MSc Thesis

Improving social housing using a sea of open data

October 2020

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Improving social housing using a sea of open data

The potential role of open data in the
decision-making process regarding
the energetic improvement
by housing associations.

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Abstract

In the challenge of climate change, energetically improving the existing residential buildings offers a way to reduce the CO_2 (carbon dioxide) emissions of the built environment. In the Netherlands, housing associations own and maintain almost a third (2.3 million housing units) of the entire Dutch housing stock and could therefore play a significant role in the reduction of CO_2 emissions. To come to this reduction, housing associations first have to choose which housing unit they would like to energetically improve, followed by the decision of when and how. In this decision-making process, they utilize data they have generated themselves to make an informed decision. However, the role of data that is generated by another person or organization is unclear, and even less clear is the role of open data in this decision-making process. Against this background, this thesis explores the role of open data in the decision-making process by housing associations in the energetic improvement of housing units. It studies the approaches housing associations apply in the energetic improvement of housing units, stakeholders of housing associations in the energetic improvement, possibilities and limitations of the available and relevant data to the decision-making process, desirable features of the conventional decision-making support systems and unconventional yet relevant decision-making support systems regarding the energetic improvement by housing associations. The data is collected by reviewing policy documents, conducting and transcribing sixteen semi-structured interviews and observing decision-making support systems. The research shows that open data could play an enabling role in the decision-making process regarding the energetic improvement. It informs housing associations about the plans of stakeholders, what is happening in the vicinity of their real estate and explore pairing opportunities. It is very useful to housing associations in a first analysis but might fall short for more extensive analysis. Thus, open data enables housing associations to start using another person or organization's data in their decision-making process.

What is of importance for data analysis is the housing association's primary data and its data quality. Anyone can analyze open data but analyzing open data in combination with the housing association's primary data is what makes it valuable in the decision-making process regarding the energetic improvement. In the end, it is not the open data itself which will cause a reduction in CO_2 emissions. It is the collaboration between stakeholders in the heat transition which will. The necessary collaboration in the heat transition not only requires open data, but also the acknowledgement and involvement of stakeholders in the decision-making process regarding the energetic improvement.

Keywords
Energetic improvement, housing associations, decision-making, open data, support systems.

Preface

Last night I watched David Attenborough: A Life on Our Planet on Netflix. An intriguing story from a great presenter and scientist. His story captivated me and made me contemplate the importance of the decisions we take today and how they impact the future. In his story, he narrates how climate change is jeopardizing human existence. A narrative which has captivated me for years and was my driver to pursue the Metropolitan Analysis, Design and Engineering (MADE) master and write this thesis. By the end of his story, Attenborough shows how we could live in balance with nature, bring back biodiversity and combat climate change. One of the solutions he illustrates are the use of sustainable energy from natural sources such as water, wind, solar and geothermal. It relieved me to see that in the Netherlands we have policy which pushes our society switch to sustainable energy. This thesis will hopefully provide a small puzzle piece in the large puzzle we have to solve as a society to switch to sustainable energy and combat climate change.

My fascination for real estate and housing associations begun in the MADE master. In this master I was able to explore many different topics; ranging from waste to water, food, mobility, energy and housing. Eventually, I found myself naturally drawn to the topic of housing, the similar topic to what I studied in my bachelor's degree. When I developed my thesis proposal, I imagined that after working part-time on the thesis for over a year, I would be fed up with the topic. The opposite is true. The use of data in the decision-making process still excites me. But it is my appreciation for the unique organizations of housing associations that has grown the most. The organized congregation of real estate, social and financial interest with the purpose to provide quality housing to those who are in need is a prime example of a sustainable organization. An organization we as Dutch society should be very proud of and cherish.

The title of this thesis is ‘Improving social housing using a sea of open data’. In this title ‘improving’ is a nod to the energetic improvement and ‘social housing’ refers to housing associations. ‘A sea of open data’ is inspired on the title of the group exhibition ‘Drowning in a Sea of Data’ by João Laia at La Casa Encendida in Madrid. This exhibition analyzed the role of technologies in the accelerated flow of information. It connects well with the topic and findings of this thesis. Because in this thesis I found that the findability of open data and the relevancy of the found data is often a limitation to housing associations in the use of open data.

Writing my thesis has been a challenging, but mostly enjoyable journey. I would like to express my appreciation to everyone who took time for the interviews or shared their insights in video calls, emails or conversations. I’d also like to extend my gratitude to D. Van den Berg, W. Plokker and Vabi for their support, feedback and opportunities they provided me. Special thanks to my supervisors dr. E.J. Meijers and dr. S. Kloppenburg: Thank you for the support and our pleasant meetings. This thesis would not have been possible without your insightful feedback that always provided me with the traction for the next phase.

Contents

1
Introduction

1.1 Problem definition

The cities of today are faced with many challenges, among which climate change is the most pressing as it threatens to undermine the human progress that has been achieved to date (Hoornweg, Freire, Lee, Bhada-Tata and Yuen, 2011). Cities are a key contributor to climate change, as urban activities are major sources of greenhouse gas emissions with an estimated 75 percent of global CO_2 (carbon dioxide) emissions (United Nations Environment Program, n.d.). According to the same source, transport and buildings are among the largest contributors to these urban CO_2 emissions. In June 2019, the Dutch Government presented the Climate Agreement as a follow up of the Paris Climate Agreement of 2015. This Dutch policy document contains 600 smaller agreements to reduce the emission of CO_2 and other greenhouse gases. In the Climate Agreement, housing associations are expected to become a front runner in the energetic improvement of the housing sector. With almost 2.3 million housing units in 2012, the housing associations own almost a third (32%) of the entire Dutch housing stock (Government of the Netherlands, n.d.). Energetically improving this share of the Dutch housing stock would create a substantial reduction in CO_2 emissions and is expected to generate knowledge about new sustainable building technologies and bring the price of these technologies down.

In light of the Climate Agreement, housing associations are improving the thermal insulation in the envelope of housing units; installing solar panels and replacing natural gas connections with district heating connections or other mechanical installations. Before they take action, housing associations first have to decide which housing unit they would like to energetically improve, followed by the decision of when and how. In this decision-making process, they utilize data they have generated themselves to make an informed decision. This involves data on the technical aspects of their buildings or the occupants living in those buildings. However, the Climate Agreement expects housing associations to innovate and become creative with the existing decision-making mechanisms to come to transparent, effective and legitimate decisions (Diran, Hoppe, Ubacht, Slob and Blok, 2020). To make these kinds of decisions, housing associations should not only look at the data they have generated themselves, but also the data that is generated by another person or organization. This is due to the fact that the technical aspects of the housing association's buildings but also the interests and resources of citizens and other stakeholders are considered crucial in this decision-making process (Diran et al., 2020). Including another person or organization's data in their decision-making process is a challenge for housing associations. Certainly, when a survey showed that among Dutch housing associations only a third (34%) qualifies their own data quality as good and a similar share (29%) developed a data strategy (CorporatieNL, 2020).

1.2 Research aim

Taking the problem definition into consideration, this thesis explores the role of open data in the decision-making process regarding the energetic improvement by housing associations. Specifically, the approaches housing associations apply in the energetic improvement, stakeholders of housing associations in the energetic improvement, possibilities and limitations of the available and relevant data to the decision-making process, desirable features of the conventional decision-making support systems and unconventional yet relevant decision-making support systems regarding the energetic improvement by housing associations.

This research contributes to extending our knowledge concerning the heat transition and the use of data in the decision-making process. Earlier researches studied the use of data in the decision-making process, but these were either not focused on the heat transition, housing associations or both. Several studies focused on the use of data in the heat transition in general (Janssen, Matheus, & Zuiderwijk, 2015; Blomqvist, & Thollander, 2015). While other research (Citroen, 2011; Lepri, Oliver, Letouzé, Pentland, & Vinck, 2018; Luthfi and Janssen, 2019) studied the use of data in the decision-making process regardless of the type of company or industry or focused on other companies than housing associations. One essay did study the potential role of data for housing associations but focused on governance and not on the heat transition (Frankowski, Scherpenisse, Van der Steen, & Twist, 2015). One other study by Diran, Hoppe, Ubacht, Slob and Blok (2020) did address the use of data in the decision-making process in relation to both the heat transition and housing associations. However, in this study housing associations were addressed as a data user and data provider of a larger data ecosystem. Meaning that housing associations were considered next to the other stakeholders in the heat transition. This thesis sets out to apply that specific focus to the heat transition and housing associations.

1.3 Research questions

Considering the research aim, problem definition as described above, the following research question and five sub research questions were formulated. These questions will help to develop knowledge about the use of data in the decision-making process regarding the energetic improvement by housing associations.

Main research question

What is the potential role of open data in the decision-making process regarding the energetic improvement of housing units by housing associations?

Sub research questions

1. What are the approaches housing associations apply in the energetic improvement of housing units?
2. What are the stakeholders of housing associations in the energetic improvement of housing units?
3. What are the possibilities and limitations of the available and relevant data to the decision-making process regarding the energetic improvement of housing units by housing associations?
4. What are desirable features of the conventional decision-making support systems regarding the energetic improvement of housing units by housing associations?
5. What are unconventional yet relevant decision-making support systems regarding the energetic improvement of housing units by housing associations?

1.4 Reading guide

The thesis will continue with the following structure: Chapter 2 will present the theoretical background, which discusses the most important concepts of this thesis as described in academic literature. Before moving on to the empirical results, chapter 3 provides a policy background by discussing the Climate Agreement and related policy documents. Chapter 4 explains the methodology and list the interviewed employees of housing associations and other professionals and the observed decision-making support systems. The empirical results about the approaches in the energetic improvement, data in decision-making and decision-making support systems are presented in chapter 5, 6 and 7. In chapter 8 the findings of this thesis are concluded by answering the sub research questions and main research question. And in chapter 9 these findings are discussed and recommendations for policy and future research are provided.

2
Theoretical background

2.1 Introduction

This chapter will provide a theoretical background on the themes of the energetic improvement, real estate management and data. This will be done by discussing the concept of energy demand, energy use and energy performance gap in section 2.2. In section 2.3, the concepts of the three management layers (portfolio, asset and property) in real estate management are discussed. And finally, the concepts of primary, secondary and tertiary data, open data, purchasable data, and relational and non-relational databases are discussed in section 2.4. These concepts will provide a background which will help answer the research questions of this thesis in the following chapters.

2.2 Energetic improvement

Housing units which have reduced their energy demand and energy use and applies renewable sources to supply energy are considered energetically improved (Dutch translation: energetisch verbeterd). The energetic improvement is one of the core concepts of this thesis as it is what housing associations perform to achieve a CO_2 reduction. In other studies, different concepts are applied such as retrofitting (De Feijter, Van Vliet, & Spaargaren, 2019), renovation (Guerra-Santin et al., 2018) and energy efficiency measures (Filippidou, Nieboer, & Visscher, 2016). These concepts and energetic improvements in essence all imply a reduction of the energy demand and energy use of an existing residential building. However, energetic improvement is applied in this thesis as it is the closest translation to the Dutch concept 'energetisch verbeteren' which was consequently used in the interviews for this thesis. To clarify the concept of energetic improvement, the concepts of 'energy demand' and 'energy use' are discussed next. In their book on sustainable urban environments, Van Bueren, Van Bohemen, Itard and Visscher (2012) establish the core concepts for the design of sustainable urban environments. They argue that to understand the concept of energetic improvement, a basic understanding of the energy chain is required. The energy chain (see Figure 2.1) shows the processes in the built environment from supply to demand on building level. The principal components in this energy chain are the energy demand, primary energy use and energy supply. The energy demand is "the energy that should be brought into a building to ensure that all comfort and health parameters like temperature, humidity and lighting intensity can be kept at the desired level" (Van Bueren et al, 2012, p. 123). The primary energy use (hereinafter: energy use) is the energy that is required to meet the energy demand. The primary energy use does not need to be equal to the energy demand as buildings installations could convert one amount of energy into a large amount (e.g. heat pump) or smaller amount (e.g. electric water heater). The energy supply is the conversion of renewable energy sources (e.g. sun, wind, tidal and so forth), inorganic nutrients (e.g. uranium for nuclear energy) and organic matters (e.g. coal, oil and gas) into energy (e.g. heat, electricity and so forth) which can be transported to buildings for consumption (Van Bueren et al, 2012). A housing unit is an accommodation intended for living (Corponet, n.d.). Thus, an energetic improvement aims to reduce the energy demand of a housing unit so that less energy is used, and less energy needs to be supplied.

The energy use of a residential building is dominated by applications for space and water heating. In the energetic improvement, the focus is placed on the space and water heating but in the residential sector energy is used for multiple purposes. In

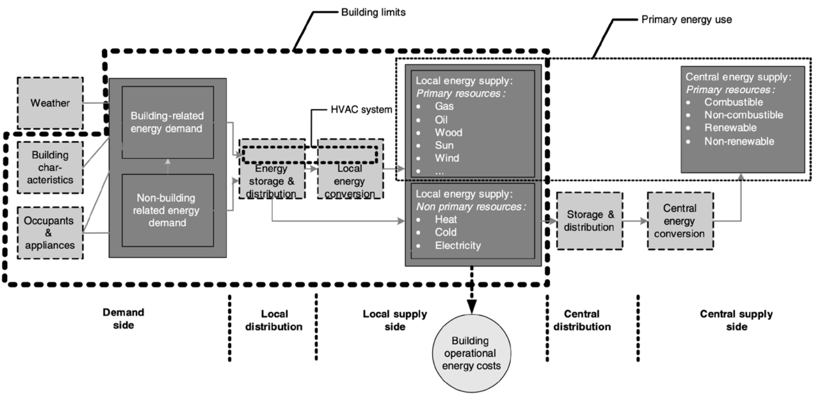


Figure 2.1 - Energy chain in buildings (Van Bueren et al., 2012).

Figure 2.2, Van Bueren et al. (2012) show that the total final energy use of a residential building in the 19 OECD (Organisation for economic co-operation and development) countries could be categorized in space heating, water heating, cooking, lighting and appliances. The graph also shows that space heating and water heating dominate almost 60% of the total energy used in a housing unit. The remaining part of the energy is used to power appliances such as lighting, refrigerators, air-conditioning and computers. These numbers only apply to the residential sector and differ particularly between cold and warm climates. However, more recent numbers provided by Eurostat (2018) which focus on the Netherlands show that space heating and water heating are even 80% of the total energy use (see Figure 2.3). Because space and water heating dominate the energy consumption, they also provide the largest potential to reduce the energy demand and energy use.

The energy performance gap

One of the challenges for housing associations in the energetic improvement is that they often do not accomplish the reduction in energy use they expect. This problem is also referred to as the 'energy performance gap' and hinders housing associations in achieving the CO_2 reductions that are expected of them. It was not mentioned as part of the problem statement of this thesis as it is already studied in other researches. In their article, Majcen, Itard and Visscher (2016) explain that their previous research showed that:

> In the Netherlands, well performing dwellings consume more [energy] than expected and poor dwellings consume up to half less than expected (Majcen et al. (2013a, 2013b) causing the actual energy savings to be smaller in reality than expected. [...] The theoretical consumption can diverge from the actual consumption by as much as 50% less or 30% more. (p.83)

According to Van den Brom (2020), many studies have attempted to gain insights in how these energy performance gaps occur. What is evident is that the building energy simulation models, which are used to calculate the potential reduction in energy use, have to make assumptions about the occupant's energy-related behavior. This behavior differs considerably from each other in practice. Where the studies differ is in their reports of how much of this variance could be explained by the occupant's behavior. This variation ranges from 4.3% to 51% (Van den Brom, 2020).

In literature, two recommendations were found which use data to assist in overcoming the energy performance gap. According to Majcen et al. (2016), one opportunity to overcome the energy performance gap is the use of large datasets about buildings' thermal performance and actual consumption. Analysis of these datasets should offer insights into specific combinations of measures and allow for the identification of the best practices (Majcen et al., 2016). While Majcen et al. focus on more accurate calculations of the potential reduction, De Feijter, Van Vliet and Spaargaren (2019)

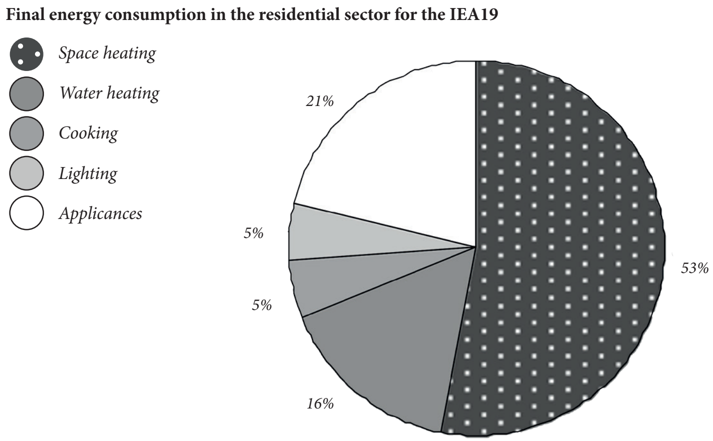


Figure 2.2 - Final energy consumption in the residential sector by use for 19 OECD countries (Adapted from Van Bueren et al., 2012).

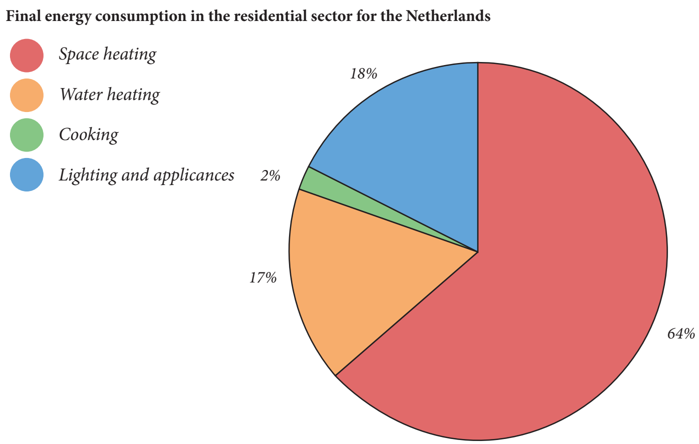


Figure 2.3 - Final energy consumption in the residential sector by use for the Netherlands (Based on Eurostat, 2018)

focus on how housing associations could assist occupants in performing the associated energy-related behavior. This is because an energetic improvement is not only a technical change within a housing unit but also requires a behavioral change from its occupants. In their article, they provided practices of recruitment and appropriation which housing associations could apply to achieve this behavioral change. Examples of these practices in which data is generated or used are conducting upfront questionnaires and conducting evaluations and monitoring buildings' energy performance afterwards. Through these practices, housing associations would be better informed about what measures suit certain housing units and occupants and the actual effectiveness of their energetic improvement. Thus, using large datasets to analyze the buildings' energy performance and actual consumption and applying practices of recruitment and appropriation could assist in overcoming the energy performance gap.

2.3 Real estate management

The legal obligation for housing associations in the Netherlands is the duty to secure the quality of housing units (Ministry of the Interior and Kingdom Relations, 2005 in Roders, 2015). This legal obligation dictates the tasks of a housing association and how they are organized. To secure the quality of housing units, Roders (2015) states that housing associations should not only be aware about the technical state of their real estate, but the quality of life of their occupants and financial continuity of the organization as well. The issue of climate change, among others, is what could challenge the financial continuity of the organization. Housing associations should therefore take the resilience to climate change into account in the management of their real estate to maintain a good market value in the future (Roders, 2015). Van der Kuij (2014) connects to this by stating that the tasks of housing associations involve a broad spectrum of activities ranging from commercial project development to societal investments in neighborhoods and occupants. But these activities are also self-proclaimed, diffuse and mostly unmeasurable. This illustrates that the legal obligation of housing associations is clear, but that the activities they execute are broad and often self-proclaimed.

The energetic improvement is an activity which falls within the professional discipline of real estate management. Van der Kuij (2014) concludes in his doctoral thesis that real estate management could be conceptualized by the management triad by Van Driel (1988, in Van de Kuij, 2014) (see Figure 2.4). He concludes this after an extensive discussion on how the concept of real estate development and management developed in literature over the years. In the management triad, a distinction is made between a portfolio, asset and property management level. To these three management levels, Van der Kuij added a fourth level: fund management. The level of fund management the financial and societal objectives of the housing association and the dividend objectives of activities are determined. These should enable the housing association to accomplish their objectives and not endanger the continuity of the housing association. In this thesis, the focus is placed on the three management levels in the management triad. According to Van de Kuij, portfolio management is considered as the strategic management of the entire real estate portfolio of a housing association through which the financial and societal objectives as set on the fund management level could be accomplished. The portfolio are all housing units (and other real estate) one housing association owns and/or maintains. At asset management, the tactical decisions made by the portfolio management are further specified. This results in investment programs in projects for the transformation and exploitation of existing and future sub-portfolios. Sub-portfolios is a portion of the housing association's portfolio based on for instance municipality, neighborhood or type of housing unit. Van der Kuij therefore considers asset management as the management of the sub-portfolio. The investment programs of asset management are brought into practice (operational) by the property management. Property management is the execution of activities as part of the real estate maintenance, leasing to tenants and additional housing services. In Table 2.1 an overview of the activities of the real estate management levels is provided. In the management triad, policy and objectives are extended top-down (from fund to property management) and results and information are extended bottom-up (from property to fund management) (see Figure 2.4) (Van der Kuij, 2014). Employees of a housing association who work on the portfolio and asset management are called portfolio and asset managers. This illustrates that real estate management could be distinguished in three management levels, namely: portfolio, asset and property management.

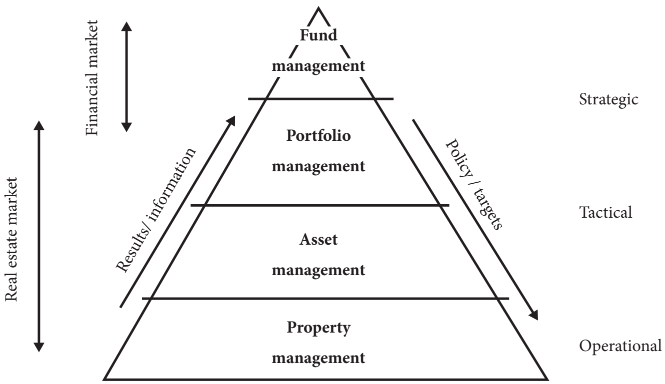


Figure 2.4 – Three management levels (management triad) and fund management level of real estate management (Based on Keeris, 2002 and others, in Van der Kuij, 2014)

Management level	**Output**	**Relation with real estate development**
Strategic: fund management	• Objective organisation • Yield requirements	• Objectives which real estate management could contribute to
Strategic: portfolio management	• Target portfolio • Investment policy / plan • Assessment framework	• Potential development portfolio • Investment plan and assessment framework for launching and developing projects
Tactical: asset management	• Investment program (transformation program) • Exploitation program • Optimization plan (sub) portfolio	• Acquisition plan and transformation plan for new en existing (in ownership) locations
Operational: property management	• Maintenance result • Rentability • Customer satisfaction	• Requirements future maintenance • Connection with existing portfolio in maintenance

Table 2.1 – Overview of the activities of the real estate management levels (Adapted from Van der Kuij, 2014)

These portfolio and asset managers are however not the bodies who are making the decisions. The people who do make the decisions within a housing association are the bodies and/or employees with decision-making authority. The distribution of this authority varies per housing associations. According to Van der Kuij (2014), the managing director, the management or director team, the supervisory board and/or boards of commissioners are common bodies with decision-making authority. In a project such as the energetic improvement, the project is divided into phases which feature scheduled decision-making moments. At these moments, the bodies and/or employees with decision-making authority decide about the continuation of the project. In the meantime, portfolio and asset managers elaborate on the project. They do this by obtaining a certain understanding about the technical condition of their real estate, the quality of life of their occupants and financial means that they have available. The bodies and/or employees with decision-making authority use this information to inform their decisions. In summary, the actual decisions within housing associations are made by bodies or employees with decision-making authority, such as the managing director, the management or director team, the supervisory board and/or boards of commissioner.

2.4 Primary, open and purchasable data

Primary data is generated by the housing association and secondary or tertiary data is generated by another person or organization. In his book, Kitchin (2014) explains that data which varies by producer is described as primary, secondary and tertiary data. According to Kitchin (2014):

> Primary data are generated by a researcher and their instruments within a research design of their making. Secondary data are data made available to others to reuse and analyze that are generated by someone else. So one person's primary data can be another person's secondary data. Tertiary data are a form of derived data, such as counts, categories, and statistical results. Tertiary data are often released by statistical agencies rather than secondary data to ensure confidentiality with respect to whom the data refers to. For example, the primary data of the Irish census are precluded from being released as secondary data for 100 years after generation; instead the data are released as summary counts and categorical tertiary data. (p. 7-8)

This example by Kitchin (2014) speaks about open data. Thus, open data starts as primary data and is then released as secondary or tertiary data. But this does not cover the whole definition of open data. Multiple studies have attempted to define open data (Tammisto, & Lindman, 2012; Kitchin, 2014; Pasquetto, Sands, Darch, & Borgman, 2016). These studies concluded that it is challenging to find a comprehensive definition for open data because it differs between scientific communities and organizations and 'open' not only refers to the data provider but to the user as well. For instance, a data provider might open their data externally, but legal, technical or social restrictions might limit the user from accessing the data. To describe the complexity of the definition of open data, Kitchin (2014) listed the ideal characteristics of open data. However, this complex definition of open data is not necessary, and a straightforward definition would suffice for this thesis. The straightforward definition according to Pollock (2006, in Kitchin, 2014) is: "Data is open if anyone is free to use, reuse, and redistribute it – subject only, at most, to the requirement to attribute and/or share-alike" (p. 49). Thus, open data in the context of this thesis is defined as data which is generated by another person or organization (secondary or tertiary data) and made available to anyone for free with no restriction for use, reuse, and redistribution.

Data ecosystem

An overview of the data platforms and portals from which housing associations could collect data for the decision-making process regarding the energetic improvement is provided in a data ecosystem. The amount of available open data is growing (Tammisto, & Lindman, 2012; Pasquetto, Sands, Darch, & Borgman, 2016). Diran et al. (2020) state that this also applies to open data on energy systems. But that it is not always clear to stakeholders in the heat transition such as housing associations which relevant data to their decision-making process was made available by other stakeholders. They argue that a data ecosystem could add value to the heat transition as it provides knowledge to the decision-making processes of all stakeholders in the heat transition. A data ecosystem is “a concept that refers to an overview of the relationships between data users, data providers, tools, and the data infrastructure” (Diran et al., 2020, p. 2). In their research, they developed a framework for developing data ecosystems and applied it to the heat transition in the Netherlands (see Figure 2.5). In this data ecosystem housing associations are also incorporated as data providers and data users. The study also revealed a lot of data platforms or portals from which housing associations could collect open data (see Appendix A) and data sources which are (sometimes not yet) available and relevant for their decision-making process regarding the heat transition (see Figure 2.6).

Housing associations could contribute to a more mature data ecosystem by providing open data and fully embracing data-driven decision-making. Diran et al. (2020) conclude in their research that the current data ecosystem for the heating transition

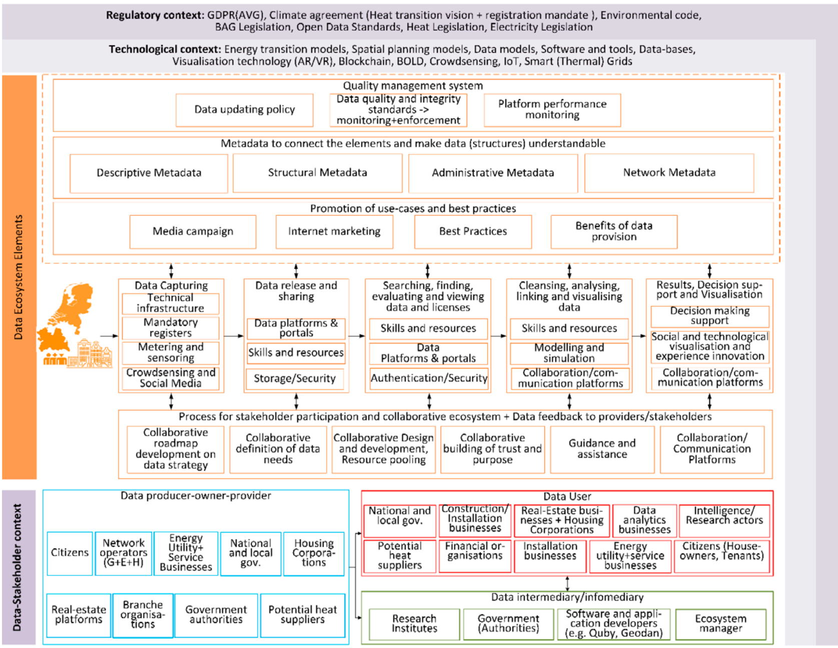


Figure 2.5 - The data ecosystem 2.0 design to support the heat transition in The Netherlands (Diran et al., 2020).

is still in its infancy phase. A mature data ecosystem would provide all stakeholders in the heat transition with the data they require in their decision-making process. They found that stakeholders are most in need of data on heat demand, dwelling characteristics, investment and planning cycles, preferred natural gas alternatives and end-user characteristics and behavior. One way for housing associations to contribute to the data ecosystem is to provide open data on the dwelling characteristics such as energy labels, building envelop and building installations (see Figure 2.6). Next to the provision of data, Diran et al. conclude that a stable and adequate data infrastructure and the use of technologies, such as big and open linked data by stakeholders in the heat transition are requirements for a mature data ecosystem. In other words, fully embracing the use of data in their decision-making. This shows that housing associations are able to contribute to the data ecosystems by providing open data and fully embracing the use of data in their decision-making.

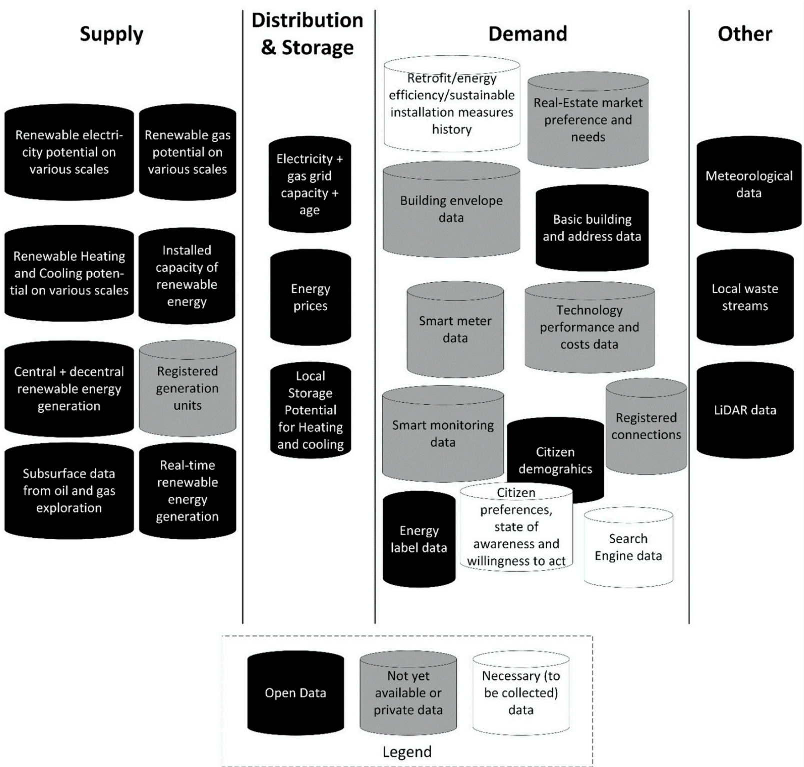


Figure 2.6 - Overview of data sources (current and potential) with relevance for the heat transition (Diran et al., 2020).

The collection of open data also requires housing associations to rethink how they store the data that they generate and collect. Kitchin (2014) explains that in recent years a development is taking place in regard to digital storage solutions. Relational databases with small amounts of structured data are complemented by non-relational databases that can handle very large volumes of unstructured data. In a relational database, a shared field (the indexical key) is the link between two or more tables containing data. This creates structured data and enables querying of this data. The data in a non-relational database does not necessarily have a shared field or similar structure. Examples of unstructured data are Facebook posts, tweets, pictures and videos all stored in one database. Advances in database design and machine learning techniques enable the storage and analysis of this unstructured data. This rise of non-relational databases aligns with the larger development around big data. According to Kitchin (2014), there is not an agreed academic or industry definition of big data. The most common definition refers to the 3V's: volume, velocity and variety (Laney, 2001; Zikopoulos et al. 2012, in Kitchin, 2014). Volume refers to size of the data which is expressed in either gigabytes, terabytes or even petabytes of data. Velocity refers to the time in which the data is created, sometimes near real-time. Variety refers to the diversity in types of data, data could for instance be structured and unstructured in nature. Open data does not necessarily have the same shared field or structure that the housing association applies. Which means that the collection of open data results in a larger diversity of data types in the databases of housing associations. Or in other words, the collection of open data will lead to more unstructured data. Thus, open data requires non-relation databases because it is a step towards a big data approach.

2.5 Conclusion

This chapter has discussed the concept of energy demand, energy use and the energy performance gap in relation to the energetic improvement. It also discussed the concepts of real estate management and the definitions of primary, secondary and tertiary data. When overlooking the literature discussed in this theoretical background, the following insights are gained: First, a housing unit is considered in this thesis energetically improved when its energy demand and energy use are reduced and is supplied with energy from renewable sources. However, housing associations often do not accomplish the reduction in energy use they expect in practice. This could be overcome through the use of large datasets to calculate the expected reduction or applying more practices of recruitment or appropriation. Second, energetic improvement is an activity which falls within the professional discipline of real estate management. In real estate management, three management levels (management triad) are defined, namely: portfolio, asset and property management. Portfolio and asset managers are however not the bodies who are making the decisions. The decisions within housing associations are made by bodies or employees with decision-making authority, such as the managing director, the management or director team, the supervisory board and/or boards of commissioner. Third, primary data is generated by the housing association and secondary or tertiary data is generated by another person or organization. Secondary data is primary data that is released without any adaptation. Tertiary data on the other hand is released in summary counts and categories. In this thesis, open data is considered as data generated by another person or organization (secondary or tertiary data) and made available to anyone for free with no restriction for use, reuse, and redistribution. Lastly, an overview of the data platforms and portals from which housing associations could collect data for the decision-making process regarding the energetic improvement is provided in a data ecosystem. Housing associations are also able to contribute to this ecosystem themselves by providing open data and fully embracing data-driven decision-making. At the same time, the collection of open data requires non-relation databases because it is a step towards a big data approach.

3
Policy background

3.1 Introduction

This chapter discusses the policy documents relevant to the topic of the energetic improvement. The core policy document in this regard is the Dutch Climate Agreement. In section 3.2 this policy document, along with the related policy documents such as the Convenant energy reduction social housing sector (Dutch translation: Convenant energiebesparing huursector), Paris Agreement, Climate and energy exploration (Dutch translation: Klimaat- en Energieverkenning [KEV]) and the European Green Deal will be discussed. Next, in section 3.3 the heat strategies by the Expertise Centrum Warmte are presented. Followed by the new energy performance standards which are announced in the Climate Agreement in section 3.4. These policy documents will provide a background which will help answer the research questions of this thesis in the following chapters.

3.2 Climate agreement

Prior to the Climate Agreement housing associations made arrangements within the sector about the energetic improvements of their housing units. In 2012, housing associations agreed together in the Convenant energy reduction social housing sector to achieve an average energy label B on sector level in 2020 (Aedes, n.d.). The Convenant was part of the Energy agreement (Dutch translation: Energieakkoord) which was the predecessor of the Climate Agreement. According to Aedes (n.d.), Netherlands Environmental Assessment Agency (Dutch translation: Planbureau voor de leefomgeving [PBL]) concluded in 2017 in the National energy exploration (Dutch translation: Nationale Energieverkenning [NEV]) that the target of an average energy label B on sector level in 2020 will not be achieved. In the same year the sector agreed in the Aedes agenda 2020-2023 to make a catch-up and achieve an average energy label B on sector level in 2021. The current Aedes benchmark shows that the housing associations are on track to achieving this target (Aedes, n.d.). This illustrates that even prior to the Climate Agreement housing associations were committed to the energetic improvement and the Climate Agreement provided further support for their efforts.

In June of 2019, the Dutch Government presented the Climate Agreement as a follow up of the Paris Climate Agreement of 2015. Discussing these policy documents help to understand where current energetic improvements by housing associations originated from. In the Paris Climate Agreement, all nations agreed into a common cause to undertake efforts to combat climate change (United Nations, 2015). To reduce the risks and impacts of climate change, the nations agreed to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and where possible below 1.5°C. To undertake efforts, the Dutch government (2019) developed the Dutch Climate Agreement. The policy document contains 600 smaller agreements to reduce the emission of greenhouse gases. The Climate Agreement consists of five pillars: Built Environment, Mobility, Industry, Agriculture and land use and Electricity. In appendix B all points of the Climate Agreement relevant to housing associations are noted. This summary of the Climate Agreement will only consider the chapter about the Built Environment and part about Electricity (related to the built environment) as it is the only relevant pillar to this thesis.

The overall aim of the Climate Agreement is to reduce the emitted greenhouse gases by 49% by 2030 relative to 1990. Since the presentation of the Climate Agreement this aim is established in Dutch law by the Climate Law. Housing associations fall in the domain of the built environment and should contribute by realizing a CO_2 reduction of 3,4 Megatons by 2030. This CO_2 reduction could only be reached if 1,5 million buildings of the 7 million existing residential buildings in the Netherland transition away from natural gas as main heat source to more sustainable alternatives by 2030. To achieve this, housing associations and other commercial or private owners should steadily increase the annual number of energetically improved existing residential buildings from 50 thousand in 2021 to 200 thousand in 2030. These numbers indicate how large the task of the energetic improvement is for the housing associations.

Climate and energy exploration (KEV)

However, these measures in the Climate Agreement turn out to be insufficient. According to the KEV 2019 (PBL), the overall aim to reduce the emitted greenhouse gases by 49% by 2030 relative to 1990 will not be reached based on the measures presented in the Climate Agreement. In the KEV, the Planbureau voor de Leefomgeving (PBL) reports annually on the current expected emission of greenhouse gases in 2030, the state of affairs in regard to energy and the climate, the advances or setbacks in the process of achieving the overall aim and expected future developments. The KEV was introduced by the Climate agreement and the first edition was presented in November 2019. In this edition, PBL states that a reduction between 43% and 48% relative to 1990 will be reached by 2030. In this range reaching 48% would involve choosing maximum effective elaborations of the policies and an accumulation of windfalls. PBL also mentions that there is not much attention spend on the additional reduction which should be reached between 2030 and 2050. According to the Climate Law, emitted greenhouse gases should be brought back with 95% by 2050 relative to 1990. Evidently, the greenhouse gases reduction until 2030 will focus itself on the emitting sources which are easier to eliminate. This will result in a larger challenge between 2030 and 2050, when the remaining, harder to eliminate sources should be eliminated (PBL, 2019). In summary, based on the current outlook by PBL, the intended CO_2 reductions will not be reached which makes the already hard task to meet the goal of 95% reduction by 2050 even harder.

European Green Deal

The European Commission aims to reduce the emitted greenhouse gases with at least 55% by 2030 relative to 1990. In December 2019, the European Commission presented the European Green Deal as a new growth strategy for the European Union. The commission presented a roadmap including key policies and measures in the same document and proposes to raise the European aim for CO_2 reduction to at least 50% and towards 55% by 2030 relative to 1990. This is in line with what is mentioned in the Climate Agreement as it states that the Dutch government (2019) pleads internationally for an increased European aim of 55% by 2030 relative to 1990. A more recent document by the European Commission (2020) shows that the commission is currently leaning toward a European aim of 55% and are even considering a CO_2 reduction of 60% by 2030 relative to 1990. In summary, the European Commission is proposing a European aim higher than the current Dutch aim which will require housing associations to reduce more CO_2 in the future.

RES and heating transition vision

However, this higher European aim does not mean a change in how the Dutch government approaches the heat transition. In the Climate Agreement the Dutch national government (2019) expects, local and regional governments to start the heat transition by developing the Regional energy strategy (Dutch translation: Regionale energie strategie [RES]) and the heating transition vision (Dutch translation: Transitievisie warmte). The Netherlands is divided in 30 RES regions (see Figure 3.1) each containing multiple municipalities delivering an energy strategy for their region. The RES has to cover at least the production of renewable electricity, the energy transition in the built environment and the required energy storage and infrastructure. Regions are free to extend the range of topics they include. Subsequently, *Colors differentiate the RES regions*

Figure 3.1 - The Netherlands divided in 30 regions containing each multiple municipalities. Each region will deliver their own RES (Dutch Government, 2019).

municipalities are tasked to develop and present a heating transition vision for their municipality before the end of 2021. Municipalities base their heating transition visions on the RES of the region there are in. In this document, municipalities will state what type of energy provisions are present or will be present in the future. The Climate Agreement expects municipalities to involve stakeholders such as housing associations in the development of the heating transition visions. Eventually, the heating transition visions will provide housing associations with information about which heat strategies will be applied to which neighborhood in the future. In other words, the municipal heating transition visions will provide important information to the decision-making processes regarding the energetic improvement by housing associations. Currently, most municipalities have delivered a concept of definitive heating transition vision and housing associations are energetically improving their housing units to achieve an average energy label B on sector level in 2021. But the clarity that the heating transition visions will assist them to increase the annual number of energetically improved residential buildings. Once the heating transition visions are definitive, the municipalities will start working on neighborhood execution plans (translation: wijkuitvoeringsplan) to realize the heat production, storage or infrastructure they promised in the heating transition vision (Dutch national government, 2019). This illustrates that of the documents following out of the Climate Agreement the heating transition vision provides the most relevant information to the decision-making process of housing associations regarding the energetic improvement.

3.3 Heat strategies by the Expertise Centrum Warmte

The Expertise Centrum Warmte presented five heat strategies to assist municipalities in developing their heating transition vision. These heat strategies could also provide an indication to housing associations of what the possible future strategies for their existing housing units are. The heat strategies are presented in a guide for municipalities with the information about how they could develop the heating transition vision (Expertise Centrum Warmte, 2020). The guide consists of two parts: a handbook and start analysis. The ‘Handbook for local analysis’ (translation: Handreiking voor lokale analyse) introduces five strategies (see Figure 3.2) containing combinations of technological building solutions. These five strategies consist of 13 variations (1A and 1B, 2A to 2D, 3A to 3E, 4 and 5) which differ slightly. Appendix C contains an overview of these five strategies and their 13 variations. These strategies provide an indication to housing associations of what the possible future strategies for their existing housing units are.

3.4 BENG, EP and NTA8800

Heat strategies by the Expertise Centrum Warmte

Strategy 1: Individual heat pump

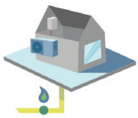
This is an All-electric strategy with far-reaching building insulation. The building is heated with an electric heat pump with buffer tank. The radiators are replaced with a low temperature (LW) delivery system such as floor heating or LT radiator. This strategy includes two variants: an air or ground heat pump.

Strategy 2: District heating with medium and high temperature source

In this strategy the building is heated with a district heating network with an output temperature on medium level (70°C). The network is supplied through a heat source with a temperature of 70°C or higher. The peak boilers run on green gas. This strategy includes variants based on different heat sources (industrial residual heat, geothermal, a biomass plant or bio cogeneration plant).

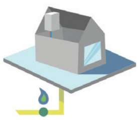
Strategy 3: District heating with low temperature source

This strategy exists of heating with a district heating network which is supplied through a low temperature heat source. The temperature is too low to directly make domestic hot water and for space heating changes are required. The designer of the system has the possibility to collectively (for a group of buildings) or individually (per building) bring the heat to a sufficient high temperature (70°C).



Strategy 4: Renewable gas* with hybrid heat pump

In this strategy a combination of an electric air heat pump and high efficiency boiler on renewable gas is applied. The heat pump uses an outdoor unit which is attached or stands close to the building. The outdoor air and natural gas air are the most important heat sources. The gas burners are deployed when the heat pump's capacity is insufficient for space and water heating. This could be a heat pump which is placed next to the existing high efficiency boiler.



Strategy 5: Renewable gas* with high efficiency boiler

In this strategy a standard high efficiency boiler is applied. It is assumed that the gas is of natural gas quality and no change is required to the boiler. In a future version of the Handbook (March 2020) a variant with hydrogen is added.

* - *The future availability of green gas is limited.*

Figure 3.2 – The five strategies which are applied (Adapted from Expertise Centrum Warmte, 2019).

In the Climate Agreement, the government acknowledges that the existing energy standard will not suffice once these new heat strategies are implemented. Therefore, they announced that new energy performance standards will be introduced. After a postponement of the deadline, the new energy performance standard BENG and EP will replace the current standard ('energy performance coefficient' (EPC)) as of the first of January 2021 (Rijksdienst voor Ondernemend Nederland, n.d.-a). Housing associations use these energy performance standards to calculate the expected energy saving as well as the energy performance of their housing units after it is energetically improved. In other words, they could be considered similar to the building energy simulation models as described in the literature background (chapter 2) about the energy performance gap. According to the Netherlands Enterprise Agency (Dutch translation: Rijksdienst voor Ondernemend Nederland) (n.d.-a) BENG stands for 'almost energy neutral building' (Dutch translation: Bijna Energie Neutraal Gebouw) and EP stands for 'energy performance' (Dutch translation: Energieprestatie). The difference between the two is that the BENG applies to newly constructed and the EP to existing housing units. These standards are based on the Trias Energetica and calculate the energy performance of a newly constructed housing or existing housing unit based on three indicators:

1. The (maximum) energy demand in kilowatt hours per square meter usable area per year.
2. The (maximum) primary fossil energy use in kilowatt hours per square meter usable area per year.

The BENG and EP indicators

Existing building		EP-1: Energy demand	EP-2: Primary fossil energy use	EP-3: Share renewable energy	TOjuly: Overheating
New building requirements		BENG-1	BENG-2	BENG-3	TOjuly:
	Residential building	65 kWh/m2	50 kWh/m2	40%	Maximum 1.2
	Row house	55 kWh/m2	30 kWh/m2	50%	

Table 3.1 – BENG and TOjuli indicators newly constructed housing units are required to meet after January 1, 2021. No requirements apply to existing housing units (Adapted from Vabi, n.d.-a).

3. The (minimal) share of renewable energy in percentages.

The maximum and minimum indicators only apply to the BENG indicators. In addition to these three indicators a fourth indicator is added to minimize the risk of overheating called: TOjuly. Nowadays, we are confronted with hot summers. This, in combination with energy efficient housing units could cause overheating as heat could become trapped inside the building's insulation. For this reason, TOjuly is added as

Energy label NV	Usable area according to the NTA 8800						Energy label class	EP-2 from January 1, 2021 [kWh/m2]
	< 25 m2		>= 25 m2 and < 40m2		> 40 m2			
	Single family	Multi family	Single family	Multi family	Single family	Multi family		
	52	48	48	44	44	40	A++++	<= 0,00
	52	48	48	44	44	40	A+++	0,01 - 50,00 (new build)
A	52	48	48	44	44	40	A++	50,01 - 75,00
A	48	44	44	40	40	36	A+	75,01 - 105,00
A	44	40	40	36	36	32	A	105,01 - 160,00
B	40	36	36	32	32	28	B	160,01 - 190,00
C	36	32	32	28	22	15	C	190,01 - 250,00
D	32	28	22	15	14	11	D	250,01 - 290,00
E	22	15	14	11	8	5	E	290,01 - 335,00
F	4	1	4	1	4	1	F	335,01 - 380,00
G	0	0	0	0	0	0	G	> 380

Table 3.2 – Proposed rearrangement of the energy labels (Adapted from Vabi, n.d.-a).

fourth indicator to the BENG and EP. The method to measure and calculate all these indicators is called the NTA 8800 (Rijksdienst voor Ondernemend Nederland, n.d.-a). Developer of software for housing associations, Vabi, was closely involved in the development of the BENG and EP. According to Vabi (n.d.-a) newly constructed housing units have to meet the BENG indicators as shown in Table 3.1. Meanwhile, the EP will replace the Energy Index for existing housing units. The existing method of energy labels will remain, but a rearrangement is proposed (see Table 3.2). This illustrates that as a result of the Climate Agreement, housing associations should not only reduce energy demand of their housing units but also calculate the energy performance of that housing unit differently.

The introduction of the BENG and EP also poses a challenge to housing associations as the standards are integrated in the Dutch 'housing valuation system' (Dutch translation: Woningwaarderingsstelsel [WWS]). The 'housing valuation system' provides a systematic approach to housing associations and its tenants to determine a reasonable rental price for a housing unit. The BENG and EP will be integrated in existing legal documents such as the building code (Dutch translation: Bouwbesluit), energy labels and rent price legislation such as the WWS (Dutch Government, 2019). According to Vabi (n.d.-a), the BENG and EP are favorable for housing units which have favorable geometric proportions (such as intermediate houses and apartments) or are all electric. And the BENG and EP are unfavorable to housing units which have unfavorable geometric proportions (such as corner houses or detached houses), small housing units and NOM housing units with compensation of solar panels. NOM refers to 'zero on the meter' (Dutch translation: Nul op de meter). From the perspective of the entire Dutch social housing stock, the introduction of the BENG and EP will not result in a variation. But in individual cases this transition could lead to variations in energy labels and therefore in rent (Vabi, n.d.-a). This means that after the introduction of the BENG and EP, housing associations are able to collect more rent for housing units with favorable conditions and less for housing units with unfavorable conditions. It is important to stress that this is not a sudden alteration which has to take place as of the first of January 2021. This situation only applies when housing associations generate a new energy label. New energy labels are generated for instance after an energetic improvement or once it expires after 10 years (Vabi, n.d.-a). Which means that the alteration of the WWS and therefore the rental prices is a gradual process spread over 10 years.

3.5 Conclusion

This chapter discussed the Dutch Climate Agreement. The policy document gives direction as it aims at a reduction of emitted greenhouse gases by 49% by 2030 relative to 1990. Prior to the Climate Agreement, housing associations have agreed to ensure that every housing association has an average energy label B by 2021. Furthermore, PBL concludes in the KEV 2019 that the intended CO_2 reductions will not be reached, which makes the already difficult task of meeting the goal of 95% reduction by 2050 even more strenuous. Additionally, the European Commission suggested a higher European aim of 55% reduction by 2030 relative to 1990. But most importantly the Climate Agreement is a 'call to action' for housing associations and other stakeholders in the heat transition. It provides information to housing associations about what kind of support they can expect from municipalities and regional governments in the future. This involves regional governments developing Regional energy strategies (RES), and municipalities developing heating transition visions and neighborhood execution plans. For the development of the heating transition vision, the Expertise Centrum Warmte developed strategies for municipalities. These strategies also provide housing associations an indication of what the possible future strategies for their existing housing units are. The Climate Agreements also announced the introduction of the new energy performance standards BENG and EP, which requires housing associations to calculate the energy performance of their housing according to these standards from January 2021 onwards. The introduction of the BENG and EP will lead to gradual alterations of energy labels and rental prices over the course of 10 years.

4
Methodology

4.1 Introduction

This thesis explores the potential role of open data in the decision-making process regarding the energetic improvements by housing associations. This chapter will describe the methodology applied in this research to uncover this potential role. Section 4.2 explains which methods are applied in this thesis and why. Followed by section 4.3, 4.4 and 4.5 introducing the interviewed housing associations and other professionals and the observed decision-making support systems.

4.2 Study design

For this thesis empirical data was collected through a combination of interview and observation data collection. The interview data collection was performed by conducting semi-structured interviews among employees of Dutch housing associations or other professionals who have experience with either the energetic improvement of existing housing units, the decision-making of housing associations and/or the use of data in the decision-making. The observation data collection was performed by observing websites, instruction videos, leaflets and other documents about decision-making support systems which were provided by the respective software developers. The combination of these two methods allowed the study of both the current and potential role of open data in the decision-making process of housing associations. The interview data collection provided insights the approaches housing associations apply in the energetic improvement of housing units, stakeholders of housing associations in the energetic improvement, possibilities and limitations of the available and relevant data to the decision-making process and the desirable features of the conventional decision-making support systems regarding the energetic improvement by housing associations. The observation data collection allowed further exploration of unconventional yet relevant decision-making support systems. The semi-structured interviews suited the aim of the empirical data collection as it covered both pre-selected topics and allowed for further exploration of topics which the interviewees provided in the conversation. This exploration also revealed topics which housing associations struggled with and have not found a solution for. For these topics additional interviews were conducted with other professionals to cover these specific topics and explore solutions for these issues. The observation of websites, instruction videos, leaflets and other documents was the most suitable within the constraints of this thesis. An observation of the actual operations of support systems would be the ideal method. However, it was not possible to perform this kind of observation due to the Covid-19 pandemic, time constrains and commercial concerns.

Next to the empirical and observation data collection, desk research was performed by reviewing academic literature and policy documents. This desk research provides a theoretical and policy background for the sub research questions of this thesis. To clarify, it provides a background for the sub research questions about the approaches housing associations apply in the energetic improvement, stakeholders in the energetic improvement and the possibilities and limitations of available and relevant data in this decision-making process by housing associations regarding the energetic improvement.

4.3 Interviewing housing associations

In the selection of housing associations for the interviews, the aim of an equal geographical distribution over the Netherlands (see Figure 4.1) and balance in the size of the housing associations (see Figure 4.2) was pursued. This was done to ensure that the data is not distorted by local conditions or that larger or smaller housing associations dominated the collected data. In Figure 4.2, the size distribution is shown in combination with their average Energy Index in 2017 and 2019. The average Energy Index are added to show how much progression the interviewed housing associations made in the time period prior to the interview. For this research 13 Dutch housing associations were interviewed, namely in alphabetical order: De Delthe, Havensteder, Parteon, Rondomwonen, Stadlander, Vivare, Wierden en Borgen, Wonen Limburg, Woonservice, Woonstad, Wormerwonen, Ymere, Zeeuwland. Employees with different roles and role descriptions were interviewed for this thesis, namely: an asset manager, portfolio managers, a managing director, data specialists, real estate staff members and sustainability, real estate and other consultants. This variety in interviewees is due to the fact that there is little homogeneity in the job titles among housing associations. These employees were selected based on their job title and description on Linkedin or other media and approached via Linkedin or email or volunteered

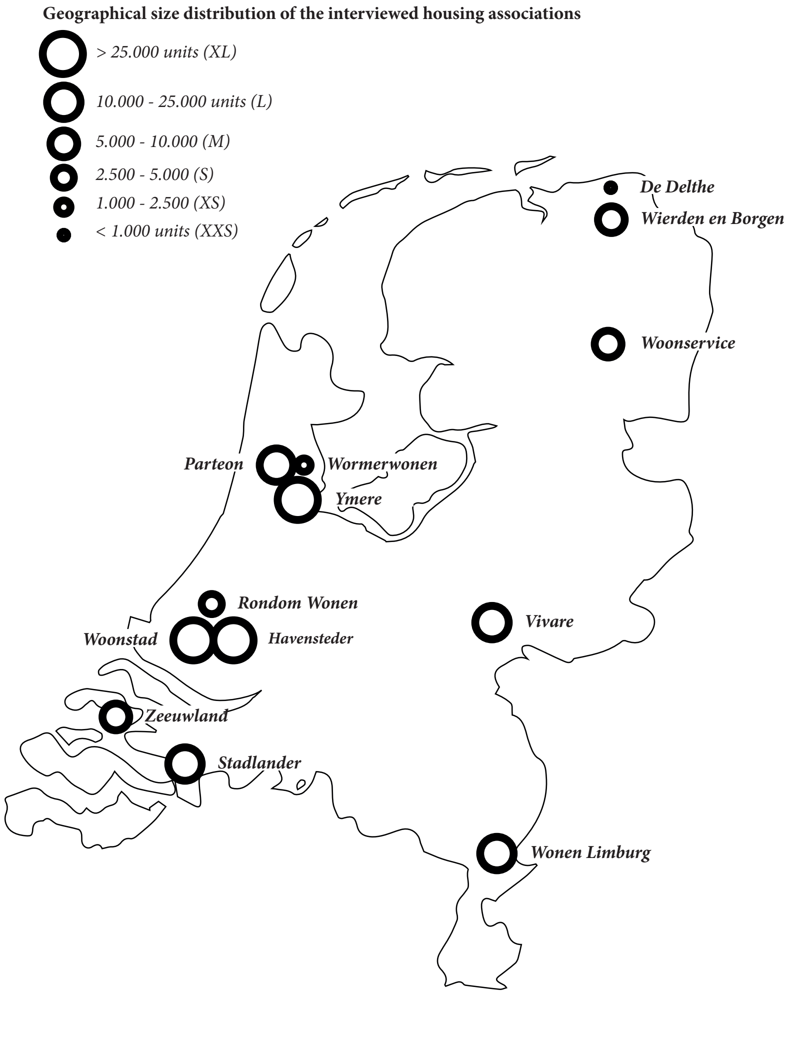


Figure 4.1 – Geographical distribution of the interviewed housing associations over the Netherlands (Based on Aedes, 2019; own image).

Size distribution of the interviewed housing associations and the progress in average Energy Index they made between 2017 and 2019

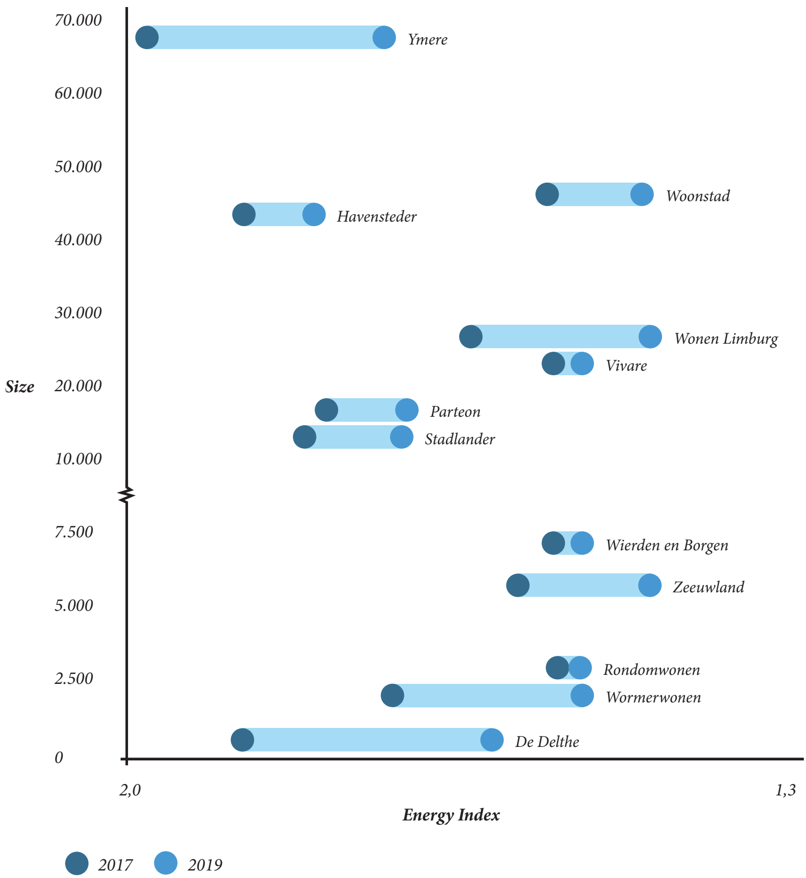


Figure 4.2 – Size distribution of the interviewed housing associations and the progress in average Energy Index they made between 2017 and 2019 (Based on Aedes, 2019; own image).

after a general mail request to the housing association. Appendix D provides a more detailed overview of the interviewed housing associations.

The interviews were conducted in Dutch, to make it easier for the interviewees to discuss technical topics. The interview protocol as presented in appendix E is an English translation of the applied Dutch interview protocol. This also means that all quotations of interviewees are translated from Dutch to English in the empirical result chapters (5 to 7). The interview protocol comprises of questions about pre-selected topics which were asked to all housing associations. This was done to ensure that data on the most relevant topics was collected among all participating housing associations. The method of semi-structured interviews also allowed for further exploration of relevant topics to this thesis which were not among the pre-selected topics. Due to the Covid-19 pandemic, these interviews were all performed in video calls. All of the video calls were recorded and later transcribed. The transcriptions of the interviews were coded in Atlas.ti and analyzed by coding quotations, assigning relation, creating network, printing reports and manually detecting similarities and contradictions in the quotations. By doing so, the analysis software was mainly used to visualize quotations and their relations in a comprehensible way. The findings of this analysis are presented in the following empirical result chapters (5 to 7).

4.4 Interviewing other professional

Based on the relevant topics that the interviewed housing associations provided in the interviews, five other professionals were interviewed to sufficiently cover these topics in this thesis. Ortec Finance senior consultant Logemann was interviewed prior to the housing associations to test the first version of the interview protocol, gain experience with the method of semi-structured interviews and collect the first empirical data which helped shape the following semi-structured interviews with housing associations. As suggested by Logemann, an anonymized TU Delft PhD researcher was interviewed about the difference between theoretical and empirical energy performance calculation methods. Furthermore, the interviewed housing associations indicated that the collaboration with municipalities is important to housing associations and that the heating transition vision is an important document in this collaboration. This and the review of policy documents led to the interview of policy maker data driven planning Van de Vreede from the association of Dutch municipalities (VNG). She was interviewed about the progress in the data-driven development of the heating transition vision by municipalities and how data used in this development could also be used by housing associations. The interviewed housing associations also indicated that privacy is limiting them from monitoring the energy use of their housing units and collecting the energy service fee (Dutch translation: Energieprestatievergoeding (EPV)). Therefore, Stroomversnelling program manager monitoring Hommelberg was interviewed about privacy, the energy service fee and the solutions that his organization offers to associations. The consultancy company Overmorgen was mentioned by multiple interviewees which led to the interview of space and information consultant Engels. He was interviewed about the decision-making support systems they developed for municipalities and housing associations and the use of open data in the energetic improvement in general.

Similar to the interviews with the housing associations, these interviews were conducted in Dutch, performed in video calls and the recordings later transcribed. The questions in these interviews were not based on an interview protocol, but rather addressed the questions which were unanswered in the interviews with the housing associations. This allowed for further exploration of these topics. The transcriptions of these interviews were not coded in Atlas.ti and only the relevant paraphrases were selected from these interviews to support the story in the following empirical result chapters (5 to 7).

4.5 Observing decision-making support systems

The conventional decision-making support systems for the observation data collection were selected based on interviews. This list was complemented with support systems which were presented in the CorporatieGids 2019 by CorporatieMedia. The interview data provided features of the support system which housing associations found desirable in the energetic improvement. These desirable features are presented in chapter 7 about the decision-making support systems. The observation studied if the decision-making support systems consisted of these desirable features. In this observation media was studied which was provided by the software developers themselves such as websites, instruction and/or promotion videos and product leaflets. This was done to collect the most actual and objective observation possible. Only in the case of Vabi and Overmorgen the research deviated from this observation method and data was also collected through personal communication. This was done because of Vabi's close involvement to this thesis research, which made it possible to ask questions about their support systems as well as the system of competitors. As mentioned in the previous paragraph, Overmorgen was interviewed because they were mentioned by multiple interviewees. Furthermore, unconventional decision-making support systems were found based on a web search engine and the interview data. The web search was performed using keywords from the desirable features. When asked which decision-making support systems they use (see Appendix E), the interviewee provided the name and description of an unconventional decision-making support systems. Similar to the conventional decision-making support systems, media by the software developers was observed to study if these decision-making support systems consisted of these desirable features. The findings of this observation are presented in the last empirical result chapter 7 about decision-making support system.

5
Empirical results: Energetic improvement

5.1 Introduction

This chapter presents the empirical findings of the data collected through these semi-structured interviews and desk-research regarding the energetic improvement. An energetic improvement aims to reduce the energy demand of a housing units so that less energy is used, and less energy should be supplied. This chapter starts by discussing the empirical findings about the approaches housing associations apply in the energetic improvement in section 5.2. And continues in section 5.3 by discussing the awareness about the energy performance gap, the stakeholders in the energetic improvement in section 5.4 and finishes with challenges housing associations aim to pair to the energetic improvement in section 5.5. With the empirical results this chapter will answer the first and second research questions about the approaches and stakeholders of housing associations in the energetic improvement.

5.2 Approaches in the energetic improvement

The energetic improvement itself and therefore the approach per housing associations differs substantially due to local conditions. For instance, Ignjatov (personal communication, April 10, 2020) explains that their task is relatively uncomplicated as it is clear that the majority of their portfolio will be connected to district heating from the Rotterdam harbor. Meanwhile, this task is much different in more rural areas. Donselaar (personal communication, May 26, 2020) clarifies that his organization hopes that their housing units could be provided with renewable gas in the future as this seems the only feasible solution for them. And not only geographical conditions, but also the technical condition of their real estate or the financial condition of the housing association showed to serve as reasons to apply a certain approach. This section presents the approaches which housing associations apply in the energetic improvement which were found in the interview data. An understanding about these approaches will assist in generating an understanding about what data is relevant to the decision-making process of housing associations regarding the energetic improvement.

‘No regret’ measures

What stands out in the general approach in the energetic improvement of all housing associations is the notion of ‘no regret’. ‘No regret’ refers to the premise that housing associations aim at energetic improvement measures which they do not regret investing in in the long term. In the interviews, half of the interviewees specifically mentioned ‘no regret’ measures. After overlooking all interviews, it has become clear that inexplicitly all housing associations aim at such investments. Housing associations appear to have broadly taken over this notion from the Climate Agreement as it also specifically mentions that housing associations should intend for ‘no regret’ investments. ‘No regret’ measures also connect well to the lack of knowledge almost all interviewees described as one of the procedural challenges in regard to the energetic improvement. This involves a lack of knowledge about suitable mechanical installations, the current and future availability of heat sources in the area and the future availability of the district heating in the area. For these reasons, it could be stated that ‘no regret’ is what in general characterizes the approaches of housing associations in the energetic improvement. Examples of these ‘no regret’ measures are investments in building insulations and customer-driven solar panel projects.

Improving building insulation first and installations later

The measure housing associations currently prioritize most is the improvement of the building insulation as they are in anticipation of the heating transition vision to inform their future decisions. As stated in the policy background, the heating transition visions are still in development and municipalities will present them before the end of 2021 the latest. These visions will provide clarity to housing associations about the future availability of district heating or intended heating strategies. This leads to housing associations prioritizing the improvement of the building insulation as it is a measure that they need to take regardless of the heat source and mechanical installation. Improvement of the building insulation would therefore be a first step and the replacement of the connection to a heat source and/or the mechanical installations would be a second step in the energetic improvement. This illustrates that the improvement of the building insulation is a ‘no regret’ measure for housing associations. In half of the interviews the housing associations mentioned that in their approach they prioritized the improvement of the building insulation. These were housing associations which did not intend to be frontrunners in the energetic improvement. In the other half, the housing associations were able to change the heat source and mechanical installations in combination with the improvement of the building's insulation. In these cases, this was because of clarity about the current and future availability of district heating, their stock consisted of newer housing units or they decided to demolish and reconstruct and not energetically improve housing units. Thus, housing associations prioritize the improvement of the building's insulation of their housing units and often change the heat source and mechanical installations in a second step in the energetic improvement.

Solar panels on request as "low-hanging fruit"

Solar panel projects and especially costumer-driven projects are an effective measure for housing associations from which both the housing association and occupant benefits. In recent years, the price of solar panels has dropped (Milieucentraal, 2020). This resulted in housing associations adopting this building technology in their energetic improvements. In the majority of the interviews, the housing associations mentioned that they have or had a project in place to install solar panels on their housing units. In the majority of these cases, these solar panel projects were 'customer-driven'. Customer-driven means that the tenants themselves could request the installment of solar panels on their house. These projects only apply to houses and not to apartments. This because apartments are stacked, meaning that solar panels on apartment buildings would be placed on a shared roof which would complicate the administrative allocation of the generated electricity. These housing associations also optionally offered tenants of their houses to install solar panels on top of the standard energetic improvement. The interview data shows that housing associations benefit from solar panels as they are taken into account in the housing valuation system (WWS) which allows them to raise the rental prices slightly, improves the energy labels and helps them to achieve their sector arrangements. Residents also benefit from solar panels as they decrease their energy expenses. It could not be determined from the interview data what the reasons for housing associations were to not have a solar project in place. Therefore, costumer-driven solar panel projects are an effective measure for housing associations from which both the housing association and tenant benefits.

Dealing with the worst energy labels first

'No regret' measures such as costumer-driven solar panel projects and improvement of the building insulation allows the housing associations to improve their average energy labels. As intended in the sector arrangements, the housing associations confirm in the interviews that they aim at an average of energy label B by 2021. Logically, to raise the average energy label the quickest, housing associations have to energetically improve the housing units with the worst energy labels first. Rikken (personal communication, May 6, 2020) said: "We scanned our portfolio on: Where do we have the worst energy labels? Those are projects we want to deal with first.

We want to deal with the worst energy labels from D to G first." The range of energy labels on which housing associations focused varied from the lowest energy label G to energy labels D, E or F. The interview data shows that this approach in the energetic improvement applies to all housing associations. The approach of dealing with the worst energy labels first is a very logical and widely applied approach as it enables housing associations to raise their average energy label and achieve their sector arrangement in time.

Step or leapwise approach

The improvement of these housing units with the worst energy labels (and housing units in general) takes place in a step or leapwise approach. The interview data shows that housing associations prefer to energetically improve their housing units or complexes in two or three steps to CO_2 neutral but could also decide to do it in one step or 'leap'. In the interview, Rikken (personal communication, May 6, 2020) explained the concepts of step and leapwise in the context of the energetic improvement. In the stepwise approach, housing associations energetically improve their housing units or complexes in two or three steps to CO_2 neutral. As mentioned before, the first step in this process is often the improvement of the housing unit's façade and/or roof insulation. In later steps, the connection to a heat source and mechanical installations are replaced. In this sense the stepwise approach strongly aligns with what is described in the paragraph above about the improvement of building insulation. De Delthe for instance applies this stepwise approach. Krajenbrink (personal communication, May 15, 2020): "We make our efforts in the insulation. Currently, we do as little as possible about the mechanical installation, because in general that is quite up to par among our housing units." According to Rikken (personal communication, May 6, 2020), housing associations align in the stepwise approach their energetic improvement efforts with maintenance efforts. Aligning both efforts has two benefits, as it is more efficient as maintenance staff or contractors need to visit these housing units anyway and it minimizes the disturbance for occupants. Housing associations could also decide to improve the insulation, mechanical installations and potential other items in one single step to CO_2 neutral. In the interview, Rikken referred to this as leapwise. The leapwise approach could be beneficial when an occupant moves out of the housing unit and it is empty for a while. He explains that these so-called mutations occur quite regularly which means that a substantial part of a housing association's portfolio would be eligible to be energetically improved this way. When an occupant still occupies the housing unit, the leapwise approach is less beneficial as they most likely have to leave their home during the energetic improvement. The energetic improvement is a larger disturbance to them but in principle only has to take place once. According to Rikken, this disturbance to occupants could be a motivation to housing associations to apply either a step or leapwise approach. Other motivations he mentioned are the workforce capacity to prepare and perform the energetic improvements and building characteristics (T. Rikken, personal communication, May 6, 2020). It is necessary to stress that a decision for a stepwise or leapwise approach is not an absolute but a guiding premise. In real estate management, asset managers or other real estate staff members will constantly weigh which approach suits a housing complex best, which makes that a housing association could apply both approaches simultaneous in different projects. In half of all interviews the interviewee specifically mentioned that their housing associations applies a stepwise approach After overlooking the interview data, it appears that almost all housing associations are applying a stepwise approach. In part because most housing associations are still in anticipation of the final heating transition vision to inform their decisions. Thus, housing associations are most likely to apply a stepwise approach as they are in anticipation of the final heating transition vision and intend to minimize the disturbance for occupants.

Energy service fee (EPV) approach

Ultimately, it is not the decision for a step or leapwise approach but the housing concepts which will allow housing associations to achieve a CO_2 neutral portfolio. Housing associations have a legal ability to collect an energy service fee in addition to rent (Dutch translation: Energieprestatievergoeding [EPV]) in the case of 'zero on the meter' (Dutch translation: Nul op de meter [NOM]) housing units (RVO, n.d.-b). The NOM and energy positive heating concepts contribute the most to reach the goal of achieving a CO_2 neutral portfolio. To collect the EPV, the housing unit has to comply to several criteria. The most important criterium is that the housing associations should demonstrate to the tenant that the housing unit's energy production is equal to the energy use on average. This energy is often if not always produced by solar panels. This leads to housing associations measuring the actual energy use of an individual NOM housing units. Stadlander is one of few housing associations that collects an energy service fee. Van der Sanden (personal communication, May 20, 2020) explains: "At all our housing units we placed monitoring systems which are remotely readable. We have to monitor them yearly to comply with the EPV legislation towards the legislator and on the other hand partly to provide accountability to the tenants." The data of the interview suggest that only frontrunners such as Stadlander or larger housing associations apply an EPV approach. According to Rikken (personal communication, May 6, 2020) housing associations do not apply the EPV approach because they are either technically unable to energetically improve their older existing housing units to NOM or they run into privacy issues when they would like to monitor the actual energy use. Stroomversnelling monitoring program manager Hommelberg (personal communication, June 23, 2020) confirms that around 50 housing associations have housing units from which they collect an EPV. This illustrates that only a small portion of the Dutch housing associations currently applies an EPV approach and other housing associations are reluctant to apply the EPV approach.

The non-profit organization Stroomversnelling assists housing associations and other stakeholders in accelerating the heat transition in general by developing solutions for the application of EPV and NOM housing units. Hommelberg (personal communication, June 23, 2020) explains that the ambition of the Stroomversnelling is to achieve an energy neutral built environment in 2050. To achieve this ambition, the organization develops solutions in co-operation with their members. These include housing associations, construction companies, municipalities and suppliers of heat pumps and monitoring software. The solutions they develop are geared towards easing the application of EPV and NOM housing units and accelerating the energy transition in general. Examples of these solutions are the purchasing agreement for NOM housing units, NOM certification (Dutch translation: NOM keur) and monitoring norm and application programming interface (API) for monitoring systems. The solutions they develop will eventually become available to the public (M. Hommelberg, personal communication, June 23, 2020). Thus, the solutions of the Stroomversnelling are able to assist in taking away the barriers which the housing associations face in the EPV approach.

Next to these approaches in the energetic improvement, the interview data also provided three other findings for this thesis. The first finding covers the energy performance, the second the stakeholders in the energetic improvement and the third covers the additional challenges housing associations face next to the energetic improvement.

5.3 Energy performance gap

A small number of housing associations are aware about the energy performance gap. In the interviews the clearest example of this awareness is provided by Krajenbrink. He said: "These calculation methods assume that everybody always has their heating turned on. If I sometimes see what the natural gas consumption of a certain housing unit in my portfolio should be, the question arises: If my occupant consumes this much, I am not sure what kind of job this person has. So, I wonder sometimes: What is realistic?" (personal communication, May 15, 2020). But he wonders what could be done to consider occupants' behavior. In the interviews, four other housing associations made a statement in regard to the energy performance gap. Among these are mainly smaller or medium sized housing associations. It is unclear why this is, but a reason might be that it is easier for smaller housing associations to have a closer look at their data due to their size. In the interview a postgraduate (PhD) researcher at the Delft University of Technology (TU Delft) (personal communication, April 20, 2020) also argues that awareness about the energy performance gap is growing among housing associations. For these reasons, we could state that housing associations are increasingly aware about the energy performance gap.

As an alternative to the theoretical building energy simulation model the PhD researcher is developing an empirical model. This is in line with the recommendation by Majcen et al. (2016) to use large datasets about buildings thermal performance and actual consumption. According to the PhD researcher: “Energy labels are not per se bad to use as quality indicators of your housing units to target on. But if you only target on them to reduce the actual CO_2 emissions in the Netherlands, you are probably not making the right retrofitting and policy decisions.” (personal communication, April 20, 2020). In his research the PhD researcher is developing an empirical model based on data on the building characteristics and actual energy consumption. The data on the building characteristics is the same data as is used for the calculation of the energy labels. The data on the actual energy consumption is microdata that Statistics Netherlands (Dutch translation: Centraal Bureau voor de Statistiek [CBS]) only provides to researchers under strict conditions. Eventually, this empirical model should be able to determine what measures would or would not be effective. “When such a calculation is made on a large set of housing units the occupants’ behavior will be averaged out.” ... “One housing unit may deviate substantially, because how one occupant uses the housing unit could differ much. Take 100 similar housing units with all occupants. On an average you should be able to make a good prediction at a certain moment” (PhD researcher, personal communication, April 20, 2020). Such empirical model could co-exist alongside the energy labels, BENG and EP to obtain an insight in the energy use of housing units which is closer to practice. The empirical building energy simulation model, as currently developed at the TU Delft, could assist housing in improving the decision-making process about the energetic improvement by housing associations.

5.4 Stakeholders in the energetic improvement

Next to housing associations, there are also other stakeholders in the energetic improvement. The data ecosystem about the heat transition in the Netherlands by Diran et al. (2020) (see Figure 2.6) as discussed in the theoretical background (chapter 2) provides a good overview of the housing association’s stakeholders in the energetic improvement. The interview data aligns with this overview by Diran et al. (2020) and shows that occupants, municipalities, other housing associations and grid operators are the most prominent stakeholders in the energetic improvement for housing associations.

Occupants

Smaller housing associations are more likely to consult their occupants or adjust their decisions to respond to the personal situation or requests of occupants. In the interviews, smaller housing associations explained how their size allowed them to communicate personally with their occupants. Kerssens (personal communication, May 13, 2020) explains: “The occupants have the best impression about the housing unit and know best what is lacking. When you exchange that information in an early phase and are able to indicate what could be done about it and what your financial frame is, occupants start to think along with you.” … ”You immediately engage the ambassadors in such a neighborhood”. They not only allowed occupants to inform their proposal but were also mindful about personal situation or requests of occupants during the execution of the energetic improvement. Krajenbrink (personal communication, May 15, 2020) illustrates this by providing the example of a pregnant occupant: “An employee goes in consultation with the construction company: Could you switch around these housing units? That way you plan in a slightly different way, so you could provide a tailor-made solution to a family in such a situation. Whereas you would usually say: There is a construction sequence and we could not change that.” … “Here we purposefully look at the due date of this woman’s pregnancy. It is not convenient to retrofit that housing unit then, so we pick another. The construction company usually co-operates. Usually it succeeds, because they are used to us working this way. The construction companies know this, and we select them based on this”. Larger housing associations are less accustomed to consulting occupants during the decision-making or the execution of the energetic improvement. In the Netherlands, housing associations are required to receive an approval of 70% of the occupants before they are allowed to make changes to a housing complex. This also applies to the energetic improvement. The data of the interview shows that larger housing associations have more trouble achieving this level of approvement. One of these large housing associations that is experiencing troubles in this regard is Ymere. Rohmer (personal communication, May 29, 2020) said: “These are long trajectories.” … “We are working on Decartes, one of our complexes in Amsterdam Nieuw-Sloten. I believe they want to start retrofitting next year, but there they are already organizing information evenings to excite occupants about district heating.” This illustrates, that the personal communication with occupants makes it easier for smaller housing associations to achieve the level of approvement which are legally required in the Netherlands.

Municipality and the heating transition vision

As a result of the development of the heating transition vision, the existing collaborations between the municipality and housing associations appeared to have intensified. According to the interview data, almost all housing associations appear to be involved in the development of the heating transition vision. Caris (personal communication, June 2, 2020) explains: “In Parkstad [the development of the heating transition vision] is organized regionally. In other municipalties in Limburg this is organized by the municipalities themselves.” … “There are multiple parties and housing associations around the table. There are also grid operators around the table.” … “The municipality with a lot of people.” The only housing associations which was not involved in the development of the heating transition vision of their municipality was Rondomwonen. Van Leeuwen (personal communication, May 28, 2020) explains: “I think this has a little bit to do with the composition of our municipality. Because we have relatively few rental housings compared to owner-occupied housing. Pijnacker is a horticulturists village of origin. Here, the home ownership is relatively high. So, that puts less pressure on the municipality to involve the housing association. For them, it is nice to make steps together but with that they are not going to pull it off.” … “The only initiative which the municipality of Pijnacker now has is about climate adaption.” Thus, the development of the heating transition vision appeared to have intensified the collaboration between municipalities and housing associations.

Other housing associations

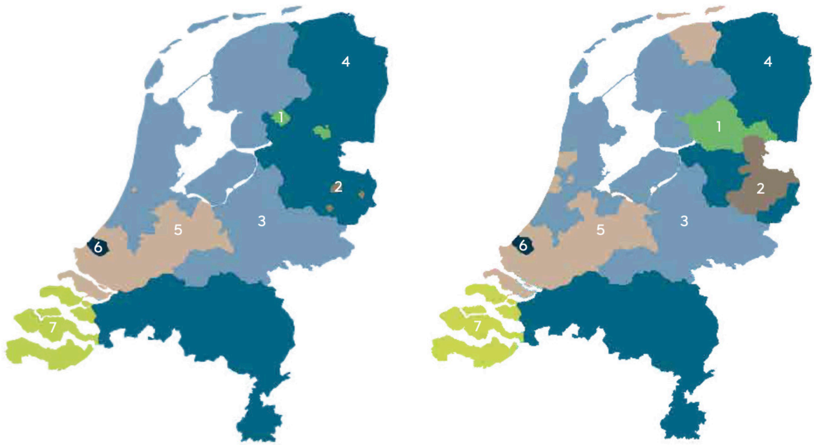
In the development of the heating transition visions, municipalities often involve all housing associations which operate within their municipality. This also resulted in intensification of collaborations between housing associations. In the interviews, almost all housing associations mentioned that they collaborated with neighboring housing associations. They commonly collaborate with neighboring housing associations on various topics. In the interview data two collaborations stood out. The first is the Amsterdam federation of housing associations (Dutch translation: Amsterdamse federatie van woningcorporaties [AFWC]). Rohmer (personal communication, May 29, 2020) explains that before the Climate Agreement and as a response to the Paris Agreement, the housing associations in this federation, municipality and grid operators agreed to actively collaborate to disconnect housing units in Amsterdam from natural gas. The second, is the collaboration between housing associations from the province of Limburg, called the C8. Caris (personal communication, June 2, 2020) explains: “The C8 collaboration was started as an informal collaboration of the eight largest housing associations of Limburg. And they target multiple subjects. Sustainability is one of them. For the last year and a half, we frequently come together to explore a number of sustainable subjects together.” For these reasons, we could state that housing associations in rural areas are more likely to set up collaborations on a regional or provincial scale and housing associations in urban areas on a city scale.

Grid operators

As Rohmer already explained in the previous example, grid operators are important stakeholders for housing associations to consult in the decision-making process as they have a lot of data on the energy systems. According to Netbeheer Nederland (2019), the task of grid operators is to carry out the transport of electricity and natural gas, connecting producers and consumers to the grid, maintaining of the grid and investing in expansion of the grid. The task of the grid operators is to manage the grids in fixed areas of the Netherlands (see Figure 5.1). In the interviews, all housing associations confirmed that they recognized the grid operators as important stakeholder in the energetic improvement. In these cases, the housing associations were very interested in collecting data fr2om the grid operator to inform their decisions. But the grid operators are also interested in data of the housing associations, as the interview with Scheer (personal communication, May 20, 2020) illustrates: “In the energetic improvement task, we of course have to speak with [the grid operator]. They must make it technically possible. Especially when it is about electrification to move that capacity across the grid.” He also explains both parties are looking to intensify the collaboration. Scheer: “They have an incredible amount of data. They ask us: Come with your plans! Let us know what you are thinking of doing already. Even if it is in 10 years. Then we could take that into account. Vice versa we perhaps want to know how their infrastructure works and what their plans are. I think that there is increasing willingness to share that with each other” (personal communication, May 20, 2020). Thus, grid operators are able to provide the housing association with data to inform their decision-making regarding the energetic improvement, but grid operators are also interested in the data of housing associations.

Regional division of the grid operators

Electricity **Natural gas**



1. *RENDO*
2. *Coteq*
3. *Liander*
4. *Enexis*
5. *Stedin*
6. *Westland Infra*
7. *Enduris*

Figure 5.1 – Regional division of grid operators in the Netherlands (Netbeheer Nederland, 2019).

5.5 Pairing opportunities

Housing associations do not see the energetic improvement as an isolated task and often attempt to pair other challenges or activities to the energetic improvement. According to Council for the Environment and Infrastructure (Dutch translation: Raad voor de leefomgeving en infrastructuur [Rli]) (2018 in Uyterlinde, Hal, Kunst, Coen, & Bouwman, 2019), you explore pairing opportunities (Dutch translation: koppelkansen) when you research what is at play in a neighborhood and respond to this with one intervention that has an effect on multiple areas. An example of a pairing opportunity which was mentioned multiple times in the interviews was the pairing of scheduled (re)placement of grid infrastructure by grid operators with the energetic improvement by housing associations. Ignjatov (personal communication, April 10, 2020) explained: "In the Schipperskwartier in Crooswijk" … "the street needs to be excavated, the sewage system needed to be replaced. That is also an occasion in which we immediately replace the grid connection of those houses, so that the street does not need to be excavated multiple times over. Yes, we [and the grid operators] know to find each other." This shows that if a housing association and the grid operator inform each other about their intentions, they could pair their efforts. Another example is when a grid operator extends the district heating network. The housing associations could energetically improve their housing units in that area around the same time and prepare them to receive district heating. In the interviews, housing associations also mentioned other challenges they face next to the energetic improvement (see Figure 5.2).

Housing associations in some regions are challenged by population shrinkage, housing shortages, poor building foundations and/or reinforcements due to earthquakes. A clear example of pairing a challenge to the energetic improvement is provided by Krajenbrink (personal communication, May 15, 2020): "We have almost 150 housing units [with energylabel] F, G and H. That is quite substantial. Those I want to deal with first. A part of those housing units you could improve because you also need to let the reinforcement take place. As you need to reinforce, you could also energetically improve them. Then you are able to make a great combination". The reinforcement of housing units is a challenge which only applies to certain geographical regions in the Netherlands. These challenges are referred to in this thesis as regional challenges. The interview data shows that housing associations in rural regions such as the provinces of Groningen, Drenthe and Zeeland are facing population shrinkage in parts or entire areas of operation. While housing associations in the Randstad or in other larger cities have to construct new housing units to combat the housing shortage in the Netherlands. The challenge of poor building foundations was only explicitly mentioned by housing associations in the Zaanstreek (area around the Dutch city Zaanstad). However, it is expected that more housing associations are challenged by

Figure 5.2 – Other challenges housing associations face next and aim to pair to the energetic improvement (own image).

poor building foundations. In all of the cases in which the housing association faced regional challenges, they decided not to energetically improve but instead demolish and reconstruct the affected housing units. This meant that housing units were demolished, and a similar amount reconstructed at the same location. Except for the case of Zeeuwland, which experiences population shrinkage in their area of operation. They would for instance demolish 7 units in a village and reconstruct only 6 new units. This allows them to construct one additional housing unit in the city of Zierikzee where there is still demand. This shows that regional challenges push housing associations to decide not to energetically improve but to demolish and reconstruct housing units.

Ymere is the only interviewed housing associations which is challenged by backlogged maintenance. They are the largest housing association in the Netherlands with around 70 thousand housing units, which makes it worthwhile to discuss this challenge separately. Rohmer (personal communication, May 29, 2020) describes that they prioritize housing complexes which suffer from backlogged maintenance in current and future energetic improvement projects. In these projects, they will apply a leapwise approach to ensure that these housing associations are effectively brought to the appropriate standard. This challenge was specific to Ymere, as none of the other interviewed housing associations mentioned that they are challenged by backlogged maintenance.

Sustainability challenges

Housing associations are challenged by sustainability themes such as climate adaptation, circularity, nitrogen emission and nature inclusion. These challenges are in this thesis referred to as sustainability challenges. The sustainability themes of nitrogen emission and nature inclusion were only mentioned by Stadlander (J. Van der Sanden, personal communication, May 20, 2020; P. Musters, personal communication, May 28, 2020). This is because their portfolio is close to a Nature 2000 conservation areas. Since 2019, nitrogen emissions are more carefully considered in the acquisition of building permits. This makes it much harder to receive building permits and limits the pace of their energetic improvement. Van der Sanden explains that this is an ongoing discussion with the municipality: “But [the municipality] must support us in this, instead of selling plots and ‘space’ to emit nitrogen to commercial real estate developers. Which creates a problem in our energetic improvement task” (personal communication, May 20, 2020). Even though nitrogen emission and nature inclusion were only explicitly mentioned in the interview with Stadlander, it is assumed that this sustainability theme also challenges other housing associations, as Nature 2000 is a network of conservation areas covering the Netherlands and Europe (see Figure 5.3). Climate adaptation and circularity were the sustainability themes which the interviewed housing associations mentioned most often. This is not surprising,

Figure 5.3 - Natura 2000 conservation areas in the Netherlands (Compendium voor de Leefomgeving, 2020).

because the Dutch government developed national programs for climate adaptation (called 'Netherlands circular in 2050' (Dutch Government, n.d.)) and circularity (called 'Delta program: Spatial adaptation' (Dutch Government, 2019)). In half of all interviews, mainly larger housing associations mentioned either or both challenges. A possible reason for this could be that larger housing associations usually have dedicated sustainability consultants creating awareness within the organization about these themes. In a few cases housing associations attempted to pair climate adaptation or circularity with the energetic improvement. Rikken (personal communication, May 6, 2020) illustrates this by saying: "For instance, decoupling rainwater drainage and such matters. In places where we could easily take that up, we shall do so. But we do not generate extra resources for this theme currently." The interview data suggest that climate adaptation and circularity are sustainability challenges which get a lower priority compared to the energetic improvement, but housing associations are not unwilling to contribute to climate adaptation and circularity when possible. In summary, it is assumed that nitrogen emission and nature inclusion affect more housing associations than just Stadlander. And climate adaptation and circularity are sustainability challenges which housing associations attempted to pair to the energetic improvement.

5.6 Conclusion

This chapter discussed the approaches housing associations apply in the energetic improvement, the awareness among housing associations about the energy performance gap, the stakeholders in the energetic improvement and the challenges housing associations aim to pair to the energetic improvement. Based on these empirical results, the following could be concluded about the energetic improvement: In the energetic improvement, housing associations aim at measures they do not regret in the long term such as improvements in the building's insulation and customer-driven solar panel projects. The goal of the energetic improvement is to reduce CO_2 emission and improve the average energy label. To achieve this as soon as possible, housing associations focus on the housing units with the worst energy labels. To disturb the occupants as little as possible, housing associations prefer to energetically improve their housing units or complexes in two or three steps (stepwise). A housing complex is a group of housing units which because of administrative or other corporate reasons could be distinguished through which a similar type of maintenance, development and policy is possible (Corponet, n.d.). But other various conditions might force the housing associations to decide to energetically improve in a single step (leapwise). The NOM and energy positive building concepts reduce the most CO_2. When housing associations construct or energetically improve to these building concepts they have the legal ability to collect an energy service fee in addition to the rent. However, very few housing associations have NOM or energy positive housing unit and collect an energy service fee. This is because it is technically difficult to energetically improve existing buildings to this level or because of privacy concerns around the required monitor of the actual energy use. The non-profit organization Stroomversnelling is offering solutions in this regard. Local conditions often dictate which approach a housing association applies in the energetic improvement. Housing associations demonstrated awareness that their energetic improvements are not achieving the expected reduction in energy use (energy performance gap). The empirical building energy simulation model which is currently developed at the TU Delft could provide a solution in this regard. Such a model could co-exist alongside the 'almost energy neutral building' (BENG) and 'energy performance' (EP) standards and provide housing associations with empirical predictions on the expected reduction in energy use. In the energetic improvement, housing associations are dealing with many stakeholders. The most prominent stakeholder in the energetic improvement are occupants, municipalities, other housing associations and grid operators. In their efforts, they attempt to pair the energetic improvement with other challenges they face wherever possible. Examples of these challenges are reinforcement of buildings due to earthquakes, population shrinkage, backlogged maintenance, circularity and climate adaptation. In this chapter, a better understanding was obtained about how housing associations approach the energetic improvement and what kind of obstacles they face in their efforts. With this understanding, we are able to shift our focus to the use of data in the decision-making process regarding the energetic improvement.

6

Empirical results: Data in the decision-making process

6.1 Introduction

Now that the approaches and challenges for housing associations in the energetic improvement are clear, this chapter focusses on the decision-making process regarding the energetic improvement and the data used in the process. It starts by discussing the data that housing associations generate themselves (primary data) and the importance of data quality in that regard in section 6.2. Next, the use of open data is discussed in section 6.3. This involves the attitudes of employees of housing associations, possibilities, limitations and future opportunities of open data. In section 6.4 the use of purchasable data is discussed because the interviews show that housing associations purchase data once open data does not provide them with the data they desire for their decision-making process. With the empirical results, this chapter will answer the third research question about the possibilities and limitations of the available and relevant data.

6.2 Primary data

Housing associations generate large amounts of detailed data themselves which they can use in their decision-making process regarding the energetic improvement. This mainly involves data on their real estate. Vabi (n.d.-b) studied the possibility of a generic data model for housing associations which stores primary data on their real estate. As a result of this study, they described 17 data categories. The housing associations mentioned half of these primary data categories. The data categories which were specifically mentioned in the interviews were: address details, tenants' details (housing associations mentioned: income of occupants), complex strategies, allocation criteria (indented target group), rent and WWS (respective rent and housing valuation system) real estate characteristics (building year, insulation values, energy labels, square meters), constructional details (building plans and sections), mechanical installation, and maintenance history. This shows that these categories are the most relevant to the decision-making process regarding the energetic improvement. This illustrates that housing associations have a large amount of detailed data in their databases on their real estate as well as their occupants.

Data quality and housing complex sessions

In the decision-making process, it is of importance that the data that housing associations have in their databases is of good quality. According to Aedes (2020), data is of good quality when it is fit for the intended use in the decision-making, planning and the execution of operational processes. The data could contain errors or not consist of the required properties which consequently decreases the quality. Woonservice big data consultant Boersma (personal communication, June 18, 2020) explains: "With us [the data quality] is well managed. Very simple, one time two years ago they took all data which was on paper – which you still see at many housing associations – and scanned and digitalized it. So, everything is perfectly stored in the system and that saves a whole lot of time." In the interviews, seven housing associations mentioned data quality in relation to primary data of which four mentioned that they are running or completed a data quality project. Parteon consultant Corporán Souverein (personal communication, May 28, 2020) illustrates this by saying: "When I was hired three years ago, the project 'Data op orde' was just completed. Our data is quite good and accurate." Therefore, we could state that housing associations are aware of the issue of data quality and taking action to improve it with a temporary project.

However, data quality is not only about improving but also about preserving. This is also stressed in a step-by-step plan which branch organization Aedes presented in January of 2020. This step-by-step plan describes how housing associations could improve and preserve their data quality. This is done through 10 steps, namely:

1. Raising awareness
2. Determining the problem
3. Prioritizing and making arrangements
4. Analyzing causes
5. Determining possible solutions
6. Executing the improvement plan
7. Securing the result
8. Cleansing and supplementing data files
9. Terminating data factories
10. Evaluating (Aedes, 2020).

In the document by Aedes these steps are described in more detail. What these steps show is that the improvement of the data quality requires the organization to be aware of the issue of data quality and their behavior while using data (step 1). And that the data quality could be improved through the development and execution of an improvement plan (step 2 to 6) but that efforts are required to preserve the data quality sustainably (step 7 to 10). Thus, data quality is not a temporary project for housing associations but an ongoing process of improvement and preservation.

One of the possible solutions which could assist housing associations in improving and preserving their data quality are housing complex sessions. According to Verkoeijen (2019), knowledge and experiences which employees gather in the field are shared with the aim to enrich the result of a complex performance analysis to determine the optimal complex strategy and policy. Rikken (personal communication, May 6, 2020) illustrates this by saying: “We verify [our data] twice per year in housing complex sessions with all colleagues in that area. Then you are talking about an area manager, rental service manager and somebody from minor repairs and systemic maintenance (Dutch translation: buurtbeheerder, verhuurmedewerker en iemand van klachtenonderhoud en planmatig onderhoud). We bring them together and ask them: We see this data. Does that correspond with your experiences when you are in this neighborhood or what you run into? This risk of data is always that it incomplete, outdated or should be interpreted slightly different. For instance, a high mutation degree could be caused by a lot of elderly people living there. It does not have to mean that the product is undesirable. So, you must place it in the right perspective.” The only other housing association which specifically mentioned housing complex sessions was Wonen Limburg. Caris (personal communication, June 2, 2020) explained that they organize housing complex sessions after the developed concrete execution programs to explore if there are other reasons to invest in these complexes: “At Wonen Limburg we have 11 objectives” … “The aim is to contribute to as many objectives as possible with one investment”. In summary, in the decision-making process regarding the energetic improvement data can only be used when it is of good quality. The step-by-step plan by Aedes and housing complex sessions could assist housing associations in improving and preserving this data quality.

6.3 Open data

Housing associations are already, to varying extents, accustomed to collecting open data for their decision-making process. The data which is generated by another person or organization and made available to housing associations for reuse and analysis is referred to as secondary or tertiary data. Open data is most of the time tertiary data as it should be kept confidential to whom the data refers to. According to the data of the interview, ten out of the thirteen housing associations collected open data in the past. These consisted mainly of larger housing associations. The amount of data which was collected in these cases differed significantly. This ranged from yearly collection of the real estate valuation (Dutch translation: waardering onroerende zaken (WOZ)) from the municipality to dedicated data teams searching frequently for open data. The three housing associations which mentioned that they did not collect open data in the past were mainly smaller housing associations.

However, this does not mean that these smaller housing associations did not use open data in the past. Smaller housing associations are often unaware that the data which is provided in the support systems is often open data by default. The interview data and the analysis of the support systems show that software developers regularly process open data in their systems. A good example of such open data items is the basic registration addresses and building number (Dutch translation: basisregistratie adressen en gebouwen (BAG)) provided by Dutch Land Registry and Mapping Agency Kadaster. According to CorpoNet (2012), the BAG allows for a uniform exchange of data between housing associations and stakeholders. Such stakeholders are mainly other governmental organizations such as the municipality. In other words, BAG is used in the relational database of housing associations as shared field (the indexical key) to link tables of data. Thus, the smaller housing associations are also using open data, but are less aware about it.

Data providers

Housing associations mainly collected open data from governmental bodies. Open data could come from many types of organizations, but not all of this data is relevant for the decision-making process of housing associations. The several open data portals or platforms from which the interviewed housing associations collected data and used it in their decision-making process regarding the energetic improvement were Klimaatmonitor by Rijkswaterstaat, Open data Statline by CBS, PDOK by several governmental bodies, BAG register by Kadaster, Open data portals or platforms by municipalities, Planbureau voor de Leefomgeving and the Leefbarometer by the Ministry of Home Affairs. The Leefbarometer is a monitor for the livability of areas and neighborhoods in the Netherlands (Ministry of Home Affairs, n.d.). These data platforms and portals align well with the platforms and portals by Diran et al. as described in the theoretical background (see Table 2.2) in chapter 2. This illustrates, that housing associations are accustomed to collecting open data from governmental bodies through different data platforms or portals.

In the future, much of this open data from governmental bodies will be made available in an open data platform called VIVET. VIVET stands for Improvement information provision energy transition (Dutch translation: Verbetering informatievoorziening energietransitie). According to Van de Vreede (personal communication, June 17,

Organization	**Open data portal or platform**	**Data**	**Link to data source**
Cadaster	BAG viewer	• BAG • Year of construction	https://bagviewer.kadaster.nl/lvbag/bag-viewer/index.html
CBS	CBS in de buurt	• Income • Living costs • Age composition of neighborhoods and more	https://cbsinuwbuurt.nl
National government	Nationale dataportaal	• Livability monitor • Solar potential	https://data.overheid.nl
Governmental bodies	PDOK platform and viewer	• 3D building objects • BAG • Natura 2000 and more	https://www.pdok.nl
Governmental bodies	Nationale energie atlas	• Energy use • Sustainable generation • Infrastructure • Energy potential	https://www.nationaleenergieatlas.nl/kaarten
Grid operators		• Energy use • Energy infrastructure • Age or replacement time frame of the infrastructure	https://www.enexis.nl/over-ons/wat-bieden-we/andere-diensten/open-data
Local governments		• Property values by the municipality (WOZ) and more	https://maps.amsterdam.nl
Rijkswaterstaat	Klimaatmonitor	• CO_2 emissions • Share renewable energy	https://klimaatmonitor.databank.nl/dashboard/
Ministry of Home Affairs	Leefbarometer	• Livability monitor	https://www.leefbaarometer.nl/kaart/ - kaart

Table 6.1 - Overview of data platforms and portals according to the interviews that housing associations collected for their decision-making.

2020) from the housing associations of Dutch municipalities (VNG) Multiple of the earlier mentioned governmental bodies are collaborating to make the data from the government which is necessary for the energy transition more easily accessible to other parties. VIVET is currently still in development. In April 2020, these collaborating governmental bodies presented a work plan for 2020 and in the first quarter of 2021 the work plan for 2021 will be written (VIVET, 2020).

Next to governmental bodies, grid operators provide very relevant data to housing associations for the decision-making process regarding the energetic improvement. In almost all interviews, the housing associations explicitly or inexplicitly mentioned that they were interested in viewing the energy use of their real estate. They were able to collect data on the energy use as open data from grid operators. This data provides them with an insight in how much energy a housing unit consumes before and after the energetic improvement and how much could potentially be reduced. The housing associations primarily described how they used this data in the decision-making process prior to the energetic improvement and less so afterwards. A full overview of the data platforms and portals housing associations mentioned in the interviews is presented in Table 6.1. This shows that data on the energy use from grid operators is among the most important to include in the decision-making process of housing associations regarding the energetic improvement.

Attitude towards open data

The majority of the interviewees had a positive attitude towards the use of open data in their decision-making process. In the interviews, interviewees were asked what they think is the potential role of open data in the decision-making by housing associations regarding the energetic improvement of their housing units. The majority responded positively to this question. The three interviewees who were neutral or negative were mainly smaller housing associations. This aligns with the result about the housing associations which used open data in the past. Donselaar (personal communication, May 26, 2020) answered: "That is of course still very difficult to say. We are contacted by many parties that want to convince us to do something with data. But I always say: You first need to know what you need and what you want to do with the data before you purchase something." This answer is quite similar to the answers of De Delthe and Rondomwonen. These smaller housing associations were indecisive about the potential of open data. Meanwhile, Kerssens (personal communication, May 13, 2020) was less convinced about the role of open data. He answered: "Despite all of this data, you just need to let your eyes continuously go over your real estate." … "That is also why I like working for this organization. I know the people and the families. That is a much larger treasure of information that larger housing associations often do not have." Due to their size, Wormerwonen and other smaller housing associations are able to consult occupants and by doing so collect information that is valuable to their decision-making process. The remaining interviewees were positive about the role of open data in their own decision-making, such as Musters (personal communication, May 28, 2020): "I see much future in that. I think soon we are able to connect data on a number of areas to each other. [Which enables us] to shift very quickly if we have the right information." Tuinbergen (personal communication, April 21, 2020): "In terms of topics, open data could certainly help us further. To do neighborhood analysis and such." … "But on the level that I usually need [data] to build a model that it is often to zoomed out (Dutch translation: te hoog over) and a to high aggregation level." Caris (personal communication, June 2, 2020): "In my opinion, there is in any case more open data [available] than we can now foresee or use." … "I think that the clustering of that data and overlaying it – the steps that we are currently taking – are very nice ones." Boersma (personal communication, June 18, 2020): "I think [open data] could really serve as a support in the decisions that you need to make." This illustrates that open data in general is considered an added value to the decision-making regarding energetic improvement by housing associations, but the use of open data to smaller housing associations is less clear.

Housing associations also show awareness of the added value their data in an open format could have to their stakeholders. Rohmer (personal communication, May 29, 2020): "I think it could mainly help with making things understandable and learning from each other." Rikken (personal communication, May 6, 2020): "I think the more open data you have at your disposal the better you are able to have a conversation. Open data provides everybody with the same insight." Scheer (personal communication, May 20, 2020): "I think that we need to keep doing more with [open data]." And continues by describing a recent conversation with their grid operator: "They have a tremendous amount of data. They ask us: Come with your plans." … "The other way around we perhaps want to know more about their infrastructure. What are their plans. I think there is increasingly more willingness to share that with each other." Van Lobenstein (personal communication, April 23, 2020): "For the transition, we should share much more information through area maps between companies such as municipalities, [grid operators], heat suppliers and other housing associations. In this, the municipality is the director of that data. I am not sure if this needs to be open source but does not have to be, I think. Only through sharing data we get away from looking inward and we will also look at the interests of others and they at ours." Corporán Souverein (personal communication, May 28, 2020): "I really think it could make a large contribution. Because at the same time we also have a lot of data. So, it is unfortunate that we do not share this with the world. Anonymized of course. I think other parties probably could do a lot with this data." Thus, housing associations are aware about the role open data could have to their stakeholders in the heat transition. In other words, they are aware that they are able to contribute to the data ecosystem of the heat transition.

Open data in the energetic improvement offers housing associations the possibility to obtain data on what is happening in the vicinity of their real estate and plans of stakeholders. Rikken (personal communication, May 6, 2020) explains: “It provided us with the insight how one neighborhood differs from other neighborhoods.” … “Through our primary system we only have a view on our occupants and our housing units. This open data allows us to involve private individuals and others in our information.” This illustrates that housing associations are interested not only in the occupants and our housing units but also what is happening in the vicinity of a specific housing unit. Rohmer (personal communication, May 29, 2020) adds to this: “We know exactly what the conditions are of our complex and what the building structure is. At the municipality it is more about the neighborhood approach and what they intend to do. That obviously has impact on our complexes.” This illustrates that open data also provides housing associations with insight in the plans of stakeholders. Both data on the vicinity of their real estate and plans of stakeholders assist housing associations in finding pairing opportunities and alignment with their stakeholders. A good example of this are grid operators such as Stedin (n.d.) which currently provide open data on energy infrastructure and the age or replacement timeframe of this infrastructure. This data provides housing associations with an insight in where certain energy infrastructure is located and what the plan of their stakeholder – in this case the grid operator – is. This illustrates that open data in the energetic improvement allows housing associations to explore pairing opportunities and obtain data on the vicinity of their real estate.

Limitations of open data

One of the limitations which discourages housing associations from using open data in their decision-making process is privacy and the anonymization of the data. Because open data is made available to anyone it should be anonymized to ensure confidentiality with respect to whom the data refers to. Van de Vreede from the housing associations of Dutch municipalities (VNG) brings up the strange situation in society around privacy: “You notice that government - and housing associations probably as well - are very cautious in the exchange of data. Legitimate, I think. But you also have the remarkable situation with the Amazons, Zalandos and Bol.coms of this world who know everything about you or at least a lot. And that we apparently find okay. Because that company needs to make a profit, we order stuff from them and that is convenient. But you also have the strange situation that the government takes a very cautious attitude with the use of data while they are serving the public interest, namely the energy transition.” One way to anonymize the data is to clustering data. For instance, the open data on the energy use provided by grid operators is grouped in at least ten neighboring connections. Rikken (personal communication, May 6, 2020) explains: “Per housing unit you want to know: What do people consume? Because of privacy we do not have a view on that and will not get insight in it. Only on postal code level." Housing associations are not able to use this data in their decision-making process because it is distorted as it might include housing units outside the housing association's portfolio and housing units with greatly varying building characteristics. The interview data suggests that housing associations aim to include data on the smallest scale legally possible, preferably a housing unit. This would allow them to link the open data to primary data which is also structured per housing unit. Donselaar (personal communication, May 26, 2020) illustrates this by saying: "We would like to see that open data on the energy use of a street becomes available. That would be very nice. Then you could see when you energetically improved a street if that was an effective effort." In the interviews, the housing associations considered open data on energy use provided by grid operators helpful for a first analysis. But open data would often be insufficient for more extensive analysis. In the next section about purchasable data, the issue of privacy in relation to data on energy use is further discussed. Thus, open data does not always provide housing associations with the desired data as it is often anonymized due to privacy.

Another limitation is that it is not always clear to housing associations which open data is available to them and how it could be relevant to their decision-making process. Corporán Souverein (personal communication, May 28, 2020) illustrates this by saying: "We as a corporation are naturally also not data specialists. We also do not have many data specialist who are fully devoted to [finding open data], to search in that data what could be relevant to us and at the same time are able to make the integration with our existing systems." And Krajenbrink (personal communication, May 15, 2020) said: "I often do know these websites, but the question is what I as a small housing association exactly need to with that [open data]." There we no similar notions in other interviews but it is expected that this limitation applies to all housing associations who do not have dedicated data specialist in house. This illustrates that the findability of open data and relevancy of the found open data is a limitation for housing associations in the use of open data.

Future opportunities of open data

Housing associations could benefit from receiving the heating transition vision as open data in a format which allows for extensive data analysis, such as an area map with data layers. As stated in the policy background, municipalities are tasked to present their heating transition vision before the end of 2021. In the interviews, all housing associations considered the heating transition vision to be an important piece of information in their decision-making process. Donselaar (personal communication, May 26, 2020) raises this idea: "It would of course be very nice - once it is done - if the heating vision of the municipality could be imported into the [support system]." Rohmer (personal communication, May 29, 2020): "If the heating vision are integrated in [the support system] we would be able to see what the plans are in regard to the energy transition. Such things make [our] image a bit more complete." If the housing associations have such data, it would be possible for them to link their real estate data to the data of the heating transition vision. In the decision-making process this would provide them with a clear overview of which heat strategy applies to a housing unit according to the municipality. They would be able to decide to energetically improve the housing unit to the suggested heat strategy or explore possible heat strategies. This illustrates that housing associations would like municipalities to share their finished heating transition visions in a format which allows for extensive data analysis.

Other open data that housing associations could benefit from if it is made available is data on the use of district heating by grid operators. As mentioned before, grid operators currently provide open data on use of electricity and natural gas. However, they do not provide open data on the use of district heating. The TU Delft PhD researcher (personal communication, April 20, 2020) mentioned this in his interview as an omission in his research. This data is not only relevant for his research but in the decision-making process of housing associations as well. It would allow them to monitor the energy use before and after the energetic improvement. With the currently available data on the electricity and natural gas use, they are able to obtain insights in the energy use before the energetic improvement. If grid operators make open data on the use of district heating available, housing associations would be able to obtain insight in the energy use after the energetic improvement through data on use of electricity and district heating. It is unclear if and when data on the use of district heating will be made available by grid operators and/or CBS. Nonetheless, it is clear that open data on use of district heating would be beneficial to the decision-making process of housing associations.

6.4 Purchasable data

Housing associations are already, to varying extents, accustomed to purchasing data for their decision-making process. Purchasable data is secondary or tertiary data which is generated by and purchased from another person or organization. In the interviews, ten out of the thirteen housing associations purchased data in the past. These are the same ten housing associations who collected open data in the past. This also means that the remaining three housing associations are mainly smaller housing associations.

The data housing associations purchased was mainly collected from grid operators, research agencies and consultancy agencies. The number of data sources from which data was purchased were considerably less than the mentioned open data sources. In the interviews, the housing associations mentioned that they purchased data on demographic information and prognoses (for instance household composition and population prognoses) by research agency such as ABF, lifestyles by consultancy agency such as MarketResponse and more specific data on the energy use by grid operators. Of these data sources, data on the energy use was mentioned most often. Five interviewees specifically mentioned that their housing association purchased data from their grid operators on the energy use. Similar to open data, data on the energy use also appears to be the most important purchasable data for housing associations include in their decision-making process.

Housing associations consider purchasing data because open data does not always provide the desired data for their decision-making process. A good example of data that housing associations collected is on the energy use. The difference between open data and purchasable data on the energy use is who assigns the clusters. Because of privacy legislation the data needs to be provided in clusters of at least ten housing units. In open data on energy use, the clusters are assigned by the grid operator and in purchasable data the housing association is able to assign the clusters themselves. Caris (personal communication, June 2, 2020) explains: “When you purchase that data it is much more accurate. Then you could request them per ten housing units. There you gain a lot more knowledge from and have a bit less distortion in the data. Because than the owner-occupied houses are not included.” … “You first provide your own list and need to make the clustering yourself.” … “We roughly made clustering based on complexes. You are allowed to put 10 housing units in one cluster according to the AVG.” The AVG is the privacy legislation in the Netherlands and stands for General regulation data protection (Dutch translation: Algemene verordening gegevensbescherming). Caris mentioned that they made cluster based on housing complex. By doing so they could assume that each cluster consist of housing units with as many (almost) similar building characteristics. The same goes for demographic information and prognoses. In these cases, housing associations would be able to request information or a prognose which is tailored to their situation. In the interviews, half of the housing associations mentioned that they purchased data on energy use in the past. Thus, purchasing data often enables housing associations to collect data on the smallest scale legally possible or tailored to their situation.

6.5 Conclusion

This chapter discussed the data that housing associations generate themselves (primary data), the use of open data and purchasable data according to the semi-structured interviews. Based on these empirical results, the following could be concluded about data in the decision-making process: Housing associations generate a lot of data and are accustomed to collecting open data and purchasing data from stakeholders. The extent to which they generate, collect and purchase data differs per housing association. Roughly speaking, the smaller housing associations were often more relucent or less aware of the use case of this data and the larger housing associations demonstrated to be more accustomed to a data-driven kind of decision-making. The issue housing associations often run into in this decision-making process is the data quality. It is important for them to keep improving and preserving the quality of the data in the databases. The housing associations were asked in the interview about their attitude toward the collection and use of open data. In general, they had a positive attitude towards it because it provides them with data on what is happening in the vicinity of their real estate and plans of stakeholders. At the same time, housing association were aware that their data in an open format could also be an added value to the decision-making process of stakeholders. What discouraged them from using open data is the findability of the open data and privacy which causes the open data to be anonymized. This meant that open data provided them with suitable data for a first analysis. But for a more thorough analysis, housing associations were looking for more detailed and accurate data. By purchasing data from stakeholders, they were able to collect such data. They mainly purchased data from grid operators, research agencies and consultancy agencies. While they collected their open data mainly from governmental bodies and grid operators. Even though there is a lot of open data on the energetic improvement available already, housing associations would benefit from both heating transition vision as open data in a format which allows for extensive data analysis and open data regarding the use of district heating by grid operators.

7

Empirical results: Decision-making support systems

7.1 Introduction

Now that the energetic improvement and use of data in the decision-making process by housing associations is discussed, this chapter focusses on the support systems which housing associations use in the decision-making process regarding the energetic improvement. Support systems are software which housing associations use to analyze data to support their decision-making. It will start by discussing the conventional support systems which were mentioned in the interviews and found as part of the analysis in section 7.2. It is important to stress that the analysis is performed based on the information which was available online. This means that the support systems covered in this chapter are not comprehensible for all support systems currently available. In section 7.3, the chapter continues by discussing which features the conventional support system miss or in other words what the desirable features of support systems are in the energetic improvement according to the interview data. Lastly, this chapter will discuss the unconventional support system which were explored in the analysis in section 7.4. With the empirical results, this chapter will answer the fourth and fifth research question about the desired possibilities of the conventional support systems and unconventional yet relevant support systems.

7.2 Conventional support systems

In the following section, the reference architecture CORA is used to categorize the conventional support systems. Network organization for Dutch IT-professionals in housing associations CorpoNet (2012) has developed a reference architecture for housing associations called the Housing association reference architecture (Dutch translation: Woningcorporatie referentie architectuur (CORA)). The five data domains that Corponet has defined in version 3.0 of CORA are: real estate, relations, contracts, project development and maintenance (see Figure 7.1). In the interview Corponet core team member and Lefier program manager information provision De Vries (personal communication, September 8, 2020) points out that the next version (4.0) of CORA is presented in September of 2020. The landscape of available support systems for the decision-making process housing associations is complex and the five domains assist in explaining this complexity. Therefore, these five categories are used to categorize the conventional support systems.

Real estate support systems

Housing associations retrieve the real estate data they need for their decision-making process regarding the energetic improvement from relational databases. A relational database is a data storage solution in which a shared field (the indexical key) is the link between two tables which contain data. This creates structured data and enables querying of this data. The support systems which fall under the category of real estate deal with information about the non-extracted minerals, then with the ground united plantation, as well as the building and constructions which are lastingly connected to the ground, either direct or through another building or construction (Corponet, 2012). In the interviews, the housing associations mentioned either Vastgoeddata by Vabi or VIP by Batavia Groep. The analysis shows that the company Luxs also provides a similar support system and that prior to the existence of these three systems, housing

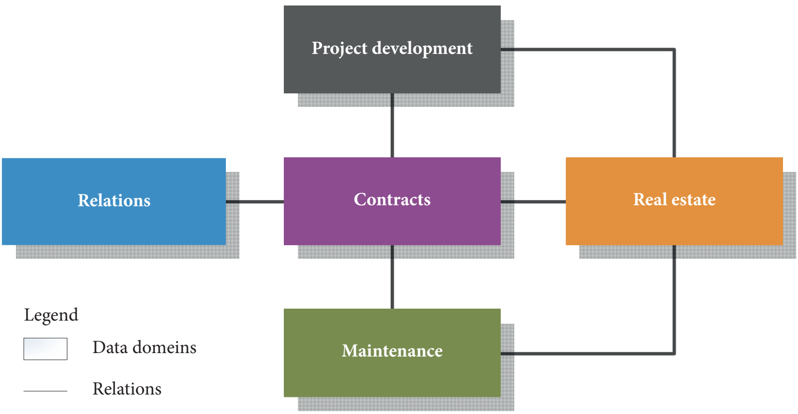


Figure 7.1 – Five data domains of CORA (Adapted from CorpoNet, 2012).

associations stored their real estate data in a Housing catalogue (Dutch translation: Woningcarthotheek). Very little information was available about Luxs and it appears that almost all housing associations have now switched to either one of the two earlier mentioned support systems. Therefore, Luxs and Housing catalogues of other software developers will not be further discussed. Vastgoeddata provides the user with a 3D representation of the housing unit or complex that the user has selected (Vabi, 2019a). In a side bar, the user is able to see all the information about this selection. This data is stored in a relational database which use the BAG as a shared field. The user is able to export this data to an Excel sheet (Vabi, 2019a). VIP is also a relational database and uses the BAG as shared field. The user is able to make a selection of one or multiple housing unit(s) or housing complex(es) and see all relevant information about this selection. VIP does not provide a 3D representation but does offer other functionalities which are similar to Vastgoeddata. The portfolio and asset managers are able to export data from these relational databases and import it into other support systems. This enables them to perform their analysis and inform the decision-making process regarding the energetic improvement. Thus, in relational databases housing association store data on their real estate and retrieve data to inform their decision-making process regarding the energetic improvement.

An example of this real estate data are energy labels, which are calculated and stored in dedicated support systems. Housing associations are legally required to have an energy label for every housing unit. The housing associations mentioned in the interviews that they calculate and store energy labels in either EPA View by Spacewell or Asset Energie by Vabi. From the analysis, it appears that these are the only two support systems which focus on energy labels. In the few cases of EPA View, it was also mentioned that the software is discontinued, and users will soon transition to the software of Vabi. Software developer Vabi (2020) also confirms this on their website. Therefore, of these two systems only Asset Energie will be discussed in more detail. As mentioned in the policy background, an energy label is valid for 10 years. However, an energy label needs to be recalculated when the housing units is energetically improved. Before an energy label could be calculated, an EPA certified staff member of the housing association or a contracted EPA consultant has to conduct a survey of the building and collect the required building characteristics. EPA stands for energy performance advice (Dutch translation: energie presetatie advise). The analysis shows that in Asset Energie the user is able to import these building characteristics. Based on this data, the system calculates the energy index and energy label. The system then allows the user to register this energy label at the database of the RVO (n.d.-c). Asset Energie also offers housing associations the functionality to simulate measures over their portfolio, entirely or partially. This falls in the category of project development. Thus, housing associations calculate and store energy labels in dedicated support systems.

Project development support systems

Portfolio and asset managers are able to see the current status of their real estate and calculate the financial, real estate and/or social impact of the energetic improvement in project development support systems. Project development are all the activities executed by a housing association that lead to a result in real estate and/or neighborhood development (Corponet, 2012). In the interviews, the housing associations mentioned the following support system in the category project development: Portfolio- en Assetmanagement Model (PAM) by Batavia Groep, Asset Management (AM) and WALS by Ortec Finance and Assets Beleidssimulatie and Asset Energie by Vabi. The analysis shows that Trace and Treasury by Aareon, Strategic policy instrument (SBI) by Ortec Finance and Reaforce by Reasult are also support systems in this category. In general, these support systems enable the user to see the current status of a portfolio, sub-portfolio or housing complex, simulate measures over their selection and calculate and visualize the impact of these measures in tables, maps and graphs. The types of measures differ per support system. In Asset Energie these are technical real estate measures such as placing solar panels, improving building insulation or changing the mechanical installation (Vabi, 2019b). As a result, the system shows for instance how much a selection of measures changes the energy index and energy label. Roughly speaking, this system only simulates the impact of the energetic improvement on housing association's real estate without considering the financial or social impact. Meanwhile, WALS, Trace and Treasury and Reaforce do the opposite. Also roughly speaking, they only simulate the financial impact of the energetic improvement without considering the real estate or social impact. In these support systems, the user is able to simulate measures about increasing or decreasing rents, investments in certain neighborhoods or housing complexes or taking up loans. The support systems PAM, Assets Beleidssimulatie, AM and SBI take an integral approach and show the financial, real estate and social impact of the energetic improvement. These systems are also clearly tuned to the three management layers. As the names suggest, AM and Assets Beleidssimulatie are developed for asset management, SBI for portfolio management and PAM is a system developed to integrate the portfolio and asset management. Vabi product owner Van den Berg (personal communicaition, September 8, 2020) explains that Ortec Finance's AM is a continued development of Vabi's Assets Beleidssimulatie. Data between SBI and AM could be exchanged to allow the collaboration between these management levels. Meanwhile, in PAM asset and portfolio managers work with the same system to simulate measures and show the financial, real estate and social impact. These measures are the same kind as the earlier mentioned measures. In short, project development either have a focus on social, financial and technical real estate measures and impacts or take an integral approach to simulate measures and show the financial, real estate and social impact of the energetic improvement.

Maintenance support systems

In a maintenance support system, data is mainly stored about when maintenance on a housing unit or complex is scheduled to take place and the respective budgets. As mentioned in the chapter 5 about the energetic improvement, housing associations often attempted to pair other challenges or activities to the energetic improvement. Maintenance is one of these pairing opportunities. Maintenance are all activities which are executed to preserve the quality of the housing association's or third party's property on the short and long term according to the set quality standards (Corponet, 2012). In the interviews not many maintenance support systems were mentioned. The housing associations did mention IBIS-MAIN by Ibis and the analysis shows that Movin'U and Vastware are two other examples of support systems in this category. In general, in these support systems the user keeps track of all the executed maintenance by the housing association and the system assists in predicting what and when maintenance is necessary. These predictions are recorded in multiannual maintenance planning and budgets. This data is relevant for portfolio and asset management as it assists them in exploring the pairing of maintenance efforts with the energetic improvement. Thus, maintenance support systems could assist in exploring maintenance as pairing opportunity to the energetic improvement.

Relations and contracts support systems

Enterprise resource planning (ERP) systems are often the focal point of the application architecture of housing associations. In the social housing sector, the ERP system is also referred to as the primary system. The relations and contracts of housing associations are often stored in a primary system. A relation is a synonym for stakeholders and is a natural or legal person or a group of persons who in the past, present or future have a relationship or have something to do with the housing associations. A contract is a record of agreements between the housing association and at least one relation about one or multiple services or products in which the rights and duties are arranged (Corponet, 2012). Data on these relations and contracts could inform the decision-making of housing associations regarding the energetic improvement. A good example of such a case is the calculation of the living costs of occupants. Housing associations are interested in obtaining an insight in how the energetic improvement impacts the living costs of occupants. The living costs includes the base rent, service costs, energy costs and municipal taxes and are possibly reduced by a rent allowance (CBS, n.d.). The primary systems store data on the base rent, service costs, rent allowance. In combination with data from the earlier mentioned support systems, the existing and future living costs of occupants could be calculated. In the interviews, the housing associations mentioned the following primary systems: XBIS Online by NCCW, ViewPoint by Itris and Wocas by Hercules. The analysis shows that Tobias AX by Aareon, Dynamics Empire by Cegeka-dsa and Fit4Woco by Ctac Software are also support systems in this category. In general, these primary systems keep track of all the communication with stakeholders such as product or service providers, their own personnel and tenants. It stores the rental agreement with and other personal information about tenants that the housing associations is allowed to store and supports services such as a customer service over the phone, a digital tenant's portal and the generation of invoices and other business letters. Some of the earlier mentioned primary systems also feature modules for maintenance, human resource processes and real estate data (housing catalogue). The interview data suggests that the smaller housing associations are more likely to use these modules than larger housing associations. The larger housing associations instead use the dedicated support system as mentioned in the categories above. Primary systems are often the focal point of the application architecture of housing associations and offer a wide variety of features which sometimes overlap with dedicated support systems.

7.3 Desirable features of the support systems

Housing associations were asked in the interviews what they think could be improved in the support systems they use for their decision-making process regarding the energetic improvement. This resulted in four desirable features.

Housing associations would like to have the possibility to analyze and present data on a map and share it with stakeholders. Van Lobenstein (personal communicaition, April 23, 2020) explains that he would like to make analysis based on maps in which information could be quickly added or left out. This would help him to get an overview of their real estate data estate on a portfolio level, make informed decisions and explore pairing opportunities. This illustrates that performing analysis on map data layers is very useful to decision-making process regarding the energetic improvement because of the scale and complexity of the task, dependency on other stakeholders such as the municipality or grid operators and availability of data. The interview data and the analysis show that conventional support systems do not have or have a limited feature which allows the user to analyze and present data on a map. For this reason, housing associations are shifting to Geographic Information Systems (GIS). These systems are used to analyze, integrate and present data on a map. Caris (personal communication, June 2, 2020) described that they are looking for ways to combine their strategic data with data from other Limburg housing associations in one GIS system. Donselaar (personal communication, May 26, 2020) mentioned that they are busy with starting a GIS project together with the municipality. In the interviews, half of the housing associations explicitly or inexplicitly mentioned that they have worked with map data layers before. Thus, conventional support systems miss a feature for analyzing map data layers.

In the conventional support systems, housing associations would also like to have the possibility to easily (and ideally automatically) exchange data between support systems. Cross-linking (Dutch translation: verknopen) involves the possibility to export data from one support system and import it into another system which it considers in its next calculation. Krajenbrink (personal communication, May 15, 2020) argues that a support system could only come to a well-considered decision if it is not only based on sustainability alone, but also considers maintenance and finances. A measure in the energetic improvement might have a very positive impact on the sustainability of that housing unit but might cause high maintenance costs in the long term. Senior consultant at Ortec Finance Logemann (personal communication, February 11, 2020) agrees that housing associations are in need of support systems which are better geared to each other. He argues that software developers need to be wary to not include similar functionalities in their products, and that they should focus on what they are good at and make sure that they collaborate with other software developers with a different focus. It appears that the scale and complexity of the energetic improvement made housing associations realize that the insights of different support systems are necessary to make an integral and well-informed decision. Similarly, cross-linking also makes it easier for portfolio and asset managers explore pairing opportunities. For instance, with data on the scheduled maintenance, a pairing opportunity with the energetic improvement could be identified. Rikken (personal communication, May 6, 2020) argues that this process of cross-linking ideally takes place automatically or on a regular basis. This illustrates that cross-linking of the data of the conventional support systems is a much-desired possibility that housing associations would like to have to make well-considered decisions in the energetic improvement.

Meanwhile, the smaller housing associations would like the support systems to be more consultative to their decision-making process. As mentioned before in the chapter 5 about the energetic improvement, all housing associations, to varying extents, miss certain knowledge. In the energetic improvement this is often knowledge about the new building technologies such as heat pumps. The larger housing associations are often less restrained to hire consultants on these topics and bring this knowledge into their organization. However, for smaller housing associations, hiring consultants is often an expensive undertaking. It is for this reason that they also see an opportunity for support systems to provide them with this knowledge. De Delthe managing director Krajenbrink (personal communication, May 15, 2020) would for instance like to tell the support system that he is able to spend one million euros on the energetic improvement and would like the support system to consult on what investments he should do. This requires cross-linking data of support systems and the support systems to also consider the data from other domains. Krajenbrink provides the example of Asset Energie suggesting measures and leaving out measures which the maintenance or financial support system calculated. This might lead to high maintenance costs or to a low policy value (Dutch translation: beleidswaarde). Zeeuwland policy consultant Donselaar (personal communication, May 26, 2020) adds to this with the example of telling the support system that he would like to achieve an average energy label A. Subsequently, the support system should provide him with the measures he should execute to energetically improve his portfolio to an average energy label A. Thus, smaller housing associations would be helped in the energetic improvement when the support systems are more consultative to their decision-making process.

In contradiction to smaller housing associations, the larger housing associations and housing associations which are more accustomed to using data in their decision-making process are noticing that they are dealing with large amounts of data. As mentioned in the theoretical background, housing associations are processing increasingly more data as part of a larger societal trend. Due to the scale and complexity of the energetic improvement, dependency on other stakeholders and availability of data, housing associations are pushed to collect and store more data to keep an overview of the energetic improvement. The interview data suggest that it is challenge for housing associations to deal with these large and growing amounts of data. Portfolio and asset managers have to analyze and visualize these large amounts of data to inform the decision-making process regarding the energetic improvement. The interview data suggests that the conventional support systems are able do this very well to a certain extent. But larger housing associations and housing associations which are more accustomed to using data are dealing with such large amounts of data that this extent does not suffice. Visualization of these large amounts of data are intended for the housing association's as well as stakeholders' decision-making processes. Corporán Souverein (personal communication, May 28, 2020) states that they would like to have a dashboard through which they could share their data with stakeholders and make that impact for occupants. The kind of data housing associations would like to share with their stakeholders are for instance their energetic improvement planning, building characteristic of their real estate and occupants' attitude towards the energetic improvement with grid operators, municipalities and other stakeholders. In short, housing associations would like to analyze and visualize large amounts of data for internal use and to share it with stakeholders.

To find possible solutions for these desirable features in the energetic improvement, housing associations are starting to use unconventional support systems. To analyze and present data map layers of grid operators, municipalities or themselves, housing associations are reaching out to the more widely used Geographic Information Systems. A mentioned example in the interviews of such system is ArcGIS by Esri. As

mentioned before, half of the housing associations explicitly or inexplicitly mentioned that they worked with map data layers and GIS before. To analyze and visualize large amounts of data on the energetic improvement, housing associations are reaching out to the more widely used business analytics service Power BI and programming language R and Python. The analysis shows that Power BI allows the user to import databases or datasets and subsequently clean, analyze and visualize that data Microsoft (n.d.). Portfolio and asset managers use Power BI to visualize data in order to share it with bodies and/or employees with decision-making authority or stakeholders in the energetic improvement. In the interviews, three housing associations mentioned that they used Power BI in the past. Boersma (personal communication, June 18, 2020) explains that they for instance use Power BI to make visualizations and aim to use it in their collaboration with the province and municipality in the future. To store the large amounts of data which housing associations are collecting about the energetic improvement, housing associations are also applying non-relation databases.
Both Boersma (personal communication, June 18, 2020) and Tuinbergen (personal communication, April 21, 2020) indicate that the data of their housing association is stored in a so-called 'data lake'. According to IBM (n.d.):

> Data lakes are next-generation hybrid data management solutions that can meet big data challenges and drive new levels of real-time analytics. Their highly scalable environment supports extremely large data volumes, accepting data in its native format from a variety of data sources. As a compliment to your data warehouse, they provide the framework for machine learning and real-time advanced analytics in a collaborative environment. (IBM, n.d.)

In other words, a data lake stores large amounts of unstructured data. It could store the data map layers from grid operators, municipalities and other stakeholders or data from the support systems, sensors of heat pumps, occupants' attitude towards the energetic improvement and so forth. This illustrates that the energetic improvement is pushing housing associations to start using more widely used data science software such as ArcGIS, Power BI, R, Phyton and data storage solutions such as data lakes.

7.4 Exploring unconventional support systems

Next to the unconventional support systems that housing associations are starting to use, free support systems are available which could inform the decision-making process of housing associations. The analysis showed that there are at least three topics about which data and free support systems are available. One of these topics is solar panels. As mentioned before in the chapter 5 about the energetic improvement, costumer-driven solar panel projects are an effective measure for housing associations to increase the energy label of a housing unit. To support such projects, housing associations need to have a rough indication whether a roof of a housing unit is suitable for solar panels. The analysis shows that there are online support

Figure 7.2 – Screenshot of the website of Zonatlas, showing a map with data on the solar panel potential of a neighborhood (own image).

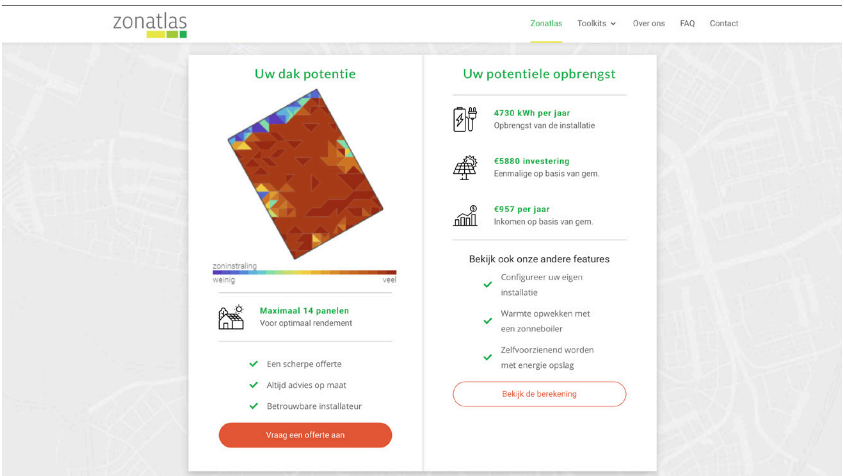


Figure 7.3 – Screenshot of the website of Zonatlas, showing a map with data on the solar panel potential of a housing unit and data on the estimated solar energy production, investment and income (own image).

systems which provide open data on this suitability. An example of such system is Zonatlas (n.d.) (see Figure 7.2 and 7.3). Their website offers two features. The first feature is a map viewer which provides an overview to portfolio and asset manager which their housing units or complexes are well suitable, suitable or less suitable for solar panels. With the second feature they are able to zoom in on specific housing units. In this web application, they could fill in the address of one of their housing units and see the solar panel potential and more relevant data. These two features provide a rough indication to housing associations. For further analysis, it appears that housing associations could also purchase this data on solar panel potential and combine it with their own data in a GIS analysis. In such an analysis, the portfolio and asset manager could for instance find which spot in their area of operation has the highest solar panel potential. This could help them focus their effort in the customer-driven solar panel projects on that area. Another topic is energy infrastructure which could be explored as pairing opportunity. As mentioned before in the chapter about data 6, grid operators currently also provide open data on energy infrastructure and the age or replacement time frame of this infrastructure. The analysis shows that grid operators such as Stedin (n.d.) provide map viewers on their website (see Figure 7.4). Portfolio and asset managers could view this data in the viewer or download the data from the website and combine it with their own data in a GIS analysis. In such an analysis, the portfolio and asset manager could for instance analyze if there is energy infrastructure which needs to be replaced soon and is close to one of their housing units. The third topic is heat sources which could be suitable for production of district heating. As already mentioned by Diran et al. (2020) in the theoretical background, WarmteAtlas is one of the data platforms that can be utilized for urban thermal energy system decision-making. The Warmteatlas (see Figure 7.5) provides data on energy potential (residual heat, waste streams, geothermal and more), energy infrastructure (district heating and natural gas) and more (RVO, n.d.-d). Portfolio and asset managers could view this data in the viewer and add their own data layer maps to the viewer. To combine the data with their own data in a GIS analysis, downloading of the individual data layer maps appears to be possible via the open data platform of the Dutch government. In such analysis, the portfolio and asset manager could for instance analyze which potential heat source is close to their real estate and find out if the installation of district heating in this area is possible. This illustrates that free support systems such as Zonatlas, open data viewer of Stedin, Warmteatlas and possibly more are available which could inform the decision-making process regarding the energetic improvement by housing associations.

Similar to the free support system, consulting companies are also responding to the desired data map layer features in the conventional support systems and are offering new GIS solutions to housing associations. The analysis shows that consultancy companies such as Atrientis with the Duurzaamheidskaart Woningcorporaties and

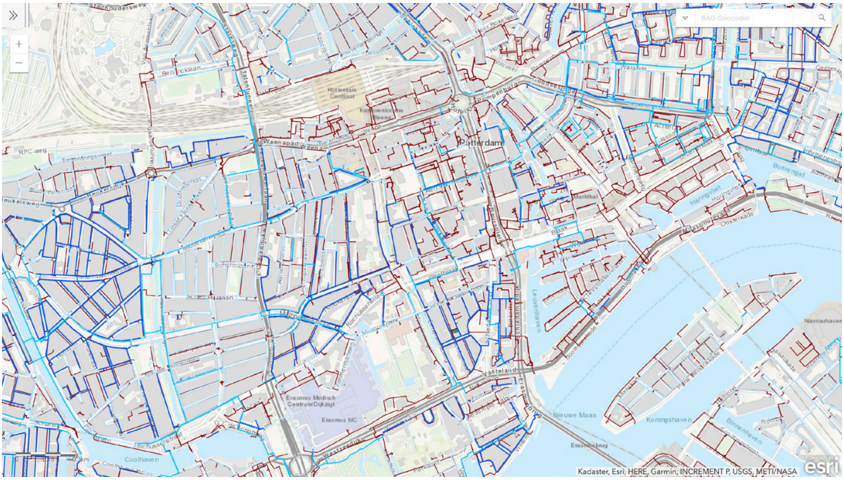


Figure 7.4 – Screenshot of the website of Stedin, showing a map with open data on the age or replacement time frame of the infrastructure of a neighborhood (own image).

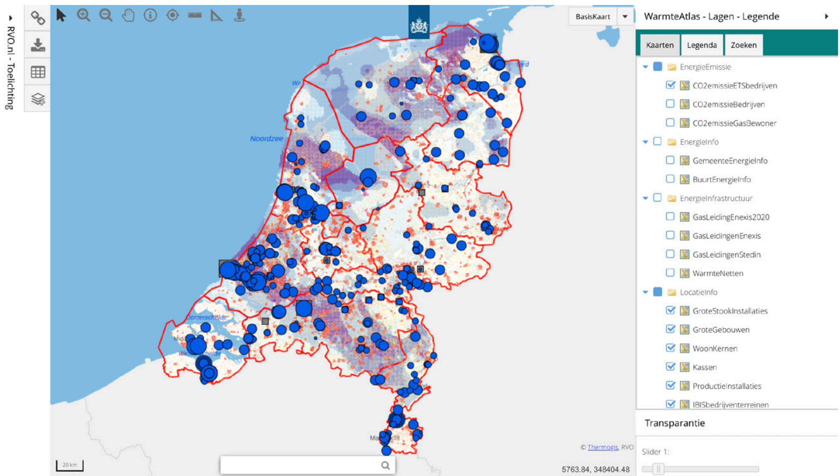


Figure 7.5 – Screenshot of the website of Warmteatlas, showing a map of the Netherlands with open data on the location of heat sources and their heat potential (own image).

Overmorgen with the Interactieve vastgoed atlas developed new support systems specific to the energetic improvement. According to the developer of Interactieve vastgoed atlas and Overmorgen consultant space and information Engels (personal communication, May 15, 2020), their Interactieve vastgoed atlas is a GIS solution which provides housing associations insight in which housing units they should energetically improve. This means that the system could indicate a cluster of housing units which would be suitable for district heating, improvement of building insulation or changing the building installation. Before the housing association can start using the Interactieve vastgoed atlas, real estate data from Vabi Vastgoeddata or Batavia Groep VIP is imported into the system. Next to this primary data, the system also uses open data on the existing district heating network, existing and potential heat sources. After this so-called data dump the system is able to generate maps which show the real estate of the respective housing association and provides the user with insights for the decision-making process regarding the energetic improvement (T. Engels, personal communication, May 15, 2020). The Duurzaamheidskaart of Atrientis (n.d.) appears to offer an almost similar GIS solution and it is expected that more smaller consultancy companies are also offering similar GIS solutions. To summarize, consulting companies developed new GIS solutions to consult housing associations in the energetic improvement.

Municipalities are facing similar challenges as housing associations and exploring GIS solutions. Municipalities are also interested in analyzing and presenting data on a map and sharing it with stakeholders. VNG policy maker data driven planning Van de Vreede (personal communication, June 17, 2020) explains that they developed a knowledge and learning program to investigate the availability of data and usefulness of that data, how to improve the data competencies employees of the municipality and the ethical discussion following from the use of data. These are similar challenges to what housing associations are facing. As a result of the program, VNG (n.d.) developed a GIS solution called the Transitievisie Warmte Viewer. The analysis shows that this map viewer uses map data layers from open data sources such as Kadaster, CBS and allows municipalities to overlay these data layers to obtain insights for the development of their heating transition vision. The map viewer shows data on the building characteristics (building year, energy label, real estate valuation, gas connections), energy use (natural gas and electricity), social characteristics of neighborhoods and climate adaption. The latter two are used to explore climate adaption as pairing opportunities to the energetic improvement. Data on building characteristics and energy use is data housing associations usually have about their own real estate. The Transitievisie Warmte Viewer provides housing associations with insights in the neighborhoods of their real estate and the data that the municipality used in their decision-making process regarding the development of the heating transition vision (VNG, n.d.). Portfolio and asset managers could analyze this data with this viewer or download it from the indicated sources and combine it with their own data in a GIS analysis. Thus, municipalities are facing similar challenges as housing associations and collecting data and developing GIS solutions for their decision-making process regarding the energetic improvement.

7.5 Conclusion

This chapter discussed the conventional support systems and desirable features of support systems according to the semi-structured interviews and discussed unconventional support systems which were explored in the analysis. Based on these empirical results, the following could be concluded about decision-making support systems: Primary systems (or ERP systems) are the focal point of the application architecture of housing associations. Housing associations often have dedicated support systems for maintenance and project development and store the data on their real estate in a relational database. In general, these are systems which are specially developed for housing associations. In this thesis, they are referred to as the conventional support systems. But these conventional support systems do not always consist of the features which housing associations desire to have in the energetic improvement. The desirable features for housing associations in the energetic improvement are:

- Housing associations would like to analyze map data layers in their support systems.
- Housing associations would like to exchange data easily and ideally automatically between their support systems.
- Smaller housing associations would like the support systems to be more consultative to their decision-making process.
- Experienced housing associations would like to analyze and visualize large amounts of data for internal use and to share with stakeholders.

The interviews showed that experienced housing associations started using unconventional support systems to analyze and visualize large amounts of data. The scale and complexity of the energetic improvement, the dependency on other stakeholders and availability of data pushed housing associations to collect more data and different types of data. This means that the energetic improvement pushes housing associations even more to use more widely used data science software such as ArcGIS, Power BI, R, Phyton and data storage solutions such as data lakes. The analysis showed that more unconventional support systems are available to housing associations which could assist them in the decision-making process regarding the energetic improvement. Support systems such as Zonatlas, open data viewer of Stedin, Warmteatlas and possibly more are available for free. They provide insight on solar panel potential, energy infrastructure as a pairing opportunity, district heating and other energy potentials. For other more refined support systems such as the Duurzaamheidskaart Woningcorporaties by Atrientis and Interactieve vastgoed atlas by Overmorgen a fee applies. Similar to the free support systems, these are all GIS solutions. This shows that analyzing map data layers is experienced by housing associations as a very useful feature of the support systems in the decision-making process regarding the energetic improvement. It is a feature which helps to get an overview over the scale and complexity of the energetic improvement. This does not mean that the easy (and ideally automatic) exchange of data between support systems and support systems being more consultative are less desirable features. These are features which only the developers of conventional support systems are able to work on.

8
Conclusion and discussion

This thesis explored the potential role of open data in the decision-making process regarding the energetic improvement by Dutch housing associations. In the Dutch Climate agreement, housing associations are tasked to energetically improve their existing housing units to reduce CO_2 emission and combat climate change. To come to this reduction, housing associations first have to choose which housing unit they would like to energetically improve, followed by the decision of when and how. In this decision-making process, they utilize data they have generated themselves to make an informed decision. However, the role of data that is generated by another person or organization was unclear, and even less clear was the role of open data in this decision-making process.

8.1 Answering the sub research questions

Against this background, a research question and five sub research questions were formulated. In this research, policy documents were reviewed, 16 semi-structured interviews conducted and transcribed, and decision-making support systems analyzed. This provided the following answers to the five research questions.

Energy performance gap and pairing opportunities

This thesis starts out by studying the approaches which housing associations apply in the energetic improvement which were found in the interview data. An understanding about the approaches will assist in generating an understanding about what data is relevant to the decision-making process of housing associations regarding the energetic improvement. The first sub question was: What are the approaches housing associations apply in the energetic improvement of housing units?

This question was addressed in the theoretical background in chapter 2 and extended with data from the interviews in chapter 5. In chapter 2, it was found that a residential building is considered energetically improved when its energy demand and energy use are reduced and is supplied with energy from renewable resources. However, housing associations often do not accomplish the expected energy reduction in practice because of unrealistic theoretic efficiencies and normalized conditions. This is referred to as the energy performance gap. Possible solutions to overcome the energy performance gap are large datasets to calculate the expected reduction and introducing more retrofit practices of recruitment and appropriation. In chapter 5, we also found that the energetic improvement differs substantially per housing associations due to geographical conditions. In their efforts, housing associations aim at measures they do not regret in the long term such as improvements in the building's insulation and customer-driven solar panel projects, prioritizing housing units with the worst energy labels and likely applying a stepwise approach. Housing associations are reluctant to construct or energetically improve building concepts which reduce the most CO_2 (NOM and energy positive building) and collect an energy service fee because of technical and privacy concerns. More importantly, housing associations attempt to pair the energetic improvement where possible with other challenges they face. Examples of these challenges are reinforcement of buildings due to earthquakes, population shrinkage, backlogged maintenance, circularity and climate adaptation.

Stakeholders in the data ecosystem

Now that the approaches of housing associations are clear, it is relevant to study the stakeholders of housing associations in the energetic improvement. This provides an understanding about who might be able to provide data to the decision-making process of housing associations. The second sub question was: What are the stakeholders of housing associations in the energetic improvement of housing units?

This question was addressed in the theoretical background in chapter 2 and extended with data from the interviews in chapter 5. In chapter 2, it was found the data ecosystem by Diran et al. (2020) (see Figure 2.5) shows the stakeholders of housing associations in the energetic improvement. The data ecosystem also provides an overview of the data platforms and portals from which housing associations could collect data for the decision-making process regarding the energetic improvement (see Appendix A). In chapter 5, we found that occupants, municipalities, other housing associations and grid operators are the most prominent stakeholder in the energetic improvement. Occupants are able to provide housing associations with information about wishes, needs or attitude towards the energetic improvement. To obtain this information, larger housing associations often look at data, while smaller housing associations are more likely to consult their occupants or adjust their decisions to respond to the personal situation or requests of occupants. The energetic improvement and the development of the heating transition visions appear to have intensified the collaboration between municipalities and housing associations. The heating transition visions will provide housing associations with information about which heat strategies will be applied to which neighborhood in the future. Housing associations are also collaborating with other housing associations which operate within their municipality because they are facing similar challenges. Grid operators are important stakeholders because they operate, maintain and eventually have to change the energy network to provide the housing units with natural gas, electricity and/or district heating. They have large amounts of data on their energy systems, are willing to share their plans and are interested in the plans of housing associations to inform the decision-making process regarding the energetic improvement.

Data from municipalities and grip operators

By studying the approaches and stakeholders the relevant core elements of the energetic improvement are discussed. Next, the focus is placed on the data used in the decision-making process regarding the energetic improvement. This to get an impression of what data is available and could be used. The third sub question was: What are the possibilities and limitations of the available and relevant data to the decision-making process by housing associations about the energetic improvement of housing units?

This question was addressed with data from the interviews in chapter 6. In that chapter, we found that housing associations have a lot of detailed data (primary data) in their databases for the decision-making process regarding the energetic improvement. For instance, on the energy label, building insulation, mechanical installation, energy use, scheduled maintenance. What could discourage housing associations from using this data in their decision-making process regarding the energetic improvement is data quality. It is of importance that this data is of good quality. Housing associations showed to be aware about this issue but less aware that this could only be achieved in an ongoing process of improvement and preservation.

It was also found that open data, while facing limitations, provides necessary insights for the decision-making process regarding the energetic improvement. Open data is easy to access which makes it helpful in a first analysis. It offers housing associations the possibility to explore pairing opportunities and obtain data on what is happening in the vicinity of their real estate. For instance, about the plans of stakeholders, where other challenges are at play or which neighborhoods experience poor livability. As prominent stakeholders, municipalities and grid operators are also the main sources from which housing associations collect open data. However, open data does not always provide housing associations with the desired data. The anonymization due to privacy, findability of data and relevancy of the found open data are what discourages housing associations from using open data in their decision-making process regarding the energetic improvement. For more extensive analysis, open data would often be insufficient. Housing associations therefore purchase data to collect data on the smallest scale legally possible or tailored to their situation.

Data layer maps and cross-linking data

Now that it is clear what data is available and relevant to the decision-making process, it is relevant to look at the decision-making support systems in which this data is used. The desirable features are studied to verify to what extend the support systems connect to the decision-making process regarding the energetic improvement. The fourth sub question was: What are desirable features of the conventional decision-making support systems by housing associations about the energetic improvement of housing units?

This question was addressed with data from the interviews in chapter 7. In that chapter, we found that these conventional support systems do not always consist of the features which housing associations desire to have in the energetic improvement. Conventional support systems are the decision-making support systems which are specially developed for housing associations. The desirable features of decision-making support systems for housing associations in the energetic improvement are:

- Housing associations would like to analyze map data layers in their support systems.
- Housing associations would like to exchange data easily and ideally automatically between their support systems.
- Smaller housing associations would like the support systems to be more consultative to their decision-making process.
- Experienced housing associations would like to analyze and visualize large amounts of data for internal use and to share with stakeholders.

Data science software and GIS solutions

Lastly, with the desirable features in mind unconventional decision-making support systems are studied. This provides an impression about how these support systems could offer housing associations some of the features they desire and which support systems might become more conventional in the future. The fifth and final sub question was: What are unconventional yet relevant decision-making support systems by housing associations about the energetic improvement of housing units?

This question was addressed with data from the interviews in chapter 7. In that chapter, we found that the scale and complexity of the energetic improvement, the dependency on other stakeholders and availability of data pushed housing associations to collect more data and different types of data. This pushes them to use more widely used data science software and data storage solutions such as data lakes. Meanwhile, the analysis showed that there are many GIS solutions available and relevant to the decision-making process regarding the energetic improvement. This shows that analyzing map data layers is experienced as very useful in the decision-making process regarding the energetic improvement. Support systems such as Zonatlas, open data viewer of Stedin, Warmteatlas and possibly more are available for free. For other support systems a fee applies.

8.2 Reflecting on data in decision-making

Having discussed the interviews with housing associations in the previous chapters, a notable observation is that open data enables communication between stakeholders in the heat transition. The scale and complexity of the energetic improvement and the dependency on other stakeholders requires housing associations to collaborate and come to transparent, effective and legitimate decisions. These requirements push them to innovate and become creative with the existing decision-making process. The attitude that housing associations demonstrated towards data in the interviews shows that they are positive about the use of data as a way to innovate the existing decision-making process. The large amount of data that housing associations currently have in their databases enable them to inform their existing decision-making process. However, using their data in combination with the seemingly unlimited number of topics of available open data offers ways to explore areas of interest they might have otherwise overlooked. As concluded, open data informs housing associations about the plans of stakeholders, what is happening in the vicinity of their real estate and enables the exploration for other pairing opportunities. This illustrates that open data enables the communication with and understanding of stakeholders.

Another observation is that collaboration in the heat transition requires more than just communication and understanding. It also requires the acknowledgement and involvement of stakeholders in the decision-making process. The interview data shows that municipalities are involving housing associations in the development of the heating transition vision. The housing associations are acknowledging grid operators as stakeholders in the heat transition. And open data from grid operators and municipalities provides great ways to communicate their plans. This suggest that grid operators and municipalities are increasingly involved in the decision-making process of housing associations. However, collaboration is not possible through the collection and data analysis of open data alone. For instance, the collection data on occupants from Statistics Netherlands (CBS) provides housing associations with a very limited view on the interests, desires and needs of occupants. They are also an important stakeholder and without their involvement, housing associations will not be able to come to transparent, effective and legitimate decisions. In contrast, the personal communication between smaller housing associations and their occupants does acknowledge and involve them as stakeholders in the decision-making process. This example shows that next to the collection of open data on stakeholders, it is vital to acknowledge and involve these stakeholders. In other words, a collaboration requires housing associations to invite stakeholders to the 'decision-making' table. After which open data is able to assist the communication and understanding between stakeholders. Thus, the necessary collaboration in the heat transition not only requires open data, but also the acknowledgement and involvement of stakeholders in the decision-making process regarding the energetic improvement.

Despite the specific focus on housing associations, the result of this thesis could be easily generalized for private and commercial homeowners and other property owners in the Netherlands. This certainly applies to the approaches that the housing associations apply in the energetic improvement and the available and relevant data for the energetic improvement. It might also apply to the desired features depending on which support systems they use. Down the road, they are also expected to energetically improve their buildings and reduce their CO_2 emissions. Despite the specific focus on the Netherlands, it is expected that the findings of this thesis also are relevant to other countries with a similar social housing arrangement. Other factors which might impact this relevancy are different heat strategies, stakeholder arrangements or data availability.

8.3 The potential role of open data in decision-making process

Now that all findings have been discussed, the main research question of this thesis can be answered. To recap, the research question of this thesis is: What is the potential role of open data in the decision-making process regarding the energetic improvement of housing units by housing associations?

In this thesis, it was found that open data could play an enabling role in the decision-making process regarding the energetic improvement. More specifically; an enabling role in the collaboration with stakeholders in the heat transition. Open data informs housing associations about the plans of stakeholders, what is happening in the vicinity of their real estate and enables the exploration for other pairing opportunities. The use of open data is very useful to housing associations in a first analysis. It opens the door for data analysis in housing associations which are less accustomed to using data in their decision-making processes; mainly smaller housing associations. For more experienced housing associations, the topics which could be analyzed with open data are quite literally endless. It is the findability of open data and relevancy of the found data which causes potential limitations. This thesis will hopefully provide leads to motivated housing associations in this regard. Another limitation is the anonymization due to privacy which might cause open data to become insufficient for experienced housing associations who perform more extensive data analysis. Purchasing this data offers them a solution to collect data on the smallest scale legally possible or tailored to their situation. What is of importance for data analysis is the housing association's primary data and its data quality. Anyone can analyze open data but analyzing open data in combination with the housing association's primary data is what makes it valuable in the decision-making process regarding the energetic improvement. In the end, it is not the open data itself which will cause a reduction in CO_2 emissions. It is the collaboration between stakeholders in the heat transition which will. The necessary collaboration in the heat transition not only requires open data, but also the acknowledgement and involvement of stakeholders in the decision-making process regarding the energetic improvement.

8.3 Recommendations for policy

Based on the findings of this thesis and taking the urgency of climate change and CO_2 reductions into account, the following policy recommendations are formulated. These recommendations may help housing associations, municipalities and software developers to find solutions for the social, technical and financial barriers that hinder the energetic improvement.

Recommendations for housing associations

1. Commit to using data in decision-making.

As stressed many times before in this thesis, data analysis starts with improving and preserving the quality of the housing association's primary data. This ongoing process may currently seem as another demanding task a housing association must fulfill. But the interviews show that data analysis is able to improve the decision-making process. This means that improving and preserving data quality is an investment which will pay itself back sooner than later. Having dedicated employees improving and preserving the data quality of the housing association's data, searching for open and purchasable data and analyzing data shows to be a worthwhile investment. Additionally, it is recommended that more experienced housing associations to explore the possibility of setting up a data lake to be ready for extensive data analysis in the future.

2. Share knowledge actively with other housing associations.

It is said more than once in the interviews by the housing associations: We are reinventing the wheels over and over again. Housing associations appear to be all very open to sharing their experiences with data analysis, but this information not always ends up in the hands of another housing association who might benefit from this experience. It appears that organizations such as Aedes or CorpoNet could play a role here. It is recommended for housing associations to share knowledge actively with other housing associations.

3. Share data with stakeholders as open data.

In light of the data ecosystem, housing associations are already, to varying extents, accustomed to collecting open data for their decision-making process. But they are not yet accustomed to providing open data to the data ecosystem. For example, data on the location of the housing association's real estate, buildings envelop, citizens attitude (preferences, state of awareness and willingness to act) and other data sources which Diran et al. (2020) mentioned in the Figure 2.6 is data that housing associations have. It should of course be considered whether this data is eligible to share as open data. It is recommended that housing associations explore what primary data could be shared as open data to the data ecosystem.

4. Involve stakeholders including occupants in the decision-making process.

Collaboration in the heat transition not only requires open data, but also the acknowledgement and involvement of stakeholders in the decision-making process regarding the energetic improvement. For instance, the collection data on occupants from Statistics Netherlands (CBS) provides housing associations with a very limited view on the interests, desires and needs of occupants. A collaboration requires housing associations to invite stakeholders to the 'decision-making' table.

5. Mind the energy performance gap.

Next to the collaboration of stakeholders, the energy performance gap is what challenges housing associations in the energetic improvement. The energy performance gap refers to the idea that housing associations often do not accomplish the expected energy reduction in practice because of unrealistic theoretic efficiencies and normalized conditions. Possible solutions to overcome the energy performance gap are large datasets to calculate the expected reduction and introducing more retrofit practices of recruitment and appropriation. It is therefore recommended to housing associations to be mindful about the energy performance gap and explore possible solutions.

Recommendations for municipalities

1. Provide the heating transition vision in a format which allows for extensive data analysis.

As stated by Donselaar, it would benefit the decision-making process of housing associations if the heating transition vision could be incorporated in the support systems. It is therefore recommended that municipalities provide their heating transition vision in a format which allows for extensive data analysis. For instance, a map data layer for GIS analysis or a data table with the strategies per neighborhood, postal code or (preferably) BAG address. Subsequently, there is a role for a government body such as the association of Dutch municipalities (VNG) to develop an open database which stores the most recent heating transitions visions. This would make it easier for software developers to incorporate the heating transition visions in their decision-making support systems.

Recommendations for grid operators

1. Provide open and purchasable data on the usage of district heating.

Grid operators already provide data on the use of natural gas and electricity both as open data and purchasable data. However, housing units in the heat transition are moving away from natural gas and many are connecting to district heating networks. Data on the use of district heating is not yet available. It would benefit housing associations if this data would be made available as open and purchasable data. It will provide them insight in the effectiveness of their energetic improvement when the energy use before and after the energetic improvement could be collected.

Recommendations for software developers

1. Make cross-linking of data between support systems easier and automatic.

The interviews showed that the cross-linking of data between support systems was the most prominent improvement housing associations would like to see in the conventional decision-making support systems. Software developers are already working on this through formal collaboration. This is development which could be persisted to improve cross-linking. But it will most likely lead to segregated software ecosystems as we see among the large tech giants. This will not benefit the housing associations in all cases. It is therefore recommended that software developers collectively develop an open source exchange method between support systems for housing associations based on CorpoNet’s reference architectures CORA and VERA.

Subsequently, it is also recommended that software developers build features into their support systems that frequently (at least daily) and automatically push data to other selected decision-making support systems. It is recommended that software developers make cross-linking of data between support systems easier and automatic.

2. Create features which consult smaller housing associations

Many smaller housing associations rely on the insights they obtain from the decision-making support systems because hiring consultants is an expensive undertaking. Therefore, they would like the support systems to be more consultative. This could for instance mean that the employee tells the support system what investment he is able to make or what energy label he is aiming to achieve. The support system subsequently should then consult the employee on which measures are wise to execute with that investment or which measure are necessary to achieve that goal. It is therefore recommended that software developers create features which consult smaller housing associations.

3. Assist housing associations in sharing open data.

In line with the recommendation for housing associations to share data as open data with their stakeholders, software developers could assist housing associations in this. For instance, by incorporating export functionalities for open data in their support systems. These export functionalities should, at the very least, check if the exported data is suitable to be shared as open data according to the privacy legislation. It is therefore recommended that software developers assist housing associations in sharing open data.

8.4 Reflecting on the methodology

In the research, semi-structured interviews and observations were performed to come to the empirical findings as presented earlier. The semi-structured interviews suited the explorative nature of this research while offering a structure resulting in interviews which often did not last longer than an hour and stayed within the scope of this research. The semi-structured interviews were the right method for this thesis. In the final few interviews it was noticeable that the data became saturated. Meaning that similar answers and little new insights were provided by additional interviewees. This saturation indicated when the interviewing could stop. What constrained the comparison of interview data was the wide variety of job titles in the social housing sector. In the selection of interviewees, it was hard to find employees of different housing associations with similar job titles. All efforts were made to find and enthuse employees with a similar set of job activities.

What was left out of the scope of this thesis was how a housing association could make the optimal decision. This is because the task of the energetic improvement differs so substantially due to geographical conditions. It is up to the employee of the housing association such as portfolio and asset manager to come to this optimal decision for their housing association. Nonetheless, it would be very valuable for housing associations to learn about each other's decision-making process. This requires a more extensive scientific research but would be better served with learning programs by organization such as Aedes.

The method which was envisioned at the start of this thesis to collect empirical results on the decision-making support systems was an observation of the actual operations of the support systems by interviewees. After the formal interview, the interviewee would be asked if he or she could show how they operate the support system they mentioned in the interview. This would provide an in-depth view on the possibilities and limitations of the support systems. Due to the Covid-19 pandemic and time constrains, this ideal method was not possible. Commercial concerns made it impossible for software developers to provide in-depth information which was appropriate for a scientific comparison. The observation of websites, leaflets and other documents was therefore selected as the most suitable within the constraints of this thesis. Due to inexperience in this regard, the literature review was less extensive than ultimately desired. A more extensive literature review could have been performed at the start of this research by a systematic literature searching and thorough review of the relevant and found literature.

8.5 Recommendations for future research

1. Study the desirable features through an observation of the actual operations of decision-making support systems.

As mentioned earlier in this chapter, the observation of the actual operations of the decision-making support systems by interviewees was not possible due to the Covid-19 pandemic. This would be the ideal method to study the desirable features for the conventional support system. Such observation would provide an in-depth view on the possibilities and limitations of the support systems. It is therefore recommended to future researchers to study the desirable features through an observation of the actual operations of decision-making support systems.

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Appendix A:
Data platforms and portals

The following two tables are adapted from Diran et al. (2020)

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
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 ...

Data-Platform/Portal	Theme	Description
(continuation)		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, Labor 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 neighborhood level.
PDOK Platform and Viewer-Kadaster	Energy use, Sustainable generation, Energy potential, Spatial area mapping, Spatial planning, (Subsurface) infrastructure, Hydrological system	PDOK, or Public-service on the map, is a national geographical data portal or platform which combines, releases and visualizes 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 ...

Data-Platform/Portal	Theme	Description
(continuation)		more detailed and accurate local data relative to 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 visualization and analysis of that data. The data utilized for the Energy platforms and the visualization 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-Cadaster	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

Tabe A.1 - Overview of data platforms or portals that can be utilized for urban thermal energy system decision-making in the Netherlands; clicking on the platform name directs the reader to the online resource. (Adapted from Diran et al., 2020)

Data-Platform/Portal	Level	Geo-Visualization	Monitoring	Benchmarking	Potential	Download
PICO	national, regional, local, neighborhood	yes	yes	no	yes	area maps with data layers
Warmteatlas	national, regional, local, neighborhood	yes	no	no	yes	no
Nationale EnergieAtlas	national, regional, local, neighborhood	yes	no	no	yes	no
Klimaatmonitor	national, regional, local, neighborhood	yes (limited)	yes	yes	no	yes (CSV, PDF, PPT, GIF, Open Office etc.)
CBS in uw buurt	national, regional, local, neighborhood	yes	yes	no	no	area maps with data layers
PDOK Platform and Viewer	national, regional, local, neighborhood	yes	yes	no	yes	data sets + area maps with data layers
Energy atlas/platforms of provinces and municipalities	national, regional, local, neighborhood	yes	yes	no	no	varies per platform
Open Data Portals or platforms of national and local governments	national, regional, local, neighborhood	yes	yes	no	no	download data sets
BAG Viewer	national, regional, local, neighborhood	yes	no	no	no	area maps with data layers

Tabe A.2 - Overview of the data platform or portal functionality (Adapted from Diran et al., 2020)

Appendix B:
Summary of the Climate Agreement

General notes

1. The overall aim is to bring back the emitted greenhouse gasses by 49% by 2030 relative to 1990 (from this point referred to as “the overall aim”).
   a. The government pleads internationally for an increased European aim of 55% by 2030 relative to 1990.
   b. The Dutch course of actions are depending on European agreements, for instance European CO_2 reduction targets are expected in 2020.
2. The Climate Law will establish the overall aim of 49% reduction by 2030 and 95% reduction by 2050 in Dutch law.
   a. The Climate Law introduces the Climate plan (translation: Klimaatplan), Climate and energy exploration (translation: Klimaat- en Energieverkenning) (KEV) and Climate Bill (translation: Klimaatnota) as accountability cycles.
   b. The Climate plan will be presented at least once every five years and contains the government’s policy in broad terms for the coming ten years.
   c. The KEV will be presented annually by the Planbureau voor de Leefomgeving (PBL) and reports on the current expected emission of greenhouse in 2030, state of affairs in regard to energy and the climate, advances or setbacks in the process of achieving the overall aim and expected future developments.
   d. The Climate Bill will be presented annually and the governments appreciation and additional policy resolutions to achieve the overall aim.
   e. These Dutch accountability cycles correspond with the European accountability cycle.
3. Multiple institutions were participants in the creation of the Climate Agreement, among which were housing associations and Aedes as branch association.
4. The government aims at solutions which are financially and technically feasible, fit spatially and are supported by the public.
   a. For some solutions not all these criteria might apply. It is up to the

government and businesses to improve these conditions.

5. Many solutions involve electrification or district heating, which puts pressure on the energy infrastructure. Additional agreements and preconditions are established in order to support the energy sector in the expansion of the infrastructure.
6. The reduction will be on the account of the sector in which the reduction takes place and not be calculated double. This for instance applies to residual heat from industry for households. In a future study the results and effects of the sector overarching agreements will be investigated.
7. The Climate Agreement will be brought into practice by the Regional Energy Strategies (RES).
    a. For this assignment The Netherlands will be divided in 30 regions. Each region will deliver their own RES.
    b. In the RES governmental and public bodies, grid operators (natural gas, electricity and heat), business and if possible inhabitants present collectively made decisions.
    c. The RES will cover the production of renewable electricity, the heat transition in the built environment and the required energy storage and infrastructure.
    d. These topics will be connected to specific areas projects and implementation and execution of these projects.

Built environment

1. In order for the domain of the built environment to contribute to the overall aim it should realize a CO_2 reduction of 3,4 Megatons by 2030 (from this point referred to as “the aim of the domain built environment”).
    a. This means that of the 7 million existing residential buildings 1,5 million buildings need to be retrofitted by 2030.
    b. Current buildings are characterized by poor insulation and supplied by natural gas. And future buildings are characterized by proper insulation and supplied by sustainable heat and electricity, either produced on household level or elsewhere.
    c. The number of annual retrofitted existing residential buildings should be steadily increased. From 50.000 residential buildings in 2021 to 200.000 in 2030.
2. The motivations for change are climate change, discontinuation of natural gas from the Dutch province of Groningen, a lower energy bill and more comfortable housing.
3. The major challenge in this transition are not the technical, financial or administrative tasks, but is the social task of bringing together all stakeholders.
    a. Housing associations are expected to retrofit residential buildings with a neutral effect on the tenant’s cost of living.
    b. The desires of residents and other local conditions determine the pace and result of the retrofitting process.
    c. It is crucial to actively involve and address residents in the retrofitting process. Examples of how residents could be involved are available.
    d. The Climate Agreement focusses on building owners (homeowners, housing

associations and others) to act in retrofitting the building(s) they own. Little to none is mentioned about residents taking actions or what could be done to support this group.

4. Municipalities are tasked to present their energy vision per neighborhood (translation: Wijkgerichte aanpak) before the end of 2021. In this document municipalities will state what type of energy provisions are present or will be present in the future.
   a. Building owners could base their decision making on these documents.
5. The proposed technical solution in the Climate Agreement are supplying buildings with district heating, retrofitting to all-electric buildings (no energy provision other than electricity), hybrid solutions with improved insulation and efficient natural gas boilers.
   a. The government will investigate further if the current infrastructure for natural gas could be exploited for green gas or hydrogen. The current understanding is that this is easier for green gas and more difficult for hydrogen as it requires development.
   b. Pilot project, scale-up, subsidies, standardization and digitalization are proposed solutions to achieve a more efficient and cheaper range of technical solutions.
   c. The government Is relying on Aedes and the housing associations to take the lead in the pilot projects as they manage larger parts of the housing stock.
6. A standard (BENG) will be introduced in 2020 to quantify the heat consumption for residential buildings in kWh per square meter per year.
   a. In 2050 this standard will become mandatory for all rental housing in order to protect tenants.
   b. This standard could be used for financing and subsidies.
   c. For some residential buildings the solutions above and standard might not apply as they will not become financially, technically or aesthetically feasible. This could be especially relevant for insulation. The government will investigate for these buildings if an exception should be made.
   d. The standard will be integrated in existing legal documents such as the building code (Dutch translation: Bouwbesluit), energy labels and rent price legislation, such as the residential building valuation scheme (Dutch translation: woningwaarderingsstelsel [WWS]).
7. The government will investigate if building-related financing and other financial measures is possible in order to create attractive, accessible and responsible investments.
8. The government is investigating opportunities to monitor the progress on municipal level. One opportunity is to request energy consumption on level ‘postal code 6’ every two years.

Electricity

1. In order for the domain of the electricity to contribute to the overall aim it aims to bring back the emitted greenhouse gasses by 49% by 2030 and 100% by 2050

relative to 1990 (from this point referred to as “the aim of the domain electricity”). This translates into a CO_2 reduction of 20,2 Megatons by 2030.

   a. This would mean scaling up the production of electricity through renewable source to 84 TWh.

2. The main proposed technical solution for production in the Climate Agreement is wind turbines at sea. This would translate into large scale wind parks in the North Sea. Other proposed technical solution are hydrogen or other energy carriers, flexibilization of the consumption side, smart grids and storage.
   a. Hydrogen is considered as an energy carrier which on a medium-term (2030) and/or long-term (2050) could fulfil a couple crucial functions. This crucial function in the built environment could be providing an alternate heat resource to buildings which for several reasons could be difficult to make sustainable.
   b. Government will bring together and support businesses and institutions to facilitate and stimulate the transition to renewable electricity production.
3. The transition following out of this Climate Agreement will change the consumption of and profile of electricity. Electrification in the domains industry, mobility and the built environment are possible tracks to sustainability.
   a. The pace and scale at which the transition takes place in these other domains has great impact on the functioning of the electricity system.
   b. Applying hybrid solutions or electricity storage solution would contribute significantly to the desired flexibility.
   c. Grid operators and businesses will develop a system for congestion management through local flexibility (flexible consumptions, storage systems and production plants) based on market principles. This system might require a standard for flexibility for appliances to function well.
   d. Government will bring together and support businesses and institutions to facilitate and stimulate infrastructural expansion and adaptation to support the transition to renewable electricity.
4. One trend in this transition is this electrification is decentralization. This means that citizens, collectives, businesses or institutions produce their own renewable electricity or provide electricity to the grid.
   a. Grid operators are challenged to facilitate this transition and trend at the least possible costs sufficient network capacity. This is especially relevant to housing as existing electricity network connections might not be sufficient for future electricity consumption.
5. The current set-off regulation will be valid until 2022. This regulation allows citizens and business to deduct the electricity they produce and provide to the grid from their energy consumption. A new regulation will be introduced in 2023.
6. A new regulation for energy cooperations will be introduced which enables local residents to participate in sustainable energy projects in their immediate vicinity more easily.

Appendix C:
Strategies of the Expertise Centrum Warmte

The heat strategies of the Expertise Centrum Warmte as presented in chapter 3 about the policy background involve of 11 variants. Because the information of Expertise Centrum Warmte is complex an extensive overview of the strategies and sub-strategies is provided in Table A.1. It should be noted that in all strategies the electricity network connection is maintained. In contradiction to the rest of this thesis, this table was placed on a larger paper size due to the size of the table.

Strategy	Variant	Connection		Temperature district heating:	Requires adding capacity to energy grid:	Energy carrier:	Housing unit			Temperature upgrade							Energy source	Comment
		Natural gas	District heating				Insulation upgrade to:	Placement of additional appliances:	Means of heat emission:	Incoming temperature:	Collective upgrade:			Individual upgrade:				
											Upgrade by:	Upgrade to:	Purpose:	Upgrade by:	Upgrade to:	Purpose:		
1	A	Removed	N/A	N/A	Yes	Electricity	Label B	Combination heat pump, buffer tank	Low temperature radiators	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Outside air	
	B	Removed	N/A	N/A	Yes	Electricity	Label B	Combination heat pump, buffer tank	Low temperature radiators	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Ground	
2	A	Removed	Added or maintained	High temperature	No	Water	Label B	N/A	Conventional radiators	70°C	N/A	N/A	N/A	N/A	N/A	N/A	For instance residual heat from industry	
	B	Removed	Added or maintained	High temperature	No	Water	Label B	N/A	Conventional radiators	70°C	N/A	N/A	N/A	N/A	N/A	N/A	Geothermal sources	If the area is suitable geothermal:
	C	Removed	Added or maintained	High temperature	No	Water	Label B	N/A	Conventional radiators	70°C	N/A	N/A	N/A	N/A	N/A	N/A	Geothermal sources	If the area is **not** suitable geothermal:
	D	Removed	Added or maintained	High temperature	No	Gas en water	Label B	N/A	Conventional radiators	70°C	N/A	N/A	N/A	N/A	N/A	N/A	Renewable gas (Cogeneration plant)	Only if enough renewable gas is available.
3	A	Removed	Added or maintained	Low temperature	Possibly	Water	Label B	Combination heat pump	Low temperature radiators	30°C	N/A	N/A	N/A	Individual heat pump	Desired level	Room heating and hot tap water	For instance residual heat from data centers	Temperature of the water upgraded per individual housing unit by the combination heat pump.
	B	Removed	Added or maintained	Low temperature	Possibly	Water	Label B	N/A	Conventional radiators	30°C	Collective heat pump	70°C	Room heating and hot tap water	N/A	N/A	N/A	For instance residual heat from data centers	
	C	Removed	Added or maintained	Low temperature	Possibly	Water	Label B	Booster heat pump	Low temperature radiators	30°C	Collective heat pump	50°C	Room heating	Individual heat pump	70°C	Hot tap water	For instance residual heat from data centers	Temperature of the water upgraded by a collective heat pump to 50°C and per individual housing unit to 70°C by the booster heat pump.
	D	Removed	Added or maintained	Very low temperature	Possibly	Water	Label B	Booster heat pump	Low temperature radiators	15°C	Collective heat pump	50°C	Room heating	Individual heat pump	70°C	Hot tap water	Heat and cold storage	
	E	Removed	Added or maintained	Very low temperature	Possibly	Water	Label B	N/A	Conventional radiators	15°C	Collective heat pump	70°C	Room heating and hot tap water	N/A	N/A	N/A	Surface water stored in a heat and cold storage	
4		Maintained	N/A	N/A	Possibly	Gas	Label B	Hybrid heat pump	Conventional radiators	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Renewable gas	Depending on the state the gas grid needs to be improved.
5		Maintained	N/A	N/A	No	Gas	Label B	Existing high efficiency boiler	Conventional radiators	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Renewable gas	

Tabe A.1 - Extensive overview of the five strategies and their variants (Based on Expertise Centrum Warmte, 2019).

Appendix D: Interviewees

All interviews were semi-structured and performed through an video call in Dutch according to the interview protocol (Appendix D). Except for the interview with P. Lobenstein of Havensteder. He prefered to reply to the questions of the interview protocol in writing. The full list of interviewed housing associations is presented in Table A.2. The indicated sizes and size categories are according to Aedes Benchmark 2019. The full list of interviewed other professionals is presented in Table A.3. Next, a short background regarding the energetic improvement of each interviewed housing association is shared. These are ordered in alphabetical order.

Size categories

Extra large:	more than 25.000 housing units.
Large:	between 10.000 and 25.000 housing units
Medium:	between 5.000 and 10.000 housing units
Small:	between 2.500 and 5.000 housing units
Extra small:	between 1.000 and 2.500 housing units
Extra extra small:	less than 1.000 housing units (Aedes, 2019)

1. De Delthe

De Delthe is challenged by the structural reinforcement of around 80 housing units next to the energetic improvement. In recent years these housing units suffered damage from recent earthquakes and will be demolished and reconstructed. A third of the remaining housing units have an energy label lower than F and will be energetically improved in the coming years. The personal communication with residents and flexibility around the individual circumstances of residents are key in the approach of De Delthe.

	Housing association	Name	Role	Date	Size (# housing units)	Province
1	Woonstad	I. Ignjatov	Sustainability specialist	April 10, 2020	Extra large (approx. 46.700)	South-Holland
2	Vivare	J. Sicco Smit	Sustainability consultant	April 17, 2020	Large (approx. 23.600)	Gelderland
3	Woonstad	W. Tuinbergen	Data consultant	April 21, 2020	Extra large (approx. 46.700)	South-Holland
4	Havensteder	P. Van Lobenstein	Program and innovation consultant	April 23, 2020	Extra large (approx. 43.300)	South-Holland
5	Vivare	T. Rikken	Asset manager	May 6, 2020	Large (approx. 23.600)	Gelderland
6	Wormerwonen	R. Kerssens	Project director	May 13, 2020	Extra small (approx. 2.000)	North-Holland
7	De Delthe	B. Krajenbrink	Managing director	May 15, 2020	Extra extra small (approx. 500)	Groningen
8	Stadlander	J. Van der Sanden	Program manager of integral urban renewal	May 20, 2020	Large (approx. 14.100)	North Brabant
9	Wierden en Borgen	H. Scheer	• Policy consultant	May 20, 2020	Medium (approx. 7.200)	Groningen
10	Zeeuwland	N. Donselaar	• Policy consultant	May 26, 2020	Medium (approx. 5.700)	Zeeland
11	Parteon	E. Corporán Souverein	• Consultant	May 28, 2020	Large (approx. 16.000)	North-Holland
12	Rondomwonen	E. Van Leeuwen	• Project manager real estate	May 28, 2020	Extra small (approx. 2.400)	South-Holland
13	Stadlander	P. Musters	• Real estate consultant	May 28, 2020	Large (approx. 14.100)	North Brabant
14	Ymere	R. Rohmer	• Sustainability consultant	May 29, 2020	Extra large (approx. 67.000)	North-Holland
15	Wonen Limburg	M. Caris	• Sustainability consultant	June 2, 2020	Extra large (approx. 26.100)	Limburg
16	Woonservice	B. Boersma	• Big data consultant	June 18, 2020	Small (approx. 5.600)	Drenthe

Table A.2 – List of interviews, housing associations, name and role of interviewee, data, size and province of the housing association.

2. Havensteder
Havensteder started a program to improve the insulation of 800 housing units per year in 2015. This strategy was chosen as to them it is unclear which heat source will replace natural gas. The main procedural challenge Havensteder faces in their effort to energetically improve their housing units are a lack of financial resources. Currently, they are in need of a heating transition vision by the municipality to base their decision-making upon.

3. Parteon
In addition to the energetic improvement Parteon is challenged by many housing units with poor building foundations. Because of this additional challenge, the investment required for retrofitting and demolition and reconstruction were almost similar, with reconstruction resulting in a final product with a high quality. This led them to change their strategy from retrofitting to demolition and reconstruction. In their efforts they offer resident the possibility to sign up for a retrofitting initiative. This initiative is called 'Opgewekt wonen'. The initiative enables residents to achieve 'zero on the meter' by providing solar panels, a heat pump and possibly insulation and collecting a contribution of 50 to 60 euros in return.

4. Rondomwonen
Most housing units of Rondomwonen are well insulated as they are relatively new. It is therefore that their average energy label is currently at C. However, the investment capacity for the newer housing units is limited as a loan still needs to be repayed. This means that in their effort to energetically improve their housing units Rondomwonen faces lack of financial resources as a procedural challenge.

5. Stadlander
Stadlander both retrofits and demolishes and reconstructs housing units to energetically improve them. In additional to the energetic improvement, the housing associations is tasked to constructed new housing units in the area. The main challenge Stadlander faces is nitrogen emission because of the proximity of their operation area to a Nature 2000. This limits them for instance in the acquisition of building permits.

6. Vivare
Vivare is currently focused on improving the insulation of a building as it is still unclear what heat source will be available in the future. In these efforts they aim to pair their energetic improvement with maintenance.

7. Wierden en Borgen
The housing units of Wierden en Borgen also suffered damage from recent

	Company	Name	Role	Date	Topic
1	Ortec Finance	M. Logemann	Senior consultant	February 11, 2020	Decision-making by housing associations
2	Technical University of Delft	Anonymized	PhD researcher	April 20, 2020	Empirical building energy simulation model
3	Overmorgen	T. Engels	Consultant space and information	May 15, 2020	Interactieve vastgoed atlas
4	Vereniging van Nederlandse Gemeentes (VNG)	G. Van der Vreede	Policy maker	June 17, 2020	Knowledge and learning program data driven planning
5	Stroomversnelling	M. Hommelberg	Program manager monitoring	June 23, 2020	Energy service fee and privacy
6	Wormerwonen	R. Kerssens	Project director	May 13, 2020	Small (approx. 2.000)

Table A.3 – List of interviews, housing associations, name and role of interviewee, data, size and province of the housing association.

earthquakes and will be demolished and reconstructed. The housing association owns units in the city of Groningen as well as the rural areas of the province. Therefore, they also face shrinkage as additional challenge in addition to the energetic improvement. Wierden en Borgen works with client direct maintenance (Dutch translation: klant gericht onderhoud) which means that residents are able to request solar panels and maintenance.

8. Wonen Limburg

The lack of district heating in the province of Limburg is the main challenge of Wonen Limburg. Currently they focus on improving the insulation of their housing units. Together with seven other housing associations, Wonen Limburg takes part in an informal collaboration in which they explore themes such as the energetic improvement.

9. Woonservice

The combination of personal communication with residents and the use of big data is what characterized the approach of Woonservice. In retroffiting projects Woonservice collects input from their residents through surveys to analyze and improve their process and decision-making.

10. Woonstad

The advantage Woonstad has compared to other housing associations in The Netherlands is that 90 percent of our portfolio will probably be connected to residual heat. In 2019, Woonstad set up a competition called the ‘Energy challenge’ in which they asked market players to submit their building solutions to reduce CO_2 emissions. Woonstad has a dedicated data team which assist the organization in tackling challenge related to data.

11. Wormerwonen

Many housing units of Wormerwonen suffer from poor building foundations. As a result, they have decided to demolish and reconstruct many of their housing units in the future. District heating will probably not be an option in their operation area. Most housing units will be fitted with a heat pump, resulting in ‘all electric’ strategy. The personal communication with residents is what characterized the approach of Wormerwonen.

12. Ymere

Ymere faces backlogged maintenance which needs to be dealt with in the near future. In their efforts, they are trying to pair the energetic improvement to this backlogged maintenance. As the operation area of Ymere covers multiple municipalities, they experience large differences between them. The involvement of residents is and will a challenge to Ymere in their efforts to retrofit their housing units.

13. Zeeuwland

They hope their housing units could be provided with renewable gas in the future as this seems the only feasible solution to them. The personal communication with residents is what characterized the approach of Zeeuwland. They both retrofit and demolish and reconstruct housing units to energetically improve them. In some village they experience shrinkage as additional challenge. In these village they sometimes demolish for example 7 units in village and reconstruct only 6 new units. This allows them to construct one additional housing unit in the city of Zierikzee where there is still demand.

Appendix D:
Interview protocol

<u>The interviews were performed in Dutch.</u>
<u>This interview protocol was translated from Dutch to English.</u>

Part I: Introduction

Thank you for the opportunity to interview you. Explain the master, the subject of the thesis and the goal and structure of this interview.

- What is your role in [name of the housing association, hereinafter association]?
- When a decision needs to be made at [association], what is your role or your tasks?

Part II: Energetic improvement of housing units

- At [association], are you already executing activities based on the agreements from the Climate Agreement?
- What is a produceral challenge you encounter when you work on projects related to the Climate Agreement or the energetic improvement of housing units? Is that a lack of information, time, expertise or resources?
- After the Climate Agremeent, housing associations were involved in the development of the heating transition visions. Is that also the case for [association]? If yes, which other parties were involved in that development?

Prompts for eliciting stories:

- Explain the situation. What happened?
- When? How often did it happen?
- Who was involved? How did they respond?

- How was it resolved?
- What did you do next?
- Was there anything else you could have done?
- Was this situation unique? Repeated?

Part III: Decision-making for housing associations

- Could you describe how the decision-making regarding the energetic improvement of housing units at [association] takes place?
- What role does data play in the decision-making regarding the energetic improvement of housing units of [association]?
- Did you also look at other aspects next to the energetic improvement? If yes, which aspects and do you do this often or just in this project?
- What do you and [association] need to be better supported in the decision-making regarding the energetic improvement housing units?

Part IV: Decision support systems

- Which decision-making support systems do you use when you need to make a decision about the energetic improvement of housing units?
- What could be improved about these decision-making support systems?

Part V: Use of data in decision-making

- Did you use open data in your decision-making before? And could describe that situation?
- Which solution did open data offer you compared to other types of data?
- What would discourage/encourage you to use open data in your decision-making regarding the energetic improvement of housing units?
- Could you describe how you think the use of open data could impact the decision-making process of housing associations about the energetic improvement of housing units?

Part V: Closure

We've come to the end of my questions.

- Is there anything else you would like to talk about?
- Is there perhaps somebody in or outside [association] which would be interesting for me to interview?

Thank them again for participating. Ensure that their data will be kept confidential.