt is the digital portal which maps CBS Statline data geographically on the neighbourhood level.
PDOK Platform and Viewer - Kadaster	Energy use, Sustainable generation, Energy potential, Spatial area mapping, Spatial planning, (Subsurface) infrastructure, Hydrolaugical system	PDOK, or Public-service on the map, is a national geographical data portal or platform which combines, releases and visualises the geo-data-bases from the geo-register (Kadaster), BAG, AHN, Ministry of internal affairs and kingdom relations, Ministry of economic affairs, CBS, National Hydrological Instrumentarium and "Het Waterschaps Huis".
Energy atlas or platforms of provinces and municipalities e.g. Warmte transitie Atlas Zuid Holland and Lokale Energie Etalage	Energy use, Sustainable generation, Infrastructure, Energy potential, Spatial area mapping, Spatial planning	These portals have comparable functionality as the above-mentioned platforms. However, the focus is on the specific area (province or municipality) for which the platform is built and maintained. Often these local platforms are enriched with more detailed and accurate local data relative to e.g. the platforms from the national government.
Open Data Portals or Platforms of national and local governments e.g. Utrecht Open Data - Municipality of Utrecht' Dutch National Data portal - the National Government and Waarstaatjegemeente.nl - VNG	Ranging over various variables on society, economy and the environment	These portals focus on the release of the open data and less on the visualisation and analysis of that data. The data utilised for the Energy platforms and the visualisation on those platforms is often also released over the open data portals in raw format. The data portal of the national government released 12,397 data-sets up to now, while the local portal in Utrecht has released 605 data-sets
BAG viewer - Kadaster	Address location, Building function, Building surface, Building contour, Built year	The BAG Viewer presents BAG data online, both graphically and on a map. Different layers can be selected depending on the zoom level. The BAG viewer is not meant to extract large portions of BAG data, for this more suitable API's, such as BAG Extract, are developed

Table 6.7: An overview of the data-platform or portal functionality

Data-platform/portal	Level	Geo-visualisation	Monitoring	Bench-marking	Potential	Download
PICO	national, regional, local, neighbourhood	yes	yes	no	yes	maps of visualised area with data layers
Warmteatlas	national, regional, local, neighbourhood	yes	no	no	yes	maps of visualised area with data layers
Nationale EnergieAtlas	national, regional, local, neighbourhood	yes	no	no	yes	no

Table 6.7 continued from previous page

Data-platform/portal	Level	Geo-visualisation	Monitoring	Bench-marking	Potential	Download
Klimaatmonitor	national, regional, local, neighbourhood	yes (limited)	yes	yes	no	yes (CSV, PDF, PPT, GIF, Open Office etc.)
CBS in uw buurt	national, regional, local, neighbourhood	yes	yes	no	no	maps of visualised area with data layers
PDOK Platform and Viewer	national, regional, local, neighbourhood	yes	yes	no	yes	data-sets + maps of visualised area with data layers
Energy atlas or platforms of provinces and municipalities	national, regional, local, neighbourhood	yes	yes	no	no	varies per platform
Open Data Portals or Platforms of national and local governments	national, regional, local, neighbourhood	yes	yes	no	no	download data-sets
BAG viewer	national, regional, local, neighbourhood, individual	yes	no	no	no	maps of visualised area with data layers

PLATFORMS AND PORTALS ENCOUNTERED IN THE INTERVIEWS

The interviews with stakeholders in the Dutch heat transition addressed the extent to which these stakeholders work with data and data portals or platforms. First it should be mentioned that two main types of platforms can be derived from these interviews, namely:

- Communication and participation platforms: platforms with the aim to redefine the participation and communication process in the heat transition.
  - With the Participatory Value Evaluation method, (Researcher, TU Delft, 2018) aims to provide a platform where citizens can express their preferences for the measures to be taken in the heat transition, while providing the citizens with insights on the consequences of their decisions for both themself and the collective.
  - Network operator Stedin established an online platform for users to post questions and express their opinion on proposals of the network operator. This provides the network operator with insights on the state of mind of the clients and which questions they have (Product Developer, Stedin, 2018).
- Data and information (knowledge) platforms or portals: platforms with the aim to release data to users, but also to add value to the data by means of linked data, data analysis and (geo)visualisation. The platforms mentioned previously, PICO, Klimaatmonitor, Nationale EnergieAtlas, Warmteatlas, PDOK, CBS in uw Buurt, and the local atlases, can all be placed under this category.

In the interviews with the service providers behind the platforms, namely CBS, RVO, Kadaster and Geodan, it is stated by all three providers that the utilisation of the platforms is in line with their expectations. Kadaster mentions that annually around eight million downloads occur on PDOK and this remains stable. However, the service requests, these are requests for data at the source, doubles annually. In 2018, Kadaster processed over 11 million service requests, while this was respectively six million and three million for 2017 and 2016 (Product Owner, Kadaster, 2019).

On the contrary to the positive feedback on the platform utilisation by the platform providers and although most of the interviewees acknowledge the existence of the energy platforms, there is a low utilisation of the platforms among the other interviewees. The only specific notion on the utilisation of the data platforms is made by (Product developer, Eneco, 2018) on PICO, PDOK, and the national and regional energy atlases, and (Chairman, Gasvrij Scheveningen, 2018) on the Warmteatlas and Waarstaatjegemeente.nl. It should be noted that it may be that the interviewee does not work with the platforms, but that the platforms are utilised by other departments or colleagues within the organisation, hence the result is not generisable to the entire organisation represented by the interviewee.

In Utrecht, for the case of Overvecht-Noord, no use of data platforms was reported. Data is provided via direct contact with the source-holder, e.g. network operators, or intermediates e.g. Kadaster. It is stated that the municipality is still in a phase where the available platforms are explored to determine what may be useful (Strategic adviser, Municipality of Utrecht, 2018).

6.2.3. THE LINK BETWEEN ONLINE PLATFORMS AND THE DATA-BASES

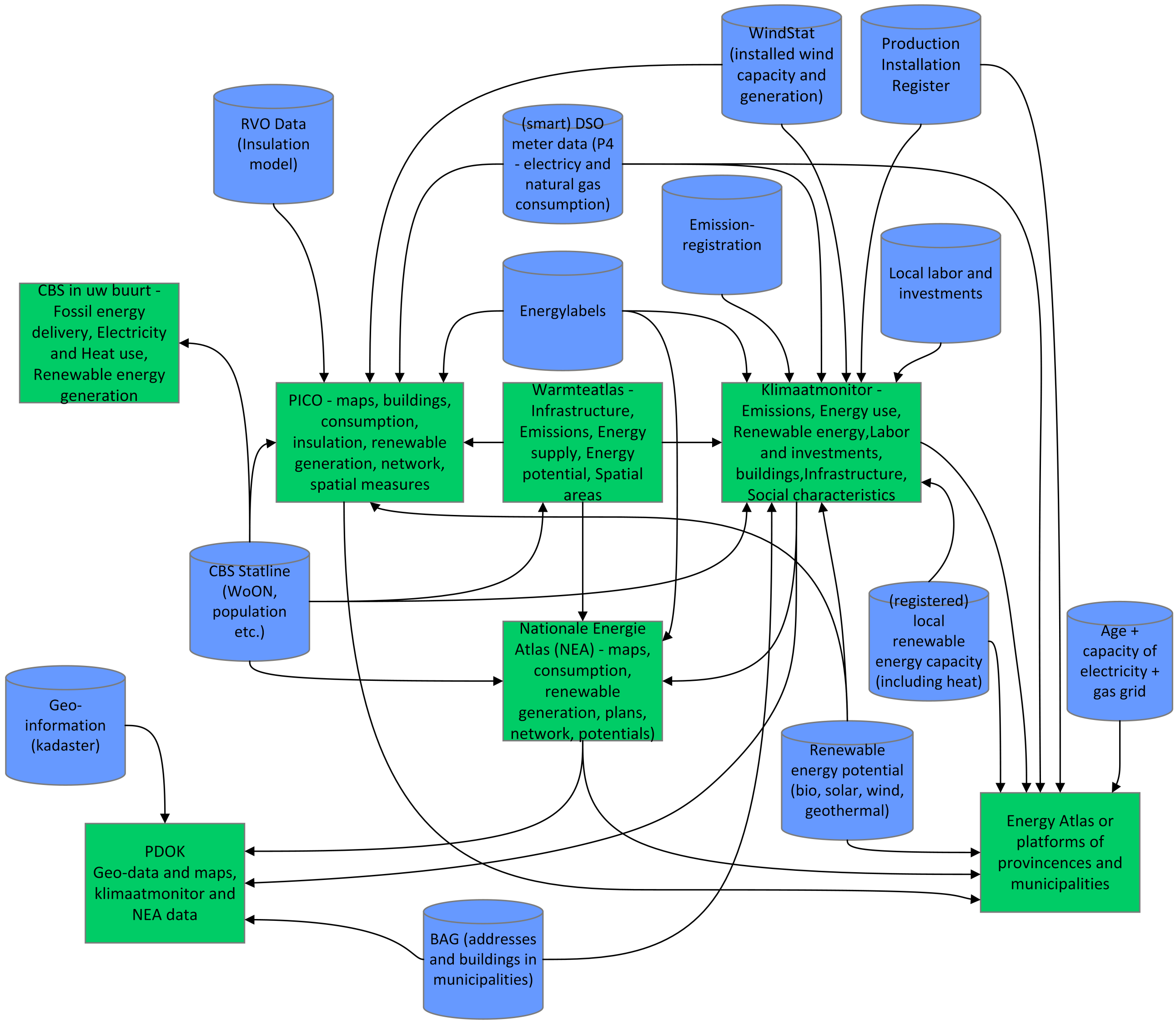


Figure 6.3: Visualised how the data platforms utilise the data from sub-section 6.2.1, own figure

In sub-section 6.2.1 and 6.2.2, respectively the data-bases and online platforms are presented. This sub-section, as can be seen in figure 6.3, elaborates on how these online platforms are linked to the data-bases for the provision of data, but also to the other platforms to combine and improve platform functionality. These links indicate towards the ecosystem of online platform and data-bases.

Among the platforms, the Klimaatmonitor boasts the highest diversity in connected data-bases, ranging from energy supply related aspects, to dwelling characteristics, and social-economic aspects such as the labour market. In figure 6.3 this can be observed from the numerous incoming arrows to the Klimaatmonitor. The local energy atlas for the provinces and municipalities have comparable diversity in the connected data-bases.

As can be derived from the outgoing arrows in figure 6.3, the Klimaatmonitor also serves as a supplier of data to platforms such as the National EnergyAtlas and the local Atlases, mainly for the data to be geographically visualised since the Klimaatmonitor only has limited geo-visualisation functionality.

The Warmte Atlas by the National Expertise Center Heat under RVO in the Netherlands, contains the data-bases owned and maintained by RVO. It is the only platform which only focuses on the heat demand and supply and is well connected to the other platforms predominantly as a supplier of geo-data in the form of map layers and non geo-data.

The PICO platform is thus the only platform with energy models connected. Furthermore, PICO is a much more on itself standing platform with considerably less links with other platforms compared to for instance the Klimaatmonitor, Warmteatlas and the National EnergyAtlas.

As the central platform for the release of open geo-data, PDOK is linked to the Klimaatmonitor and the Nationale EnergieAtlas, and provides the option to load layers from these platforms on the maps in PDOK.

From the visualisation of the platforms and the links between platforms, but also the links to the data-bases, it can be concluded that there is a lively and extensive ecosystem among these platforms. This raises the question whether it is clear for the data-users and other stakeholders how these links are established and how the ecosystem can be exploited by benefiting from the interrelations. Taking these links into account, section 6.4 will propose an improved DE 2.0. Moreover, questions are raised on what the challenges and barriers are which withhold stakeholders to be more engaged in the ecosystem. In the following sub-section it is presented what the main barriers are encountered in the ecosystem of data-bases and platforms presented in this sub-section.

6.2.4. BARRIERS TO DATA-DRIVEN APPROACHES AMONG THE CURRENT STAKEHOLDERS

In this sub-section the barriers experienced by the interviewees when adopting data-driven approaches within the current Data Ecosystem are presented. In sub-section 6.2.1, the inventarisation of the data-bases and data platforms or portals were be discussed, and it became clear that there is a large amount of data currently available or data that could become available in the foreseeable future through, among others, the platforms mentioned. However, at the current stage of data and platform applications for the heat transition, recurring challenges and barriers are encountered. This sub-section elaborates on the barriers encountered in practice.

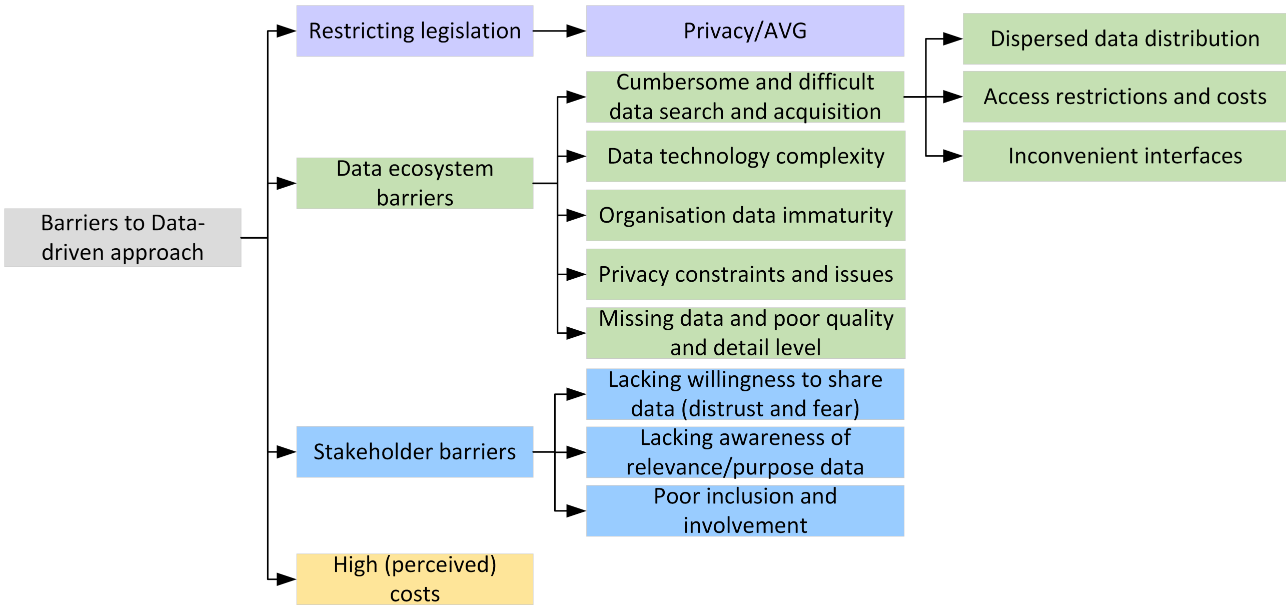


Figure 6.4: Categorisation of the identified knowledge gaps among the interviewees

The interviews with stakeholders in the Dutch heat transition, included questions which address how familiar these stakeholders are with data and data portals or platforms and which challenges and barriers they encounter during the development and execution of the data-driven strategy. In figure 6.4 it is depicted how these barriers can be categorised based on a cluster analysis on coding similarity. From this overview it can be observed that many encountered barriers, overlap with the barriers mentioned in literature as was presented in sub-section 3.1.3. The following barriers are encountered in practice:

- Privacy legislation, namely the "Algemene Verordening Gegevensbeheer" (AVG) as the Dutch implementation of the EU General Data Protection Regulation (GDPR), and the unfamiliarity on how to deal with this AVG and privacy sensitive data of consumers is the most recurring barrier stated by the interviewees, namely 11 out of the 18 interviewees. Privacy legislation is not only impacting the release of data, but also the analysis of data and technologies such as Big and Open Linked Data (BOLD). The application of BOLD, by linking general data to derive individual and richer information is perceived as illegal and thus limits these activities (Business Developer, Eneco, 2018).
- Difficult and lengthy processes to find and access the necessary data via the appropriate platforms or portals is the second most mentioned barrier. There is a lot of time and expertise required to get access to the data and to utilise the data effectively, among others, this is caused by the dispersed distribution of data and inconvenient interfaces. This process is experienced as inconvenient, devious, and complex by several interviewees and for

instance HoogravenDuurzaam questions whether the added value of the data and platforms outweighs the hassle (Chairman, HoogravenDuurzaam, 2018). In addition, the data may be subject to restrictions and costs and this is experienced as a barrier (Strategic Adviser, Kadaster, 2018).

- On the data ecosystem, other barriers include the immature state of organisations with regards to data-driven strategies. Organisations such as the municipality of Utrecht, Heijmans and the citizen initiatives are struggling to comprehend the technological complexity and lack the facilitating data ecosystem to support them in developing and executing the data-driven strategies. In the commercial sector, businesses lack the skills and do not have a clear business case with the added value of utilising and sharing data, hence this is a barrier towards the participation of the commercial sector in the Data Ecosystem (Project Director, Heijmans, 2019).
- Poor data quality and incomplete data, e.g. missing entries in the BAG, and poor data-base compatibility when combining data are a significant barrier (Business Developer, Eneco, 2018).
- The most detailed data available as Open Data on platforms and portals are on the regional and municipality level, there is little outreach to the neighbourhood level or lower. The lack of detailed data is thus a barrier.
- Distrust under citizens leads to hesitation and a low willingness to share data, for instance citizens opt to turn off the smart meter or not register PV panels. This is enforced by the fact that it is not always clear what the purpose is of the data, and if citizens are not convinced by the purpose, the willingness to share data is low (Business Developer, Stedin, 2018; Statistical Officer, CBS, 2018). The poor inclusion of the citizens as data source in the data ecosystem is considered a barrier towards fostering the willingness and awareness.
- Legislation vs. policy instruments, there is a mismatch between, on the one hand, what policy instruments are imposing on actors in terms of the data and services they need to deliver, and on the other hand, the restriction posed by legislation such as privacy legislation. Due to the legal position of the network operators they are not allowed to add value to the data they own, e.g. visualising the data is not allowed. However, adding value to data is expected from the network operators in for instance the Regional Energy Strategies. The network operators are thus limited to release only raw open data (Business Developer, Stedin, 2018).
- For organisations looking to organise the Data Ecosytem and improve the release of data, a barrier mentioned is the lack of cooperation by data-owners such as the energy providers (Statistical Officer, CBS, 2018).
- Finally, the high perceived costs of the data-driven strategies necessary for the training and acquisition of skilled labour and the acquisition of the IT infrastructure and software, is commonly mentioned as a barrier withholding the large scale roll-out of data-driven strategies.

Below, quotes by the interviewees follow to place the above-mentioned barriers in context of their reasoning:

> *"Simply scaling up the data we have received for Overvecht, which we received through an experiment, to the entire city is already complicated. Regardless of the fact that we have not done this much yet, regardless of the fact that it has to be done under certain legal agreements, because those organisations find out that they have to gather the data from everywhere and they do not have it all lying on the shelf, that it has been collected in a different way and for a different purpose than we want to use it, and that it is very much a matter of definition, well then you also have to talk about how everyone can access it and how can you maintain it so that it can be used again next year, all these aspects come into play and it is very unruly." (Strategic Adviser, Municipality of Utrecht, 2018)*

> *"Sufficient information is in itself available to support the energy transition, but this information is difficult to access for the municipalities and regions concerned, it is fragmented or it is behind payment. This is the opinion of us and our colleagues at other government organisations. Important obstacles are the fragmented supply and data protection rules, as a result, available energy consumption data may not be shared at connection level."(Strategic Adviser, Kadaster, 2018)*

> *"the information about the location of networks, also private heat networks, is not publicly available or freely available to governments if there is no purpose of excavation. So a legal basis is needed to also be able to use that data for the energy transition."(Strategic Adviser, Kadaster, 2018)*

> *"I think that the Dutch are more sensitive to privacy than other countries, with the possible exception of Americans. In the Netherlands it is therefore stipulated in law that the transmission of consumption data from the smart meter is only allowed with the consent of the residents and that is not the case in other countries."(Business Developer, Stedin, 2018)*

These barriers, complementing the barriers found in literature in sub-section 3.1.3, will be taken into account to establish a Data Ecosystem 2.0 design in section 6.4. Before, going over to the DE 2.0, the next section addresses technological advances which can contribute in acquiring missing data and complement the landscape of data-bases currently available.

6.3. TECHNOLOGY POTENTIAL FOR DEMAND SIDE DATA

In this section light will be shed on the innovations in DE which can contribute to realise the DE 2.0. Several technologies addressed by the interviewees as innovation to overcome the challenges and improve the data-driven support of the heat transition are addressed. These technologies mainly target the data acquisition on the demand side, the area where the stakeholders experience the most blind spots. In addition to the opportunities of each technology, the challenges or downside of the technologies are addressed. It should be noted that this section does not present an in-depth and comprehensive analysis of the technologies. The aim is to introduce these technologies in the context of the heat transition DE, identify knowledge gaps for further development and implementation and spark further research on these knowledge gaps and opportunities.

6.3.1. BLOCKCHAIN, THE DISTRIBUTED LEDGER TECHNOLOGY

TECHNOLOGY POTENTIAL AND USE-CASES

Blockchain (BC) technology surfaced as a potentially disruptive and general purpose technology that will influence society, businesses and governments and support information exchange and storage where trust and authentication is important (Ølnes et al., 2017). In short, BC is a peer-to-peer network of computers with which transactions can be made. Hereby the BC controls whether the transaction is complying with the necessary criteria, and if consensus is reached on the compliance of the transaction, then the transaction becomes part of the chain. A copy of the chain is placed on each computer or node within the network and is visible to everyone, hence the name distributed ledger (Swan, 2015). Through its fundamental characteristics, BC can be utilised for the asset registry, inventory and information exchange for both tangible assets, e.g. dwellings, and intangible assets, e.g. ideas, information and intention (Ølnes et al., 2017). Hereby it is commonly mentioned that BC technology makes the intermediary party, such as the banks in the case of financial transaction, unnecessary. It is thus a decentral network without the central authority to necessarily control transactions (Swan, 2015). Based on these fundamental characteristics, the benefits of BC technology which are specifically relevant for the DE in the heat transition are (Gaetani et al., 2017, Karafiloski and Mishev, 2017, Ølnes et al., 2017):

- Transparency: data access is democratised and transaction history is visible.
- Trust: eliminating the intermediary can solve the issues with the lack of trust by data-providers, such as citizens, in central authorities to control their data.
- Data integrity and quality: accurate and correct data due to the consensus mechanism for data exchange.
- Access to information: due to the distributed storage of data, access can be gained faster and more convenient.
- Security: also a benefit of the distributed nature.

Two identified potential use-cases for BC in the heat transition DE are:

1. Kadaster is developing a concept that looks at how people stay in control of their data, by using BC technology to arrange access to the data adequately. In the envisioned "bouwdossier" or construction file under the Digital System of the Environmental Code, where each dwelling registers a set of structural and performance characteristics, the expectation is that the data-bases on the dwellings will grow immensely. What Kadaster did is to determine, for the bouwdossier, what information is relevant to have about an object, and subsequently make a prototype with a BC, according to a demand-driven approach as plead for by Ølnes et al. (2017). This BC prevents a mega centralised data-base in the Netherlands with all those objects, but enables to have the data at the source, the citizens, where the citizens as dwelling owners or tenant remain in control over their data. Questions remain on how, with a BC, it can be ensured that the data that is requested is recent and correct data provided by the stakeholders. In addition to this data integrity question, for the implementation of the BC Proof of Concept on a bigger scale, challenges remain on both the strategic and operational/technological front (Product Owner, Kadaster, 2019; Strategic Adviser, Kadaster, 2019). This challenge of scalability is underpinned by Batubara et al. (2018).

2. BC can play a role in the transactions within decentral energy systems and investments by energy corporations or comparable joint financial efforts by citizens. These transactions entail the investment in the infrastructure, and how to acquire the funds among the members, but also the allocation of benefits among the contributing members. An example is a data intensive system where the investment, e.g. a neighbourhood heat grid with a collective heat pump, is coupled to a data monitoring system for maintenance and control and where BC is implemented for remuneration and benefit allocation. The data from the monitoring and control system can be used in consensus models to reach consensus on whom pays what based on the actual use of heat and the initial investment contribution.

Technological challenges

Previously stated, scalability is a challenge encountered by (Product Owner, Kadaster, 2019; Strategic Adviser, Kadaster, 2019) and underpinned by Batubara et al. (2018). Furthermore, depending on the specific BC technology used, the transactions require large amounts of energy, because of the extensive computer network, continuously calculating the chain algorithms. To illustrate this, the transaction of one Bitcoin may require around 200 kWh of electricity, this is more than the average household electricity consumption in the Netherlands Mantel (2018). Note that this challenge is tied to specific BC technology types, on the other hand, there are innovations which provide energy efficient BC.

On the operational side, Karafiloski and Mishev (2017) reports on challenges remaining regarding the consensus models, to reach consensus on the nodes of the computer network, and the validation of transactions.

Finally, where data integrity is a potential benefit of BC as stated by Ølnes et al. (2017), it remains a challenge to control and guarantee the quality and integrity of the data transferred over BC (Product Owner, Kadaster, 2019). Gaetani et al. (2017) acknowledge that it is challenging to guarantee the data integrity in novel BC designs, where the aim is to increase the performance to today's standards.

6.3.2. Big and Open Linked Data: linking data for new insights

Potential and use cases

Linked Data can be described as a method to release structured and machine-readable data which can be connected over web semantics, and as a method to reduce barriers for data previously linked over other methods (Janssen and Kuk, 2016, linkeddata.org, nd). In the context of the heat transition and the current DE, with heterogeneity among data and significant data still needed to be collected and opened up, it is interesting to explore the possibilities of Big and Open Linked Data (BOLD) as presented by Janssen and Kuk (2016). BOLD refers to a diversity of data that needs to be linked to generate new insights.

Among the interviews conducted for this research, several interviewees stated to be aware and even utilising BOLD methods to gain insights from the dispersed distribution of energy related data. BOLD is considered a solution to combine data-bases with aggregated data in order to derive more detailed data on for instance the dwelling-level. Such a use-case is presented in the following quote, where utility company Eneco is utilising open data to automate the process of determining the lowest-cost routing of DHN:

> *"You can do smart things by combining data, so that gaps in data-bases can be compensated by other data-bases, but you can also derive correlations from linked data. ... we are working on combining data-bases and writing algorithms so that we can automate the desired functionality. So we try to combine data in such a way that the whole contains more information than the sum of individual parts." (Business Developer, Eneco, 2018)*

CBS is working on Linked Data methods to be able to generate richer insights from data that is strictly constrained by privacy legislation, see the following quote:

> *"So what we are investigating now is if we can apply or develop technical methodologies to still analyse each other's data by linking that data to each other. And I think there is still a future there. That you will get sources available in this way that you did not receive before because you were simply guaranteed that it cannot be used without privacy infringement. The parties will then be more interested in sharing data with each other commercially."(Business Developer, CBS, 2018)*

In addition to these use-cases by Eneco and CBS, the following use-cases for BOLD are proposed by the interviewees:

- Linking citizen characteristics such as obesity and awareness, with dwelling and energy use characteristics, such as energy labels, to gain more insights on the citizen logic (Chairman, Gasvrij Scheveningen, 2018).
- The municipality in Utrecht is linking data from various parties such as the Network operators and Housing corporations for the heat transition vision (Strategic Adviser, Municipality of Utrecht, 2018).
- Kadaster is a leader in the field of Linked Data and have a clear philosophy of smart linking at the source, in which BOLD has a significant role, as an alternative to data-base expansion. For instance, Kadaster does not necessarily see an extension to the BAG, but they do see that the BAG is more and more integrated with other data. It is not the intention to create one central data-base that contains all the data, but to combine data at the multiple sources. In this way, BAG can be combined with the Land Registry Basic Registration, or with data about neighbourhoods from CBS. By keeping data distributed and at the source the need for centralised infrastructure is reduced, and so too are the costs. Finally, Kadaster believe that the possibilities to gain insights through linking data are endless (Product Owner, Kadaster, 2019; Strategic Adviser, Kadaster, 2019).

TECHNOLOGICAL CHALLENGES

While CBS state that BOLD provides the possibilities to gain insights which could not be possible without linking data, due to privacy infringement, (Business Developer, Eneco, 2018) argues that one of the barriers regarding Linked Data is privacy. This is illustrated with the example where there is data-base A, with no specific information about a particular home and data-base. However, if this data-base is combined with other data-bases and something can be calculated about the individual home, that is not allowed. So, there are also barriers on combining general data to calculate individual aspects, due to a grey area in the privacy legislation and its interpretation for BOLD.

Moreover, (Business Developer, Eneco, 2018), states to encounter problems with regard to the compatibility of data-bases if those data-sets need to be combined.

6.3.3. CROWD-SENSING: INVOLVING THE PEOPLE

POTENTIAL AND USE CASES

To embed the stakeholder and citizen engagement in the evidence-informed approach, Crowd-Sensing (CS) is a possible means to include the citizen participation and gather citizen data. CS can be described as a new paradigm to efficiently acquire data by means of, among others, the sensors embedded in the wide-spread modern-day mobile devices, see figure 6.5. Hereby the human involvement plays a clinical role, whereby human mobility provides endless opportunities for the sensing coverage and the data transmission (Ma et al., 2014). The application of CS to foster crowd participation in smart cities is presented by Cardone et al. (2013) and in this study the focus is not only on the acquisition of data from mobile devices, but also how to steer actions and decisions by the holders of the mobile devices in the desired direction. This latter addresses the actuating functionality in CS.

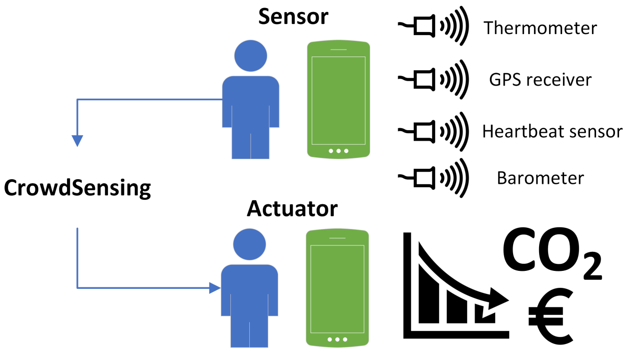


Figure 6.5: An overview of the Crowd Sensing concept, adapted from (Ma et al., 2014)

Given the fact that there is a need for data on consumer behaviour, perceptions and willingness to cooperate and be involved in heat transition decision-making, the municipality of Utrecht is looking for ways on how to gather this data (Strategic Adviser, Municipality of Utrecht, 2018). This search reaches further than the conventional surveys, which is a resource intensive process and does not provide the ability to have frequent updating of the data (Strategic Adviser, Municipality of Utrecht, 2018; Statistical Officer, CBS, 2018). In this search, CS can have a role to establish a communication link between the citizens and the municipality and other decision-makers, for up-to-date and direct data on aspects such as citizen behaviour and preferences.

In Utrecht, citizen initiative HoogravenDuurzaam, is experimenting with basic versions of this direct manner of digital data generation from their members. During Information Sessions, digital tools, although non-sensor based, are utilised which allows the attendants to express their preference on the role they see for themselves and for other stakeholders in the heat transition. With this insight HoogravenDuurzaam set out a plan on the heat transition in the district, taking into account which citizen groups to actively include and which groups to approach less actively (Chairman, HoogravenDuurzaam, 2018).

TECHNOLOGICAL CHALLENGES

Accompanying the opportunities of CS as novel technology, are significant challenges. Ma et al. (2014) report on challenges in the field of: 1) the randomness of human mobility and dynamics, complicating the reliability of CS quality in terms of coverage and latency, 2) privacy issues preventing citizens to share data on e.g. time of space heating, which may imply when people are at home or not, 3) participation rate, for a high participation rate, citizens need to be thoroughly incentivised on the sensing, data transmission and actuating part. In the context of CS in smart cities, this city-wide level is also the scale at which the heat transition takes place, it is a challenge to balance system scalability and CS accuracy (Cardone et al., 2013).

After addressing the technologies of BC, BOLD and CS, as the final building blocks of the DE, with the stakeholders, data-needs and data supply already addressed earlier as building blocks, the following section will present the design of the DE 2.0.

6.4. THE PROPOSED DATA ECOSYSTEM 2.0

In this section the DE2.0 is proposed as an improvement on the current DE, by taking into account the three building blocks: 1) the information needs in the heat transition, 2) the existing and potential data-bases and platforms with the encountered challenges and barriers, and 3) the discussed technologies to improve on the data capturing, exchange and utilisation. The DE for Utrecht in sub-section 6.1 surfaced an under-representation of four elements from the DE framework as presented in sub-section 3.2.6 namely: a quality management system, meta-data, use-case promotion and the feedback system. Hence, these elements attract specific attention in the DE 2.0, exhibited in figure 6.6.

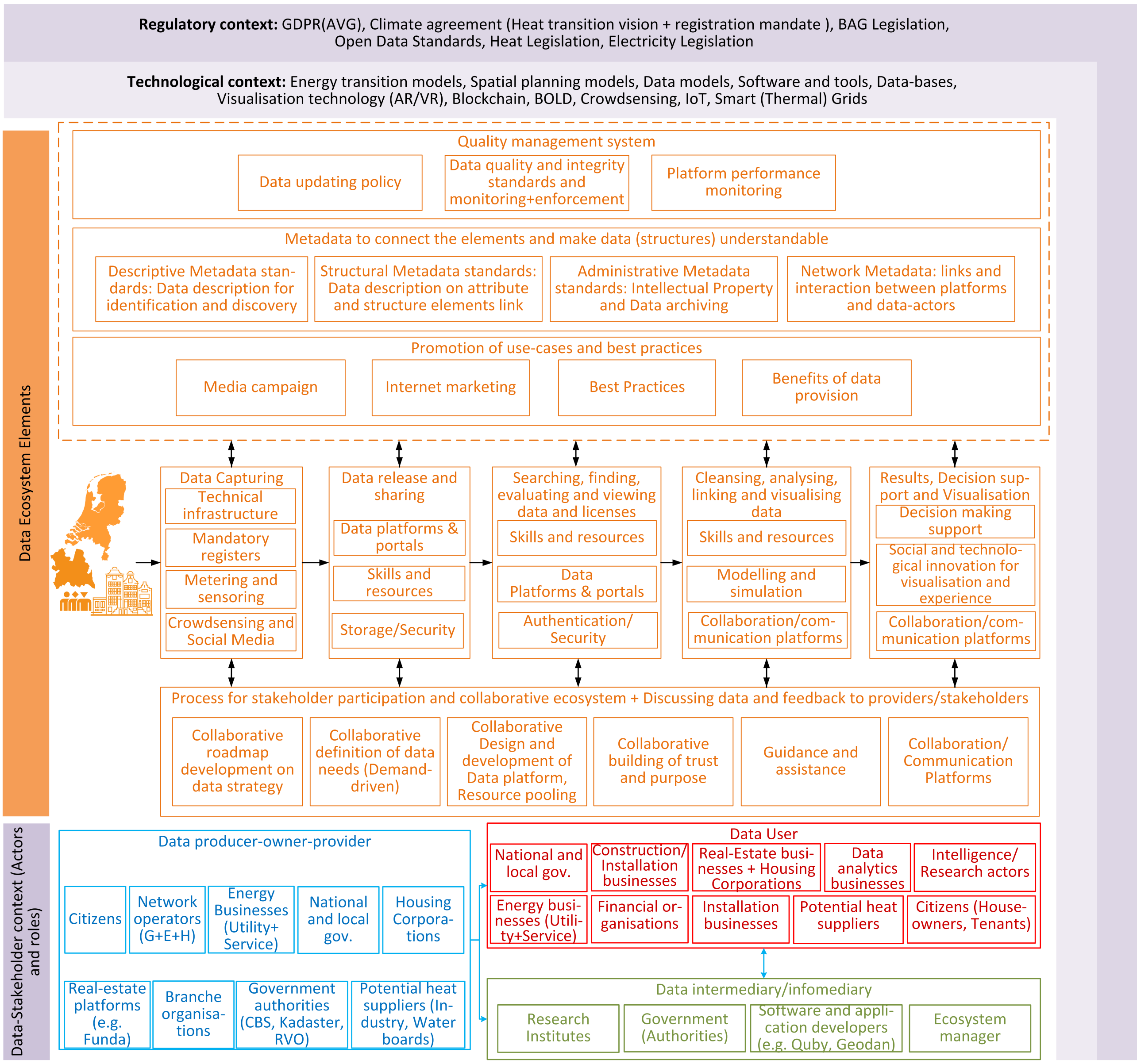


Figure 6.6: The new Data Ecosystem 2.0 proposed for the heat transition in the Netherlands, own figure

6.4.1. THE DATA ECOSYSTEM ELEMENTS 2.0

The following paragraphs each elaborate on the DE elements which are added to, or, adjusted from the Utrecht DE which is sketched based on the DE framework as presented in 3.2.6. The additions and adjustments are aimed to meet in the needs for the heat transition in the Netherlands. The initial DE framework and the DE 2.0 proposal are made subject to an expert validation in which Dr. Anneke M.G. Zuiderwijk-van Eijk, Assistant Professor at the TU Delft and a leading researcher in the field of Open Data and Data Ecosystems, participated. This validation session yielded issues on the initial design regarding: overlap between elements, lacking graphical visualisations and the ambiguity among terms used.

A new quality management system

Poor data quality and incomplete data is explicitly stated by several data-users interviewed, as challenge when utilising open data. Furthermore, the quality of insights gained from the current data platforms, is also stated to be difficult to guarantee, in particular by the Citizen Initiatives. The existence of a quality management system is thus critical for data-user and stakeholders to have confidence in the decision support provided by open data-driven applications and platforms. In the current DE, geo-data standards are established by Geonovum, while other data-types lack standards when compared to geo-data. For an overall effective DE, reaching further than geo-data, this quality system should be expanded to all other types of data. Relevant for the heat transition are thus energy potential data, data on technology performance and costs, and data on the consumer's demand and behaviour. A fair share of this data is not geo-data, leaving a significant share of the data without quality standards. Moreover, the quality management system should not be limited to the development of standards, but should also communicate these standards towards the DE participants and, moreover, monitor and enforce the compliance to these quality standards. For the provision of data to the energy transition, the following criteria should be included in the quality management system for data and infrastructure: reliability, completeness, topicality, continuity, independence, veracity (source integrity and quality), and interoperable data formats (Dekker et al., 2019). By ensuring these quality factors for the DE, the barriers and challenges encountered in the current DE, as presented in section 6.2.4, can be eliminated.

Rich meta-data

Meta-data is important for users to gain a thorough understanding on the data and assess whether the data suits their needs. In addition, meta-data may benefit the DE in improved storage, preservation, accessibility, visualisation and interoperability of open data (Zuiderwijk et al., 2014). The three type of meta-data necessary in DE 2.0 are (Riley, 2017): 1) *descriptive meta-data* on the characteristics of the data, enabling convenient data identification and discovery, 2) *structural meta-data* on the composition, structure and organisation of the data-base, enabling transparency and architectural improvement, and 3) *administrative meta-data* on the intellectual property of data and data archiving, enabling clarity on the conditions for use.

In addition to the above-mentioned meta-data, it is proposed to establish meta-data standards on the landscape of data-bases and platforms, and the associated providers and users of those. The term proposed is *Network meta-data* and this Network meta-data should provide clarity to providers, users and intermediates on the links between data-bases and platforms. Network meta-data may contribute in the interoperability between data-bases and the extent to which platforms can complement each other in terms of functionality and released data. Hence, the challenge of dispersed data and difficulties with finding the appropriate data or platform is directly targeted by this element.

Use-case promotion to improve data and platform use

For open data systems to be effective, a field of users and data providers of significant scale is necessary. From the interviews it could be derived that the utilisation of platforms and portals currently available is very low. In order to improve the use of the data and get most out of the potential, use-case promotion informs and inspires users about data applications. It is proposed to promote best practices and innovative use-cases in which the added value and purpose of data utilisation becomes clear to the users. Here, users are both parties developing software and tools to add value to data, but also the consumers in the context of the heat transition, the citizens, which do not necessarily directly utilise data, but are a rich source of data. Being aware of the added value of the data, motivates citizens, and other decision-makers such as municipalities, to utilise data-driven tools and methods to support their decision making. In addition to the data demand side, by clearly promoting the use-cases, the purpose of data utilisation becomes better known by the data-providers, incentivising data sharing.

Process for stakeholder participation and Data Ecosystem collaboration

Process support on the demand side

In the heat transition there is a strong demand for process support by the actors which have to make decisions and investments, such as the municipalities, housing corporations and the citizens (Business Developer, Stedin, 2018; Consultant, Overmorgen, 2018; Chairman, HoogravenDuurzaam, 2018; Energy Ambassador, EnergieU, 2018; Strategic Advises, Municipality of Utrecht, 2018). This process support ranges from the technical to economic aspects, but also process support regarding the identification and utilisation of data-driven decision support methods and tools. In the proposed DE 2.0 there is the addition of the stakeholder participation and collaboration element, which is merged with the element mentioned by Zuiderwijk et al. (2014) on the discussion of the data and the provision of feedback to the data providers and stakeholders. This element should account for the inclusion of the data providers and users early in the DE where data infrastructure, products and services are designed and developed, all the way to the utilisation, and in general the complete data life-cycle. On the demand side, for the data-users, the aim is that this inclusion creates 1) data products and services with the functionality that take the needs of the users into account adequately, a demand-driven approach, and 2) increased familiarity to the products and services from the early start. This is expected to result in an increased utilisation of data products and services.

Trust among data suppliers

On the supply side, as presented in section 6.2.4, there is a lack of trust by citizens in authorities and businesses which aim to capture or acquire, and utilise citizen data. This distrust is caused by privacy concerns, but moreover so, by the the citizens not being aware of what the purpose is of the data utilisation. Without knowing what the data will be used for, citizens are very hesitant to share data (Product Developer, Stedin, 2018; Product Owner, Geodan, 2018; Statistics Officer, CBS, 2018; Geo-Architect, RVO and Geonovum, 2018). The proposed DE 2.0 element of "Process for stakeholder participation and Data Ecosystem collaboration", aims to built trust and awareness on the supply side, by including (potential) data suppliers in the identification and definition of the added value of data utilisation and the functionality of data products and services. Ultimately, the enhanced trust can foster the willingness of citizens and other data holders to share data.

Hence, by adopting this inclusive and demand-driven approach, and first determine what the needs are of the stakeholders in the heat transition, and what data is necessary to address those needs, the purpose of the data-driven approach is clear and both data suppliers and users are made aware of the added value of data. This is expected to boost trust, confidence, and the sense of relevance, and ultimately result in an increased willingness to share data by the data suppliers and utilisation of platforms and portals by data user.

Data quality assessment and feedback

Finally, in the current DE there is no presence of data assessment and feedback towards the data providers in order to improve the data quality where needed. The two-way feedback between users and providers over the development and life-cycle of platforms, as proposed in this element, targets the continuous improvement of the data and platform quality. The Energy Policy Lab, elaborated in chapter 7, can play a relevant role in this element of organising and guiding the interaction between users and providers.

RESULT AND DATA COMMUNICATION AND VISUALISATION

It is mentioned by Reinhart and Davila (2016) that it is still a challenge to communicate immense amounts of data to stakeholders as comprehensible and actionable information. This aspect was first embedded in the element of cleaning, linking, analysing and visualising data, in the DE framework derived from literature. However, the visualisation or presentation of results is proposed to be taken separately in DE 2.0, due to the different nature and dependence on different theories and processes as compared to the more technical aspects of data cleaning, linking and analysis. For instance socio-psychological research is relevant to determine what and how to visualise insights from data to citizens, but less relevant regarding data cleaning, linking and analysis (Product Owner, Geodan, 2018). By taking the data visualisation in a separate step, it is also made more accessible for parties which are specialised in these visualisation technologies, such as Virtual Reality and Augmented Reality, to be engaged in the DE. Do note that these two elements are strongly intertwined, and need to align the activities to each others objectives.

6.4.2. THE DATA ECOSYSTEM CONTEXT 2.0

DATA-STAKEHOLDER CONTEXT

In the Data-Stakeholder context, it is plead to enable *the role of the DE Manager*. The responsibility on the earlier mentioned Data Quality System, can be taken up by the DE Manager which is currently absent in the DE for the energy transition. Several organisations pick up tasks on the organisation and management of the DE, but there is no coherence in the DE management, leading to duplicate functionality of data platforms, and poor interoperability. DE wide meta-data management and coordination of the stakeholder participation process, are also tasks which can be picked up by the DE Manager.

In the national program to improve the information provision in the energy transition, these tasks are proposed to be carried out by a Data Commission, consisting of experts from key stakeholders namely: Ministry of Economic Affairs and Climate, Ministry of Internal Affairs and the Kingdom Relations, CBS, Kadaster, PBL, Rijkswaterstaat and RVO (Dekker et al., 2019). In this proposal by Dekker et al. (2019), the sole participants in the Data Commission are public parties and Data Intermediates according to the role definition in this research. However, from the DE approach it is recommended to expand the composition of this DE Manager with representatives from: 1) the data suppliers, e.g.

the network operators, 2) the data users, e.g. the energy utility and service businesses, and 3) the standards organisations, i.e. Geonovum. With this composition, the relevant interest are represented in the DE Manager, fostering comprehensive DE organisation and management.

REGULATORY CONTEXT

In the regulatory context, the Climate Agreement plays an important role. In Dekker et al. (2019) it is stated that this agreement may provide the legislatory basis to impose certain mandates on the citizens to register for instance the PV panels on their roof and the insulation measures taken. In the DE this could thus lead to an increase in the data availability by addressing the currently present blind spots of missing data.

In addition, the "Environmental Code" or "Omgevingswet" will turn in a significant presence in the DE for the energy transition when enacted by 2021. By means of the anticipated "construction file" or "Bouwdossier", encompassing a digital archive on each dwelling containing relevant building envelope data, under the "Digital Scheme of the Environmental Code" or "Digitaal stelsel Omgevingswet", novel instruments are provided to enrich the data availability on dwellings. For these instruments to be effective, and ensure that the data needs for the heat transition are adequately met by these instruments, it is beneficial that these instruments are developed and implemented within the DE with the interrelations and knowledge on current challenges and barriers. The development of these instruments in the DE, by involving the DE actors, opens up the knowledge on the data needs in the heat transition encountered and identified by these actors and enables the construction file to be equipped with the relevant and necessary data variables.

TECHNOLOGICAL CONTEXT

The technological context of the current DE for the heat transition can be described as sparsely populated and in its infancy. Currently, energy transition models such as Vesta MAIS utilise available data-bases and the available platforms are casually used by stakeholders in an attempt to visualise and comprehend the challenges in the heat transition. To this point, actual decision making has not been supported adequately in a data-driven way from the technological context. This can be assigned to the technology being in its infancy, governance and decision-making processes not completely embracing data-driven support, but also the lack of critical data mainly on the demand side. Although technology is steadily improving, these technologies in the field of data analysis and visualisation are not relevant without the adequate data supply. Hence, the technological context is recommended to be expanded with innovations in the line of Blockchain for secure and reliable data storage and exchange, CrowdSensing for advanced citizen data acquisition, BOLD for enhanced insights from distributed and diverse data, and Artificial and Virtual Reality (AR/VR) to provide end-users with an engaging and familiar experience, rather than conventional data visualisation.

6.5. CHAPTER CONCLUSION

Chapter 6 addressed the following SQs:

> Section 6.1 ⇒ *3. How can a DE be composed and how does the current DE look like for the Dutch heat transition, what are the shortcomings and challenges?*
>
> Section 6.2 ⇒ *4. Which Open and Big data sources are currently, or could potentially, be made available to support evidence-based policy and decision-making by targeting the knowledge gaps derived in SQ 2, and what are the barriers for the utilisation of this data?*
>
> Section 6.3 ⇒ *5. Through which technology and/or methods can the missing data identified in SQ 3 be acquired, and the Data Ecosystem be improved towards the 2.0 proposal?*

DATA-BASE AND DATA PLATFORM INVENTORY AND BARRIERS

This study produced an extensive, but not exhaustive, inventory of data-bases currently available, with relevance for heat transition decision making. A total of 24 data-bases are presented in this inventory, categorised over: supply side data, demand side data, building stock data and energy statistics data. It can be concluded that the majority of the data openly available nowadays is on the supply side. The infrastructure data for distribution and storage is also openly available. However, on the demand side, including the dwelling characteristics and the end-user characteristics and behaviour, there is little data captured and released as open data. A significant share of the demand data thus remains to be released, while there also is data with great potential which remains to be captured, namely: 1) citizen preferences and attitudes towards the alternatives for natural-gas and retrofit measures, and 2) data on dwelling envelope retrofit and thermal installation measures already conducted in dwellings.

Besides the data-bases, an inventory is produced on the data platforms or portals targeting energy, and in particular heat. This inventory yielded 9 platforms with varying functionality and data feed. It could be concluded that when placing these platforms and data-bases in the context of an ecosystem, there already is a very rich ecosystem. However there is very little known on the links and interaction between the platforms and data-bases. This means that several platforms have redundant functionality, while other platforms complement each other with their functionality. However, because the overview of the ecosystem is poor, opportunities to jointly utilise platforms are left unexploited.

Data-driven strategies have the potential to address these knowledge gaps, however significant barriers are experienced by the stakeholders in the development and execution of effective data-driven strategies in the current DE. The design of the DE2.0, needs to take into account barriers regarding: 1) restricting (privacy) legislation, 2) data ecosystem barriers e.g. difficult and cumbersome data search and acquisition and poor data quality and detail level, 3) stakeholder barriers, e.g. lacking willingness to share data, and 4) high perceived costs.

Technological innovation for DE 2.0

The interviews yielded three technologies or methods to obtain the missing data or improve the insights from the current data. First, *Blockchain* provides opportunities to store, organise and exchange data, while effectively addressing challenges regarding transparency, trust, data quality and integrity, security, and data access (Karafiloski and Mishev, 2017).

Second, *Big and Open Linked Data or BOLD*, as presented by Janssen and Kuk (2016) offers attractive opportunities for enhanced insights from distributed and diverse data in the context of the heat transition and the current DE, with heterogeneous data formats, scattered distribution of data, and missing data.

Third, *CrowdSensing or CS*, is a possible means to include the citizen participation and gather citizen data to embed the stakeholder and citizen engagement in the evidence-informed approach. CS can be described as a new paradigm to efficiently acquire data by means of the sensors embedded in, among others, the wide-spread modern-day mobile devices.

Where these technologies offer endless possibilities, and pilots are run by the more progressive actors in the DE, such as Kadaster, many challenges and barriers are encountered on both the technical side, e.g. the scalability of the system and to control and guarantee the quality and integrity of the data transferred over BC, but also on the social side, e.g. how to embed these technologies in society and how should decision-making processes and structures need to change to benefit from these technologies. These challenges and barriers require further research, for the technologies to play a significant role in the future DE.

From DE 1.0 to DE 2.0 in the heat transition

The DE for the heat transition is in its infancy phase at this point with challenges, barriers and shortcomings in all elements as proposed by the DE framework derived from literature. Of the eight elements, the current DE is particularly falling short in the Data discussion and feedback, Meta-data, Use-case promotion and Quality management system. In addition, the data feed is sub-optimal whereby, in particular, little to no data is included on the citizens. Currently, energy transition models such as Vesta MAIS utilise available data-bases and the available platforms are casually used by stakeholders in an attempt to visualise and comprehend the challenges in the heat transition. To this point, actual decision making has not been supported adequately in a data-driven way from the technological context. This can be assigned to the technology being in its infancy, governance and decision-making processes not completely embracing data-driven support, but also the lack of critical data, mainly on the demand side. Where the technology is steadily improving, these technologies in the field of data analysis and visualisation are not relevant without the adequate data supply. In order to establish a DE which effectively supports the decision-making for the heat transition, the lacking data supply on heat demand, dwelling characteristics, and citizen attitude and perceptions require the main focus. This will require, not only stable and adequate data infrastructure and technologies such as BC, CS and BOLD, but also an adequate quality management system, new roles such as the DE Manager, and a process for stakeholder participation and DE collaboration. The latter fosters a DE where trust among data suppliers enables quality data supply, and continuous interaction enables a DE which is aware of the specific data needs and targets those data needs effectively and efficiently.

7

TNO's Energy Policy Lab

In this chapter the Energy Policy Lab (EPL) by TNO is the subject of attention. In sub-section 3.7 the EPL was introduced, and this chapter will further elaborate on the EPL application in the heat transition by answering the following SQ:

> *6. What are the requirements and functionality of a data-driven method, such as TNO's Energy Policy Lab, to be of added value in the realisation of sustainable and inclusive Urban Thermal Energy Systems in the proposed Data Ecosystem 2.0?*

Before heading to the design functionality and requirements for the EPL in section 7.2, section 7.1 elaborates on the link between the EPL and the DE.

7.1. Linking the Policy Lab approach to the Data Ecosystem

The Policy Lab (PL) approach for data-driven policy making by van Veenstra and Kotterink (2017) encompasses the development, experimentation and implementation of methods for effective data-driven policy making according to three phases: 1) predictive problem definition, 2) design and experimentation, and 3) implementation and evaluation. These are steps or phases which, from the data-driven perspective, show a link to the DE elements, whereby the steps or phases can benefit from the data infrastructure, products and services developed and exploited within the DE. In figure 7.1 it is depicted how the PL approach relates to the EPL and the DE. In this section it will be discussed how the PL approach can be linked to the DE elements and benefit from those links.

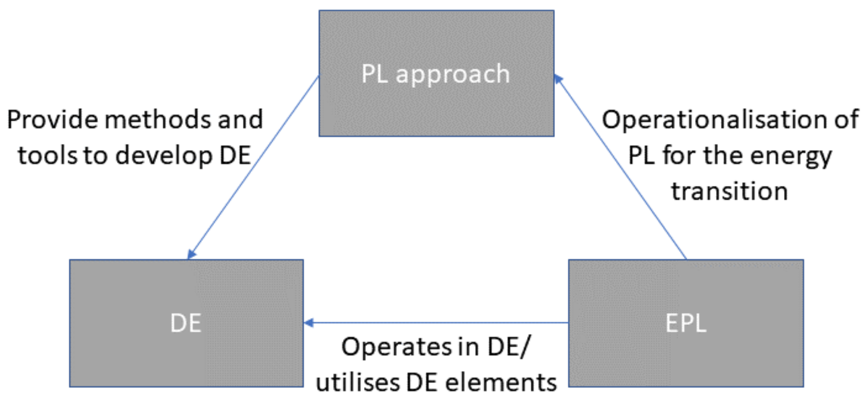


Figure 7.1: The relation between the PL approach, the EPL and the DE, own figure

Predictive Problem Definition

The first phase in the PL approach entails the predictive identification and definition of the problems requiring policy intervention, and the interpretation of policies imposed by higher governments on the regional and local governments. In the process of comprehending the problems as perceived by the governments and stakeholders, and deriving the associated inter-dependencies among these problems, the PL approach can be applied for input towards

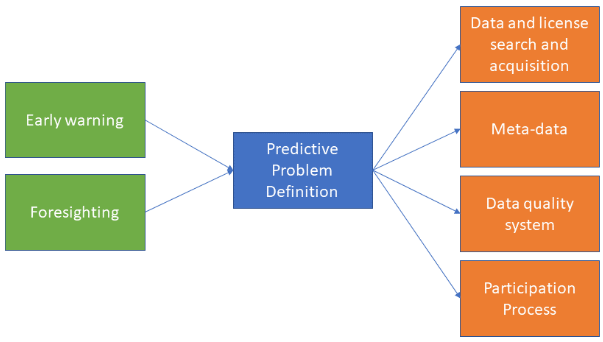


Figure 7.2: How the Problem definition phase relates to the Data Ecosystem, own figure

the DE elements of the *quality management system* and *the meta-data to connect the elements*. More specifically, by understanding the problems, and the knowledge gaps which complicate decision-making for those problems, necessary data can be identified, and the requirements in order to capture and acquire that data can be conveyed to the Data management system and the meta-data schemes. By implementing these needs in the quality management system and meta-data schemes, the necessary conditions can be created to effectively capture, release and utilise the necessary data in the DE.

For the predictive ability to define the problems proactively, this phase searches for the appropriate data and where that is missing, collects the relevant data. Methods and processes developed for this data search and acquisition, directly contribute to the *data and license search and acquisition element*. In particular for the heat transition, with its bottom up and decentral nature, the policy measures require detailed demand and behavioural data from the end-users as previously discussed in this thesis. In order to gather this end-user data, it is of paramount importance to co-create the data generation and acquisition with the owners of the data: citizens and businesses. This co-creation contributes in the *participation and feedback process element* of the DE.

POLICY DESIGN AND EXPERIMENTATION

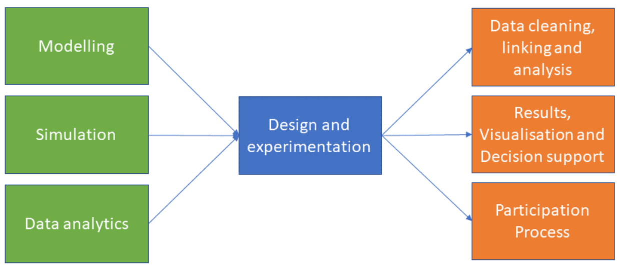


Figure 7.3: How the Design and Experimentation phase relates to the Data Ecosystem, own figure

The second phase of the PL approach targets the design and experimentation of policy measures and instruments. This is the phase were naturally, data-driven policy making is utilising advanced analytical methods and tools to gain insights on the data and support the policy decisions. Previous data-driven methods have not yet sufficiently taken into account co-creation, the focus was rather on the application of advanced analytical methods with the data available from the first phase (Poel et al., 2015). These advanced analytical methods contribute in the *Data cleaning, linking and analysis element*, while methods and tools developed and implemented to visualise the results and support decision-making, are of added value for the *Results, Visualisation and Decision support element*. Finally, there is a need to embed the methods developed in this phase in the *participation process element* and enable co-creation of policy.

POLICY IMPLEMENTATION AND EVALUATION

In the third phase of the data driven policy cycle, the phase of Implementation and Evaluation, data-driven methods enable short cycled policy and decision making, along the lines of adaptive policy making, where monitoring of the policy progress provides insights in the pathway towards achieving the policy goals (van Veenstra and Kotterink, 2017). In particular for the energy transition which is commonly described as an incremental process with the adoption of a variety of available technologies and processes, this adaptive cycle provides the opportunities for up-to-date

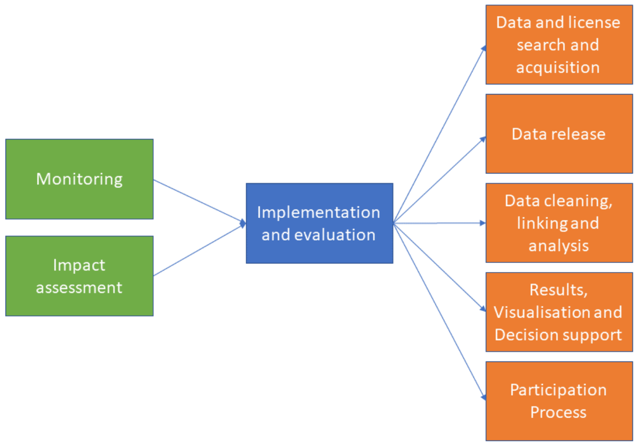


Figure 7.4: How the Implementation and Evaluation phase relates to the Data Ecosystem, own figure

and effective policies, thereby preventing the delay of decisions due to uncertainty at policy makers, the market and citizens. This phase depends on the methods for progress monitoring and impact assessment, and the data feed to these methods is an important part of the *Data and license search and acquisition element*. For the data acquisition activities put in place to acquire the data necessary for monitoring and impact assessment, e.g. how many citizens adopted a heat pump after a policy was implemented to incentivise heat pumps, a close interaction between the *Participation process element* and *the Data and license search and acquisition element* is necessary. This interaction should enable the co-creation and support of citizens and stakeholders to provide the necessary data.

For the transparency and support of the adaptive policy process, it is important to release data on the monitoring and impact assessment of policy. With this, not only can citizens decide on making different decisions, but market parties can anticipate on what is necessary to be developed and brought into the market in terms of products and services to get the heat transition on track towards the predefined goals. This is related to the *Data release element*, but also to the *Participation process element* to enable the desired reaction on the released data. How this data is presented to the citizens and stakeholders, is part of the *Results, Visualisation and Decision support element*.

In the following section it is presented which functionality and requirements are perceived as to be of added value for the EPL application in the heat transition. Recall that this EPL is an example of applying and operationalising the PL approach in the energy transition.

7.2. EPL Functionality and Requirements

In figure 7.5 it is exhibited what share of the interview data for each interviewee refers to the EPL, this provides insights which interviewees see a need for the EPL. Subsequently, these parties can be targeted by TNO to form a coalition on the development and application of the EPL. On average about 7% of the interview is allocated to the EPL, whereby there is a large group of interviewees around that average, but also a group which is well above the average. Namely the RVO, EnergieAmbassadeurs(EnergieU), Gasvrij Scheveningen and the Researcher at the TU Delft paid above average attention to the EPL. On the other hand, Geodan, Heijmans, Kadaster, HOMIJ DEC and the Volksbank showed significantly less interest in the EPL. It thus makes sense to approach the interested parties for the development of the EPL. However, with the aim to reach as much as possible of the actors and stakeholders, among others for the data provision and impact, it might be even more important to convince the currently uninterested parties of the EPL or comparable initiatives. The rest of this section will address the functional and requirement analysis conducted for the EPL for its development and application in the heat transition.

7.2.1. Desired functionality of an EPL

The interview framework addressed the EPL with the interviewees and included questions on what the interviewees consider as the added value of an EPL for them in the context of the heat transition. Consequently, following the analysis of the interview data in the NVivo software package, the main EPL functions derived are as follows (presented in an order of decreasing relevance):

- f1: *enable experimenting with (policy) measures* - the EPL is expected to include models and tools, both physical and digital, to enable experiments with transition policy, but also energy measures both before and behind the meter on the generation and use.

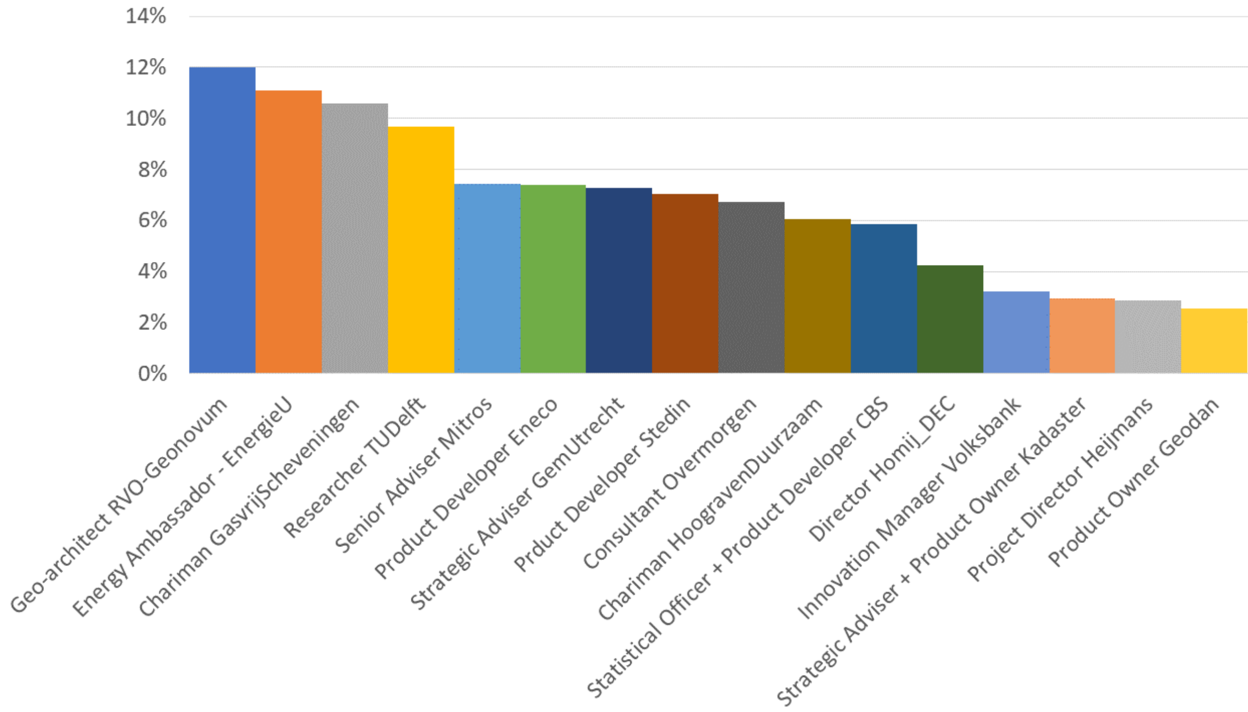


Figure 7.5: The relative interest expressed in the EPL by the interviewees, in % of the interview transcript

- f2: *provide decision making support and include assessment frameworks* - the EPL is expected to provide decision making support to the users and be equipped with an assessment framework which fits the stakeholder requirements and interests.
- f3: *capture and release data on the energy system and stakeholders in local data-bases* - the EPL is expected to capture and release data in a local data-base on various aspects regarding the technical energy performance, demand, generation, awareness, behaviour and preferences. This is, among others, necessary for the data-driven functionality f6, f10 and f11, but also for the validation of assumptions made on the local level due to the lack of data.
- f4: *provide means and services to find and acquire the relevant data and knowledge* - the EPL is expected to have adequate knowledge on the Data Ecosystem and be able to guide users towards the relevant data and knowledge and assist them in the acquisition, processing and utilisation of the data.
- f5: *guide the utilisation of existing tools and platforms* - the EPL is expected to have thorough understanding in the landscape of tools, instruments and platforms available to support the heat transition, and subsequently guide the users in the move towards, and the use of the suitable tools, instruments and platforms.
- f6: *progress monitoring* - the EPL is expected to provide the decision-makers of insights on the progress made in the energy transition, this is relevant for policy makers, but also citizens, to determine where the transition pathway requires adjustments.
- f7: *facilitate co-creation and knowledge exchange* - the EPL is expected to facilitate the co-creation process among citizens and stakeholders in the local heat transition policy making and execution. During this process, the EPL should support the knowledge exchange and capacity building among these stakeholders.
- f8: *support the definition of knowledge questions* - the EPL is expected to guide decision-makers in the definition of concrete and workable (e.g. for the data scientist) knowledge questions, based on the knowledge gaps, which are supported by the stakeholders.
- f9: *linking or connecting parties* - the EPL is expected to have an extensive network and be able to link the decision-makers with suitable data suppliers, service providers or partners.
- f10: *transition models and tools* - related to f2, the EPL is expected to be equipped, or have access to, models and tools on the building physics, inhabitant characteristics, environmental planning, behaviour and financing. These methods and models are to identify, analyse and assess measures to replace natural-gas and improve energy efficiency of households.
- f11:*provide data visualisation and analysis means* - related to f2 and f10, the EPL is expected to be equipped with, or have access to, sophisticated data analysis and visualisation technology.

It can be concluded that although it is appreciated that the EPL boast in-house models and tools, these are not among the most important functionality, with this functionality being on the lower end of the relevance spectrum. Recall that the functionality presented above, are presented in an order of decreasing relevance, whereby the relevance is measured by the references made to the functionality in the qualitative data. The stakeholders add more value towards the guidance in the utilisation of existing models and tools, instead of building and developing new models and tools. In table 7.1 it is presented to which functionality each interviewee attaches importance, or alternatively, which interviewees attach value to each functionality. From this table it can be observed that f1, f2, and f3 are by far the most widely referenced functionality of an EPL in the heat transition by the interviewees. When taking a closer look on these functionalities, it can be observed that although f1 or "enable experimenting with (policy) measures" is the most referenced functionality as it is presented first in the list above, table 7.1 shows that it is not the most widely referenced functionality. Functionality f3 or "capture and release data on the energy system and stakeholders in local data-bases" has the widest distribution in references. Nevertheless, for an EPL to be valued and attractive for a wide array of stakeholders, the inclusion of these three main functionalities is essential.

Table 7.1: EPL functionality relevance as indicated by the interviewees

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10	f11
CBS - Statistical Officer and Product Developer	✓	✓	✓				✓	✓		✓	
Eneco - Business Developer	✓		✓				✓				
EnergieU - EnergieAmbassadeurs	✓	✓	✓			✓					✓
GasvrijScheveningen - Chairman	✓		✓	✓		✓			✓		
GemUtrecht - Strategic Adviser		✓		✓				✓			
Geodan - Product Owner	✓		✓								
Heijmans - Project Director		✓	✓							✓	
Homij DEC - Director			✓								
HoogravenDuurzaam - Chairman		✓	✓								
Kadaster - Strategic Adviser and Product Owner	✓		✓							✓	✓
Mitros - Senior Adviser Technology	✓	✓	✓								
TU Delft - Researcher	✓		✓				✓				
Overmorgen - Consultant	✓		✓				✓				
RVO/Geonovum - Geo-architect	✓	✓	✓								
Stedin - Product Developer								✓			
Volksbank - Innovation Manager Sustainability		✓		✓		✓				✓	

7.2.2. ASSESSMENT REQUIREMENTS OF AN EPL

The interview framework included questions on the requirements of the EPL, where the interviewees were questioned on what criteria they would assess the added value and efficacy of the EPL as possible decision support service. Among the interviewees there was consensus that the most important criteria is that the EPL meets the user demands regarding the support in the heat transition. These demands are thus the EPL functionality as presented previously. Other than meeting the demand, following the analysis of the interview data in the NVivo software package, the research yielded the following requirements (presented in an order of decreasing relevance):

- r1: *findability and accessibility* - the EPL should be easy to find and gain access to by the user.
- r2: *high utilisation rate* - the EPL should have a high utilisation rate and assess all possibilities on how to make stakeholders enthusiastic to participate and keep participating with adequate levels of commitment and motivation.
- r3: *convenient and interactive user interface* - the user should conveniently, without much hassle, be able to utilise the EPL service, whereby sufficient interaction should occur with the user. For this requirement, interface means, both physical and digital, should be well assessed and implemented.
- r4: *data and service quality and detail level* - the EPL should utilise data of high quality, integrity and detail level, for the service to be of high quality.
- r5: *standardised data formatting* - the EPL should process and produce data according to accepted standards, in order for the data and results to be compatible with other local data-driven initiatives and activities.
- r6: *embedded in the process of decision-making and transition* - the EPL should be well embedded in the process of decision-making in the heat transition, whereby sufficient attention should be on the social aspects with respect to the behaviour of the citizens and governance of the process.

In table 7.2 it is presented to which requirements each interviewee attaches importance, or alternatively, which interviewees attach value to each requirement. Requirement r1 or the EPL "findability and accessibility" is the most referenced requirement as it is presented first in the list above, table 7.2 shows that it is also the most widely referenced requirement.

Given the link between the PL approach and the DE, and the derived functionality and requirements in the previous two sections, the proceeding section will present implementation recommendations to TNO for the EPL.

Table 7.2: EPL requirements as indicated by the interviewees

	r1	r2	r3	r4	r5	r6
CBS - Statistical Officer and Product Developer	✓	✓			✓	
Eneco - Business Developer	✓	✓				✓
EnergieU - EnergieAmbassadeurs	✓		✓	✓		
GasvrijScheveningen - Chairman	✓	✓	✓	✓		
GemUtrecht - Strategic Adviser						
Geodan - Product Owner			✓			
Heijmans - Project Director						
Homij DEC - Director						
HoogravenDuurzaam - Chairman	✓			✓	✓	
Kadaster - Strategic Adviser and Product Owner	✓		✓	✓		
Mitros - Senior Adviser Technology		✓				
TU Delft - Researcher	✓	✓	✓			
Overmorgen - Consultant	✓			✓		✓
RVO/Geonovum - Geo-architect	✓	✓	✓			
Stedin - Business Developer	✓	✓	✓	✓	✓	
Volksbank - Innovation Manager Sustainability						

7.3. IMPLEMENTATION RECOMMENDATIONS TO TNO

After presenting the link between the PL approach and the DE in section 7.1, and the main functions and requirements for an EPL in section 7.2, this sub-section proceeds with recommendations on the development and implementation of an EPL by TNO for application in the heat transition.

7.3.1. AREA OF EPL APPLICATION

In general, the activities of the interviewees where it is stated that support from the EPL is of added value and desired are (presented in order of decreasing relevance):

- Public Decision Making
  - heat transition planning - the heat transition Vision
    - Sequence determination of districts to be disconnected and the associated timeline according to which the disconnection should take place.
    - The optimal solution(s) derivation per district as alternative to natural-gas.
    - Execution plan of the decision on the district sequence and technology selection, this includes the non-technical aspects, such as awareness creation and collaboration.
  - heat transition execution, this entails the monitoring of the progress and the guidance in the adaptive actions on the execution of the previously mentioned heat transition Vision
- Private Decision Making
  - Research and Development on new products and services, and new project design and engineering. Needs here are targeting the citizen preferences, and system interdependencies for new products and services, to contribute in system integration.
  - Pilots and Living Labs, the need here is for a method and party to facilitate coalition forming and learning among the coalition with the ultimate aim to scale up pilots.
  - Exploration, maintenance, replacement and decommissioning: guidance in the citizen engagement and data provision on system performance for impact assessment of the decisions on a project life-cycle over the steps mentioned.

In terms of the governance hierarchy, there is a gap with respect to the organisation and support of energy policy and initiatives between the national level and the local level. There is thus an opportunity for the EPL to bridge this gap by aligning local initiatives and policy with national policy. This functionality is for instance relevant towards the Regional Energy Strategies (RES) and how to align the local initiatives to these RES. The spatial impact of energy measures proposed by the RES, and the impact of integration with local plans in the public space is input which is considered necessary for the RES to be realistic on the local content, and which can be provided via the EPL.

On the same note, the support to the municipality on how to cooperate with the local initiatives and provide space for them to flourish is also a question on the table of municipalities (Strategic Adviser, Municipality of Utrecht, 2018). The EPL can contribute by promoting the best practices of these local initiatives towards the other citizens in an aim to enable mass movement. In addition, by means of data-driven adaptive policy, the impact of the local initiatives can be mapped, while policy can be made on how to scale-up the local initiatives.

Finally, in demand-based services such as the provision of specific statistics by CBS, a large variety can be observed in the questions posed by clients active in a certain geographic area, such as municipalities. This is, among others, because different municipalities may be in different phases of the policy making cycle and the transition, leading to different knowledge levels or even different perceptions of the problem (Strategic Adviser, Municipality of Utrecht, 2018). For the EPL to be equally effective for all municipalities, it is important to include methods and tools related to the derivation of the knowledge level and the definition of the accurate knowledge questions.

7.3.2. The EPL development

The high variety in the demand by different municipalities and stakeholders, is expected to have an impact on the composition and organisation of the EPL. Based on this expected impact, the following is recommended for the EPL development:

- A core of analytical methods and tools which is stable, transparent and trusted among actors and stakeholders, subject to step-wise development in cooperation with industry partners and stakeholders. This will lead to an EPL which is supported, and contributes in coping with the challenge that data-driven methods are often difficult to comprehend, leading to poor confidence and trust in the results of data-driven methods.
- Of the functionality which is desired from the EPL, regarding for instance the analytics and transition models, a significant share can already, or partially so, be provided by certain platforms or the open source model Vesta MAIS. However, the interviewees are not sufficiently aware of these possibilities. It is proposed for the first step of the EPL, to link and optimise the utilisation of existing platforms and models in an coherent and inclusive approach for the EPL, and make this part of the analytical core of the EPL.
- Include methods to find the similarities between the needs and demands of actors and stakeholders, consensus on the problem definition, so these can be tackled by the core of analytics and decision support tools.
- Include variety and flexibility in the communication and visualisation methods so these can be deployed in line with the specific needs and characteristics of each stakeholder or stakeholder group.

7.3.3. Data in the EPL

Since the EPL depends on data-driven methods and tools, data quality and integrity, affects the quality and efficacy of the EPL. In the post-factual era, and in particular for policy that is intrusive and penetrates behind the door of citizens, such as energy policy, citizens are critical regarding the quality of the utilised data (van Veenstra and Kotterink, 2017)(Researcher, TU Delft, 2018). Hence, it is of great importance that not only should the data be easily accessible and in the adequate formats for convenient processing, analysis and visualisation in the EPL, but the data used should be of high quality, representative for the target group of the policy, sufficient detail, and up-to-date.

For adequate representativeness and detail of the data, it is of paramount importance for the data acquisition to be organised and executed in close cooperation with the citizens and stakeholders with clear communication on the purpose of the process and the data. For instance, the data with the purpose to derive insights on the support of the citizens for a certain measure or technology, needs to properly represent all groups in society, on the contrary to only the enthusiastic citizens being present at the information sessions organised to inform people on the alternatives for their district.

Poel et al. (2015) state that the utilisation of modern data-driven methods in policy making by governments is commonly aimed at enriching the statistics and insights they have, rather than facilitating co-creation. It is recommended for the EPL to be implemented in such a way that it not only contributes in the enrichment of statistics and knowledge of policy makers, but also to the actual co-creation of the knowledge base, policy implementation and the provision of services in the execution of the policy.

7.3.4. methods in the EPL

From stakeholders such as the municipality and citizen initiatives, there is a big demand for insights on the attitude of citizens towards current and future policy measures. Currently these parties do not possess over the adequate methods or tools to gain this information in a manner which is low-threshold for the data acquisition and enables a high frequency of data updating with a high coverage over the field of citizens and stakeholders. As a method aiding the energy transition, it is highly recommended to include such functionality in the EPL. For this function, sentiment analysis and social network analysis are believed to have potential in policy design and experimentation and policy implementation and evaluation (van Veenstra and Kotterink, 2017). Sentiment analysis can be defined as the process of computationally mining and analysing opinions, in order to derive insights on for instance the attitude of stakeholders (Pang et al., 2008). Social Network Analysis can subsequently contribute in measuring and analysing the structural properties of networks and relationships, yielding insights in the relations between the entities and how these can be approached for effective policy (Steketee et al., 2015).

7.4. CHAPTER CONCLUSION

In this chapter the Energy Policy Lab (EPL) by TNO was the subject of attention. In sub-section 3.7 the EPL was introduced, as an operationalisation of the PL approach for the energy transition, operating in a data-ecosystem in order to realise the data-driven potential. This chapter elaborated further on the EPL application in the heat transition by answering the following SQ:

> *What are the requirements and functionality of a data-driven method, such as TNO's Energy Policy Lab, to be of added value in the realisation of sustainable and inclusive Urban Thermal Energy Systems in the proposed Data Ecosystem 2.0?*

TNO is looking into the development of the EPL to facilitate the energy transition, and incorporate design science and ICT with the aim to research how local government, companies, citizens and other stakeholders can co-create policy to shape the energy landscape in their neighbourhood/municipality.

The following functionality of the EPL could be derived from the interviews: 1) experimenting with (policy) measures, 2) decision-making support and assessment frameworks, 3) capture and release energy system and stakeholders data, 4) means and services to find and acquire the relevant data, 5) guide the utilisation of existing tools and platforms, 6) progress monitoring, 7) facilitate co-creation and knowledge exchange, 8) support the definition of knowledge questions, 9) linking or connecting parties, 10) transition models and tools, and 11) data visualisation and analysis means.

How well the EPL performs in providing these functions is stated to be the main criteria to assess the efficacy of the EPL, furthermore, the following requirements are derived from the qualitative data: 1) findability and accessibility, 2) utilisation rate, 3) convenient and interactive user interface, 4) data and service quality and detail level, 5) standardised data formatting, and 6) embeddedness in process of decision making and transition.

Finally, it could be concluded that much of what the interviewees require in terms of functionality can already, or partially so, be provided by certain platforms or the open source model Vesta MAIS. However, the interviewees are not sufficiently aware of these possibilities. It is proposed for the first step of the EPL, to link and optimise the utilisation of existing platforms and models in an coherent and inclusive approach for the EPL.

8

Discussion and Conclusion

This final chapter concludes the thesis with the research conclusion, where the research questions will be revisited and concisely answered. After summing up the main findings, these findings are assessed and placed in the context of the wider scientific body on the Urban Thermal Energy Systems, data-driven decision-making, Big and Open Data Ecosystems, and Policy Labs. The contribution of the results will be presented, together with recommendations on how to further improve the knowledge by both policy makers and academics, but also the limitations of this study are addressed.

8.1. Conclusion: the main findings

The main research objective of this thesis was:

> To research the current Data Ecosystem (DE) in the Dutch heat transition and propose a DE 2.0 taking into account the shortcomings and challenges of the current DE and the data needs of methods and tools to support the stakeholders.

Following the research objective, the research question for this research is described as follows:

> *How and under which Data Ecosystem can Open and Big Data be utilised to improve the information provision and support decision-making in the transition towards a sustainable urban thermal energy system, in the Netherlands, given the perceptions and resources of stakeholders?*

The main research question was divided in 6 sub-research questions (SQ), each contributing input to answer the main research question. In the following paragraphs a concise answer is provided for each SQ.

> 1. What are the socio-technical characteristics of urban thermal energy systems, with the associated actors and roles?

The answer to this question is provided over two chapters, in chapter 2 the technical part of the socio-technical system is derived from literature, while in chapter 5 the social side of the socio-technical system is sketched based on the empirical data.

For the Dutch heat transition in the Urban Thermal Energy Systems, an extensive field of technologies at different states of maturity, sustainability and affordability, and with different characteristics on the energy source, temperature, and being an individual or collective system can be identified. This technology poses ample opportunities to shift toward a low-carbon urban thermal system, however, the need to invest in, and adapt to these alternatives for natural-gas is met with significant challenges and barriers. The challenges can be summarised in high capital and installation costs and the allocation of cost among public and private parties, the perceived low technological maturity, uncertain operational costs, house space requirements, and noise pollution. In addition, passivity, hassle, and a lack of interest or knowledge on the alternatives are commonly stated as barriers. These challenges will be further studied in chapter 5 on how they are encountered in the Dutch situation.

The socio-technical system around the heat transition can be described as very extensive, actors and stakeholders can be divided over roughly seven categories: citizens, government, government authorities, market (construction, technical installation, energy utility and service, etc.), Intelligence (research and advisory), Real-Estate (developers, intermediates, and housing corporations), and Other (from network operators to financial institutions and local citizen initiatives). This extensive field of actors and stakeholders operate in an equally extensive field of technologies, to make decisions, invest and adopt alternatives for natural-gas in the heat supply.

In the actor and stakeholder field, one of the most interesting findings is that many of the actors and stakeholders are still in the process of comprehending the problem of natural-gas in the built environment and searching for their role to realise this. Given that these stakeholders are not yet aware of their role, it is also unclear what resources they have available for the heat transition, while their attitude towards the transition is broadly varying and unstable over the field. It is commonly mentioned that the government should be establishing the facilitating conditions, this will provide the stakeholders of clarity on their role, after which they can proceed to decision-making in the heat transition.

From the DE perspective some clear roles can be distinguished, for instance Stedin as network operator is taking the role as data supplier because their legal status forbids them to add value to the data. The municipality with the heat transition vision, and utility companies are taking the role as data user in supporting the planning and development activities in the heat transition. Kadaster and CBS are establishing themselves as true Data intermediates, whereby the role entails, on the one, hand DE organisational aspects regarding the establishment and maintenance of databases and the facilitation of the stakeholders involved in that process. On the other hand, there are the data aspects where they add value to data and release data for users to process. The role of standards organisations is an important one in DE to ensure data quality and interoperability, however such an authority only exists for government geo-data. For other data types this role is still vacant, yet badly needed.

> 2. Among the decision-making of the actors and stakeholders for heating in the built environment, what knowledge is lacking, hence preventing effective decision-making?

From the empirical data it can be concluded that the stakeholders often address challenges in co-occurrence with knowledge gaps. In other words, many of the challenges in the heat transition are a consequence of lacking or sub-optimal knowledge, entailing inadequate information provision to the decision-makers responsible and accountable for decision-making in the heat transition, and stakeholders affected by these decisions. The identified knowledge gaps can be defined over five main themes: 1) the energy system and environment, 2) the data ecosystem, 3) dwellings and end-users, 4) market and economic aspects, and 5) the decision-making process.

Of these categories, the most knowledge gaps, measured by the variety that can be derived from the empirical data, fall under the themes of 1) the energy system and environment, and 2) the dwellings and end-users. In particular, very little is known about 1) the detailed characteristics of dwellings that impact the potential and costs of retrofit and thermal installation upgrades, 2) the perceptions and attitude, leading to the willingness to participate by the citizens and building owners, and 3) the preferences of stakeholders for natural-gas alternatives and their role in the heat transition.

> 3. How can a DE be composed and how does the current DE look like for the Dutch heat transition, what are the shortcomings and challenges?

This SQ was answered in two chapters. First in chapter 3, sub-section 3.2.6 the DE framework was presented, consisting of five elements related to the Data Life-Cycle: 1) Data capturing and pre-processing, 2) Data release, 3) Data and license search, view and assessment, 4) Data cleaning, linking, analysis and visualisation, and 5) Data discussion and feedback. Moreover three elements related to the organisation of the DE: 6) Quality assessment system, 7) Meta-data to link elements , and 8) Use-case promotion. Furthermore these elements are surrounded by the technological context, the regulatory context and the data-stakeholder context consisting of data suppliers, data users, and data intermediates. Finally, challenges and barriers are derived on the elements in the DE related to the life-cycle of Big and Open Data for local policy and decision-making.

The second part of the question, how does the current DE look like, is answered in chapter 6, section 6.1 where the current DE was sketched based on the case of the heat transition in Utrecht, and the study assessed 1) the process of declaring Overvecht-Noord as the first district to be disconnected from natural gas, and 2) the regional study with the national Vesta MAIS model for the impact assessment of dwelling and spatial measures. Of the 7 elements, the current Data Ecosystem is particularly falling short in the Data feedback, Meta-data, Use-case promotion and Quality management system. In addition, the data feed is sub-optimal whereby, in particular, little to no data is included on the demand side.

> 4. Which Open and Big data sources are currently, or could potentially, be made available to support evidence-based policy and decision-making by targeting the knowledge gaps derived in SQ 2, and what are the barriers for the utilisation of this data?

This study produced an extensive, but not exhaustive, inventory of data-bases currently available, with relevance for heat transition decision making. A total of 24 data-bases are presented in this inventory, categorised over: supply side data, demand side data, building stock data and energy statistics data. It can be concluded that the majority of the data openly available nowadays is on the supply side. The infrastructure data for distribution and storage is also openly available. However, on the demand side, including the dwelling characteristics and the end-user characteristics and behaviour, there is little data captured and released as open data. A significant share of the demand data thus remains to be released, while there also is data with great potential which remains to be captured, namely: 1) citizen preferences and attitudes towards the alternatives for natural-gas and retrofit measures, and 2) data on dwelling envelope retrofit and thermal installation measures already conducted in dwellings.

Besides the data-bases, an inventory is produced on the data platforms or portals targeting energy, and in particular heat. This inventory yielded 9 platforms with varying functionality and data feed. It could be concluded that when placing these platforms and data-bases in the context of an ecosystem, there already is a very rich ecosystem. However there is very little known on the links and interaction between the platforms and data-bases. This means that several platforms have redundant functionality, while other platforms complement each other with their functionality. However, because the overview of the ecosystem is poor, opportunities to jointly utilise platforms are left unexploited.

Finally, the research on the challenges and barriers experienced when utilising these data-bases and platforms resulted in: 1) restricting (privacy) legislation, 2) data ecosystem barriers e.g. difficult and cumbersome data search and acquisition and poor data quality and detail level, 3) stakeholder barriers, e.g. lacking willingness to share data, and 4) high perceived costs. These challenges and standards were found to be in line with what is found in literature and are taken into account for the design of the DE2.0 in chapter 6.

5. Through which technology and/or methods can the missing data identified in SQ 2 be acquired, and the DE be improved towards the DE 2.0 proposal?

The interviews yielded three technologies or methods to obtain the missing data or improve the insights from the current data. First, *Blockchain* provides opportunities to store, organise and exchange data, while effectively addressing challenges regarding transparency, trust, data quality and integrity, security, and data access (Karafiloski and Mishev, 2017).

Second, *Big and Open Linked Data or BOLD*, as presented by Janssen and Kuk (2016) offers attractive opportunities for enhanced insights from distributed and diverse data in the context of the heat transition and the current DE, with heterogeneous data formats, scattered distribution of data, and missing data.

Third, *CrowdSensing or CS*, is a possible means to include the citizen participation and gather citizen data to embed the stakeholder and citizen engagement in the evidence-informed approach. CS can be described as a new paradigm to efficiently acquire data by means of the sensors embedded in, among others, the wide-spread modern-day mobile devices.

Where these technologies offer endless possibilities, and pilots are run by the more progressive actors in the DE, such as Kadaster, many challenges and barriers are encountered on both the technical side, e.g. the scalability of the system and to control and guarantee the quality and integrity of the data transferred over BC, but also on the social side, e.g. how to embed these technologies in society and how should decision-making processes and structures need to change to benefit from these technologies. These challenges and barriers require further research, for the technologies to play a significant role in the future DE.

6. What are the requirements and functionality of a data-driven method, such as TNO's Energy Policy Lab, to be of added value in the realisation of a sustainable and inclusive residential heat system in the proposed DE 2.0?

TNO is looking into the development of the EPL to facilitate the energy transition, and incorporate design science and ICT with the aim to research how local government, companies, citizens and other stakeholders can co-create policy to shape the energy landscape in their neighbourhood/municipality.

The following functionality of the EPL could be derived from the interviews: 1) experimenting with (policy) measures, 2) decision-making support and assessment frameworks, 3) capture and release energy system and stakeholders data, 4) means and services to find and acquire the relevant data, 5) guide the utilisation of existing tools and platforms, 6) progress monitoring, 7) facilitate co-creation and knowledge exchange, 8) support the definition of knowledge questions, 9) linking or connecting parties, 10) transition models and tools, and 11) data visualisation and analysis means.

How well the EPL performs in providing these functions is stated to be the main criteria to assess the efficacy of the EPL, furthermore, the following requirements are derived from the qualitative data: 1) findability and accessibility, 2) utilisation rate, 3) convenient and interactive user interface, 4) data and service quality and detail level, 5) standardised data formatting, and 6) embeddedness in process of decision making and transition.

Finally, it could be concluded that much of what the interviewees require in terms of functionality can already, or partially so, be provided by certain platforms or the open source model Vesta MAIS. However, the interviewees are not sufficiently aware of these possibilities. It is proposed for the first step of the EPL, to link and optimise the utilisation of existing platforms and models in an coherent and inclusive approach for the EPL.

THE MAIN RESEARCH QUESTION: DATA ECOSYSTEM 2.0

After addressing the sub research questions, and gathering all necessary knowledge, the main research question, presented earlier in this section, can now be answered. On the question how and under which Data Ecosystem Open and Big Data can be utilised to effectively improve the information provision and hence accelerate the heat transition, the Data Ecosystem 2.0 is presented below in figure 8.1.

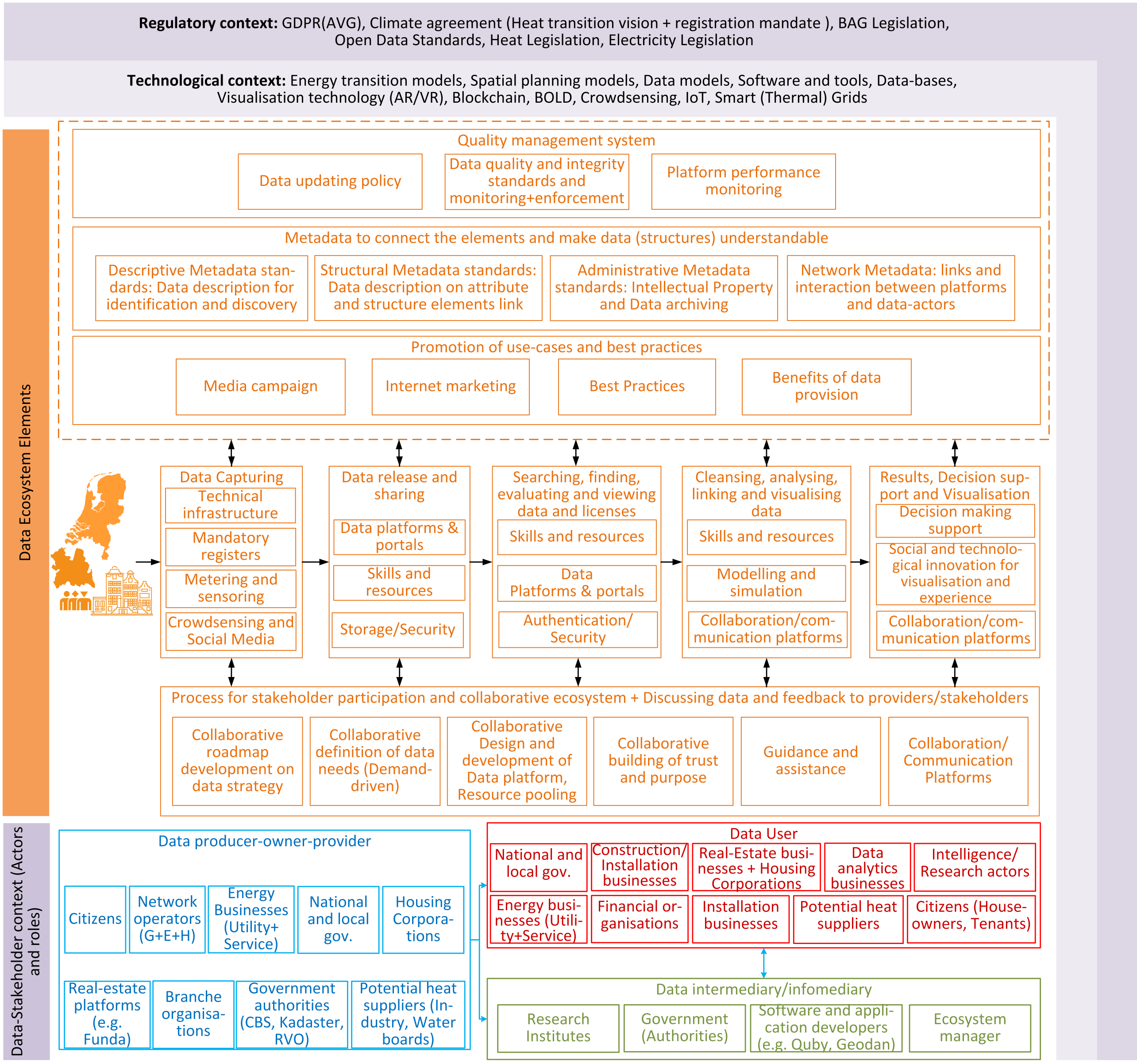


Figure 8.1: The new Data Ecosystem 2.0 proposed for the heat transition in the Netherlands, own figure

DE 2.0 takes into account the shortcomings of the current DE, the data needs derived from the knowledge gaps identified among the stakeholders in the heat transition, the inventory of available data-bases and platforms, potential technologies, but also the challenges and barriers experienced.

The DE for the heat transition is in its infancy phase at this point with challenges, barriers and shortcomings in all elements as proposed by the DE framework derived from literature and presented in sub-section 3.2.6. Of the eight elements, the current DE is particularly falling short in 1) the Data discussion and feedback, 2) Meta-data, 3) Use-case promotion and 4) Quality management system. In addition, the data feed is sub-optimal whereby, in particular, little to no data is included for the demand side on the citizens. Currently, energy transition models such as Vesta MAIS utilise available data-bases and the available platforms are casually used by stakeholders in an attempt to visualise and comprehend the challenges in the heat transition. To this point, actual decision-making has not been supported adequately in a data-driven way from the technological context. This can be assigned to the technology being in its infancy, governance and decision-making processes not completely embracing data-driven support, but also the lack of critical data, mainly on the demand side. Where the technology is steadily improving, these technologies in the field of data analysis and visualisation are not relevant without that adequate data supply. In order to establish a DE which effectively supports the decision-making for the heat transition, the lacking data supply on heat demand, dwelling characteristics, and citizen attitude and perceptions requires the main focus. This will require, not only stable and adequate data infrastructure and technologies such as BC, CS and BOLD, but also an adequate quality management system, new roles such as the DE Manager, and a process for stakeholder participation and DE collaboration.

In the DE 2.0 a new element is thus proposed, namely the process for *stakeholder participation and DE collaboration with data discussion and feedback*. This process aims to contribute in increased involvement of the stakeholders, leading to a better familiarity with the ecosystem, but also fosters trust among data suppliers for an improved willingness to share data. Moreover, this element also inherits data discussion and feedback. By doing this along the DE, first, the quality of the data and infrastructure is continuously assessed and ideally improved, and second, continuous interaction enables a DE which is aware of the specific data needs, and targets those data needs effectively and efficiently.

Finally, new roles are proposed, among others, that of the Data Ecosystem Manager. Not only is that entity responsible for data standards and quality assurance, but also to coordinate the previously mentioned process of stakeholder participation and DE collaboration.

The next section places this research and the main findings in the wider context of earlier research and provides a discussion of these results and the overall methodology.

8.2. DISCUSSION

This final section will discuss the main findings of this research in the wider context of existing literature, subsequently the limitations of the research are presented. Furthermore, the societal and scientific relevance will be revisited, and recommendations will be provided towards policy makers and future research. Finally a reflection of the study program CoSEM in relation to this research is presented.

8.2.1. DISCUSSION OF THE FINDINGS

Previous studies on the knowledge gaps and information provision in the energy transition, see for instance Dekker et al. (2019) on the information provision towards the Dutch energy transition, present knowledge gaps which predominantly address the supply side. On this supply side, potential data sources are mapped with regards to the potential and cost factors of sustainable heat sources such as geothermal and solar energy. Accordingly, Dekker et al. (2019) propose infrastructure, services and products developed on this supply side. However, empirical data collected by this study indicates that it is the demand side which is poorly mapped at this point. This forms an issue as the bottom-up and highly diverse nature of the heat transition requires ample knowledge on the preferences and attitude of end-users. This is in particular the case in a transition, where not every end-user is equally enthusiastic and aware of the needs and urgency behind the transition. Local approaches need to do justice to the willingness of each citizen and stakeholder to participate and have an active role. To this end it is necessary to attain up to date information of the preferences of these stakeholders regarding their role and participation.

A fair share of the commonly mentioned challenges and barriers in literature on Big and Open Data in energy systems, are also found to be present in the derived challenges and barriers encountered in the current DE in the Dutch thermal system by this research. For instance recurring barriers such as inconvenient data access, poor findability, inadequate or poor data availability, and Lacking data standards, as presented in leading work for Open and Big Data in energy systems by Chen et al. (2017), Göçer et al. (2016), Linder et al. (2017), Mathew et al. (2015) and Reinhart and Davila (2016), are confirmed by the interviewees. However, new barriers surfaced from the empirical data on the heat transition in the Netherlands. Barriers such as: distrust among citizens leading to poor willingness to share data, contradicting policy requirements and legislation, and the dispersed character of data over various platforms and owners, are not found to be reported in literature before.

Data-driven research on building energy performance is found to be predominantly on utility dwellings, see for instance Miller (2017). This can be assigned to the higher homogeneity, better availability of data, and often greater potential for energy savings in the case of utility dwellings. On the residential side, the challenges to obtain quality data are commonly experienced as greater relative to the utility dwellings. Moreover, this research surfaced certain challenges which are not found and taken into account in the existing DE literature and literature on the challenges and barriers regarding data-driven approaches for residential dwellings. For instance, due to the intrusive nature of energy policy, a high level of importance is attached to the quality of data used for data-driven decision making. In addition, the lack of trust among citizens to share energy consumption data with network operators, which have the metering infrastructure installed to obtain that data, is a unique challenge.

The reported lack of case studies in the field of DE, is addressed by this research. It could be shown that DE elements presented by DE literature are indeed considered as relevant in the case of the heat transition. Moreover, it could be exhibited that although the importance of these elements is acknowledged, real life DEs are lacking in the organisational elements. For the Urban Thermal Energy System DE, it was found that the element of a quality management system is a critical absentee, resulting in recurring challenges with respect to data quality and integrity. Finally, among studies proposing elements on effective DE, such as Demchenko et al. (2014), Mercado-Lara and Gil-Garcia (2014), Zuiderwijk et al. (2014) and Shin and Choi (2015), it can be observed that none address both Big and Open Data Ecosystems as the focus is on either Big or Open Data. The study presented in this thesis took an integrated approach, looking into both Big and Open Data, due to the nature and scale of data in the Urban Thermal Energy System. As a result the derived DE analysis framework and the DE 2.0 design form a more comprehensive picture, where both Big and Open data are considered, and where the scope reaches further than technology, towards the Data-Stakeholder context and the Regulatory context.

8.2.2. RESEARCH LIMITATIONS

This research yielded interesting findings on the information provision in the heat transition, nevertheless, there are limitations related to the research methodology and resources available. These limitations will now be addressed, to be taken into account by future research.

CHOICE OF THE DATA ECOSYSTEM APPROACH AND LIMITATION

The Data Ecosystem approach is a fairly novel approach which takes a very broad view on objects, actors and interactions to include for and around data-driven strategies. This is a strength of the DE approach, enabling a comprehensive understanding. However, a limitation is that this approach stays on the meta-level. Hence, further research is necessary to operationalise findings from the DE approach on the data infrastructure and activity level. Recommendations on possible future research, with the findings from this study as the starting point are presented in sub-section 8.2.4.

LIMITATIONS ON THE CHOICE OF INTERVIEWEES AND THE CODING

The selection of the interviewees is guided by the field of relevant actors and stakeholders which could be derived from the first round of three exploratory interviews. Based on the proposed field, an interview strategy was set up containing the interview protocol and the criteria which interviewees should comply with. This selection method required significant resources to find and approach the desired interviewees. As a result, this research did not manage to interview all stakeholder in Urban Thermal Energy Systems. For instance, the potential heat suppliers such as the sewage and waste water entities and industry, and the businesses developing data-driven solutions for both public and private parties, are not interviewed in this research. From the latter, businesses developing data-driven solutions, participation was difficult to arrange because these parties are all in a very competitive market at this time and are hesitant to provide information on their vision and products.

All with all, high confidence was placed in the richness of the information derived from the interviews, as the main means of data collection, to surface the relevant findings on the complex challenges and barriers in the heat transition, and the social interactions among stakeholders at the basis of data exchange. These interviews were conducted face-to-face or over (video)call. However, a limitation of qualitative case studies may be related to the interpretivism, where Miles and Huberman (1994, p. 281) talk about "person-specific, artistic, private/interpretive acts which cannot be viably verified or replicated by others". This limitation can be related to the data treatment in this research and the lack of coding verification, due to the fact that the interview data was only coded by the author. Discussions and verification did take place on the definition of codes and the derivation of themes, however the actual assignment of the codes to the interview data was subject to the author's interpretation of the interview data.

OTHER LIMITATIONS

On the heat transition case in Utrecht, but also on data platforms in the Netherlands and the DE in Urban Thermal Energy Systems, little to no scientific literature is available. This resulted in the use of non-scientific, or grey literature, for the Utrecht case and DE elements in the Netherlands.

The DE framework derived from literature and the application of this framework to design the DE 2.0 did not undergo the thorough validation as would be desired. The validation was twofold. First, both the DE framework and DE 2.0 designs were made subject to expert validation where the completeness and topicality were assessed. Second, the DE framework underwent empirical validation by applying it on the Utrecht case and by assessing in the interviews if the DE elements are acknowledged by the interviewees. This validation can be improved by increasing the participants in the expert validation, and applying the framework to different municipalities to compare the generisability of the Utrecht case.

This study targets the data-driven support in the heat transition and aims to provide an as complete as possible picture on the relevant data types and the technical aspects around the data life-cycle in Urban Thermal Energy Systems. However, it should be mentioned that due to the meta-level of the analysis, the total of data types included in the study is non-exhaustive and subject to fast development.

Finally, the study derived challenges and barriers encountered in the heat transition and the data-driven support thereof. Although these findings provide a rich picture on these challenges and barriers, the results cannot be directly generalised to the organisation represented by the interviewee. The challenges and barriers mentioned might be based on personal experiences or limited to the department in which the interviewee is active, whereas the rest of the organisation might not encounter these challenges and barriers, or they might encounter different challenges and barriers.

8.2.3. Scientific and Societal relevance

Societal Relevance

After presenting the results of the study in this thesis, the author remains confident that this research indeed delivers in the initially anticipated societal relevance of contributing in the improvement of the information-provision in the heat transition to eventually accelerate a cost effective, future-proof, and inclusive heat transition. This contribution takes place via the DE insights where the data landscape is sketched according to the challenges and barriers in the heat transition, but also via the contribution to the EPL by TNO which aims to improve local climate policy to be in line with the current day dynamics and complexity of local energy systems.

Scientific Relevance

Over the course of this research it became apparent that energy policy research is lacking behind other sectors in promoting open and reproducible data strategies and methods (Pfenninger et al., 2017, Poel et al., 2018). To that regard, this research directly contributes to the scientific body on the role of Big and Open Data in specifically local energy policy.

Where the field of DE is well covered on a conceptual level, e.g. the research by Zuiderwijk et al. (2014) on the essential elements in a general Open DE, there is little research on DEs within the field of energy. A search for the key-words of "Data Ecosystem" and "energy" in several combinations, yielded one result, namely the study by Kontokosta (2013) on energy disclosure regulation to transform the market for energy efficiency. Further searches on the release and utilisation of Open and Big energy data yields more results, for instance in the area of smart electricity grid research, however not through the comprehensive approach like the DE approach to take into account the complexity and dynamics of local thermal energy systems. Hence, this study contributes to the existing literature on DEs with the body of knowledge developed for the specific case of the heat transition in the Netherlands. This specific case application, takes the field of DE research into more depth on for instance the interrelations between the entities involved and how this impacts data disclosure and utilisation.

Furthermore, where previous studies on data-driven approaches in the energy transition mainly accounted for open and geographic data on energy potential and energy assets, this research includes the perspective of the citizens and how data from these citizens with potential insights on their attitude and preferences can enrich the DE in the heat transition. With this, this research contributes in filling the gap on the role of end-user energy data in energy policy research for thermal energy systems.

Finally, the established inventory on Big and Open data and data platforms or portals available for application in the heat transition, provides researchers looking to engage on data-driven research with an overview of the available data. In this way the research contributes to kick-start future data-driven heat transition research in the Netherlands, with an improved understanding on the available data, and of the DE with the stakeholders involved and the complex interrelations.

8.2.4. Recommendations

From the main findings of this research, recommendations can be made towards the policy makers in the heat transition. These recommendations address how the proposed DE 2.0 can become reality. In addition, based on the main findings, but also new research questions which surfaced during this research, recommendations will be presented to spark future research.

RECOMMENDATIONS FOR POLICY MAKERS

The following recommendations can be made towards policy makers involved in both the heat transition information provision and general governance reform towards data-driven strategies:

- **Target social innovation with data-driven methods and tools:** In the context of the heat transition in urban thermal energy systems, the main recommendation is that data-driven support for policy-making should reach further than the generation of facts and statistics on the supply of sustainable heating such as geothermal well capacity and cost factors, or DHN and its connected heat sources. A bigger role should be fostered in an underestimated aspect of the heat transition, namely social innovation. This will equip the policy makers with improved tools to cope with the challenges of varying and contradicting perceptions, levels of awareness and willingness to participate. In situations where it would be desired, but not realistic to directly involve each and every citizen in heat transition decision-making, data-driven methods and tools provide endless possibilities to gain insights on the social transition dynamics and interact with the citizens in an effective and low-threshold manner. Hence, it is recommended to policy makers to partly shift the attention from data on the supply side, towards the demand side and the citizen characteristics. In order to realise this, by means of capturing and utilising the necessary citizen data and enabling the desired interactions, it is recommended to establish the necessary changes in the DE accordingly. These changes target the data infrastructure and technology regarding the data value-chain, but moreover, the regulatory context to establish a regulatory basis for data release mandates for end-users, and extended authorisations towards data-intermediaries such as the network operators.

- **Foundation of the DE Manager and the Quality Management System**: To coordinate the development of an effective DE, with an adequate Quality Management system to cope with issues on data quality and integrity, standards and utilisation, it is plead to enable the role of the DE Manager. In the national program to improve the information provision in the energy transition, these tasks are proposed to be carried out by a Data Commission, consisting of experts from key stakeholders, namely: Ministry of Economic Affairs and Climate, Ministry of Internal Affairs and the Kingdom Relations, CBS, Kadaster, PBL, Rijkswaterstaat and RVO (Dekker et al., 2019). In this proposal, the sole participants in the Data Commission are public parties and Data Intermediates according to the role definition in this research. However, from the DE approach it is recommended to expand the composition of this DE Manager with representatives from: 1) the data suppliers, e.g. the network operators, 2) the data users, e.g. the energy utility and service businesses, and 3) the standards organisations, i.e. Geonovum. With this composition, the relevant interest are represented in the DE Manager, fostering comprehensive DE organisation and management.

- **Establish the regulatory basis through climate policy:** For the DE to evolve with a rich supply of data to increase the role of data-driven methods and tools, a sound regulatory basis is essential. This regulatory basis should target the parties releasing data, such as data release obligations for the citizens, the data-intermediaries, such as extended data-processing authorisations for the network operators, and data-users, such as data security measures for energy utilities. The establishment of the Data Quality System and the DE manager, as proposed in this research, are recommended to be founded via this regulatory basis. To establish this regulatory basis, it is recommended to utilise the momentum which is currently present in climate policy. In particular the Climate Agreement, the Environmental Code, and to a lesser extent the Regional Energy Strategies, can provide the regulatory framework to embed the regulatory basis for data-driven strategies and an advanced DE.

- **Prioritise the low hanging fruit:** Where the regulatory basis will contribute towards the realisation of the advanced DE on the medium- to long term, recommendations can also be made on steps which can improve the state of the DE on the short term with relatively less effort. Given the encountered challenges of dispersed data distribution and the consequent issues related to data quality and interoperability, surfaced by this study, it is recommended that the short-term focus of policy makers should be on the consolidation and improvement of existing data sharing and utilisation platforms and portals. Hereby, on the contrary to the trend of initiating new and specific data initiatives, which only adds to the disperse nature of the DE and the challenges to navigate the DE, adequate efforts should be guided towards the understanding and communication of existing links and relations between data initiatives, and the promotion of the functionality and added value of these platforms. Eventually, these efforts aim to increase the familiarity of the current DE and improve the utilisation of the existing facilities and infrastructure, while interest and momentum is created to engage on the mid- to long term development of the future DE.

RECOMMENDATIONS FOR FUTURE RESEARCH

After addressing the recommendations towards the policy makers, the following presents recommendations towards future research, based on the findings of this research and the new research questions surfacing from this research:

- This research was kept on an exploratory level regarding the willingness of citizens and stakeholders to release and utilise data. Due to the lack of quantitative data, no statistical statements can be made regarding the relations between the factors and the relative importance and impact of each factor. It is recommended to extend the research on the willingness to share energy and dwelling data to the statistical level and quantify the importance of the factors.
- The technologies explored to have potential in closing the gaps between the current and desired DE, e.g. BC, BOLD, and CS, are found to still pose major barriers in their current state of maturity. No research could be found on, in particular the application of BC for secure and reliable data exchange and storage in energy systems, while pilots in the Netherlands with this technology have surfaced major challenges regarding its practicality and scalability. Hence, it is recommended to initiate research on the implementation of these technologies, for the socio-technical needs and characteristics of the heat transition, regarding both the technological and operational aspects, as well as the societal embeddedness.
- Commercial parties possess important data which can significantly contribute in data-driven public decision support if that data becomes available. However, it was stated as a challenges that businesses in the energy sector are not aware of how to quantify the value of releasing their data, hence cannot develop profitable businesses propositions to release data as a commercial asset. Subsequently, it is recommended to study possible strategies and business cases for commercial parties in the energy sector on how data can become a business asset, in order to incentivise the commercial parties to release this data, enrich the DE, and improve the information provision.
- Finally, another field of research can be on how to embed the DE findings in policy making, in other words, research on policy measures which enable the realisation of the proposed DE 2.0 in the operational spheres of the Dutch heat transition. Relevant aspects here are: models for subsidies or alternative incentives, organisational models for the DE manager, and governance models for common data infrastructure.

8.2.5. REFLECTION ON THE LINK WITH THE COSEM PROGRAM

This research is conducted in the context of the Master program in Complex Systems Engineering & Management (CoSEM). In short, it can be stated that this program not only provided the author with the necessary tools to tackle a complex challenge such as the heat transition, but also the appropriate mindset to do so. The appropriate mindset entails, among others, the multi-actor system (MAS) perspective to comprehend the multi-actor and multi-disciplinary characteristics of urban thermal energy systems and its information provision by means of data-driven strategies. Characteristics which are at the essence of the complexity in heat transition, and which require thorough understanding before engaging on any successful pathway towards realising the transition. In particular the courses which specifically targeted this MAS perspective were: Designing MAS from an Engineering Perspective (SPM4123), Designing MAS from an Actor perspective (SPM4133), and MAS Design: an Integrated View (SPM4142). The CoSEM program also provided in much of the necessary domain knowledge to comprehend the technical aspects of the heat transition, courses which target these aspects are: Design of Systems in Energy and Industry (SPM4510), Technology and Economy of Future Energy Systems (SPM4540), and Systems Innovation in Energy and Industry (SPM5530).

In addition, the domain specialisation brought together like-minded students with interest in sustainability and the energy transition, and drives them to develop and train the necessary skills to accelerate this transition. The methods of education, which included a large share of team-work provided the author with valuable interaction with these like-minded student to further shape and sharpen the understanding and opinion of the author in these subjects.

8.2.6. PERSONAL REFLECTION

Finally, it can be stated that this research has been experienced as a very dynamic and challenging process, where the author has experienced a significant growth in maturity regarding the management of a research project. Initially the ambitions were set too high, and this turned out to be unfeasible with the resources available. In addition, the current state of the heat transition, characterised as uncertain and highly dynamic added to the necessary iterative approach in adjusting and executing the research approach. During the research, the author engaged in many relations with actors in the heat transition. These relations have a sustainable character, where due to the interest in the research expressed by the interviewees, interest is also expressed to further elaborate on the relation in future research and undertakings. This drives the author to remain involved in the field of study and contribute in solving the challenges of these actors in the heat transition.

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A

Interview Questions

A.1. Example of an Interview protocol with the Strategic Adviser at the Municipality of Utrecht

A.1.1. Procedure

First of all, the researcher wants to express his gratitude to the respondent for taking the time to take this interview. The interview will be limited to 90 minutes and, only with the respondent's consent, it will be recorded for analysis. Recording the interview will provide the interviewer with the necessary possibility to focus on the questions and keep the flow in the interview. In the proceeding sub-section A.1.2 the interview questions are presented in Dutch, the interview will also be conducted in Dutch, unless the respondent desires otherwise. After the analysis, the researcher will send the respondent a brief report with the points out of the interview which want to be either used in the results or quoted in the report, for validation by the respondent. Finally the results of the analysis are documented in the thesis and the respondent will be provided with a digital copy of the thesis, once the thesis is successfully defended.

A.1.2. Interview questions

1. How would you describe your role at the municipality of Utrecht?
2. How would you describe the role of the municipality of Utrecht in the heat transition?
3. What are the three largest challenges in the heat transition according to you?
4. What would you say are the most important knowledge gaps which challenge your role in the heat transition and require more attention and research?
5. Which actors/stakeholders do you currently consider necessary participants for the heat transition?
6. Which of these actors/stakeholders should pick up a more active role? What should that role be?
7. Can you elaborate on how the municipality is involving and engaging stakeholders, and in particular the citizens/end users, in the policy-making and decision-making on the the heat transition?
   (a) During which moments are these stakeholders involved?
   (b) To what extent do participants want to be actively involved in the decision-making on neighbourhood level?
   (c) How would you say, can this interaction be improved?
   (d) Where is extra support and expertise required?
8. How much experience do you have with collecting/saving/analysing or in general working with data ((Linked) Big and Open Data) in the daily operations [1...10]?
9. Can you name some of these activities where you work with data?
   (a) what data sources do you use?
   (b) which data platform or portal are used?
   (c) which software/technology is applied for these activities?

10. Can you tell me more about the interaction/cooperation between the municipality of Utrecht and organisations which generate and manage databases such as CBS, Kadaster etc.?
11. What are barriers to utilise Linked Big and Open Data of any kind, for the municipality of Utrecht and broader within the heat transition related research?
12. What functionality should the Energy Policy Support Lab (EPSL) be able to perform to be of added value for the municipality of Utrecht and the relevant actors to make good decisions and reach the goals in the heat transition?
13. On what criteria would you assess whether the EPSL is of added value for the heat transition?
14. What data is necessary according to you for the EPSL to fill these functions?
15. What do you see as relevant (existing or potential) data which you could supply to the EPSL in supporting the heat transition for all relevant parties?
16. What is your willingness towards sharing data with:
    (a) the citizens [1...10]
    (b) research institutes and universities [1...10]
    (c) other commercial parties (energy companies, construction companies) [1...10]
17. What are barriers to share this data with the above-mentioned parties?
18. What data from citizens/end-users do you see as necessary to enable co-creation among the relevant stakeholders of decision making in the heat transition on for instance collective or individual investments in energy-saving retrofits and heating and/or cooling technology?
19. How do you think that the data from citizens/end-users can be utilised in the EPL, together with the citizens/end-users? What can your role be in this process?
20. What do you see as barriers or challenges to utilise this data from the end-user/citizens in the EPL where various parties (public and private) come together?
21. Through what means/technology should the citizens/end-users and you as the municipality of Utrecht be involved in the EPL (e.g. digital platform, physical meetings, hybrid combinations)?

B

Coding Scheme

Table B.1: The coding scheme, including the thematic hierarchy established after the cluster analysis, consisting of themes and multiple levels of sub-themes. The fifth and sixth column respectively indicate in how many sources the code is applied, and how frequent the code is referenced.

Level 1 - main theme	Level 2	Level 3	Level 4	Sources	References
aim, criteria or requirement				16	250
	accuracy			6	11
	alignment and coordination of decision making, resources and efforts			7	26
	anonamised			5	8
	wide reach			3	3
	commitment			1	2
	common understanding and comprehension			6	13
	compatibility			1	1
	condition or requirement			10	21
	consensus			6	17
		on the problem		4	9
		on the solution		1	2
	customer, client and citizen centred			1	1
	disconnect from natural gas			8	13
	granularity and detail			10	19
	improve			8	17
	indicators, parameters or criteria			10	15
	optimisation			5	5
	performance			3	4
	standardisation			7	10
	sustainability			11	28
	technological feasibility			2	2
	transparency			8	11
	unburden			9	17
ample platforms				4	5
approach or strategy				11	34
	adaptive			2	5
	integrated			7	8

Table B.1 continued from previous page

Level 1	**Level 2**	**Level 3**	**Level 4**	**Sources**	**References**
	partnerships			14	32
	Wijk aanpak			4	8
barrier				16	148
	data access barriers			5	11
	hassle			5	7
	privacy constraints and issues			13	46
		data not traceable to single address		3	3
		postcode6		5	9
	restrictions			7	12
benefit				4	5
bring data together				5	8
building stock				9	56
	existing buildings			8	23
	maintenance and refurbishment			2	5
	new built buildings			6	16
	sustainable buildings (NoM, Gas free)			2	5
challenges				16	226
	complex and complicated			9	33
	dispersed data and information			6	11
	economic			2	3
	organisational (policy, law, regulation)			3	3
	social			2	2
	technical			3	4
	uncertainty and instability			9	18
	variety and diversity			11	29
characteristics				16	258
	age or built year			4	7
	appliances, heating system, installation in dwelling			8	21
	architectural			2	3
	building characteristics			14	89
		building type		5	20
		energy label		11	23
		ownership		6	8
		surface area		2	2
		value of the dwelling		2	2
	energy generation patterns			3	3
	energy use patterns			13	47
	Gas and electricity connection			4	6
	heat grid connection			2	3
	heat supply per use			4	12

Table B.1 continued from previous page

Level 1	**Level 2**	**Level 3**	**Level 4**	**Sources**	**References**
		cooking		4	5
		hot water		2	2
		space heating		3	3
	high density urban area			1	3
	history of retrofit and energy measures			7	11
	household composition			4	6
	lifestyle			2	5
	location			5	10
	social cohesion and sense of safety			1	1
	socio-economic characteristics such as income			6	12
citizen involvement and inclusion among other stakeholders				16	247
	choice for data sharing consent			5	17
	co-creation, participation and cooperation among stakeholders			16	101
	get people going and involved in an inclusive approach			15	46
	means for citizen inclusion			5	17
	motivation and incentive			10	26
	own initiative, preferences and freedom of choice of the end-users			11	40
collective				8	14
comparisons				7	14
data access				12	41
	data access in desired format			8	13
	easy access			2	2
	restrictions on data			4	6
	timely access on demand			5	6
data aspects				16	344
	data issues or barriers			10	27
		data breach or leak		3	3
		dirty, wrong or faulty data		3	6
		missing or incomplete data/blind spots		8	15
		volume		2	3
	data ownership			5	6
	data safety and security			3	11
	data solution proposal			2	7
	data stated as necessary or relevant			15	81
	data type			15	150
		aggregated data		5	12
		big data		2	5

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Level 1	Level 2	Level 3	Level 4	Sources	References
		commercial data		6	10
		data in native format		1	3
		externally vs internally sourced data		2	4
		geo-data		4	10
		micro-data		1	9
		open data		7	27
		real-estate data		1	2
		real-time data		3	8
		smartphone data		2	6
		structured data		11	46
			metering and sensing data	8	25
			registers	5	17
			statistics	1	4
		unstructured data		2	6
			qualitative data, text	1	3
			social media posts	1	3
	data warehousing			7	15
	insights and knowledge (evidence, facts and numbers) from data			9	23
	purpose of data acquisition and utilisation			10	20
	secured environment			4	4
data-driven				14	36
data ecosystem elements				16	264
	cleansing, analysing, enriching, combining, linking and visualising data			14	83
		data analysis		11	37
			calibrate, verify and validate data	3	8
			cluster analysis	1	2
			forecasting	3	3
			models	3	3
		data visualisation		9	22
	interpreting data and providing feedback to data supplier and stakeholders			6	12
	meta-data to connect the elements			3	4
	pathways for users on how data can be used			4	7
	quality management system			5	7
	releasing and publishing (open) data			17	57
	searching, finding, evaluating and viewing data and the related licenses			14	95
		data acquisition and availability		12	63

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Level 1	Level 2	Level 3	Level 4	Sources	References
			crowdsourcing over mobile phone	3	3
			new data sources	6	16
			registry entries	3	4
			surveys	4	15
data technologies				15	205
	3D			1	1
	algorithm			3	6
	applications and software			7	15
	automation and digitisation			3	7
	BIM			2	2
	blockchain			2	8
	communicating and connected systems IoT			1	4
	data platform or portal			6	25
	datafication			1	6
	data-tooling			2	6
	distributed an protected household data environment			4	4
	GIS			7	16
	linked data			10	56
	sensors			4	6
	smart meter			3	10
	social gamification and competition			2	4
	social media			5	9
	to experience over VR/AR			5	20
databases				8	26
	BAG			6	14
	KLIC			4	4
detail level				15	147
	building			7	16
	district			12	30
	household or dwelling			12	40
	municipality			9	18
	national			4	11
	neighbourhood			6	8
	province			4	7
	street			4	4
Do it yourself				1	4
economical aspects				16	175
	cost allocation			6	10
	costs OPEX			13	55
	financial feasibility and profitability			5	10
	financial flows			1	4
	financing			12	31
		object related financing		2	6

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Level 1	Level 2	Level 3	Level 4	Sources	References
		payback period		3	9
	investments CAPEX			8	24
	societal costs			2	3
	tariffs and the energy bill			4	9
emotions				12	36
	(dis)trust			8	15
	attitude			7	9
	fear			4	5
	scepticism			3	5
Energy Policy Lab (EPL)				16	155
	EPL added value or functionality			16	76
		disclose or publish data on energy use and generation		3	3
		enable experimenting with measures and or policy		9	16
		establish local database of high quality		5	5
		facilitate co-creation and knowledge exchange		4	5
		guide the definition of concrete knowledge questions for analysis		3	4
		guide the utilisation of existing tools and platforms		4	6
		inform and educate end-users		1	1
		linking or connecting parties		1	2
		monitoring		3	5
		provide decision making support		8	10
			assessment framework	1	2
			energy models on building and inhabitant characteristics for energy advise	3	4
			provide data visualisation and analysis	2	2
	provide means and services to people on how to find or acquire the relevant data and knowledge			4	6
	validate assumptions on detailed (household) level			1	1
	EPL requirements			12	59
		accessibility, applicability or usability		10	15
		convenient and interactive user interface		7	9
		data and service quality and detail level		6	7
		data format for data acquisition and publication		3	5

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Level 1	Level 2	Level 3	Level 4	Sources	References
		embedded in process of decision making and transition		2	3
		enthuses for high utilisation rate		7	10
	life-cycle phase			4	13
		develop and test		4	6
		train users		3	3
		utilise and improve		2	4
energy service or product				12	43
	energy advice or consultation, measures to take			9	24
	energy technology solutions			2	3
	financing tool			1	1
	retrofit services and materials			1	1
energy system				16	235
	balancing and control			4	12
	capacity			6	10
	CO2			8	16
	demand			9	25
	electric mobility			3	3
	electricity			4	11
	energy efficiency			6	12
	good local solutions			3	3
	heat			10	32
	infrastructure			7	17
	natural gas			8	19
	network, grid and storage			9	38
	supply and source			10	27
energy technology				16	231
	electricity technology			10	34
	technology performance			3	8
	thermal technology			15	171
		all-electric heat pumps		14	55
		block heating		2	2
		district heating		15	85
			conventional HT	3	3
			modern LT	3	4
			third party access	4	4
		geothermal sourced		3	3
		natural gas based boilers		2	6
		synthetic gasses (hydrogen, biogas)		6	7
		thermal installation		2	2
		WKO		2	2
energy transition				14	36
establishing data infrastructure				3	4
extent, rate				0	0

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Level 1	Level 2	Level 3	Level 4	Sources	References
	high			16	70
	low			13	38
	medium			7	13
externally driven based on client needs				9	28
impact and consequences				15	30
individual				7	9
information overflow				2	3
innovation				13	42
institutions (policy and legislation)				16	172
	goals and targets			7	9
	instruments and measures			10	22
		energy regulations		3	3
		subsidies		9	16
		taxes		1	1
	Klimaatakkoord			3	3
	legislation			13	75
		AVG		8	28
		law enforcement and execution		1	2
		omgevings wet		3	17
			digitaal stelsel, bouwdossier	2	10
		warmte wet		4	6
	Regionale Energie Strategieën (RES)			4	6
	tables and groups behind decision making			6	12
	to force and impose			2	3
	Warmte Transitie Visie			8	19
interaction and communication (interfaces)				16	161
	interaction means			14	80
		digital		11	25
			information sessions	7	25
			physical	9	20
	what is the storyline			6	10
interests of commercial or political nature				9	20
internally driven, part of the organisation's vision				4	5
knowledge gaps for the heat transition				16	111
misc				0	0
	central			5	13
	conflicting			4	5
	decentral			8	18
	desired			11	22

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Level 1	Level 2	Level 3	Level 4	Sources	References
	increase			3	7
	lacking			12	25
	negative			9	13
	no			13	40
	positive			10	17
	top-down vs. bottoms-up			6	12
	undesired			6	9
	yes			7	7
models and tools				7	25
	choice models			1	1
	digital or virtual model			3	7
	physical model house prototype			1	3
new project				6	8
opportunities and potential				8	16
organisation data maturity				14	30
platforms and portals				11	99
	communication and participation platform			2	2
	data platform or portal			6	25
	platform users			2	5
	platforms existing			10	53
		energielabelatlas (EPBD)		3	3
		Klimaatmonitor		4	4
		Nationale EnergieAtlas		1	2
		PDOK		3	28
		PICO		4	10
		waarstaatjegmeente.nl		1	2
		Warmteatlas		2	2
	support and information platforms			4	6
project phase and process activities				14	109
	execution			8	16
	exploration, maintain			2	3
	extension and expansion			4	5
	new product research and development			8	14
	pilot proeftuin			2	5
	planning			10	51
		execution plan		3	6
		plans on non-energy related aspects		3	5
		sequence of Districts		4	12
		solutions per district		3	9
	project design and engineering			4	9
	replacement and decommissioning			1	2

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Level 1	Level 2	Level 3	Level 4	Sources	References
public space interventions				4	4
research, organisation is in the state of exploration				14	34
resources				13	41
	material and equipment			1	1
	money			7	10
	skilled labour			12	16
		data scientists		5	11
	time			8	12
responsibility, legal ground and authority				6	16
retrofit and facade interventions e.g. insulation				9	25
role in the heat transition				16	172
	active role			6	12
	passive role			2	2
	role in relation to data			11	65
		data client		2	2
		data intermediate		6	17
		data owner		3	5
		data supplier		9	41
	to direct, take the lead			7	11
scaleability and benefits of scale				5	7
sense of awareness and urgency				11	23
social acceptance and support				10	24
stakeholders				16	807
	branch organisation			6	13
	citizens			16	217
		de stille meerderheid		3	5
		front-runners		5	14
		private homeowners		6	11
		renters		7	28
	energy cooperatives			8	15
	environmental organisations			3	9
	experts and technicians or skilled labour			2	3
	financial institutions			4	10
	Geonovum			1	3
	government			16	211
		municipalities		16	132
		national government		13	34
		provinces		8	15
	government authorities			11	66
		CBS		6	25
		Kadaster		10	20
		PBL		2	2

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Level 1	Level 2	Level 3	Level 4	Sources	References
		RVO		5	12
	housing corporations			13	50
	intelligence			8	14
		energy consultant or advisor		2	4
		research and education institutes		6	9
	local citizen centred initiatives			8	23
	market			16	81
		construction companies		6	15
		energy utility and energy service companies		13	31
		hardware companies		3	3
		installation companies		7	11
		insulation companies		2	2
	market regulator (ACM)			1	2
	network companies			11	43
	potential heat suppliers			2	4
	real estate developers and intermediates			6	11
	technology, application and software developers			3	4
	VvE			2	2
highly diverse field of actors and disciplines				7	13
stakeholders and actors necessary for the heat transition				14	22
static vs. dynamic				3	5
subsurface, underground pipes and excavation work				4	9
time-line and associated tempo				10	19
	current situation			2	5
	future			4	6
tool or method				7	30
urban environmental development				5	10
use-cases				16	151
	learning			8	16
		assumptions,estimations and guesses		5	23
		best practices		5	6
		existing expertise and experience		12	29
		inform, educate and train		9	14
		information and knowledge exchange		11	20
		mind map, ideas, perceptions		3	5
	monitoring			9	27
		energy use monitoring		3	5

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Level 1	Level 2	Level 3	Level 4	Sources	References
		equipment performance monitoring		1	6
		progress monitoring		5	7
	predict and forecast			3	3
	process and procedures in the realisation of the heat transition			15	105
		decision making		12	42
			system choices and interdependencies	3	4
		process support and facilitation		12	35
user behaviour and behavioural change				7	11
willingness				15	63
	to cooperate			6	10
	to have an active role and be included			2	4
	to share data			14	42

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