Ex-ante assessment of social acceptance of sustainable heating systems in Amsterdam South East using Cross-Impact Balance analysis

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Preface

This report is a master thesis, written as part of the MSc programme of 'Complex Systems Engineering and Management' at the Delft University of Technology. The multidisciplinary aspects of this master programme is reflected in this report. This thesis was also written in collaboration with the city of Amsterdam and the Amsterdam research institute for advanced metropolitan solutions. This master thesis has been written to contribute to the incorporation of citizen values in the transition to sustainable heating in Amsterdam South East. For the scientific community, this thesis has contributed to the better understanding of what Cross-Impact Balance analysis can mean for understanding scenarios for future value change, particularly in sustainable transitions.

Acknowledgment

This thesis proved to have many challenges. The research topic changed in objective and scope throughout the duration of this thesis, mainly due to external influences that were out of my control. Nevertheless, with the guidance and support of my daily and external supervisors, Tristan and Else, I was able to find a topic and scope of research that was still interesting and relevant. Before starting my thesis I knew I wanted to conduct research in collaboration with an external company. I am grateful to Else for having given me the opportunity to help Amsterdam South East in their efforts to transition to a more sustainable city. I would also like to thank my other supervisors, Ibo and Niek, for being understanding of the challenges I encountered while conducting my research and providing feedback throughout the entire thesis process. I would also like to thank the interviewees for their time and their interesting insights into the important aspects of citizen values in the sustainable heating transition.

I would like to thank my sister, Dhanya, and aunt, Sunita, for pushing me to move forward while writing my thesis. Finally, I would like to thank my parents, Suresh and Rita, for providing me with the opportunity to study in Delft and for their support throughout my thesis. Having been apart in the middle of a pandemic is no easy feat, but the constant phone calls for advice was very helpful. *No mud, no lotus.*

Viren Suresh Mirchumal

Delft, September 2021

Executive summary

The municipality of Amsterdam plans to transition away from its reliance on fossil fuel-based energy sources for residential heating by 2040. In order to accelerate this process, the municipality has laid out a roadmap that details possibilities for sustainable heating on a per-neighborhood basis. One neighborhood of particular interest is Geerdinkhof in Amsterdam South East. Citizens in Geerdinkhof have yet to start a concrete transition to sustainable heating. Nevertheless, a transition must take place in the long-term. There are three long-term sustainable transitions that can take place within Geerdinkhof; a high temperature district heating network, collectively-owned options and heating options per individual household.

The present research refers to citizen social acceptance of these long-term transitions for sustainable heating. It would be ideal to address the possible lack of social acceptance for a new technology before it is implemented. It is argued that social acceptance issues can best be anticipated by understanding the underlying value conflicts associated with technologies. Values are considered important regarding social acceptance of technologies, and it is increasingly argued that values should be more carefully integrated in sustainability projects. When two values are in conflict, it is often the case that one is favored over the other. Values are not static in nature, and are subject to change over the lifetime of a technology. Value change can be defined as *"the changing of prioritizations among values over time*". However, literature indicates that very few tools have been implemented for ex-ante analysis of social acceptance, especially when observing value change. It is argued that the consequences of value conflicts on a future lack of social acceptance can be anticipated by identifying scenarios of value change. The main research question is:

What are socially accepted long-term sustainable heating options in Geerdinkhof given possible value change scenarios?

The methodology for discovering plausible value-change scenarios must be identified. Both qualitative and quantitative scenario analyses present strengths and limitations. System element relationships are usually described using mathematical equations, based on assumptions of these interactions. However, interactions between system elements that are vague or uncertain are not always exactly quantifiable, such as "values". Moreover, scenario analysis literature also indicates that the use of argumentations and causal chain analysis is more appropriate given these uncertainties of defining

mathematical equations. Nevertheless, the addressees of scenario analyses usually require concrete figures, testing or evaluation of impacts on system elements that qualitative models do not (always) provide.

In order to best balance the need for both quantitative and qualitative scenario analysis, Cross-Impact Balances (CIB) was chosen as the methodological approach for this thesis. This method can construct qualitative and semi-quantitative scenarios systematically. The scenarios generated from this methodology rely heavily on the information elicited from expert interviews and literature research. In total, five expert interviews were held in order to construct the required Cross-Impact matrix that generates scenarios. This matrix contains all factors, referred to as 'descriptors' in CIB terminology, that are deemed influential for future social acceptance of sustainable heating systems in Geerdinkhof.

Many values can be identified when considering local sustainable transitions. Values in the transition can be divided into collective (i.e. procedural justice, privacy) and individual values (i.e. affordability). It is argued that there exists a causal relationship between collective and individual values, where either collective values predict individual ones or vice versa. Moreover, literature has argued that individual value change is a driving factor for sustainable transitions to be realized. This research therefore argues that when considering values for CIB analysis, it will be through the lens of individual values. When conducting interviews, it was mentioned that the individual values of **affordability** and **comfort** are at the forefront of the heating transition.

CIB research is approached in two distinct phases. Phase one entails identifying the most influential descriptors for social acceptance through literature research and expert interviews. The chosen descriptors in the present research are; *the development of investment preferences, the average disposable income of a citizen in Geerdinkhof, the development of environmental concern, the development of heating prices, the development of appliance prices, the development of climate change and temperatures and the development of community relationship*. Each descriptor is divided into descriptor states, indicating possible future trends of each descriptor. The accounting of how individual descriptor states directly influences other descriptor states are recorded within a cross-impact matrix. These relationships are given by experts and quantified into 'judgments', numerical values that suggest the relationship between these states, which can have either a promoting or restricting effect. Phase two entails forming these judgments through interviews, which form the basis of scenario generation. One scenario generated in a CIB analysis is the combination of one descriptor state per descriptor. The judgments between these states go through a computational algorithm to discover the internal consistency of each scenario. In total, 3888 scenarios are generated. However, not all scenarios were deemed “internally consistent” in the CIB analysis.

The analysis produced a total of 23 internally consistent scenarios of value change. This thesis defines “internally consistent” scenarios of value change as a reflection of how *the prioritization of values shift over time*, considering the mathematically plausible combinations of CIB calculations. The present research also analyzed, through a method called “succession analysis”, which of these 23 possible consistent scenarios were most frequently found after replacing one inconsistent descriptor state with a consistent descriptor state. This procedure of replacing inconsistent states until a consistent scenario is found is performed for each of the 3888 scenarios generated.

Considering the heavy work-load to analyze each scenario individually, the scenarios were divided into seven broad scenario clusters, based on how values may trend. A sensitivity analysis was carried out to observe the extent to which the questionable relationships between factors affect the total amount of possible consistent scenarios generated. It was found that there is no extreme divergence in the number of consistent scenarios.

For each scenario cluster, the most fitting of the three possible heating initiatives in Geerdinkhof were assessed. Moreover, succession analysis indicated that a HT district heating network was the most fitting heating initiative as a result of the most commonly found scenario. However, it cannot be conclusively stated that this initiative is the most suitable, given that the succession analysis also indicates that the least commonly found scenario also suits HT district heating.

Nevertheless, a recommendation can be provided on the best possible procedure that the municipality can take in order to facilitate more socially accepted heating initiatives. These scenarios of value change and other factors are related to both the trends of neighborhood factors (disposable income, community bond, investment preferences, environmental concerns) and external factors (heating prices, appliance prices, climate change). Ex-ante assessment of social acceptance is therefore dependent on observing these possible trends. A recommended procedure would be to observe trends and make a policy decision, preferably before the implementation of the District Heating network in 2030. It is recommended that the municipality assess the current trends in both neighborhood and external factors, and compare them to the findings in the present research. This observation could be through participatory methods, such as surveys. In this way, the municipality can elicit information from citizens regarding their views and stance on certain initiatives, values and factors. This would also need to be complimented with research into the external factors mentioned in this thesis, particularly regarding appliance or heating prices.

It is important to note that citizens would also need to demonstrate the need for sustainable initiatives. Currently, citizens in Geerdinkhof have demonstrated a willingness to adapt to sustainable solutions, but the majority have yet to act. Interviewees suggested that it could be due to a lack of information on the imminent nature of the sustainable transition or due to lack of the sense of urgency for this transition. A pre-requisite for this procedure is a growing sense of urgency and interest to act on this transition from citizens. A recommendation would be for the municipality to continue to emphasize the importance and urgency of the impending transition, for example through information campaigns or neighborhood gatherings.

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1. Introduction

The goal of Chapter 1 is to provide an overview of the challenge of assessing the long-term social acceptance for sustainable heating systems in Amsterdam South East. This is done by first introducing the current situation of the need for sustainable heating in Amsterdam in section 1.1. Then, section 1.2 explains why assessing social acceptance of the transition to sustainable heating systems is necessary and challenging. Finally section 1.3 provides a direction for the present research, which will be used in Chapter 2 to identify knowledge gaps that form the basis of the research performed in this thesis.

1.1 Sustainable heating transition in Amsterdam South East

The Dutch Climate agreement has indicated different sustainability goals that must be met in the coming 30 years for many sectors, including the built environment (Rijksoverheid, n.d.). One of these goals for the built environment is to completely reduce the reliance on natural gas for residential heating by 2050. In accordance with this, the municipality of Amsterdam wishes to transition away from fossil fuel usage in households and focus on more sustainable forms of heating (Gemeente Amsterdam, 2020a). The municipality's goal is to reduce carbon emissions, by reducing the reliance on natural gas, which currently heats roughly 90% of homes and businesses in Amsterdam (Amsterdam.nl, n.d.). The municipality has laid out a roadmap ("Transitievisie Warmte Amseterdam") in order to best foster this transition (Gemeente Amsterdam, 2020b) for each neighborhood in Amsterdam. This roadmap provides many possibilities of sustainable heating, such as district heating, forms of all-electric solutions, or other forms of 'sustainable gas'. Furthermore, according to these transition roadmaps, one of the crucial aspects in order to support these transitions is the public support of citizens.

One neighborhood that is of particular interest is Geerdinkhof. In collaboration with the municipality of Amsterdam and Energie lab Zuidoost, Geerdinkhof was selected as the scope of the present study. Geerdinkhof is particularly interesting as a research topic for several reasons. Not only does this neighborhood have to transition to a natural gas-free form of heating, but it also has the consequence of being a "District heating neighborhood" in the transition roadmap of the municipality. This means that if citizens in Geerdinkhof do not present alternative ways to provide sustainable heating for themselves to the municipality by 2030, they will be forced to switch to a district heating network as their main source of heating supply. Moreover, citizens in Geerdinkhof have yet to start a concrete transition to sustainable heating. This is interesting, considering that other neighborhoods in the South East are a bit further in the transition process. As will be detailed later in this thesis, these citizens have differing opinions on this transition. Some citizens do not see the urgency for sustainability, while other citizens have demonstrated entrepreneurial spirit regarding collective action. Nevertheless, a transition must take place in the long-term. The present research intends to focus on the citizen social acceptance aspect of these long-term transitions in Geerdinkhof.

1.2 Social acceptance for future sustainable heating systems

In order to understand social acceptance of future sustainable systems, the term 'social acceptance' must first be clarified. Social acceptance is a term that is difficult to clearly define. Wüstenhagen et al. (2007) attempts to address this by dividing the term social acceptance into three categories: socio-political acceptance, community acceptance and market acceptance. Socio-political acceptance is acceptance on the most general level, indicating whether stakeholders are in favor of a technology and encourage it via policies. Market acceptance is defined as the rate of market adoption of an innovation, emphasizing whether citizens are willing to adopt new technologies. However, the present research is mainly interested in investigating the term social acceptance from the "community acceptance" perspective. This is related to the local energy consumers' resistance or protests that can lead to significant conflicts in the implementation of a sustainable heating network. Community acceptance is characterized by a time dimension, typically following a U-shape pattern: going from high acceptance to low acceptance during the siting phase, and back up again once the project is up and running (Wüstenhagen et al., 2007). A graphic of these three categories of social acceptance from Wüstenhagen et al. (2007) is illustrated in Figure 1.

Figure 1: Wüstenhagen et al (2007)'s definition of social acceptance

“Acceptance” can be defined as “a positive attitude towards technology or a measure” (Batel, 2020). This positive attitude can be interpreted as either passive or active acceptance (von Wirth et al., 2018). Active social acceptance is characterized by actively supporting, promoting or adopting the technology in question, whereas passive acceptance is considered to be a tolerance for the technology in question with no supportive behavior. Moreover, Batel et al. (2013) suggests that as long as citizens do not actively oppose or contest energy infrastructures, they are accepting them.

Fostering social acceptance for renewable energy transitions has been a topic of discussion among many governments worldwide (Batel et al., 2013). Deployment of large scale transitions can often be met with public opposition (Batel, 2020). Social tensions may arise if for example the renewable technology displays drawbacks that were not assessed before implementation (de Wildt et al., 2021). Evans et al. (2017) argues that incorporating citizen acceptance at early stages of project implementation is key to implementing effective sustainable solutions. However, ex-ante assessment of social acceptance is quite difficult to attain (de Wildt et al., 2021). It would be ideal to address this possible lack of social acceptance for a new technology before it is implemented. De Wildt et al. (2021) states that ex-ante assessment of social acceptance is hard to predict for two reasons. Firstly, implementing renewable technologies are very specific to the local conditions in which they will reside i.e. type of housing and other existing infrastructure. Secondly, it is argued that even if project developers knew the exact impact the technology would have, the local perceptions of the impacts of the new technology is highly unpredictable due to intertwined (psychological) factors.

This difficulty in anticipating social acceptance stems from the fact that there is a discrepancy between perceived social acceptance during the planning phase and the revealed social acceptance during the deployment and operation of the new technology (de Wildt et al., 2021). Furthermore, design requirements or policy guidelines are not effective in fostering social acceptance ex-ante (de Wildt et al., 2021). Instead, the present research argues that social acceptance issues can best be anticipated by understanding the underlying value conflicts associated with technologies (de Wildt et al., 2021; Milchram et al., 2018).

1.3 Value change in sustainable heating system design

According to van de Poel & Royakkers (2011), 'Values' can be defined as "*lasting convictions or matters that people feel should be strived for in general and not just for themselves to be able to lead a good life or realize a good society"*. Relevant values for sustainable technologies are for example environmental sustainability, reliability or affordability (Milchram et al., 2018). Values are considered important regarding social acceptance of technologies, and it is increasingly argued that values should be more carefully integrated in sustainability projects (Mouter et al., 2018). Social acceptance issues can be caused by unsatisfied expectations concerning values (Wüstenhagen et al., 2007), and the difficulty in resolving these acceptance issues can be explained through value conflicts (van de Poel, 2009).

Van de Poel (2009) defines value conflict as "*when the realization of a value inhibits or otherwise limits the realization of another value, or more specifically "two or more values conflict in a specific situation if, when considered in isolation, they evaluate different options as best".* De Wildt et al. (2021) argue that value conflicts arise when technological systems that are designed to achieve certain values, often come at the expense of other values. When two values are in conflict, it is often the case that one is favored over the other. For example, values such as *reliability* are in conflict with *privacy* when it comes to using personal consumer energy data in smart meters.

Van de Poel (2016) states that the design of technologies can have an impact on human values, and if not properly considered can lead to conflicting values. This implies that values are not static in nature, and are subject to change over the lifetime of a technology. This fits with one of the five definitions of "value change" given by van de Poel (2018). One definition of value change that is of interest for the present research is *"the changing of prioritizations among values over time*". Moreover, prioritization of values entails which values to prioritize or how they are balanced, weighed or judged (van de Poel, 2018). This prioritization may change over time, especially when considering designs for technical systems. Van de Poel (2018) gives an example in the design of car safety, where both passenger and pedestrian safety are relevant values for car design. Nevertheless, emphasis was placed more on passenger safety initially, while pedestrian safety increasingly became important over time.

The direction for the present research will be to address future value change in sustainable heating systems for households in Geerdinkhof. However, assessing value change is not a commonly used approach for social acceptance. In the following chapter, the research problem will be addressed.

2. Research problem

The goal of Chapter 2 is to create a research structure that explains how social acceptance of long-term heating initiatives in Geerdinkhof can be assessed through understanding how citizen values may change over time. Section 2.1 will deal with this issue and identify the knowledge gaps to formulate the problem statement. Then section 2.2 will explain the research objectives. Section 2.3 will explain the research questions. Finally, the scientific and societal relevance of the present research will be discussed in section 2.4.

2.1 Knowledge gap and problem statement

Chapter 1 has indicated that ex-ante assessment of social acceptance is a difficult task and is seldom integrated into long-term sustainable transition. Moreover, it is argued that methods such as establishing design requirements or policy guidelines for sustainable transitions are not effective in fostering social acceptance. Instead, the present research argues that the consequences of value conflicts on a future lack of social acceptance can be anticipated by identifying scenarios of value change (de Wildt et al., 2021).

An example is given by de Wildt et al. (2021). Assume the two values of environmental sustainability and affordability in the current energy transition are in conflict. Assume at first that citizens are willing to pay higher prices (affordability) for sustainable heating (environmental sustainability). Suppose a scenario were to occur where an economic recession hits, thereby changing the preferences of citizens. An economic recession is an example of a scenario of value change that can possibly result in a lack of social acceptance.

Therefore, the present research suggests that a form of scenario analysis is required for assessing value change, which can inform future social acceptance issues. However, literature indicates that very few tools have been implemented for ex-ante analysis of social acceptance, especially when observing value change. Some studies have indicated different factors or themes that influence acceptance of certain renewable technologies (Hall et al., 2013), but have no focus on the way in which these factors have an influence on the long-term acceptance of the technology. The study of de Wildt et al. (2021) attempts to analyze future value change scenarios with the use of agent-based modelling (further discussed in Chapter 3). They remark that their research should be tested in other cases, perhaps with different methodologies and within different city districts.

Considering the knowledge gap of insufficient research on long-term value change scenarios analysis for local sustainable transitions, the following problem statement is formulated:

There is a lack of methods to analyze and build scenarios of value change.

This problem statement will be addressed by the research conducted in this thesis.

2.2 Research objectives

The present research intends to assess a potential future lack of social acceptance of sustainable heating in Geerdinkhof by evaluating how values may change over time. As a result, two main research objectives are formulated. Firstly, the present research intends to contribute to the academic literature regarding anticipating social acceptance for sustainable transitions, through value change research. The second research objective is to discover possible future scenarios concerning value change in the sustainable heating transition in Geerdinkhof and provide recommendations by analyzing these scenarios of value change and assessing which form of sustainable heating best suits particular scenarios.

2.3 Research questions

In order to reach the research objective, the questions presented in this section have to be answered. The main research questions for the proposed research is:

What are socially accepted long-term sustainable heating options in Geerdinkhof given possible value change scenarios?

In order to provide an answer to the main research question, the following sub questions are posed:

1. Which methodologies are effective in generating future scenarios regarding value change?

This sub question relates to the first part of the research objective. Section 2.1 argues that there is a lack of research on methodologies that attempt to explore scenario analysis based on value change. Chapter 3 is devoted to exploring the possible methodologies and choosing one that is deemed effective for generating future scenarios regarding value change that will be used throughout the rest of this thesis.

2. What are the key factors for value change of sustainable heating within Geerdinkhof?

Generating scenarios requires insight into the factors that influence possible futures. When considering value change for the sustainable heating transition in Geerdinkhof, it is important to delineate the key factors to take into account when applying the scenario generating methodology chosen from sub question 1. These factors are explored and detailed in Chapter 5.

3. What are the future scenarios of citizen value change for heating options within Geerdinkhof?

This sub question is dedicated to the second part of the research objective, which is to identify possible future scenarios concerning value change in the sustainable heating transition in Geerdinkhof. These generated scenarios will be detailed in Chapter 6.

4.What are the implications for long-term heating options given possible value change scenarios and resulting social acceptance issues?

This sub question also relates to the second part of the research objectives. Recommendations for which long-term options in Geerdinkhof will be related to the generated value change scenarios from the previous sub question. These recommendations are also elaborated in Chapter 6.

2.4 Scientific and societal relevance

The present research contains many aspects of both scientific and societal relevance. Both aspects are discussed in the following subsections.

2.4.1 Scientific relevance

The scientific relevance pertains mostly to the knowledge gap identified in section 2.1. This thesis intends to contribute to the lack of existing scientific knowledge and methods used to build scenarios of value change particularly in support of sustainable transitions. De Wildt et al. (2021) attempted a very similar approach of value-based scenario analysis for sustainable heating in the Netherlands, with the use of the Agent-Based modelling methodology. This is one of the methodologies that are reviewed and compared in order to answer SRQ1, and further elaborated in Chapter 3. Another point of scientific relevance is the conceptualization of values and value change. This research intends to argue for specific types of values and value change, in order to best combine these concepts with the eventual scenario building tool.

2.4.2 Societal relevance

In terms of societal relevance, this thesis aims to bring new insights for the municipality of Amsterdam and the neighborhood of Geerdinkhof in particular with regard to social acceptance. These insights mostly pertain to the social acceptance required for the local heating transitions that will need to take place in the coming decade. Mouter et al. (2018) indicate that it is important for values to be integrated throughout the design of energy cases. The relevance of this thesis is therefore in the incorporation of citizen values in particular, and not those of the municipality or heat suppliers. Moreover, understanding whether the underlying human values in sustainable heating design are met for citizens in Geerdinkhof can help in ex-ante assessment of design choices within the neighborhood. The municipality can take action to address these social acceptance issues before implementation. Lastly, often times moral values are not incorporated in the assessment of new sustainable heating technologies. Common assessment tools tend to look more at the monetary effect of the system as a whole, such as Cost-Benefit analyses. This thesis intends to include the normative effect (value change) of the system that is often neglected.

3. Methodology

This chapter will first detail the different methodologies that exist to explore future scenarios in section 3.1, with an emphasis on value change. This exploration of methodologies then leads into section 3.2, where the chosen methodology to be used in the rest of the research, Cross-Impact Balance analysis (CIB), is further explained. Lastly, section 3.3 describes the approach for data collection and verification of the present research.

3.1 Exploring value change through scenario analysis techniques

The present research intends to anticipate a possible future lack of social acceptance by identifying scenarios of value change. Swart et al. (2004) define a scenario in the context of sustainability science as *"coherent and plausible stories, told in words and numbers, about the possible co*-evolutionary pathways *of combined human and environmental systems"*. Scenario analysis is effective in describing plausible future developments through either projection, assumptions or simulations. It allows for investigating critical system elements that can influence these scenarios. These type of analyses are useful for long-term strategic planning (Weimer-Jehle et al., 2020). One of the key findings in de Wildt et al. (2021) is that the use of scenario discovery techniques is effective for ex-ante assessment of social acceptance. Moreover, scenario analysis methods have been widely used in the field of energy system transitions (Xiao et al., 2019). Moreover, a scenario can describe future developments in a specific geographic area, making use of different system elements such as socio-demographic characteristics (age, genders, education, income) but also exogenous elements such as economic developments or climate change (Duinker & Greig, 2007). A diverse array of both qualitative and quantitative scenario generating methods have been used to conduct different forms of research. The following subsections intends to discuss different approaches, both qualitative and quantitative, and argue for one methodology to be applied in the present research.

3.1.1 Qualitative scenario analysis methodologies

There are many qualitative scenario analyses methods employed in literature. Many of these methodologies explore storyline-based scenarios (Thomas, 2012). For example, Weimer-Jehle et al., (2020) used a literature review approach of Story-and-Simulation to construct scenarios for the energy transition. Many other studies also follow storyline based scenarios for environmental planning, which can be used to include different viewpoints on how future trends may develop (Swart et al., 2004). However, such methodologies also contain their limitations. For example, in the Story-and-Simulation methodology, it was found to be difficult to assess the role of social acceptance from the perspective of stakeholders, due to the differing opinions and motivations that stakeholder present (Weimer-Jehle et al., 2020). Moreover, interpretations of experts for qualitative storylines can be highly subjective (Rounsevell & Metzger, 2010) and may often simplify system factors used in the analysis to an extent that they no longer capture every influence that these factors have on the system (Almeida et al., 2017).

3.1.2 Quantitative scenario analysis methodologies

Quantitative scenario analysis often relies on projecting or forecasting scenarios that have an output in mathematical terms (Thomas, 2012). The benefit of these methodologies is that they rely on formal models, using mathematical algorithms to represent key features of systems (Swart et al., 2004). They are mostly used for predictive analysis, appropriate for well understood systems over sufficiently short time spans (Swart et al., 2004). Many different quantitative methods have been used for decision-making in energy transitions. An example of a quantitative scenario analysis methodology is Agent-Based Modelling. De Wildt et al. (2021) use this methodology to assess value conflicts and social acceptance for sustainable heating systems. Another example is found in the research conducted by Liu et al. (2015), where they use a System Dynamics approach to test how different policies effect the carbon emissions in Beijing public transportation. However, a commonality between these quantitative scenario analysis methods is their limitation in dealing with uncertain developments in complex systems or quantifying historical data (Almeida et al., 2017; Marttunen et al., 2017). Moreover, quantitative scenario analysis on its own can prove to be challenging and time consuming due to their strict criteria with regard to inputs.

3.1.3 Comparisons and chosen method

Kemp-benedict (2002) argues for two analytical challenges that scenario modelling must address in order to better plan for future change. One addresses complex behavior, arising from many interrelated components of a system, which is better dealt with from narratives of qualitative analyses. Another analytical challenge is complicatedness, or the many factors to keep in mind such as actors, constraints and resources. These challenges are better dealt with in quantitative analysis. As has been documented, both qualitative and quantitative scenario analyses present strengths and limitations. According to Swart et al. (2004), the limitations of quantitative analysis means that it should be complemented by qualitative scenario analysis, due to its ability to better capture other system-influencing factors such as values. Implementing qualitative narratives that shape values into quantitative scenario analysis provides a broader perspective than is possible from mathematical modeling alone.

In scenario analysis literature, system element relationships are usually described using mathematical equations, based on assumptions of these interactions. However, interactions between system elements that are vague or uncertain are not always exactly quantifiable (Kunz & Vogele, 2017). Similarly, the notion of "values" and their interactions with system elements, especially regarding sustainable transitions, is very difficult to exactly quantify (van de Poel, 2009). Moreover, scenario analysis literature also indicates that the use of argumentations and causal chain analysis is more appropriate given these uncertainties of defining mathematical equations (Kunz & Vogele, 2017). On the other hand, the addressees of scenario analyses usually require concrete figures, testing or evaluation of impacts on system elements that qualitative models do not (always) provide (Kunz & Vogele, 2017).

Cross-Impact Balance (CIB) analysis is one approach that can provide a balance for the needs of both quantitative and qualitative scenario analysis. CIB constructs qualitative and semi-quantitative scenarios systematically (Weimer-Jehle, 2006). Moreover, CIB can be used as a tool for a combination of mathematical modelling and storyline analysis, combining advantages of qualitative models (e.g. intuitive logic) with advantages of quantitative ones (e.g. simulation of system element interactions) (Kunz & Vogele, 2017). A combination of both quantitative and qualitative analysis is found to be the most preferential form of scenario analysis in literature (Marttunen et al., 2017), and the advantages of CIB analysis allows for deeper understanding of complex systems such as energy models (Kunz & Vogele, 2017).

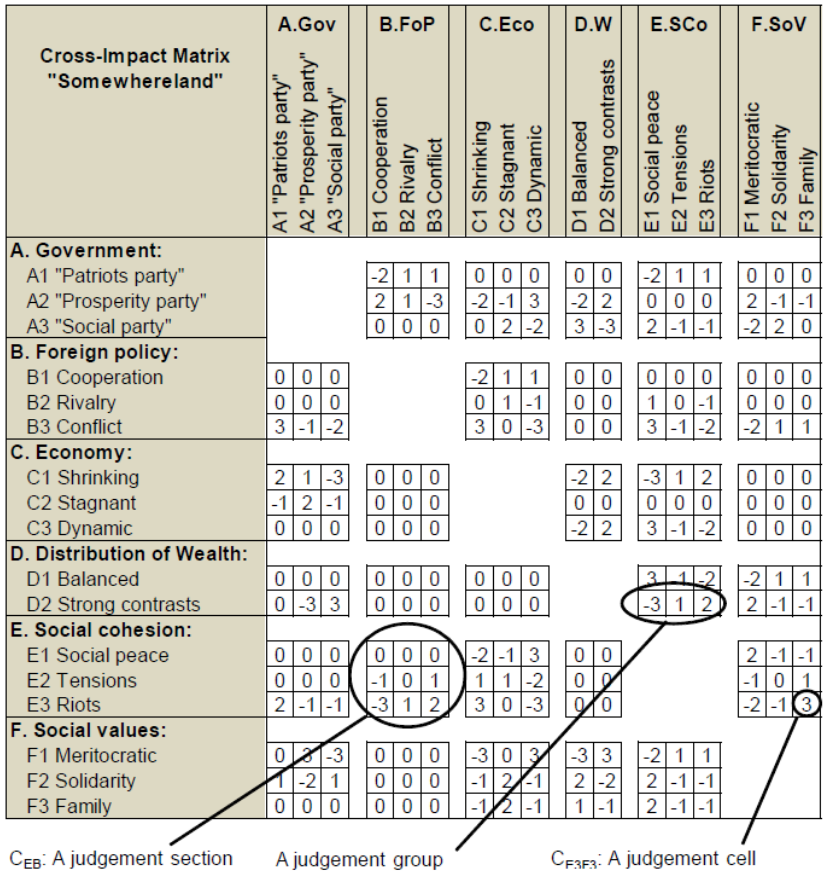
Scenarios in CIB analysis are generated based on combinations of different states of system elements, or factors. Clarifying the relationship between factors is one of the key strengths of CIB analysis. Weimer-Jehle et al. (2020) state that CIB is a well suited tool for understanding critical system element relationships and is therefore suitable to construct comprehensive storylines or scenarios. Compared to other methodologies for scenario exploration such as Agent-Based Modelling, CIB is a more fitting approach for exploring long-term future trends in a specific region based on the complex relationships among system factors. CIB not only generates plausible scenarios, but also acts as a database of knowledge obtained from experts, detailing critical relationships between system elements (Weimer-Jehle et al., 2020). In short, CIB is chosen based on the advantages of combining quantitative and qualitative scenario analysis, constructing comprehensive storylines and tracing the critical relationships between system elements. Moreover, CIB has the capability of integrating storylines for long-term scenario analysis in different disciplines, including sustainable energy transitions (Weimer-Jehle et al., 2020).

3.2 Cross-Impact Balances

CIB is a scenario modelling technique developed by Weimer-Jehle (2006). CIB takes a combinatorial approach to scenario development, placing the most important factors within a matrix and decomposing them into scenario factors with discrete states (Schweizer & Kriegler, 2012). These factors are called *descriptors* in CIB terminology, and are divided into *descriptor states.* These states indicate possible future trends of each descriptor. The accounting of how individual descriptor states directly influence other descriptor states are recorded within a cross-impact matrix according to the question (Weimer-Jehle, 2006):

''If the only piece of information [given to you] about the [future of the] system is that [scenario factor] X has the state x, [would you expect the] direct influence of X on [scenario factor] Y as a hint that [scenario factor] Y has the state y (promoting influence, positive points assessed) or as a hint that [scenario factor] Y has not the state y (restricting influence, negative points assessed)?''

This question entails that pairwise connections are made between descriptor states, referred to as 'judgments'. These judgments are elicited from experts or by selecting conclusions from literature (Schweizer & Kriegler, 2012). This participatory process with experts can be done individually, via interviews, or in group meetings or workshops. An example of a Cross-Impact matrix filled with judgments, along with the appropriate terminology of judgment sections, judgment groups and judgment cells within a matrix, is presented in Figure 2. The numerical values in Figure 2 are an example of judgments. The process by which these numerical values are filled into a CIB matrix is further elaborated in Chapter 5.



Cross-Impact Matrix "Somewhereland"	A.Gov: A1 "Patriots party"	A2 "Prosperity party"	A3 "Social party"	B.FoP: B1 Cooperation	B2 Rivalry	B3 Conflict	C.Eco: C1 Shrinking	C2 Stagnant	C3 Dynamic	D.W: D1 Balanced	D2 Strong contrasts	E.SCo: E1 Social peace	E2 Tensions	E3 Riots	F.SoV: F1 Meritocratic	F2 Solidarity	F3 Family
A. Government:																	
A1 "Patriots party"				-2	1	1	0	0	0	0	0	-2	1	1	0	0	0
A2 "Prosperity party"				2	1	-3	-2	-1	3	-2	2	0	0	0	2	-1	-1
A3 "Social party"				0	0	0	0	2	-2	3	-3	2	-1	-1	-2	2	0
B. Foreign policy:																	
B1 Cooperation	0	0	0				-2	1	1	0	0	0	0	0	0	0	0
B2 Rivalry	0	0	0				0	1	-1	0	0	1	0	-1	0	0	0
B3 Conflict	3	-1	-2				3	0	-3	0	0	3	-1	-2	-2	1	1
C. Economy:																	
C1 Shrinking	2	1	-3	0	0	0				-2	2	-3	1	2	0	0	0
C2 Stagnant	-1	2	-1	0	0	0				0	0	0	0	0	0	0	0
C3 Dynamic	0	0	0	0	0	0				-2	2	3	-1	-2	0	0	0
D. Distribution of Wealth:																	
D1 Balanced	0	0	0	0	0	0	0	0	0			3	-1	-2	-2	1	1
D2 Strong contrasts	0	-3	3	0	0	0	0	0	0			-3	1	2	2	-1	-1
E. Social cohesion:																	
E1 Social peace	0	0	0	0	0	0	-2	-1	3	0	0				2	-1	-1
E2 Tensions	0	0	0	-1	0	1	1	1	-2	0	0				-1	0	1
E3 Riots	2	-1	-1	-3	1	2	3	0	-3	0	0				-2	-1	3
F. Social values:																	
F1 Meritocratic	0	3	-3	0	0	0	-3	0	3	-3	3	-2	1	1			
F2 Solidarity	1	-2	1	0	0	0	-1	2	-1	2	-2	2	-1	-1			
F3 Family	0	0	0	0	0	0	-1	2	-1	1	-1	2	-1	-1			

Figure 2: Example CIB matrix, with matrix terminology (Weimer-Jehle, n.d.)

Constructing a CIB matrix is a two-step process, referred to as phases in this report. The first phase includes collecting and choosing the most important descriptors. Again, these are elicited from expert interviews or literature research (Schweizer & Kriegler, 2012; Weimer-Jehle, 2006). Once all relevant system elements have been investigated, phase 2 may commence. This phase involves eliciting answers from experts (or reviewing literature) in order to answer the above judgment question posed by Weimer-Jehle (2006) and fill in these judgments within the CIB matrix.

After constructing the CIB matrix, a computer program for CIB analysis (known as the ScenarioWizard tool (Weimer-Jehle, n.d.)) can compute scenarios and assess these scenarios to present only those scenarios which are deemed "internally consistent". The general idea is that only consistent scenarios are the more likely future developments, according to CIB theory. The following subsections will address the question of what internal consistency means and what this means for understanding value change.

3.2.1 What are internally consistent scenarios?

Every scenario generated from a CIB matrix is a combination of one descriptor state per descriptor. However, not all combinations are deemed internally consistent. The simplest way to conceptualize a consistency check for one specific scenario is by a network of influences. An example of a consistency check is provided by Weimer-Jehle (n.d.) and the network of influences for this example is illustrated in Figure 3. The arrows indicate the numerical judgments between each descriptor state (judgments are further elaborated in Chapter 5). In CIB analysis, a scenario element is considered well-founded if the sum of all influence values of the arrows pointing to a descriptor state is as high as possible. It is considered well-founded because the theoretical foundation of CIB analysis attempts to maximize the impact scores within a given scenario, according to the *principle of consistency* (Weimer-Jehle, 2008). These impact sums of the example by Weimer-Jehle (n.d.) are shown as the black boxes below the elements in Figure 3.

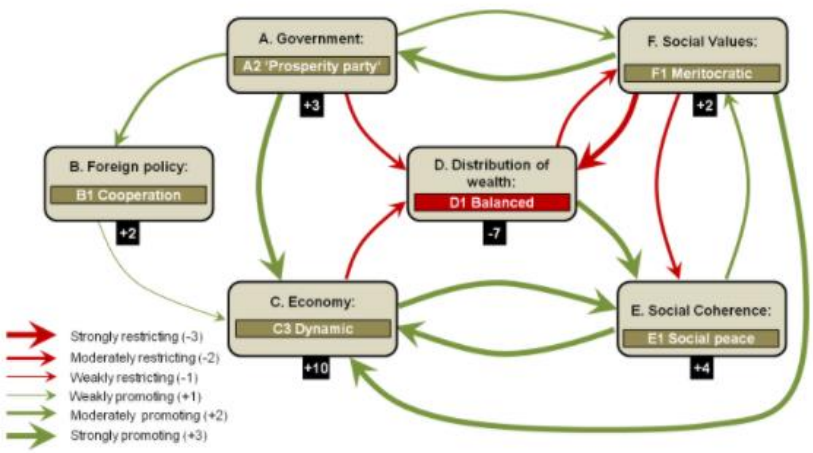


Figure 3: An example of network influences for a scenario (Weimer-Jehle, n.d.)

Somewhereland	A			B			C			D		E			F		
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	E1	E2	E3	F1	F2	F3
A. Government:																	
A1 "Patriots party"				-2	1	1	0	0	0	0	0	-2	1	1	0	0	0
A2 "Prosperity party"				2	1	-3	-2	-1	3	-2	2	0	0	0	2	-1	-1
A3 "Social party"				0	0	0	0	2	-2	3	-3	2	-1	-1	-2	2	0
B. Foreign policy:																	
B1 Cooperation	0	0	0				-2	1	1	0	0	0	0	0	0	0	0
B2 Rivalry	0	0	0				0	1	-1	0	0	1	0	-1	0	0	0
B3 Conflict	3	-1	-2				3	0	-3	0	0	3	-1	-2	-2	1	1
C. Economy:																	
C1 Shrinking	2	1	-3	0	0	0				-2	2	-3	1	2	0	0	0
C2 Stagnant	-1	2	-1	0	0	0				0	0	0	0	0	0	0	0
C3 Dynamic	0	0	0	0	0	0				-2	2	3	-1	-2	0	0	0
D. Distribution of wealth:																	
D1 Balanced	0	0	0	0	0	0	0	0	0			3	-1	-2	-2	1	1
D2 Strong contrasts	0	-3	3	0	0	0	0	0	0			-3	1	2	2	-1	-1
E. Social cohesion:																	
E1 Social peace	0	0	0	0	0	0	-2	-1	3	0	0				2	-1	-1
E2 Tensions	0	0	0	-1	0	1	1	1	-2	0	0				-1	0	1
E3 Unrest	2	-1	-1	-3	1	2	3	0	-3	0	0				-2	-1	3
F. Social values:																	
F1 Meritocratic	0	3	-3	0	0	0	-3	0	3	-3	3	-2	1	1			
F2 Solidarity	1	-2	1	0	0	0	-1	2	-1	2	-2	2	-1	-1			
F3 Family	0	0	0	0	0	0	-1	2	-1	1	-1	2	-1	-1			
Impact balances:	0	3	-3	2	1	-3	-9	-1	10	-7	7	4	-1	-3	2	-1	-1

Figure 4: Cont'd example, highlighted rows form a scenario (Weimer-Jehle, n.d.)

Consistent scenarios are therefore characterized by the impact sums for all descriptor states within that specific scenario being as high as possible. These are as high as possible if an exchange of the selected variant would not lead to a further increase in the impact sum for any descriptor, according to Nash equilibrium (Weimer-Jehle, n.d.). Moreover, *the principle of consistency* indicates that "every state is chosen in such a way as to ensure that no other state of the same descriptor is preferred more strongly by the combined influences of the other descriptors" (Weimer-Jehle, 2008). Figure 4 presents a CIB matrix that is the continuation of the example presented by Weimer-Jehle in Figure 3. The rows of all active variants of the scenario are highlighted. The impact scores of the highlighted rows are calculated by adding up the values in each column.

In other words, a scenario is rejected and deemed inconsistent if the impact sum of even one active descriptor state (in the case of the example given in Figure 4, descriptor state D1: Balanced) is exceeded by the impact sum of the other descriptor state of the same descriptor (D2 in this case having an impact sum of 7 according to the example in Weimer-Jehle's paper, which is more than the impact sum of -7 for D1).

3.2.2 What does internally consistent scenarios mean, in terms of value change?

The proposed research is to construct a CIB matrix with values and factors that are influential to long-term value change for sustainable heating transitions in Geerdinkhof. From the previous subsection it is clear that only the impact sums of the most positive (promoting) impact scores of descriptor states within the randomly chosen set of descriptor states will be part of what are deemed consistent scenarios.

This methodological process of scenario generation separates internally consistent scenarios from those that are inconsistent, regardless of their perceived plausibility (Schweizer & Kriegler, 2012). However, the focus lies on what is defined as 'perceived plausibility'. The CIB algorithm generates these scenarios through what is known as "mechanical" reasoning, requiring no professional judgment. Judgment in this case refers to its literal definition (the ability to make considered decisions or come to sensible conclusions), not CIB judgments. "Non-mechanical" reasoning, in contrast, refers to experts or other individuals producing judgments and conclusions of what scenarios seem more likely. Interestingly, Schweizer & Kriegler (2012) argue that, based on research of 200 cases comparing mechanical and non-mechanical predictions, mechanical methods such as CIB outperformed experts 60% of the time. In short, it seems evident that the human mind alone is not enough to process interactions of multiple causal chains between system elements. Moreover, human error is a factor when making judgments under uncertainty. For example, humans may believe that 'extreme' outcomes may be less likely than they truly are (Schweizer & Kriegler, 2012).

CIB addresses these issues by requiring human experts to focus on providing information that they are more likely equipped to handle. The information they are asked to provide are smaller in scale, such as descriptors, descriptor states, and one-on-one judgments of how one outcome of a descriptor state can be expected to directly influence the outcome of another descriptor state (Schweizer & Kriegler, 2012). These three rules form the basis for revealing complex system behavior in CIB theory. According to Weimer-Jehle (2006);*"the expert is better at recognizing the impact pattern within a complex system, and the mathematical method is better at analyzing how this impact pattern works"*.

It should be noted that CIB analysis has a complementary manner of understanding scenarios apart from the consistency checks. This manner requires slightly more computational effort but in return allows for interesting insight. In consistency checks, calculations are made to achieve the highest impact scores. Suppose an inconsistent scenario is found in a CIB analysis. Adjusting this scenario by replacing one inconsistent descriptor state to another state of the same descriptor does not usually lead to a consistent scenario. These adjustments of inconsistent descriptors often cause new inconsistencies in other nodes of the impact network. However, repeating this replacement procedure may lead to consistent scenarios, provided that one exists (Weimer-Jehle, 2008).

This replacement procedure has to be repeated with each possible scenario as a starting scenario, and adjusting the inconsistent descriptors till a consistent scenario is found. The resulting scenario is called the successor of its predecessor (Weimer-Jehle, 2006). Often the succession results in a consistent scenario after a few steps and is stable from this step onwards. Moreover, after carrying out the succession for every possible scenario (combination of descriptor states), the frequency of the found consistent scenario is calculated. As a result, a "combinatorial weight" of the consistent scenarios are given. This allows for the distinction of consistent scenarios with the help of a qualitative measure (Weimer-Jehle, 2008). Furthermore, this succession offers an idea of the direction in which the system might move from its momentary state (Weimer-Jehle, 2006).

An example is given by Weimer-Jehle (2006). Suppose 'scenario A' receives a combinatorial weight of 186, compared to scenario B's combinatorial weight of 1. It is clear that these weights are not probabilities, but frequencies of which the scenario is discovered, given the replacement procedure of every possible starting scenario. Nevertheless, this measure indicates that the developments of 'scenario A' has predominant importance compared to 'scenario B'.

In sum, there are two measurements available in the CIB analysis for the assessment of scenarios. The first is consistency checks. which explain how well a scenario corresponds to the expert judgments of the Cross-Impact matrix, calculated in the mechanical procedure. The second is the combinatorial weights resulting from replacement procedures, which tells us more of the extent to which the system might be inclined to adopt this state (Weimer-Jehle, 2006).

In the present research case of value change, this understanding of the underlying assumptions for CIB analysis provides a lens to look through. The values and the factors that influence value change chosen for this research, and the eventual judgments between them, seem highly influential to what scenarios are deemed as consistent. However, empirical evidence suggests that the likelihood of the eventual generated scenarios occurring (by mechanical procedures) are higher than what you or I would deem a likely scenario (non-mechanical procedures). This thesis therefore defines "internally consistent" scenarios of value change as a reflection of how *the prioritization of values shift over time* (van de Poel, 2018), considering the mathematically plausible combination of system elements i.e. the developments of the (selected) surrounding descriptors that have a high enough impact score in that scenario. Moreover, this thesis will look at these consistent scenarios, and check their frequency of developing i.e. "combinatorial weights", indicating the extent to which the system might be inclined to adopt that particular state.

3.3 Data collection and verification

As previously mentioned, CIB analyses rely heavily on expert interviews and literature research. A similar CIB study about sustainable heating in Amsterdam South East conducted by Sun (2020) interviewed a total of 12 experts. Another CIB study conducted by Vögele et al. (2017) about German household energy consumption made use of 10 expert interviews. However, Weimer-Jehle (2006) does not state a given minimum of experts required for this methodology. Nevertheless, given the time constraints of the present research, a total of 5 interviews were conducted for phase 1 and phase 2. In addition, literature reviews were conducted throughout this research in order to collect information regarding characteristics of Geerdinkhof and the associated heating technologies (Chapter 4) and determinant factors that influence social acceptance (Chapter 5). A majority of literature gathered is retrieved from scientific publications.

Phase 1 interviews were conducted in order to gain a deeper understanding of the local conditions and possible sustainable heating initiatives in Geerdinkhof. Moreover, the determining factors that can affect social acceptance of the citizens were clarified during these interviews. Phase 2 interviews were conducted in order to use expert knowledge to provide information on relationships between system elements i.e. judgments. These judgments are used to construct the CIB matrix and form the basis for the scenario generation. These interviews were also used for verification of judgments. Table 1 summarizes the participants interviewed for both phases. Limitations regarding interviewee views on sustainable transitions and the heterogeneity of their answers are discussed in Chapter 8.

Table 1: Summary of roles and organizations of the Participants interviewed

Phase	Interviewee(s) role	Organization
Phase 1	Energy commission Geerdinkhof	
	Senior Advisor Energy and Circular development	City of Amsterdam
	Program manager of natural gas free developments	!WOON
Phase 2	Geerdinkhof citizen, and director of a research institute	"Het Groene Brein"
	Advisor	CoForce

4. Description of heating initiatives in Geerdinkhof

This chapter will describe the possible sustainable heating initiatives that the neighborhood of Geerdinkhof may undergo in the coming years. First, the local conditions of the neighborhood are explained in section 4.1. Then, these initiatives, and their characteristics are detailed in the subsequent sections (4.2 till 4.4) and finally summarized in section 4.5. These characteristics are mainly found based on literature research and based on the interviews conducted for the CIB analysis (Appendix B). These options are not described in technical detail, as it is argued that the technical aspects are outside the scope of the present research. Nevertheless, brief descriptions of the technologies are laid out in their respective sections.

4.1 Local conditions

Currently, all households in Geerdinkhof are privately owned, and are either stand-alone or in rows of around five to six households (Allcharts, 2021). Most households and were built in the 1970's and 80's and a majority of occupants are of an older age group of around 65+ (Allcharts, 2021). The majority of Geerdinkhoffers are considered affluent, especially compared to the rest of Amsterdam South East (CBS, 2021). As of right now, a majority of households are connected to the natural gas network. However, certain households have taken smaller initiatives to become less dependent on natural gas, such as installing a small heat pump within their dwelling. Some households have installed diverse types of insulation methods, most commonly insulating windows and rooftops.

Interestingly, the composition of Geerdinkhof households and neighborhood characteristics are quite common in other neighborhoods within the Netherlands, such as a majority of privately owned households consisting of older age groups (Infonu.nl, 2021). This leads to the possibility that the findings of the present research can be replicable for other parts of the Netherlands. Although this is an interesting proposition, the findings are also largely based on the local conditions. Intrinsic with local conditions are the possible heating solutions available to a specific neighborhood. It is imperative that these possibilities are explained in terms of their relationship with citizens. As was made clear through the conducted interviews, Geerdinkhof has three broad and distinct options that will be described in the following sections. These options are:

1) A High Temperature (HT) commercial district heating network owned and operated by one central external company, most likely from Vattenfal. This is also mentioned in the Transitievisie Warmte Amsterdam. This option is henceforth referred to as the “HT District heating network” option
2) Low Temperature (LT) options, which are owned and operated by the citizens in Geerdinkhof. These options entail that either the neighborhood as a whole starts a collectively-owned heating network that oversees a collective heating system (based on aquathermal heatpumps or heat-cold storage units) or parts of the neighborhood that are in rows of households work together to install semi-collective heat pumps. These options are henceforth referred to as “collectively-owned options”
3) Every individual household is responsible for own heating provision

4.2 HT District heating network

District heating is a network of insulated pipes, distributing heat from a centralized heat source to households. These heat sources may vary depending on the production company, and can be derived from biomass, waste incineration, or residual heat from industry and data centers (ten Haaft, 2020). A typical plant pumps heated supply water which is used for household heating as well as domestic hot water. This water is heated in a heat exchanger, where the supply water can either be used directly or alternatively transferred for internal circulation. This supply water, after transferring the heat through the domestic hot water and internal room heating, is now cold and returns to the district heating plant. The water circulates in a closed pipeline (Bemmel, 2013; ten Haaft, 2020). Figure 5 illustrates the working of a typical district heating network from producer to consumer.

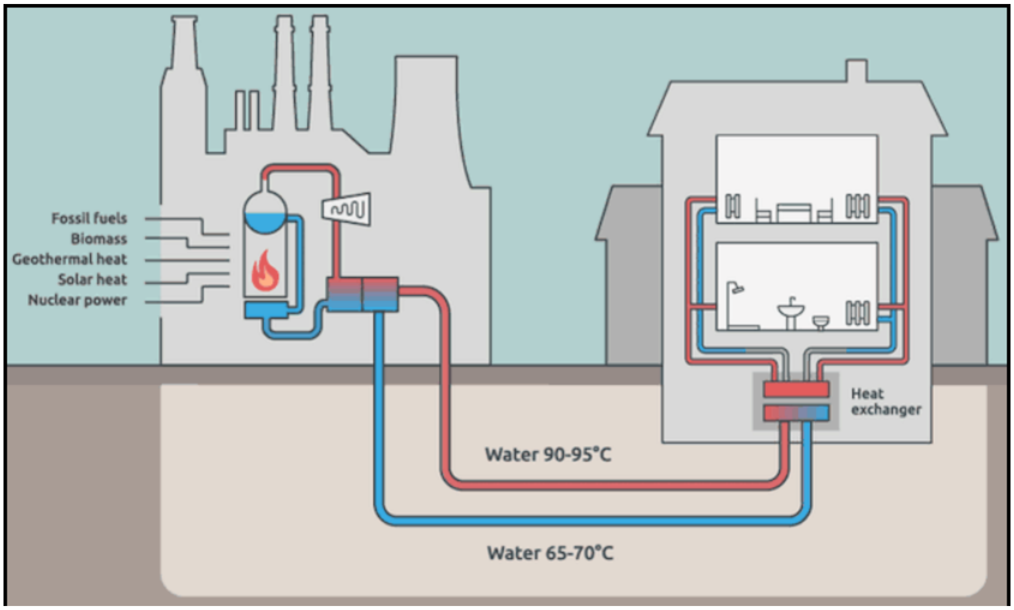


Figure 5: Illustration of district heating (Wikipedia Commons, n.d.)

As previously mentioned, the Transitievisie Warmte (Gemeente Amsterdam, 2020b) states that Geerdinkhof falls within the '"District heating neighborhood" category in the municipalities plans for heating transition. Citizens do not view this as the most popular option, as district heating companies are generally seen as a monopolistic entity with the rights to change heating prices if needed. However, citizens as of right now are not pushing or expressing interest in taking matters into their own hands to avoid this possibility. The forecasted tariffs for this network have a wide margin and can be adjusted during the networks' lifetime, due to the monopolistic nature of an external owner and operator. The costs associated with these adjustments are then pushed onto the consumer. However, the district heating options is seen as the "least headache" option for citizens, as the installation is done for them, and the level of thermal comfort is comparable to the current natural gas systems with high temperature radiant heating (Vattenfall, n.d.).

4.3 Collectively-owned options

There are two options that fall into this broad category, each of which will be detailed. Both options present the same challenges for implementation. That is a main reason why the interviewees suggested to put these together in the same category.

4.3.1 Collectively-owned heating network

One of the collective options is a collectively-owned heating network, which can be formed by a cooperative within the neighborhood. Energy cooperatives have been a growing trend within local neighborhoods in the Netherlands (Elzenga & Schwencke, 2014). Residents that are interested in disentangling from the reliance of natural gas, often in collaboration with their local municipality, can look for new local heat sources (Elzenga & Schwencke, 2014). Certain options might be surface water or waste water, wood waste from the municipality, heat from the soil or by using groundwater (Het Groene Brein, n.d.). One of the few examples of a cooperative that has formed local heat network dependent on local water resources is located Culemborg in Gelderland (Thermo Bello, n.d.).

Citizens may form a legal entity in order to reap the benefits of joint investments and shared responsibility in sustainable initiatives (Het Groene Brein, n.d.). A cooperative owns the investment and operates it together. For example, a cooperative can own and operate a windmill. This is of course preceded by a process of applying for permits, conducting studies and investments. More and more energy cooperatives are working on the theme of sustainable heating (Het Groene Brein, n.d.).

This would require great effort and interest from the majority of inhabitants of Geerdinkhof to not only form enough citizens to create a cooperative, but to also initially investigate the possibilities of sustainable heating sources. For example collective heat-cold storage units, otherwise known as “warmte-koude opslag” units or WKO’s, need to provide sufficient heating for those that subscribe to the collective system according to the law, or ‘Warmtewet’ (RVO, 2021). Furthermore, according to the Warmtewet, every household must have their heating system provide ‘sufficient heating’ of minimal 20 degrees Celsius. This would mean inspections would be mandatory that the system works efficiently according to law. Lastly, the maintenance and other costs associated with this cooperation would also fall solely on those citizens involved within the neighborhood initiative.

4.3.2 Collective heat pumps

The other option is collective (aquathermal) heat pumps that can be installed around the neighborhood for rows of five to six households, making use of the surrounding water in Geerdinkhof. Surface water that surrounds neighborhoods can be a substantial source of sustainable heat (Niessink, 2021). Fortunately, Geerdinkhof is surrounded by local surface water, illustrated in Figure 6. By extracting thermal energy from the water, storing it and upgrading it to a higher temperature using a heat pump, it can be delivered and used for domestic heating. Surface water generally has a varying temperature between 7 and 25 degrees Celsius, making it a low temperature heat source (Altena, 2018; Niessink, 2021). In order to combat this, the water can be stored in a reservoir during summer months and eventually used for heating in winter months.

Figure 6: Google Maps screenshot of Geerdinkhof and surrounding local surface water

The heat-cold balance of the aquifer is restored by adding surface water. The technique makes use of pumps and heat exchangers at the reservoir. A heat network is used to transport low temperature heat to consumers. This form of heat supply is illustrated in Figure 7 .

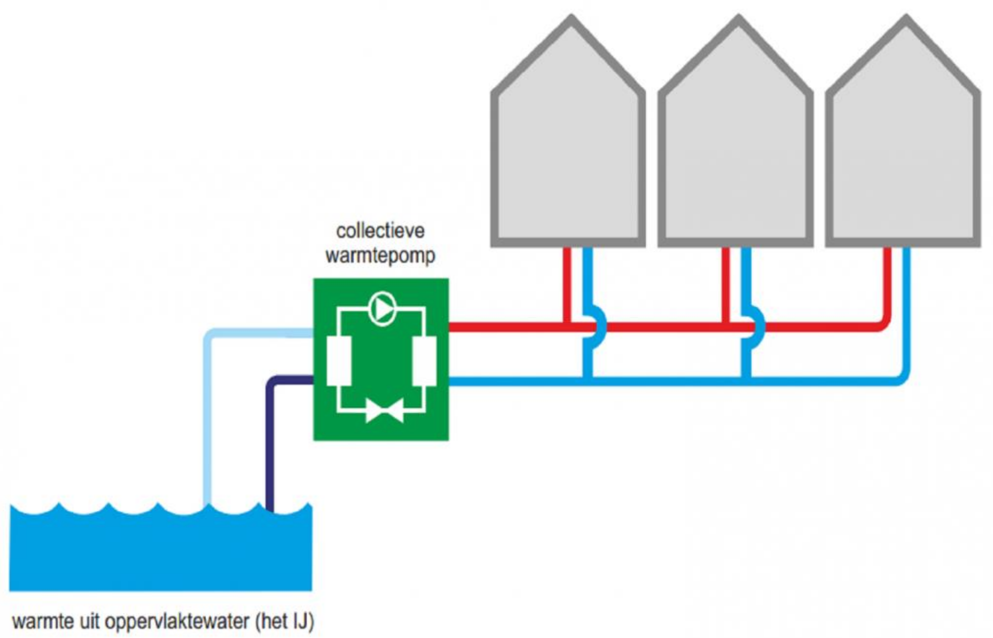


Figure 7: Illustration of a collective aquathermal heat pump(Altena, 2018)

These heat pumps are also investments that are made collectively and must be maintained by agreements between those connected to the network. The same laws apply to this type of collective network, although it is in a smaller scale of five to six households. It is also possible that different groups of five to six households around the neighborhood commit to installing collective heat pumps.

One of the characteristics is of course the benefit of cheaper heating provision as a collective. One interviewee estimated that a collective heat pump compared to an individual heat pump can save around 35% of initial costs if installed as a collective. Of course for both options it is clear that cooperation is needed between neighbors, as well as leadership and clear responsibility overviews in case of issues with the network. Furthermore, both options must adhere to the minimal temperature law, and adhere to the laws stating that collective heating households must contribute to the maximum carbon emissions per year (Brans, 2020).

4.4 Individual solutions

This is the option that some households are already pursuing currently in Geerdinkhof according to one of the interviewees. Small scale adjustments such as insulating parts of the household are not considered individual solutions, as they do not lead to a reduction in carbon emissions and use of natural gas for household heating. One option is an individual electric heat pump system installed within one household. This works similar to the heat pump described in section 4.3. The electricity used for the heat pump can be self-generated, for example through solar panel installations. This heat pump then extracts heat from the air (Remeha, n.d.). Some households in Geerdinkhof, including one of the interviewees, already make use of individual heat pumps. Of course, compared to collective solutions, this can be more expensive. For example, an all-electric solution within a house is forecasted to be expensive, especially in upfront investments (van Polen, 2020). However, heat pumps and solar panels prove to be financially viable in the long term. One drawback is the low temperature, non-radiant heat that these forms provide similar to collectively-owned options. A consequence of this is that certain household will need to invest in insulation methods.

4.5 Overview of heating initiatives

The characteristics of each option can now be summarized. In the following chapters, scenarios of future value change will be constructed, and subsequently compared to the options in terms of their characteristics and relations to values. It is important to summarize and place these options within the context of their relations to citizen views. It is interesting to note that both collective options and individual options lead to the consequence of making the district heating option obsolete, if enough households pursue them and are willing to make the effort and adjustments required to apply and install these options. Table 2 summarizes the heating initiatives and their characteristics and relation to the values. It is important to note that for the latter two options, insulation of the household can be required depending on the specific household. The costs associated with insulation as a compliment to the LT solutions is excluded from the present research. Instead, this research intends to focus on the primary source of heating. This exclusion is reflected in Chapter 8.

Table 2: Heating initiatives and their relations to Geerdinkhof

Heating initiative	Relation to values
HT District Heating network	• "Least-headache" option, least effort needed for citizens in transition • Not preferred by majority of citizens • Monopolistic tendencies, adjustable tariffs can be expensive for end consumer • High temperature, radiant heating comparable to current natural gas system
Collectively-owned heating networks	• Cheapest method per household • Organization and responsibility of system falls on shoulders of citizens • Cooperation needed between citizens • Low temperature, non-radiant heating
Individual options	• Middle ground in terms of cost • Responsibility per individual, no agreements needed between different parties • Effort in transition is still needed • Low temperature, non-radiant heating

5. CIB matrix construction

This chapter will discuss the construction of the CIB matrix used in this report. First, section 5.1 will describe and argue for the chosen values used for this research. Then, the selected descriptors and their states used for the eventual CIB matrix are selected and argued for in section 5.2. These descriptors and their states are identified through literature research and interviews. Lastly, section 5.3 explains the judgments between these descriptors, eventually leading to the final version of the CIB matrix.

5.1 The use and description of values

Many values can be identified when considering local sustainable transitions or initiatives. For example, Batel (2020) states that two values in particular, procedural justice (the fairness in allocating resources) and distributive justice (the fairness of how costs and benefits are distributed), are important to analyze when conducting research based on social acceptance of sustainable energy technologies. Other studies suggest that values such as 'Openness' or 'Respect for nature' are important to take into account when researching sustainable development (Shepherd et al., 2009). Interestingly, these values are typically conceptualized as "collective or social values" (Kenter et al., 2019). Kenter et al. (2019) make a distinction between collective and individual values in their research on describing the many perspectives on how values are delineated. According to their research, the relationship between collective and individual values on a societal scale can be thought of in many different ways. They argue that there exists a causal relationship between the two types, where either collective values predict individual ones or vice versa. This leads to the idea that individuals represent their society, and consider it through their individual perceptions and experiences (Kenter et al., 2019). Moreover, literature has argued that individual value change is a driving factor for sustainable transitions to be realized (Pappas & Pappas, 2014). This research therefore argues that when considering values for CIB analysis, it will be through the lens of individual values.

It is important to decide on which individual values to consider for this research, and how many. This thesis will focus on individual values for sustainable transitions. However, it cannot be ignored that other values play a role in sustainable transitions. For example, values such as privacy or energy justice (Milchram et al., 2018) can be identified as more collective values by Kenter et al. (2019). Moreover, Milchram et al. (2018) state that certain values can be seen as both barriers and drivers for social acceptance of sustainable energy systems (in their case smart grids). Assessing which values to consider to study social acceptance is a challenge in itself, and is further elaborated in Chapter 8.

It is first decided to only consider two values for the present research. This is mainly due to considerations with supervisors on how to effectively conduct a CIB analysis. In a previous attempt to analyze social acceptance through scenarios of value change in Amsterdam South East, Sun (2020) included four values (environmental sustainability, affordability, openness, and fairness). The findings of this research were inconclusive, as social acceptance issues were difficult to analyze due to the vagueness of interactions between four distinct values. It was therefore decided to analyze less values and include more external factors that can influence value change.

When conducting the phase 1 interviews, it was mentioned that **affordability** and **comfort** were at the forefront of the transition. These two values are interesting when researching social acceptance. As de Wildt et al. (2021) indicate in their research of ex-ante social acceptance of sustainable heating, these two values come in conflict when considering district heating and (certain combinations) with heat pumps. Even though switching to these forms of heating may improve thermal insulation, they prove to be quite costly. Moreover, these two values are some of the most determining factors for social acceptance of energy transitions according to the research conducted by Beauchampet & Walsh (2021) in nine different municipalities in the Netherlands. It is important to first provide a definition for these two values before further elaborating on other system descriptors.

5.1.1 Affordability

Affordability was considered one of the more crucial values by experts. Affordability is defined in literature in many ways. One of the ways is in a mathematical way; “a technology intervention is considered ‘affordable’ if the net change of income minus expenditure is greater or equal to zero” (Riley, 2014). Other definitions can be found in the work of Sun (2020), where affordability is defined as ‘the costs that energy consumers pay for the system fitting within a reasonable amount of their budget’. These costs or interventions can range from energy bills to investment costs for the corresponding infrastructure to any form of renovation costs. Affordability for sustainable heating is also defined in de Wildt et al. (2021) as “the extent to which households spend a reasonable amount of their disposable income on the heating and the purchase of heating related appliances”. In short, the present research considers the definition of affordability as; '*a reasonable extent to which investments in sustainable heating or thereby related appliances exceed citizen's (disposable) income'*.

5.1.2 Comfort

Comfort is an interesting value and one that can be interpreted in many ways. Moreover, interviewees found comfort to also be one of the more crucial aspects in the transition in Geerdinkhof. The interpretation of comfort, and specifically thermal comfort is historically and socially specific and is likely to change in response to changes in technologies (Ben & Sunikka-Blank, 2015). A very rigid definition of thermal comfort is "the condition of the mind in which satisfaction is expressed with the thermal environment" (Djongyang et al., 2010). A more practical definition of thermal comfort is defined as "the extent to which households receive the appropriate heating level to ensure sufficient well-being" (de Wildt et al., 2021). Thermal comfort however is not the only important factor. Interviewees expressed that a heating transition not only requires a certain level of thermal comfort, but the transition must also encompass what is known as "living comfort" (Beauchampet & Walsh, 2021). Living comfort encompasses aspects such as noise pollution, that can be generated by heat pumps for example. Other aspects of living comfort are space requirements of new technologies, such as the space required for heat pumps within a household or outside a collection of households. Another aspect of living comfort is the level of effort or interest that citizens put forth when renovating or adapting their household for sustainable transitions. In short, the present research considers the definition of comfort as; *'the extent of ease and well-being which households feel during and after the sustainable heating transition'*.

5.2 Phase one: Selected descriptors and their states

Value change of sustainable heating solutions can be affected by (exogenous) factors (Sun, 2020). These factors, henceforth referred to as descriptors, can be influential in the possible implications for which heating option is adopted in the neighborhood. The descriptors that were of importance were derived from interviews (see Appendix A) and literature research. Arguments for each descriptor will be briefly described in the following subsections.

5.2.1 Development of investment preferences

Homeowners tend to (under)invest in sustainable projects based on many factors, such as the estimated return on investment of a technology, due to possible lack of information or due to being present biased

(Fischbacher et al., 2021). Moreover, homeowners differ in what they deem as important to invest in when considering sustainable measures. Certain homeowners may wish to take smaller investments due to risk aversion or other financial reasons, while others may have more of an investment appetite for the improvement of their dwelling (Fischbacher et al., 2021). Interviewees suggested that citizens in Geerdinkhof tend to differ on this topic. Certain citizens show an eagerness for investing in their household, while others find smaller investments such as insulation methods more than enough to improve the comfort within their house. The future developments in investment preferences directly reflects the local conditions related to how energy consumers perceive the value of affordability, and is therefore chosen as a descriptor for the present CIB analysis.

5.2.2 Average disposable income

Household disposable income is a primary source for investing sustainable transitions (Zarco-Periñán et al., 2021). Moreover, the level of household disposable income can influence heating demand and consumption (Bissiri et al., 2019). Interviewees found disposable income to be relatively high for citizens in Geerdinkhof. Nevertheless, the average disposable income for a household in Geerdinkhof may change depending on the change of overall home-owners in the long term. Considering the longevity of the considered heating solutions, and the high probability of the change of home-owners in Geerdinkhof in the long term, it is argued that the average disposable income is an influential descriptor for the present CIB analysis.

5.2.3 Development of environmental concern

Citizens that acknowledge their relationship to the environment, and demonstrate a level of environmental concern, effects how they evaluate and accept sustainable solutions (Ingold et al., 2019). Interestingly, Beauchampet & Walsh (2021) find that Dutch citizens in particular can exhibit environmentally conscious behavior. However, interviewees suggested that although certain citizens exhibit levels of environmental concern through for example the installation of rooftop solar panels, there is also a level of financial incentives for these actions, such as receiving tax breaks or other subsidies. Moreover, certain citizens do not always feel the urgency of climate change and the need for sustainable transitions. It can be said that certain citizens exhibit little to no concern for environmental issues, while others are clearly more environmentally conscious. Considering that these concerns may change over time, this is taken as a descriptor for the CIB analysis.

5.2.4 Development of heating prices

Another interesting factor that has been elicited from interviews are the development of future annual household heating prices. Many studies have been conducted in order to forecast these possible developments (Arnoldussen et al., 2021; van Polen, 2020). Nevertheless, the forecasted numerical values do not provide information for scenario generation based on value change. The author has insinuated the development of heating price directions based on the interviewee responses. Moreover, the author insinuated the direction of heating prices from a study conducted by Collewet et al. (2021) that indicates how future prices may develop for sustainable heating in Amsterdam. It was found that either households generate their heat from electrical pumps or other methods involved with electricity. These prices in general are considered to be more stable than the counterpart of district heating. As previously mentioned, these supplier of district heating has monopolistic power and therefore can change the tariffs if needed. These developments are important when generating scenarios for Geerdinkhof, and is chosen as a descriptor for the CIB analysis.

5.2.5 Development of appliance prices

The adoption of appliances such as heat pumps, heat cold storage units or solar panels in order to foster sustainable heating in Geerdinkhof can have two broad pricing mechanisms, according to the interviewees. These developments really differ in high or low upfront costs that are required to be made. For example, investments needed for all-electric housing are quite high up front, but over time yield lower maintenance costs. On the other hand, an individual or collective heat pump requires less intensive upfront costs and also yields lower maintenance costs over time. Again, numerical values for appliance prices were deemed irrelevant for the present CIB analysis of value change.

5.2.6 Development of climate change and temperatures

In 2014 the royal Dutch meteorological institute forecasted different scenarios for climate change in the Netherlands (KNMI, 2014). These scenarios have been adjusted to fit within the present CIB matrix. And have been summarized as; softer winters but hotter summers, extreme winters and intense storms during summers or negligible rise in temperatures. Furthermore, climate change is deemed an exogenous factor that is of importance to sustainable projects for scenario generation studies (Weimer-Jehle et al., 2020). Furthermore, interviewees indicated that this is an important factor to consider for the transition in Geerdinkhof, and is taken as a descriptor.

5.2.7 Development of community relationship

Lastly, the development of how neighbors interact with each other is an important factor to consider for future sustainable projects. This is of particular importance for collective initiatives such as cooperatives (Majee & Hoyt, 2009). In order to realize sustainable developments, a certain level of relationship and enthusiasm must develop, according to the interviewees. Learning to coexist, forming strong relationships and working as a community is not always a given (Luederitz et al., 2013). It remains an interesting factor to consider for the developments in Geerdinkhof.

5.2.8 Summary of descriptors and their states

The present CIB matrix will consist of strong individual values of comfort and affordability, with other exogenous factors that can be deemed as collective factors (i.e. community relationship) or individual factors (i.e. average disposable income) or some combination of both (i.e. environmental concern). As previously mentioned, there is a causal relationship between individual and collective values, where either collective values predict individual ones or vice versa (Kenter et al., 2019). It is argued that these individual values can be affected by collective and individual factors, and the selection of the types of descriptors are therefore justified.

The descriptors can be divided into possible future trends. These trends were argued for or are translated from the previous subsections. Both the descriptor and the descriptor states are summarized in the Table 3. The descriptor states for the two values are taken from the CIB analysis of Sun (2020). More specifically, this thesis defines the "importance of values" as *"what individual households or citizens in Geerdinkhof find important"*. This decision is also discussed in Chapter 8.

Table 3: Selected descriptors and their states

Descriptor	States
A. Importance of 'Comfort'	'Not at all important' 'Fairly important; 'Very important'
B. Importance of 'Affordability'	'Not at all important' 'Fairly important; 'Very important'

C. Development of investment preferences	‘No preferences’ ‘Small investment preferences’ ‘Large investment preferences’
D. Average disposable income	‘Similar disposable income’ ‘Lower disposable income’ ‘Higher disposable income’
E. Development of environmental concern	‘No level of concern’ ‘Higher level of concern’
F. Development of heating prices	‘Stable electricity prices’ ‘Fluctuating district heating prices’
G. Development of appliance prices	‘Low maintenance costs but high upfront costs’ ‘Low upfront costs and low maintenance costs’
H. Development of climate change and temperatures	‘Softer winters and hotter summers’ ‘Extreme winters and intense storms during summers’ ‘H3. Negligible rise in temperature’
I. Development of community relationship	‘Higher level of community bond’ ‘Lower level of community bond’

5.3 Phase two: Judgments for descriptor relationships

The interaction among descriptors is an important component of CIB analysis. The relationships between descriptors are represented in the form of semi-quantitative judgments regarding the influences between pairs of descriptor states. More simply put, judgments are the impact that state x1 of descriptor X has on the state y1 of descriptor Y (Weimer-Jehle, 2006). These judgments must be Geerdinkhof-specific, and are therefore elicited through the conducted phase 2 interviews and partial literature research. Judgments are considered either ‘promoting’ or ‘restricting’, and are assigned to the respective cell within the CIB matrix. These judgments are given numerical values which are taken from an ordinal scale defined by Weimer-Jehle (2006), presented in Figure 8.

Figure 8: Ordinal scale of possible judgments

It is important to note that both direction ('-' or '+') and degree (0, 1, 2, 3) describe the influence between two descriptor states. Direction indicates the restrictive or promoting impact one state has on another. The degree indicates the extent to which the type of impact exerts its influence. The present research used interviews during phase 2 as a means to discover descriptor judgments. These relationships are based on the interpretation of their verbatim statements, and are translated into numerical values on the ordinal scale. The present research used the following principles to translate qualitative statements into quantitative cross-impact judgments for the CIB matrix:

1. It is first important to understand the relationship in terms of the direction and degree of the judgments. Directions were easily obtainable from statements from the interviewees, by asking their initial thoughts on whether the relationship was more promoting or restricting. The degree however required interpretation from the author or further questioning during the phase 2 interviews.
2. Every CIB matrix needs to apply the same rule, known as the "principle of compensation" (Weimer-Jehle, 2006). This rule requires the sum of each row within a judgment group to equal 0. Schweizer & Kriegler (2012) elaborate further, stating that each descriptor state is always mutually exclusive and exhaustive, implying that the promotion of one impact on certain states always go along with restricting impacts on complementary states of the same descriptor.
3. The extremes on the ordinal scale (+3 and -3) are avoided as much as possible within the present research, unless indicated otherwise. These extreme judgments are defined only in obvious or extreme cases of strong causal relationships between descriptors (Sun, 2020). Therefore, the present research tends to use a limited number of quantitative judgments, based on whether

interviewees found the relationship to be “slightly/weakly existing” (-1 or +1) or “moderately evident” (-2 or +2).

The following example is arbitrarily chosen and will be used to demonstrate how judgments were translated for the CIB matrix. Table 4 indicates the relationship between the descriptors of ‘development of community relationship’ and the ‘importance of comfort’. Paraphrasing what one of interviewees stated; “the relationship exists to a certain extent, where it is feasible for the neighborhood that if there is a higher level of bond, that this can lead to a higher level importance for comfort because you can work together to solve some of the living comfort issues regarding sustainable heating transitions”.

Going through the translation steps, the following can be deduced;

1. The relationship is weak, interpreted as 1 on the ordinal scale. The relationship is also promoting for fairly important level of comfort, not necessary very important. So a +1 at ‘Fairly important’
2. By principle of compensation, there must be a ‘-1’ within the same row. Considering that people can value comfort with a higher bond, setting ‘-1’ under very important would not fit with the argumentation. Instead, ‘-1’ is added under Not at all important
3. Again, the translation from qualitative statements to quantitative values is tricky. However, it is clear that the interviewee was not totally convinced that the relationship between the two descriptors is moderately or strongly affected.

This leads to the following judgment within the CIB matrix, given in Table 4.

Table 4: Impact of development of community relationship on the importance of comfort

		Importance of comfort		
		Not at all important	Fairly important	Very important
Development of community relationship				
	Higher	-1	1	0
	Lower	0	0	0

Brief rationales insinuated from interview responses for many other judgments are given in Appendix D. These judgments form the basis of scenario generation. One scenario generated in a CIB analysis is the combination of one descriptor state per descriptor. The judgments between these states go through a computational algorithm to discover the internal consistency of each scenario. The baseline CIB matrix is presented in Figure 9. This matrix consists of 7 descriptors with a total of 23 descriptor states, giving a total number of 3888 (=3*3*3*3*2*2*2*3*2) possible future scenarios. However, not all scenarios are deemed internally consistent. Scenario generation and this consistency check is executed in the following chapter.

	A			B			C			D			E		F		G		H			I	
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	F1	F2	G1	G2	H1	H2	H3	I1	I2
A. Importance of 'Comfort'																							
A1. Not at all important				-1	-1	2	2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2. Fairly important				0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	0	0	0
A3. Very important				1	1	-2	-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. Importance of 'Affordability'																							
B1. Not at all important	-2	1	1				-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2. Fairly important	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B3. Very important	1	1	-2				2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. Development of investment preferences																							
C1. No preferences	1	0	-1	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2. Small investment preferences	0	-1	1	0	0	0				0	0	0	0	0	0	0	-1	1	0	0	0	0	0
C3. Large investment preferences	-2	1	1	0	0	0				0	0	0	0	0	0	0	1	-1	0	0	0	0	0
D. Average disposable income																							
D1. Similar disposable income	0	0	0	0	1	-1	0	1	-1				0	0	0	0	0	0	0	0	0	0	0
D2. Lower disposable income	0	0	0	-1	0	1	1	1	-2				1	-1	0	0	0	0	0	0	0	-1	1
D3. Higher disposable income	-1	-1	2	1	1	-2	-1	-1	2				-1	1	0	0	0	0	0	0	0	-1	1
E. Development of environmental concern																							
E1. No level of concern	-1	0	1	0	0	0	1	1	-2	0	0	0			0	0	0	0	0	0	0	0	0
E2. Higher level of concern	2	0	-2	1	1	-2	-1	-1	2	0	1	-1			0	0	0	0	0	0	0	0	0
F. Development of heating prices																							
F1. Stable electricity prices	-2	1	1	1	-1	0	-2	1	1	0	0	0	0	0			1	-1	1	1	-2	0	0
F2. Fluctuating district heating prices	0	0	0	1	1	-2	0	1	-1	1	-2	1	-1	1			1	-1	0	0	0	0	0
G. Development of appliance prices																							
G1. Low maintenance costs but high upfront costs	0	0	0	2	0	-2	0	0	0	1	-2	1	0	0	0	0			0	0	0	0	0
G2. Low upfront costs and low maintenance costs	0	0	0	-1	-1	2	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0
H. Development of climate change and temperatures																							
H1. Softer winters and hotter summers	-1	1	0	1	-1	0	-2	1	1	0	0	0	0	0	0	0	0	0				0	0
H2. Extreme winters and intense storms during summers	-3	1	2	0	0	0	-3	1	2	0	0	0	-2	2	0	0	0	0				0	0
H3. Negligible rise in temperature	2	-1	-1	0	0	0	2	-1	-1	0	0	0	1	-1	0	0	0	0				0	0
I. Development of community relationship																							
I1. Higher level of community bond	-1	1	0	0	0	0	-1	0	1	0	0	0	-1	1	0	0	0	0	0	0	0		
I2. Lower level of community bond	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0		

Figure 9: Baseline CIB matrix

6. CIB matrix analysis

This chapter is dedicated to analyzing the baseline CIB matrix found in Chapter 5. First the generated and internally consistent scenarios are presented in section 6.1. Given the large amount of scenarios, section 6.1 also deals with filtering these scenarios and clustering them in order to gain a clear overview of the possible scenarios. These clusters are briefly described in section 6.2 in terms of their possible storylines. Then, sensitivity analyses are conducted and documented in section 6.3 to cover the possibilities between different descriptor judgments. Lastly, section 6.4 discusses the implications for the heating options given the discovered scenarios and given succession analysis.

6.1 Generated scenarios

In total, 23 different consistent scenarios were generated (see Appendix F). The ScenarioWizard tool (Weimer-Jehle, 2018) for CIB analysis provides one specific manner to gather overviews of constructed scenarios, a 'tableau' overview. This is a table that indicates the consistent scenarios in columns and respective descriptor variants in the rows. Sun (2020) uses the tableau option to provide a clear oversight on the relations between the four generated scenarios in his research. However, this overview lacks clarity when the number of scenarios and descriptor variants increases, as is the case in the present research.

It can be difficult to extract useful information from the large amount of scenarios. However, clustering scenarios can be useful to identify scenarios that have similar behaviors or consequences. Clustering scenarios is done in many other forms of analysis, such as probabilistic risk assessment, and is useful for providing oversight of a large sample size (Mandelli et al., 2013). The ScenarioWizard tool does not provide a manner to construct clusters in case of a large number of scenarios. This research proposes a procedure in order to cluster scenarios, particularly regarding value change, in order to provide a more comprehensive overview of the large number of scenarios.

1. Run the 'Find consistent scenario' analysis in the ScenarioWizard Tool and use the "Filter" option within the tool in order to filter the scenarios based on the descriptor variants.
2. Begin by filtering a combination of descriptor variants of the two values analyzed, in this case the "Importance of Comfort" and the "Importance of Affordability". For example, begin by filtering the two descriptor variants of "Not at all important" for both values.

3. In this case of “Not at all important”, 3 of the 23 scenarios are filtered. Check this current cluster to see where the descriptor variants of the other descriptors differ in other scenarios. If there are many different descriptor variants within a cluster, more filtering could be needed. In order to further cluster, select the next most commonly found descriptor variant under the “Filter” tab. Continue filtering till the most robust subset of scenarios are left. At times multiple variants of a certain descriptor are left within a cluster. This is a choice that the author makes, as otherwise there would be no clustering, only an explanation for 23 different scenarios.

6.2 Cluster descriptions

The clusters of scenarios identified through this filtering process are briefly described in the following subsections. Note that certain clusters contain multiple descriptor variants. For example, most of the descriptor variants in Cluster 1: “Adaptable citizens” contain one variant, with the differences being the descriptor variants of C, E and I. This trait is noticeable in every cluster, although for different descriptors. It is also important to note that when filtering the scenarios, for example those consisting of (Importance of comfort)*‘A2. Fairly important’* and (Importance of affordability) *‘B1. Not at all important’*, many (nine) different scenarios resulted with notable differences in the descriptor variants. The author found it best to continue filtering till a subset could be found that had interesting traits to develop a storyline. Lastly, certain combinations of descriptor variants for Comfort and Affordability are omitted, due to the fact that these combinations are not found when filtering the consistent scenario analysis.

6.2.1 Cluster 1: Adaptable citizens

In these scenarios, citizens with similar disposable incomes in the future develop no strong importance for comfort or affordability. This implies that citizens develop into adaptable citizens. They are willing to trade-off comfort in the transition to sustainable heating, as well as being adaptable to the pricing of this transition. This cluster also shows that whether or not citizens show environmental concern, or whether citizens have a strong community bond or not, they do not really have strong opinions on investment preferences. This cluster and the descriptor states found are given in Table 5.

Table 5: Cluster 1

Cluster 1 (3 scenarios); Adaptable citizens Importance of comfort: *A1. Not at all important*

Importance of affordability: *B1. Not at all important* Development of investment preferences: *C1. No preferences / C2. Small investment preferences* Average disposable income: *D1. Similar disposable income* Development of environmental concern: *E1. No level of concern / E2. Higher level of concern* Development of heating prices: *F2. Fluctuating district heating prices* Development of appliance prices: *G1. Low maintenance costs but high upfront costs* Development of climate change and temperatures: *H3. Negligible rise in temperature* Development of community relationship: *I1. Higher level of community bond / I2. Lower level of community bond*

6.2.2 Cluster 2: Comfort and large investment preferences

The scenarios in this cluster suggest that although affordability is not considered of importance, with citizens remaining with similar disposable income, comfort has moved to the forefront of slightly more important. Since the neighborhood has developed a higher level of environmental concern, they are willing to take larger investment preferences. These scenarios of value change occur regardless of community bond or types of climate change developments. Again, high upfront costs are found in these scenarios. This cluster and the descriptor states found are given in Table 6.

Table 6: Cluster 2

Cluster 2 (7 scenarios); Comfort and large investment preference Importance of comfort: *A2. Fairly important* Importance of affordability: *B1. Not at all important* Development of investment preferences: *C1. Large investment preferences* Average disposable income: *D1. Similar disposable income* Development of environmental concern: *E2. Higher level of concern* Development of heating prices*: F1. Stable electricity prices /F2. Fluctuating district heating prices* Development of appliance prices*: G1. Low maintenance costs but high upfront costs*

Development of climate change and temperatures*: H1. Softer winters and hotter summers / H2. Extreme winters and intense storms during summers/ H3. Negligible rise in temperature* Development of community relationship: *I1. Higher level of community bond / I2. Lower level of community bond*

6.2.3 Cluster 3: Comfort and small investment preferences

Similar to cluster 2, comfort remains fairly important to citizens with similar disposable income. The major difference between this cluster and cluster 2, is that citizens develop smaller investment preferences. This matches well with the low upfront costs in the appliance pricing. Interestingly, these scenarios only indicate softer winters and hotter summers and no other developments in climate change. This cluster and the descriptor states found are given in Table 7.

Table 7: Cluster 3

Cluster 3 (2 scenarios); Comfort and small investment preference
Importance of comfort: *A2. Fairly important* Importance of affordability: *B1. Not at all important* Development of investment preferences: *C2. Small investment preferences* Average disposable income: *D1. Similar disposable income* Development of environmental concern: *E2. Higher level of concern* Development of heating prices*: F2. Fluctuating district heating prices* Development of appliance prices*: G2. Low maintenance costs and low upfront costs* Development of climate change and temperatures*: H1. Softer winters and hotter summers* Development of community relationship: *I1. Higher level of community bond / I2. Lower level of community bond*

6.2.4 Cluster 4: Need for affordable transition

In these scenarios, affordability moves to the forefront of importance for citizens in Geerdinkhof, while comfort remains of some importance. This is backed up by the development of citizens preferring smaller investments for their heating transition. Moreover, stability in appliance pricing and low costs for heating matches these developments. These developments strongly suggest that Geerdinkhof transitions to a less affluent neighborhood with less disposable income. Affordable heating options for the transition is most likely what is needed in these cases. This cluster and the descriptor states found are given in Table 8.

Table 8: Cluster 4

Cluster 4 (3 scenarios); Need for affordable transition Importance of comfort: *A2. Fairly important* Importance of affordability: *B3. Very important* Development of investment preferences: *C2. Small investment preferences* Average disposable income: *D1. Similar disposable income./D2. Lower disposable income* Development of environmental concern: *E1. No level of concern / E2. Higher level of concern* Development of heating prices: *F1. Stable electricity prices* Development of appliance prices*: G2. Low upfront costs and low maintenance costs* Development of climate change and temperatures*: H1. Softer winters and hotter summers / H2. Extreme winters and intense storms during summers* Development of community relationship: *I2. Lower level of community bond*

6.2.5 Cluster 5: Comfort above affordability with similar disposable income

This cluster indicates that citizens develop a strong need for comfort, considering the many possibilities in climate change developments. Citizens with similar disposable income show no need for affordable transitions, regardless of heating or appliance pricing. However, this cluster shows a lower level of community relationship. This cluster and the descriptor states found are given in Table 9.

Table 9: Cluster 5

Cluster 5 (4 scenarios): Comfort above affordability with similar disposable income Importance of comfort: *A3. Very important* Importance of affordability: *B1. Not at all important* Development of investment preferences: *C2. Small investment preferences*

Average disposable income: *D1. Similar disposable income* Development of environmental concern: *E1. No level of concern / E2. Higher level of concern* Development of heating prices*: F1. Stable electricity prices/F2. Fluctuating district heating prices* Development of appliance prices*: G1. Low maintenance costs but high upfront costs / G2. Low upfront costs and low maintenance cost.* Development of climate change and temperatures*: H1. Softer winters and hotter summers / H2. Extreme winters and intense storms during summers/ H3. Negligible rise in temperature* Development of community relationship: *I2. Lower level of community bond*

6.2.6 Cluster 6: Comfort above affordability with lower disposable income

Similar to cluster 5, comfort becomes the most important value for citizens, presumably due to the two main climate change descriptors. The main difference in this cluster is the development of lower disposable income, with smaller investment preferences, low appliance pricing and stable heating pricing. And similar to cluster 5, the community relationship remains at a lower level. This cluster and the descriptor states found are given in Table 10.

Table 10: Cluster 6

Cluster 6 (2 scenarios): Comfort above affordability with lower disposable income
Importance of comfort: *A3. Very important* Importance of affordability: *B1. Not at all important* Development of investment preferences: *C2. Small investment preferences* Average disposable income*: D2. Lower disposable income* Development of environmental concern: *E1. No level of concern / E2. Higher level of concern* Development of heating prices*: F1. Stable electricity prices* Development of appliance prices*: G2. Low upfront costs and low maintenance costs* Development of climate change and temperatures*: H1. Softer winters and hotter summers / H2. Extreme winters and intense storms during summers*

Development of community relationship: *I2. Lower level of community bond*

6.2.7 Cluster 7: Best of both worlds

The importance of both comfort and affordability are relatively high for citizens in these scenarios, with similar disposable income developments. Regardless of how climate changes or how environmental concerns develop, citizens still prefer smaller investments for the heating transition. In these scenarios, lower levels of community relationship is noticed. This cluster and the descriptor states found are given in Table 11.

Table 11: Cluster 7

Cluster 7 (2 scenarios); Best of both worlds Importance of comfort: *A3. Very important* Importance of affordability: *B2. Fairly important* Development of investment preferences: *C2. Small investment preferences* Average disposable income *D1. Similar disposable income* Development of environmental concern: *E1. No level of concern / E2. Higher level of concern* Development of heating prices*: F2. Fluctuating district heating prices* Development of appliance prices*: G2. Low upfront costs and low maintenance costs* Development of climate change and temperatures*: H2. Extreme winters and intense storms during summers/ H3. Negligible rise in temperature* Development of climate change and temperatures*: I2. Lower level of community bond*

6.2.8 Conclusion

Seven different clusters of scenarios have been described in terms of their storylines and possible developments. These scenarios are deemed consistent, based on the explanation given in Chapter 3; consistent scenarios of value change are a reflection of how the prioritization of values may shift over the duration of the system. Only those scenarios that adhere to the mechanical nature of scenario generation, where only the maximized impact balances between descriptors, are taken into account. These scores are in turn contingent upon the judgments between descriptors.

These scenarios can be further tested and elaborated. One way is to test these clusters on their robustness. In order to test the robustness of these scenarios, a sensitivity analysis must be conducted. Another way to elaborate on these scenarios is through the calculated combinatorial weights. These weights of a consistent scenario indicate the frequency that a randomly chosen initial scenario (which is a subset of descriptor states) will be transformed into this specific consistent scenario. As stated in Chapter 3, this is referred to as a CIB succession procedure (Weimer-Jehle, 2018). Both the sensitivity analyses and the succession procedure, and what this means for the relation between possible future scenarios and the heating initiatives will be discussed in section 6.3 and 6.4, respectively.

6.3 Sensitivity analysis

The nature of a CIB analysis is that the judgments made within the matrix are subjective, and elicited from experts interviewed and further interpreted by the author. One implication of this subjectivity is that the results can be interpreted as weakly founded or less robust within the baseline CIB matrix (found in Chapter 5). Therefore it is proposed to perform a sensitivity analyses in order to test the robustness of the results.

Schweizer & Kriegler (2012) suggests two different methods for conducting sensitivity analysis within a CIB matrix. One method is to add a new relationship between descriptors that have no judgments filled in. This method is not as strong as it requires the author or the experts involved to create storylines for possible interactions between descriptors that do not exist in the baseline CIB matrix. The second method is more interesting for the present research. In this case, adjustments are made to already existing judgments between descriptors based on doubts of the interviewees of how these judgments can be interpreted. It is also worth noting that Schweizer et al. (2012) also state that both methods can be combined, however this is deemed too time consuming for the present research. Instead, the second method is conducted. It is important to note that for each sensitivity analysis, only the specified judgment is adjusted while the rest remain at the baseline judgments, similar to a univariate sensitivity analysis. The expected result is a change in the number of consistent scenarios. Clustering these scenarios is omitted from this present research, as it is too time consuming. However, reporting the difference in consistent scenarios can give an indication to the level of sensitivity that the baseline relationship of the selected descriptors has on the overall robustness of the baseline CIB matrix.

The following judgments are tested based on the doubts of interviewees on the relationships between descriptors. These are:

- Impact of disposable income on community bond
- Impact of disposable income on importance of comfort
- Impact climate change on importance of affordability
- Impact of environmental concern on the importance of comfort

In order to illustrate how these sensitivity analyses are conducted, one of the three analyses is presented as an example. The other three analyses can be found in Appendix E.

The impact of disposable income on community bond

As previously mentioned, the average citizen in Geerdinkhof is more affluent compared to other regions in Amsterdam South East. How their disposable income affects community bond was doubted in the phase 2 interviews. The rationale in the baseline CIB matrix is twofold. First, if the average disposable income in Geerdinkhof were to become lower, it is expected to have a weak restricting effect on higher community bond. Second, if the average disposable income were to be higher, this would also have a restricting effect on higher community bond. The rationale for the former is that if citizens have less to spend on investments for heating transitions, they are less likely to compensate or help their neighbors in joint investments such as a collective heat pump system. The rationale for the latter is if citizens have more to spend in the future, they might be more likely to attempt individual solutions first before helping their neighbor in a collective effort. The baseline relationship is presented in Table 6.

Table 12: Baseline Impact of disposable income on community relationship

			Community bond	
			Higher	Lower
Disposable income	Similar			
	Lower		-1	1
	Higher		-1	1

This rationale was considered questionable. It was suggested that higher disposable income would mean that neighbors could also have higher trust in each other to be able to invest and maintain collective projects together. It was also said that lower disposable income does not necessarily mean that joint ventures cannot work. It was suggested that even new tenants in the future will likely not have lower disposable income compared to the current tenants. Therefore, the following adjustment is made to the judgments between these descriptors baseline CIB matrix, illustrated in Table 7.

Table 13: Sensitivity analysis on the impact of disposable income on community relationship

			Community bond	
			Higher	Lower
Disposable income	Similar			
	Lower		0	0
	Higher		1	-1

As a result of this change, 27 consistent scenarios are found after running ‘find consistent scenarios’ in the ScenarioWizard tool. The number of consistent scenarios per sensitivity analysis is given in Table 8.

Table 14: Summary of resulting consistent scenarios per sensitivity analysis

Sensitivity analysis between judgments	Number of consistent scenarios
Impact of disposable income on community bond	27
Impact of disposable income on importance of comfort	23
Impact climate change on importance of affordability	23
Impact of environmental concern on the importance of comfort	22

Interestingly, two of the tested relationships between descriptors contain the same number of consistent scenarios as the baseline CIB matrix, 23. Moreover, the other two analyses did not result in drastically different results in terms of the number generated consistent scenarios. It should be noted that these scenarios can have different combinations than the clusters mentioned in section 6.2. Nevertheless, these outcomes indicates that in general the internal consistencies of most scenarios generated in section 6.1 are not very sensitive to these judgments. The impact of disposable income on community bond showed that the amount of scenarios were affected in some capacity, which indicates the sensitivity of the baseline scenarios to this relationship.

6.4 Implications for design choices

This section will attempt to bridge the discovered scenarios from section 6.1 and 6.2 with the three main heating initiatives in Geerdinkhof that were detailed in Chapter 4 and summarized in section 4.5. Certain possible future states tend to point towards a more likely option being implemented within the neighborhood. In order to best match the discovered scenarios with the best suitable heating option, these options from section 4.5 are presented once again in Table 9.

Table 15: Heating initiatives and their relations to Geerdinkhof

Heating initiative	Relation to values
HT District Heating network	• "Least-headache" option, least effort needed for citizens in transition • Not preferred by majority of citizens

	• Monopolistic tendencies, adjustable tariffs can be expensive for end consumer • High temperature, radiant heating comparable to current natural gas system
Collectively-owned heating networks	• Cheapest method per household • Organization and responsibility of system falls on shoulders of citizens • Cooperation needed between citizens • Low temperature, non-radiant heating
Individual options	• Middle ground in terms of cost • Responsibility per individual, no agreements needed between different parties • Effort in transition is still needed • Low temperature, non-radiant heating

The scenarios in cluster 1 are characterized by adaptable citizens, willing to work together and make necessary adjustments to their comfort and making investments if needed. These developments indicate that citizens can be willing to transition towards more collectively-owned systems, which are characterized by citizens being willing to take on responsibility and cooperate if needed, trading-off the normal thermal comfort for perhaps non-radiant heating.

The results of cluster 2 indicate again that citizens are willing to make high upfront costs and develop large investment preferences, perhaps at a slightly more important role of comfort. The only major difference with cluster 1 is the larger investment preference and the development of higher upfront costs for appliances. Furthermore, community relationship in this cluster has the possibility to become stronger. It can be argued that a combination of individual options, which tend to be pricier than collective options, as well as other (semi-) collective options is possible within the context of these scenario developments.

Cluster 3 on the other hand presents citizens with smaller investment preferences, with similar developments in value change as cluster 2. Considering these preferences and the possibility for growing community bond, indicates that collectively-owned systems can emerge.

Cluster 4 demonstrates the developments in similar to lower disposable income per citizen in Geerdinkhof. Moreover, lower community bond develops with a higher need for affordable heating. Furthermore, developments in smaller investment preferences and the development of stable electricity prices indicate that citizens might prefer investments in solar panels and perhaps more individual solutions for heating, as opposed to the pricy district heating or the collective options which require higher community bond.

Cluster 5 and 6 both show lower levels of community bond, and have no importance on affordability, but lay a very strong importance on the level of comfort. Cluster 5 indicates that, regardless of environmental concern, or the developments in climate change, the comfort in transition is most important. Even though cluster 6 shows lower disposable income developments, both clusters indicate that the radiant high temperature heat of the district heating option will most likely be too tempting for citizens to trade-off, considering the low effort of implementing this system compared to collective or individual options. Again, the requisite insulation methods associated with thermal comfort of LT systems are excluded from the present research.

Similarly, cluster 7 shows that citizens develop a very strong importance for comfort, but they have now developed a fairly strong importance for affordability. This cluster is characterized by the similar disposable income, small investment preferences and low level of community bond. Nevertheless, affordability is still of some importance, and could mean that this cluster best fits with the adoption of individual options.

The clusters and their respective heating options are summarized in Table 10.

Table 16: Most fitting heating option per cluster

Scenario Cluster	Most fitting heating option
Cluster 1: Adaptable citizens	Collectively-owned heating networks
Cluster 2: Comfort and large investment preferences	Semi-collective and individual options
Cluster 3: Comfort and small investment preferences	Collectively-owned heating networks
Cluster 4: Need for affordable transitions	Individual options
Cluster 5: Comfort above affordability, similar disposable income	HT District heating network
Cluster 6: Comfort above affordability, lower disposable income	HT District heating network
Cluster 7: Best of both worlds	Individual options

6.4.1 Implications for design choices after succession analysis

The storylines of each cluster has been related to the best suitable heating initiative. However, it is also important to check which of the storylines carry more ‘weight’. One way to check this is through the succession analysis, which was elaborated in Chapter 3. This succession analysis offers an idea of the direction in which the system might move from its momentary state. Weights are calculated based on the selections within the ScenarioWizard Tool to filter the "attractor weights" (under *Options - Evaluation Options)* (Weimer-Jehle, 2018). The weight of a consistent scenario indicates the frequency that a randomly chosen initial scenario will be transformed into one of the 23 specific consistent scenarios that were identified from the baseline CIB matrix. A scenario that "carries X weight" means that this consistent scenario was found from X amount of random starting scenarios after conducting the replacement procedure of continuously replacing an inconsistent descriptor state till it reaches the consistent scenario (see Chapter 3). These calculated weights for each of the 23 scenarios is given in Appendix F.

As previously stated, there are a total of 3888 possible scenarios in the baseline CIB matrix. The succession analysis indicates that 3850 of these scenarios eventually led to one of the 23 consistent scenarios. The other 38 scenarios (3888-3850) were never able to replace inconsistent descriptors enough times to lead to consistent scenarios.

The scenario that carried the most weight (711) can be found in cluster 5, which recommends HT DH options. The scenario that carries the next most weight (548) is found in cluster 2, indicating semi-collective or individual options. Table 17 indicates the most predominant scenarios and their associated heating initiative.

Table 17: Predominant scenarios found in succession analysis

Cluster of the predominant scenario	Weight	Most fitting heating initiative
Cluster 5	711	HT District heating network
Cluster 2	548	Semi-collective and individual options
Cluster 3	540	collectively-owned options
Cluster 7	466	individual options

The other scenarios can be found in Appendix F, where the weights of each scenario are given in descending order. Interestingly, scenarios 7 till 23 have a weight of 155 and lower. Moreover, scenarios 12 until 23 are weight 74 and lower. The majority of consistent scenarios are only found through the succession analysis for a very small percentage of all possible scenarios. The most predominantly found scenarios on the other hand offer an idea of the direction of value change might develop.

The other end of the spectrum also shows interesting results. For example, the scenario with the least weight (2) is found in cluster 6, which also indicates HT DH networks. Therefore, it cannot be conclusively recommended to adopt HT DH due to the most frequently found scenario (711) of value change. Moreover, these findings are dependent on the consistency check, which is dependent on the judgments, which are inherently subjective. Nevertheless, the strength of scenario analysis is the illustration of possible and probable developments. Observing these developments, assessing the current trends will need to go hand in hand with scenario analysis. A recommended approach is to match observations with the findings of these scenarios in order to choose a suitable, socially accepted heating initiative. This argument is further elaborated in the following chapter.

7. Conclusion

This chapter provides conclusions to the present research. These conclusions provide answers to the research question and sub questions mentioned in Chapter 2. The focus of this thesis lied on investigating the possible value change scenarios by constructing a Cross Impact Balances matrix. This matrix consists of values and factors that are considered influential to long-term value change for sustainable heating transitions in Geerdinkhof, according to experts interviewed.

This research attempted to provide an answer to the following research question: ***What are socially accepted long-term sustainable heating options in Geerdinkhof given possible value-change scenarios?***

An answer is provided by dividing the main question into four sub questions. An answer to each sub question is provided in the following sections.

7.1 Which methodologies are effective in generating future scenarios regarding value change?

Many methodologies exist for evaluating future scenarios, both quantitative and qualitative, and each present strengths and limitations. This thesis argues that quantitative analysis should be complemented by qualitative scenario analysis, due to its ability to better capture other system-influencing factors such as values. Implementing qualitative narratives that shape values into quantitative scenario analysis provides a broader perspective than is possible from mathematical modeling alone. In scenario analysis literature, system element relationships are usually described using mathematical equations, based on assumptions of these interactions. However, interactions between system elements that are vague or uncertain are not always exactly quantifiable. Similarly, the notion of "values" and their interactions with system elements, especially regarding sustainable transitions, is very difficult to exactly quantify. Moreover, scenario analysis literature also indicates that the use of argumentations and causal chain analysis is more appropriate given these uncertainties of defining mathematical equations (Kunz & Vogele, 2017). On the other hand, the addressees of scenario analyses usually require concrete figures, testing or evaluation of impacts on system elements that qualitative models do not (always) provide. Cross-Impact Balance (CIB) analysis is one approach that can provide a balance for the needs of both quantitative and qualitative scenario analysis. Scenarios are generated based on combinations of different states of system factors. Clarifying the relationship between factors is one of the key strengths of CIB analysis. Weimer-Jehle et al. (2020) states that CIB is a well suited tool for understanding critical system element relationships and therefore is suitable to construct comprehensive storylines or scenarios. Compared to other methodologies for scenario exploration, CIB is a more fitting approach for exploring future trends in a specific region based on the complex relationships among system factors such as values.

7.2 What are the key factors for value change of sustainable heating within Geerdinkhof?

These factors were elicited from interviews with experts and supported through literature research. The two values that are leading in the sustainable transition are the values of Comfort and Affordability. Kenter et al. (2019) makes a distinction between collective and individual values. They argue that there exists a causal relationship between the two types, where either social values predict individual ones or vice versa. This research therefore argues that when considering values for CIB analysis, it will be through the lens of individual values of Comfort and Affordability. These values are of particular interest as it is found that these two values come in conflict when considering district heating and certain combinations with heat pumps. Moreover, these two values are some of the most determining factors for social acceptance of energy transitions in the Netherlands, and in Geerdinkhof in particular. Other factors that can be deemed as collective factors or individual factors were included in the present research. Due to the causal relationship between individual and collective values, it is argued that these individual values can be affected by collective and individual factors. These factors are; the development of investment preferences, the average disposable income of a citizen in Geerdinkhof, the development of environmental concern, the development of heating prices, the development of appliance prices, the development of climate change and temperatures and the development of community relationship.

7.3 What are the future scenarios of citizen value change for heating networks within Geerdinkhof?

The CIB method generates scenarios that are internally consistent, in what is known as a 'mechanical' manner. The values and the factors that influence value change chosen for this research, and the eventual judgments between them, seem highly influential to what scenarios are deemed as consistent. However, empirical evidence suggests that the likelihood of the eventual generated consistent scenarios occurring are higher than what a general expert would deem a consistent scenario. This means that an internally consistent scenario of value change is a reflection of how the prioritization of values shift over time considering the mathematically plausible combination of system elements i.e. the developments of the (selected) surrounding descriptors that have a high enough impact score in that scenario.

In total, 23 consistent scenarios were generated in this present research. It can be difficult to extract useful information from the large amount of scenarios. It was decided to cluster these scenarios, as it can be useful to identify scenarios that have similar behaviors or consequences. By using the filtering option in the ScenarioWizard tool for CIB analysis, a total of 7 clusters of scenarios were identified based on the common value change traits. Based on these observed developments, the 7 clusters are named as:

1. Adaptable citizens
2. Cluster 2: Comfort and large investment preferences
3. Cluster 3: Comfort and small investment preferences
4. Cluster 4: Need for affordable transitions
5. Cluster 5: Comfort above affordability, similar disposable income
6. Cluster 6: Comfort above affordability, lower disposable income
7. Cluster 7: Best of both worlds

7.4 What are the implications for long-term heating options given possible value change scenarios and resulting social acceptance issues?

The most socially accepted long-term sustainable heating options are now related to these 7 clusters of possible future outcomes of value change. These clusters and their connections to the most fitting heating option are displayed below.

Scenario Cluster	Most fitting heating option
Cluster 1: Adaptable citizens	Collectively-owned heating networks
Cluster 2: Comfort and large investment preferences	Semi-collective and individual options
Cluster 3: Comfort and small investment preferences	Collectively-owned heating networks
Cluster 4: Need for affordable transitions	Individual options
Cluster 5: Comfort above affordability, similar disposable income	HT District heating network
Cluster 6: Comfort above affordability, lower disposable income	HT District heating network
Cluster 7: Best of both worlds	Individual options

In conclusion, recommendations can be provided to the city of Amsterdam regarding the social acceptance of sustainable heating transitions in Geerdinkhof. The present research has demonstrated that certain initiatives can be more socially accepted, depending on certain factor relationships and their interrelated developments. This research has also shown that certain scenarios develop more often than other scenarios, indicating more likely occurrence of specific value changes. The scenario that is most frequently found suggests the adoption of a HT DH network as being more socially accepted. However, recommendations on adopting this specific heating initiative remains inconclusive, as the least frequently found scenario also indicates HT DH network adoption. Moreover. it is difficult to make a political decision for design choices and implementation as only a modeler and advisor. Nevertheless, a recommendation can be provided on the best possible procedure that the municipality can take in order to facilitate more socially accepted heating initiatives.

These scenarios of value change and other factors are related to both the trends of neighborhood factors (disposable income, community bond, investment preferences, environmental concerns) and external factors (heating prices, appliance prices, climate change). Ex-ante assessment of social acceptance is therefore dependent on observing these possible trends. A recommended procedure would be to observe trends and make a policy decision, preferably before the implementation of the District Heating network in 2030.

For example, if it is observed that citizens do not show (1) strong importance for affordability or comfort and (2) do not show strong investment preferences and (3) show a strong willingness to adapt to different forms of heating and its' associated costs, then some forms of collectively-owned options should be promoted. On the other hand, if it is observed that citizens do not show strong willingness to investigate collective options or show no willingness to form cooperatives, and have a higher importance for comfort and not really for affordability, it could be assessed that HT district heating options will be more accepted. If again there are no strong indications for cooperation, but it is observed that citizens are willing to invest in sustainable transitions that are not the fluctuating district heating prices, then promoting individual solutions could lead to a socially accepted transition.

It is recommended that the municipality assess the current trends in both neighborhood and external factors, and compare them to the findings in the present research. This observation could be through participatory methods, such as surveys. Further elaboration on observatory methods for factors is given in Chapter 8. In this way, the municipality can elicit information from citizens regarding their views and stance on certain initiatives, values and factors. This would also need to be complimented with research into the external factors mentioned in this thesis, particularly regarding appliance or heating prices. The factors and values chosen for this research are argued for. Nevertheless, there could be other factors not taken into account that are influential for social acceptance. This topic is further elaborated in Chapter 8.

It is important to note that citizens would also need to demonstrate the need for sustainable initiatives. Currently, citizens in Geerdinkhof have demonstrated a willingness to adapt to sustainable solutions, but the majority have yet to act. Interviewees suggested that it could be due to a lack of information on the imminent nature of the sustainable transition or due to lack of the sense of urgency for this transition. A pre-requisite for this procedure is a growing sense of urgency and interest to act on this transition from citizens. Another recommendation would be for the municipality to continue to emphasize the importance and urgency of the impending transition, for example through information campaigns or neighborhood gatherings.

8. Reflection

To conclude this report, a reflection is given to provide impressions of the project realized. The purpose of this chapter is to demonstrate the limitations of the present research, with regard to the content or the process, presented in section 8.1. Section 8.2 then reflects on the social and scientific contributions of the present research. Reflections are also provided for possible directions for future research in section 8.3. Lastly, a reflection of my research process is given in section 8.4.

8.1 Limitations of the present research

Limitations of the present research can be divided into two categories. The first category refers to the limitations of CIB as a methodology and its' restrictions in terms not being able to represent all possible characteristics of the complex, value-based system in question. The limited amount and nature of factors considered for the CIB matrix are based on expert interviews. However, the question remains if these factors are the only ones of importance. Due to limitations of time constraints for the current project, only three interviews were held during phase 1 to elicit the factors used in this thesis. More exogenous factors, such as the (world or local) economy can also have an influence on the complex system in question. Another interesting point is the division of 3 scales for values (Not at all important, fairly important or very important) within the CIB matrix. These descriptor states may not entirely reflect how real world citizens view values nor how these values may develop over time. It can also be argued that the phrasing of the factors influences the interviewees interpretation of the relationships in question. In retrospect, the phrasing of certain factors can always be improved. For example, descriptor G mentions "Low maintenance costs" twice, as not to forget this aspect of appliance pricing. It could be argued to leave this part out of the descriptor states and focus solely on the high and low upfront costs. It could also be argued that the report for the descriptor of "Development of climate change" is based on a report that is a little dated (2014), as other reports suggest that more extreme winters and summers are imminent, but the extent of this will depend on the temperature increase. The limitation of phrasing is nevertheless an important note for future CIB studies.

Another limitation is the values that are deemed relevant (see section 8.3.2) for social acceptance. Nevertheless, these selected factors and their states are supported through literature reviews and interviews. It is argued that conducting more interviews can provide more insight. Comparatively, other CIB studies made use of 10 to 12 expert interviews. Differing insights could lead to some confusion on how to form the CIB matrix and the judgments, but could also lead to more possibilities for sensitivity analysis and deeper understandings of the relationships within the CIB matrix. More interviewees from perhaps different backgrounds (see section 8.3.4) could lead to a better and less biased understanding of the influential values and factors in the heating transition.

This leads to the second category of limitations, which is the subjective nature of how CIB analysis is formed. The heterogeneity of the interviewee answers needs to be mentioned. The 5 interviews were particularly convinced that a sustainable transition needs to happen, although certain opinions differed on the best or most likely procedure that Geerdinkhof should undertake. As was argued in this thesis, the subjective nature is combined with a mechanical reasoning in order to form likely future scenarios. Nevertheless, the scenarios generated are highly contingent upon the judgments and interpretations of the experts interviews and literature reviewed. This subjectivity is in the nature of conducting CIB analysis, which is unavoidable. Nevertheless, the limitation of these judgments are that the bias of the interviewees are present in the construction of the CIB matrix and therefore the scenarios. Moreover, judgments are translated by the author. These translations of these judgments into quantitative standardized values within the CIB matrix are argued for in this thesis. Nevertheless, they may not truly represent the exact relationship between descriptors. Eliciting more information from a more diverse array of experts could help in better understanding these complex relationships and representing them in the CIB matrix. Moreover, there could be subjectivity with regard to the interpretation of heating initiatives in Geerdinkhof. More specifically, it can be argued that LT systems in combination with sufficient insulation (depending on the household) can be found just as comfortable as HT heating systems. The choice in the present research to only look at the source of heating and not the additional insulation required in certain cases, along with the interpretation that LT systems can sometimes be found less comfortable than HT systems, is a consequence of the bias from interview results.

In order to combat the questionable judgments, a sensitivity analysis is performed. However, another limitation is the fact that one can question many judgments made within a CIB matrix. The present CIB matrix judgments (phase 2) only made use of two interviewees. Furthermore, it can be argued that certain judgments made within the CIB matrix are weakly or indirectly correlated. Moreover, certain judgments could have been overseen and omitted, leading to a possible incompleteness of the represented relationship between factors. This is of course due to the interpretation of the answers given by experts. Again, this seems to be the subjective nature of conducting CIB analysis, and remains a limitation of the present research. Moreover, the sensitivity analyses are tested on the number of internally consistent scenarios generated. The present research does not dive deeper into what these scenarios mean for value change, and how they differ from the set of consistent scenarios from the baseline CIB matrix, mainly due to time constraints and heavy workload of clustering many scenarios. Another point is the rigorous mechanical procedure of generating scenarios inherent to CIB analysis, excluding certain scenarios that other experts may deem possible. This remains a questionable aspect of the present research and a limitation of CIB analysis in general. Lastly, the available time that experts have are limited. Each interview conducted was for about one hour. Considering the total of 9 descriptors in the CIB matrix and the large set of possible judgments, it is assumed that more time is needed in one interview to correctly make judgments. Moreover, these participants are not familiar with CIB as a methodology and need time to understand the goal of the present research.

8.2 Contributions of the present research

The present research has provided many contributions, both scientific and societal. These contributions are detailed below.

8.2.1 Scientific contributions

This thesis has contributed to the minimal existing research on scenario-based value change analysis, such as that of de Wildt et al. (2021). Moreover, integrating qualitative analysis (literature research, interviews) and more quantitative research (CIB matrix analysis) for value change analysis is argued to be very useful for scientific research of value change, as CIB allows for the inclusion of notions and relationships that are difficult to describe, such as the notion of values. Therefore, this thesis contributes to the discussion of methodologies that can be used for value change analysis.

This thesis also contributed to the CIB methodology in three ways. First, the present research provided a three step guideline in translating expert judgments (see Chapter 5). This guideline is not present in CIB literature, where it is common for authors to make interpretations of verbatim statements (Schweizer & Kriegler, 2012; Weimer-Jehle et al., 2020). Nevertheless, some rules for this translation can contribute to future research in the construction of CIB matrices. The second contribution of the present research is the steps provided for clustering of many scenarios (see Chapter 5). This, like translating judgments, is not found in CIB literature research. Instead, clustering scenarios is used in many other forms of research, which is proven to also be applicable in CIB analysis. Moreover, clustering scenarios was discussed with supervisors in order to best delineate storylines of value change resulting from many discovered (23) scenarios. It is unclear what the threshold is for analyzing scenarios one-by-one and when to begin constructing scenarios. Nevertheless, when the amount of scenarios increases, clustering is a useful method to extract information of scenarios that provide similar behaviors or consequences. Lastly, the inclusion of a succession analysis for a value-based scenario research is scientifically relevant. By taking into account which consistent scenarios are most commonly found from the entire array of possible scenarios in a CIB matrix, the likelihood of that particular value change scenario and its' implications for sustainable heating is scientifically interesting. As it is argued in the present research, CIB has very strict and mechanical rules to define "consistency" in scenario generation. The addition of a succession analysis only attributes to the black-box-like algorithm of consistency, by distinguishing scenarios generated in a numerical "weight". This thesis contributes to the understanding of value change scenarios by attempting to describe the meaning of value change within the context of CIB analysis, and in particular "consistency" through consistency checks and succession analysis. Of course, these aspects are contingent upon two things; the authors' definition of value change and the judgments interpreted for the CIB matrix. These are aspects that must always be reflected on in future CIB research.

8.2.2 Societal contributions

The present research also makes many societal contributions. Firstly, a contribution has been made to the municipality of Amsterdam, by giving ideas of directions possible given the many scenarios generated of citizen value change in Geerdinkhof. More specifically, recommendations have been provided on how to proceed given observing certain important factor developments and comparing these to results found in this research. Secondly, the approach or findings of the present research can contribute to other neighborhoods in the Netherlands that are still in early stages in the sustainable heating transition. As one of the interviewees mentioned, the socio-demographic (age, education) and household (such as year built) attributes of Geerdinkhof are similar to many other neighborhoods in the Netherlands (Infonu.nl, 2021). Moreover, it has been argued that the incorporation of citizen values in assessment of the heating transition is an important aspect to take into account. Therefore, using the same methodology of CIB can be a useful assessment tool for ex ante analysis of social acceptance in many neighborhoods in the Netherlands.

8.3 Directions for future research

Three directions are given for future research. These directions regard further research on the notion of observing trends before implementing a heating initiative, including other values or factors for CIB analysis and coping with subjectivity of interviewees in CIB analysis.

8.3.1 Observing future trends

Directions for future research can be provided based on the research conducted in this thesis. One interesting aspect that can be tested in future research is the applicability of CIB analysis for policy design. The present research attempted to construct scenarios and relate these to possible future developments with the possible future heating transition in Geerdinkhof. It was recommended to observe trends of current developments and compare them to the scenarios found in the present research in order to best decide upon the implementation of a heating design. These observations require cooperation and participation from citizens within the neighborhood. Considering that Geerdinkhof are in the early stages of this transition, combining CIB with a participatory analysis can provide interesting insights for policy-makers, especially with regard to the insights on developments within the neighborhood.

One methodology that provides this type of analysis is a Participatory Value Evaluation (PVE). PVE is an economic assessment model that includes citizens personal considerations of different projects, essentially asking them to reveal their preferences in the form of a survey-like form (Mouter, 2018). PVE provides information on these projects, how they distribute costs, benefits and responsibilities among stakeholders (Mouter et al., 2019). Interestingly not all projects can be chosen as preferred at once, explicitly asking citizens to make decisions.

PVE has many benefits to elicit citizen preference, by allowing them to step into the shoes of a policy maker and assess the options being considered, while being informed about the impacts (Mouter et al., 2021a; Mouter et al., 2021b). Furthermore, PVE has a low barrier to participation which allows for many citizens to easily participate and conduct the survey in 20 to 30 minutes in an online format regardless of time, location, jurisdictive boundaries or physical presence (Mouter et al., 2021a). Moreover, PVE raises awareness among citizens about decisions and implications for the energy transition (Mouter et al., 2021a), which is also needed in Geerdinkhof.

Mouter et al. (2021a) indicate that most Dutch homeowners wish to be engaged in the thermal energy transition. PVE allows for their needs to be integrated into the policy design. Moreover, design of PVE is optimized for measuring the social welfare effect of public policies (Mouter et al., 2021a). This can be done by eliciting information from participants on the weights they assign to different impacts of the considered options, allowing the analyst to identify people's sensitivity for impacts (Mouter et al., 2021a; Mouter et al., 2021b).

Related to the observations of trends recommended in this research, this methodology allows the analyst to not only elicit citizens opinions on technologies, but also their current views on the developments within the neighborhood. Think of factors mentioned in this thesis such as the overall neighborhood community relationship, or the willingness to make investment preferences. Compared to standard surveys or polls, PVE provides deeper insight into the extent to which people value on potential policy over another and how this value is influenced by (societal) effects (Mouter et al., 2021b). Moreover, analysts can determine the desirability of policy options with changes in these effects (Mouter et al., 2021b).

By including these societal factors associated with overall technical aspects of incorporating the three main initiatives considered for Geerdinkhof, the municipality can gain insight on how these factors are developing currently. A possibility for a combination of CIB and PVE would be to generate scenarios that illustrate how preferences may change over time and compare that to current preferences that citizens demonstrate with a PVE analysis. Citizens can then perhaps transmit new ideas, arguments, values or conditions that were not addressed before (Mouter et al., 2021b). This can perhaps provide interesting insights for policy-makers that have to make long-term decisions on sustainable projects.

8.3.2 Future CIB studies with more values and factors

Furthering the findings of this thesis with more time and resources could possibly provide interesting and differing interpretations of system elements for the heating transition. Interviewees suggested other factors or values that may influence the social acceptance in the long term, such as trust (between citizens and monopolistic DH firms) or the development of unknown technologies or alternative gases. However, given the limited number of interviews conducted, there could also be other unknown factors that can influence the CIB findings. Therefore, another interesting direction could be to use elicited information from interviewees, and perhaps citizens, to observe common factors indicating social acceptance. This would still require translating qualitative statements into the CIB matrix, which is an inherent aspect of CIB analysis. The CIB matrix could then be considerably larger, containing more relationships. There must be a balance between implementing descriptors (and their states) in order to better understand system relationships and the complexity that results from this analysis (Schweizer, 2020). Therefore, it is suggested to limit the number of values and factors chosen, and carefully assess what is found to be most influential for social acceptance. This could be done with the compliment of observational techniques mentioned in the previous subsection.

Another interesting future study could pertain to the chosen approach for value change. More specifically, the present research regarded value change as the change of prioritization of individual values, and completely neglected certain collective values. However, it can be argued that collective values (such as *privacy, justice or trust*) are just as influential in the role of social acceptance for energy transitions (Milchram et al., 2018). Not only are individual values or collective values subject to change over time, but the way people think values should be translated into norms and design requirements are also likely to change over time, especially for the heating transition (Mouter et al., 2018). For example, *fairness* is found to be an important value among homeowners in Amsterdam (Collewet et al., 2021). Citizens may translate this value of fairness into design requirements of implementing new technologies in more affluent neighborhoods in order to test them for irregularities or hindrances that they may present, before implementing it to less affluent neighborhoods. Therefore, a future CIB study could be conducted where the *operationalization* of value change in sustainable heating design is the focus, as opposed to the *prioritization* of value change for social acceptance.

8.3.4 Coping with limited number of interviewees and their subjectivity

The CIB analysis is sensitive to the judgments within the CIB matrix. These judgments have an impact on what scenarios are deemed most consistent due to the mechanical nature of CIB calculations, explained in this thesis. Moreover, the present research only conducted five interviews for the entire CIB analysis due to time constraints. However, CIB literature does not specify requirements for the number of experts to be interviewed in order to conduct a CIB analysis. Moreover, the heterogeneity of expert answers are also influential to judgments and the subsequent findings of such an analysis. It is suggested that future research attempt to cope with the inherent subjectivity by expanding the number of interviewees and their positions within the system. This would in turn require more extensive stakeholder analysis, in order to preemptively assess their stance on the heating transition. Think of experts within the DH companies, experts that install heat pumps, or citizens from other neighborhoods with cooperatives. This would ensure more heterogeneity in judgments eventually made within a CIB analysis. Furthermore, expert reviews of CIB scenarios is highly recommended in future research. Even though CIB literature argues that the likelihood of the eventual generated scenarios occurring are higher than what you or I would deem a likely scenario, it would still be suggested to have expert reviews of generated scenarios, especially those that contain higher combinatorial weights. Again, this would require sufficient time and resources, and willing cooperation from a diverse arrange of experts.

8.4 Reflection on the process

The process of conducting this thesis proved to be quite challenging. The initial idea of this research was to conduct a PVE in neighborhood in Amsterdam South East. This proved to be very challenging, as there needs to be sufficient interest to conduct such a survey. Around halfway through the thesis progress, I decided that this survey was not likely going to happen. Perhaps it would have had more interest if the current Covid-19 pandemic did not intrude on face-to-face and in-person meetings to create more interest in such a survey. Numerous discussions with supervisors resulted in defining a scope and research topic that better suited the circumstances. By changing topics completely, I felt like I had a shorter time span to conduct my thesis. This also led to less interviews being possible, considering the short time span and all the effort that is required to learn a new methodology in CIB, let alone analyze a CIB matrix and the scenarios. Changing to a CIB analysis allowed me to take more control of my research and not depend on responses and interest for a cooperative research such as PVE, as I was allowed to plan my interviews and conduct research on my own time. I found it quite challenging to learn a new methodology and apply the necessary steps to conduct scenario analysis. However, the entire process proved to be a learning experience for which I am thankful.

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Appendix

Appendix A: Interview design

- Follow regulations according to TU Delft Ethics committee
- Send letter of consent and explain what information would be needed

Phase 1 interview design

- Briefly explain CIB as a scenario generating tool
- Define the two main values studied in this report; Comfort and Affordability
  - Affordability: *Energy consumers pay costs for the system with a reasonable amount of their budget*
  - Comfort: *thermal comfort & comfort in transition (noise pollution, installation space etc.)*
- For each value ask the following questions
  - For this value, can you identify a set of factors that might affect how the importance of these values might change over time?
  - What in your opinion would be an appropriate division in states for each factor? (e.g. "low income, medium income, high income")

Phase 2 interview design

- Briefly explain CIB as a scenario generating tool based on factors
- Define the two main values studied in this report; Comfort and Affordability
  - Affordability: *Energy consumers pay costs for the system with a reasonable amount of their budget*
  - Comfort: *thermal comfort & comfort in transition (noise pollution, installation space etc.)*
- Explain that factors influence each other and share the list of factors/descriptors and descriptor states that I have gathered
- Explain that CIB judgments can be either promoting or restricting.
    - **Example**: When the level of 'disposable Income' is 'Low', it can '**strongly promote'** the "Importance of 'Affordability' (Sun, 2020).
- Subsequently ask the following questions
  - From what you know about the citizens of Geerdinkhof, what do you expect the relationship to be and grow into hypothetically?
  - Start with the relationship between (for example)
  - Environmental concern and importance of comfort?
    - Do you find it to be more promoting or restricting?

Appendix B: phase 1 interviews summary

Group meeting between energy commission members in Geerdinhof

The housing in Geerdinkhof is either in rows or stand alone, and were mostly built in the 70s and 80s. As of right now, the heating transition is in a very early stage within Geerdinkhof, with three main options being discussed. These options are

1) A High Temperature (HT) commercial district heating network owned and operated by one central external company, most likely from Vattenfal. This is also mentioned in the Transitievisie Warmte Amsterdam. This option is henceforth referred to as the "HT District heating network" option
2) Low Temperature (LT) options, which are owned and operated by the citizens in Geerdinkhof. These options entail that either the neighborhood as a whole starts a collective cooperation that oversees a collective heating system (based on aquathermal heatpumps or heat-cold storage units) or parts of the neighborhood that are in rows of households work together to install semi-collective heat pumps. These options are henceforth referred to as "collectively-owned options"
3) Every individual household is responsible for own heating provision

As of right now, the Transitievisie Warmte states that Geerdinkhof falls within the 'Stadswarmte' category in the municipalities plans for heating transition. This implies that if the majority of inhabitants do not express any interest or provide any plans for heating transitions before 2030, the Municipality will take the decision into their own hands and work with Vattenfall to implement a district heating network. Citizens do not view this as the most popular option, as Vattenfall is seen as a monopolistic entity with the rights to change heating prices if needed. However, citizens as of right now are not pushing or expressing interest in taking matters into their own hands. Looking at the long-term, the district heating network is not the most affordable option, as the source of this network is still being developed. The forecasted tariffs for this network have a wide margin and can be adjusted during the networks lifetime. These costs associated with these adjustments are then pushed onto the consumer. However, the district heating options is seen as the "least headache" option, as the installation is done for you, and the level of thermal comfort is comparable to the current natural gas systems with High Temperature radiant heating.

Interview with Senior Advisor Energy and Circular development at the City of Amsterdam

Individual options are viewed as being cheaper compared to district heating, especially in the long-term. These options can be investing in isolation techniques such as insolation of windows and floors, or installing solar panels that can provide all-electric heating options. Another option is installing individual heating pump, which can be used for cooling as well as heating. Cooling is an aspect that district heating does not provide. However, this form of heating is Low Temperature and non-radiant, which can be seen as a drawback for citizens that are used to a certain level of thermal comfort.

There is an important underlying factor when it comes to citizens making their decision. How do they view the long-term effects of the environment. The environmental concern and deepening their knowledge and involvement in sustainable solutions.

Geerdinhof households are mostly low-rise, owner-occupied homes that consist of many older citizens that are close to retirement or retired. The citizens are considerably more financially stable compared to other regions in Amsterdam South East. Which leads to another factor that is important in the transition, the willingness to invest in small or large investments. If a home owner does not see the need for large investments in all-electric housing, heating pumps or organizing a cooperation, then this home owner may decide on smaller investments such as isolating their windows. It might not be for environmental concerns, but more for thermal comfort within their home.

Many neighborhood in the Netherlands are similar in terms of household build and inhabitants structure, so this research could be replicable to other situations.

Interview with Program manager of natural gas free developments at !WOON

Climate change is a factor to consider in terms of comfort. It is expected that the climate will be volatile in the long-term. Heating pumps can be a sustainable solution to combat the volatility of hotter summers and colder winters. Noise pollution is minimal, although it depends on the individual on the extent of their perceived disturbance. Whatever solution is chosen needs to abide by the Warmtewet, which states that each household must have the capability of at least 20 degrees Celsius heating. The Warmtewet also states that no more than one heating network can be implemented within a neighborhood. For example, if the community wishes to implement a collective heat cold storage system for every household, this must be self-organized and presented to the municipality before 2030. If this agreement is not reached, the district heating network will be implemented and no other collective network can be implemented after this.

There is research being done for the source of district heating, such as drilling tests for geothermal energy or research into biomass. However, as of this moment these options need a lot more testing which can cause the eventual tariffs of district heating to be much higher than current natural gas tariffs. These higher costs are eventually pushed to the end consumers in their monthly tariffs. On the other hand, the source for individual or collective heating pumps in Geerdinkhof will be based on either air or the water surrounding the neighborhood.

One of the major issues with the district heating network is that even if around 70% of households are connected to this network, it still is not a viable business case for Vattenfall. The Warmtewet and Transitievisie warmte indicates that every household within a neighborhood is to be connected to the district heating network, even if one particular household is self-sufficient in heating provision (all-electric for example).

One more aspect of relevance is the community relationship. In case of (semi-) collective options, certain households may choose bare higher upfront investment costs and trust that their neighbor will bare higher monthly compensation in return.

Price ranges for heating pumps;

- Warmtepomp; maandelijkse kosten?
    - Luchtwarmtepomp en 16 zonnepanelen op een gemiddeld dak van een huis in geerdinkhof; helft van de kosten stadswarmte (inclusief afschrijving)
- Kosten voor appliances
    - Warmtepomp heeft **weinig maintenance. Gaat 17 jaar mee ongeveer.**
    - **De** maandelijkse kosten is het besparen vaan een nieuwe over 17 jaar.
    - Vattenfal rekent per woning; een basis aansluitkost van 20.000 euro per huis, met 5000 euro subsidie per huis die huishoudens zelf moeten betalen. (2030 situatie zonder beslissing).
- Warmtepomp kosten?
    - Met 15000 euro kan 1-5 warmtepompen kopen
    - Voor 1 woning, heb je een warmtepomp voor 1700 euro (excl installatie). Voor 3000-4000 euro heb je als huishouden in Geerdinkhof heb je een geinstaleerde warmtepomp
    - Voor een collectief; je kunt de prijs besparen met 35% ~

Appendix C: phase 2 interviews summary

Interview with Geerdinkhof citizen, director of Het Groene Brein.

Het Groene Brein is een netwerk van 160 wetenschappers die verbinden aan concrete vraagstukken in praktijk, veel met circulaire economie en burger participatie.

Something that is worth mentioning is “the business model”. Citizens have distrust with big companies such as Vattenfall, as their monopolistic characteristic makes them eligible to adjust tariffs if needed. Citizens prefer stability in their monthly costs.

-Environmental concern and importance of comfort

 - o I can see if there’s a high level of environmental concern developing in future, then people might be willing to be less and less comfortable.
 - o Als je heel veel om het milieu geeft om het opwarming tegen te gaan, dan ben je meer bereid om comfort tegen te gaan. 1 op 1 relatie, als je heel milieu bewust bent, dan ben je bereid om comfort in te leveren (trade-off)
 - o Enquete gedaan in Geerdinkhof; bewoners zijn niet zo zeer geinteresseerd in milieu bewust zijn, het gaat meer om dat het comfortabel is en betaalbaar (200 van de 600 bewoners)
- Comfort and Betaalbaarheid are leidend in de transitie
- Convenient gap
  - o Als je een nieuwe meubel koop, heel makkelijk
  - o Als je tweede hands koopt, moeilijker maar beter voor milieu maar zit een convinient gap
  - o Ook bij warmte; heb ik systeem met HT of met LT, dan wordt je comfort lager
  - o Ik zie de mensen in de wijk niet toe bereid

-Importance of Comfort and appliance prices

- Als je naar een warmtenet kijk; dan de bewoners betalen 10.000 upfront om aansluiting te maken, en betaal je daarnaast onderhouds kosten
- Nergens 0 maintenance kosten
- Service contracts; maintenance. Quite easy. Laag
- Zit met vertrouwen; je wil langdurig weten hoe de prijzen zijn.
  - o Stel dat vattenfal de prijs over 5 jaar verandert voor maintenance kost, wantrouwen zit dan dat deze niet vast is
- Als het in de wijk is ben je zelf in charge dus meer comfortable

-Community bond and importance of comfort

- Uit enquete zei iedereen dat ze graag collectief willen inkopen (niet gevraagd of ze cooperatie willen doen) maar wel dat ze bereid collectief te doen. Veel vertrouwen
- Mensen zijn bereid om iets meer voor te schieten voor hun buren
- Ik denk dat het met comfort vrij laag is. Als je veel vertrouwen hebt dan heb je dan iets meer comfort omdat je het doet met elkaar
- Als mensen samen iets willen doen vinden mensen het wel meer comfortabel dan met een externe partij. Als je iets met elkaar doet dan ben je bereied om iets meer comofrt in te leveren, maar niet ten koste van warmte of koeling tegen te gaan

-environmental concern and importance of affordability?

- Directe relatie. In deze wijk vrij beperkt plus
- Mensen zijn best wel bereid om investeringen te doen als ze meer milieu bewustzijn
- Mensen hebben best wat disposable income, tot een bepaalde grens natuurlijk
- In het algemeen, hoe hoger environmental concern, hoe hoger de bereidheid is om te investeren
- Maar alleen als er wel een terugverdien model aan zit
    - Denk aan isoleren voor 2000 euro waar je warmte bespaart vs. 20.000 euro investeren en niet echt een zicht krijg van terug verdienen

-climate change importance of affordability?

- De zomers worden veel warmer, hittegolfen
- Iedereen is bereid dan om een airco te kopen maar is wel ingewikkeld
- Misschien is muren beter isoleren om koel te blijven, dan neemt je draagvlak voor investering toe
- Dan zijn mensen meer bereid om te betalen aangezien de warmere zomers

-community bond and importance of affordability?

- De relatie is niet echt, misschien beperkt
- Als we met elkaar doen, en het kost 10 euro per maand meer, dan kunnen we het wel doen
- Gezamenlijke inkoop met korting voor isoleren bijvoorbeeld, is korting veel belangrijker dan het samen doen

-Disposable income on heating prices

- Allemaal koophuizen in Geerdinkhof, huizenbezitters. Het is dan gemiddeld dat je iets meer disposable income, hoger dan rest van Zuid-Oost
- New tenants zullen ook meestal wat meer disposable income hebben
- Ze letten heel erg op solvabiliteit. Mijn hypotheek zit 30 jaar vast hoe veel ik moet betalen. Ik ben bereid dat ik dat kan betalen voor een vast bedrag
- Als je meer disposable income hebt dan ben je meer bereid te betalen voor solvabilitiet
- **Fluctuating district heating prices**
- Fluctueren zit dan in wantrouwen. Betrouwbaar en vast is fijner dan fluctueren

- Factor G
    - Warmtenet high upfront and maintenance kosten

-Disposable income and appliance prices

- Als je veel geld te besteden hebt dan is high upfront kosts niet erg

Interview with member of Stichting CoForce

- Comfort en heating prices
    - Vattenfall heft de mogelijkheid om gewone aanlsuiting te hebben en comfort aanlsluiting
    - Comfort optie is duurder
    - Heb ook ooit voor die keuze gestaan
    - Niet echt een relatie tussen deze twee
    - Er is wel een limiet aan hoeveel je kunt vragen voor de comfort die je voor krijgt
    - Leveringzekerheid is niet echt het probleem
    - Vertrouwen is meer een probleem. Aandeelhouders van bedrijf willen graag dat het goed doet.
- Als fluctuerende prijzen gebeurt, hoe zit dat met thermische comfort of betaalbaarheid
    - DH is monopolie. Ik als burger kan niets anders, schaat je vertrouwen in
    - Met elektriciteitsleverancier kan je makkelijker weg dan DH netwerk/warmtelevering
    - Keuze kunnen maken met elektriciteit
- Disposable income en environmental concern
    - Als burgers meer milieu vriendlijk zijn, is het wel voorstellend dat ze meer kunnen uitgeven
    - Het is wel in gradaties. Sommige zijn koplopers, en je hebt ook mensen die mee willen doen maar geen deuk in portomonee.
    - Zit er wel iets in. De grootste groep zijn de mensen die mee willen doen als het allemaal duidelijker is, meer affordable, niet te veel hassle.
- Hassle is dus ook living comfort. Hoe zit dat met klimaat verandering?
    - Grootste groep mensen denken ik zet de kachel langer aan en niet zo zeer bereid om comfort in te ruilen
    - Zeker mensen zijn die moeite willen doen voor milieu, maar over het algemeen niet extra moeite.
    - Als ik extra moeite moet doen om comfort te krijgen, en het milieu te besparen, dan denk ik dat milieu verliest
- Er kunnen ook mensen over tijd verhuizen, met andere disposable inkomen. Aangezien de langdurige initatief van warmte opties
    - Valt mee. Als je hier wil komen wonen, moet je wel affluent al zijn om dit te betalen
    - Kan best dat je jonger bent in vergelijking met je buren, maar ze zullen geen starters zijn
    - Hele wijk is heel duur om een huis te kopen
- disposable income en Importance of comfort
    - 70 plussers zullen waarschijnlijk niet geinteresseerd in investeren in langdurig warmtenet opties, ik zet me kachel wat harder
    - Maar als jongere mensen verhuizen in de toekomst, kan ik me voorstelen dat er interesse is in duurzame comfort in woning krijgen
    - Je moet iets maken wat niet alleen voor de huidig bewoners in kunnen haken, maar ook de toekomstige bewoners
- Heating prices and disposable income

  - Hoge disposable income zal niet veel invloed hebben op de hoge DH prijzen, maar in gradaties weer
  - DH is best kostbaar, worden verschoven aan bewoners
  - Warmte van warmtenet is gekoppeld aan gasprijs, die gaat omhoog, dus die wordt steeds duurder
  - Dan blijft de vraag, waar zit de voordeel van consument?
    - Comfort en HT warmte
  - Met warmtenet moet ik eerst beginnen met tussen de 10 en 15 duizend euro uitgeven, en dan komen er prijzen die initieel hetzelfde zijn als gas, en misschien overal kunnen gaan
  - Dat is ook de kracht van collectieve opties, want je moet ook relatief veel uitgeven maar long term krijg je wel besparingen want de warmte die je inkoopt is kostprijs (jij als collectief hoeft niet verdienen, alleen maintenance)
- Hoe zou een wijk breede cooperatief eruitzien
  - Veel technieken die in development zijn.
- Upfront costs and disposable income
  - Uitgeven voor veel Geerinkhoffers, zullen ze waarschijnlijk afvragen wat de nut daarvan is. Waarom zo veel uitgeven als ik in de korte termijn de pressure niet voelt
  - Dus ik denk lager investment preferences
- Community bond and climate change or environmental concern?
  - Er is wel een relatie. Higher community bond zou environmental concern creeren.
  - Contact hebben met elkaar, vanuit dat contact wordt de concern meer met elkaar uitgesproken en meer tot actie komt
  - Bijna alle bewoners benaderd in een enquete (600 woningen)
    - 50 woningen hebben iets van isolatie gedaan en in beweging
    - Dat maakt dat andere ook in beweging komen, doordat je je buurman ziet
  - Zo komt er dan een gesprek op gang over verduurzaming
  - Het gebeurt niet zo vaak maar gebeurt wel eens en kan groeien in de tijd
- Comfort and affordability
  - Niet altijd zo om allebei te krijgen. Alle opties hebben deze trade-off.
  - De vraag is, Hoeveel meer wil je uitgeven wetend dat je milieu minder belast? Lastig.
  - Ik denk dat het wel best beperkt is.
  - Mensen zijn die bijvoorbeeld 20 graden voldoende vinden.
  - Affordability is niet sterk beinvloed, het geld hebben we wel.

Appendix D: Rationale for CIB judgments

The base case judgments were introduced in Chapter 5, and are presented again in Figure 10. For each row of descriptors, the judgment selection will be briefly discussed.

	A			B			C			D			E		F		G		H			I	
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	F1	F2	G1	G2	H1	H2	H3	I1	I2
A. Importance of 'Comfort'																							
A1. Not at all important				-1	-1	2	2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2. Faily important				0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	0	0	0
A3. Very important				1	1	-2	-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. Importance of 'Affordability'																							
B1. Not at all important	-2	1	1				-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2. Fairly important	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B3. Very important	1	1	-2				2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. Development of investment preferences																							
C1. No preferences	1	0	-1	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2. Small investment preferences	0	-1	1	0	0	0				0	0	0	0	0	0	0	-1	1	0	0	0	0	0
C3. Large investment preferences	-2	1	1	0	0	0				0	0	0	0	0	0	0	1	-1	0	0	0	0	0
D. Average disposable income																							
D1. Similar disposable income	0	0	0	0	1	-1	0	1	-1				0	0	0	0	0	0	0	0	0	0	0
D2. Lower disposable income	0	0	0	-1	0	1	1	1	-2				1	-1	0	0	0	0	0	0	0	-1	1
D3. Higher disposable income	-1	-1	2	1	1	-2	-1	-1	2				-1	1	0	0	0	0	0	0	0	-1	1
E. Development of environmental concern																							
E1. No level of concern	-1	0	1	0	0	0	1	1	-2	0	0	0			0	0	0	0	0	0	0	0	0
E2. Higher level of concern	2	0	-2	1	1	-2	-1	-1	2	0	1	-1			0	0	0	0	0	0	0	0	0
F. Development of heating prices																							
F1. Stable electricity prices	-2	1	1	1	-1	0	-2	1	1	0	0	0	0	0			1	-1	1	1	-2	0	0
F2. Fluctuating district heating prices	0	0	0	1	1	-2	0	1	-1	1	-2	1	-1	1			1	-1	0	0	0	0	0
G. Development of appliance prices																							
G1. Low maintenance costs but high upfront costs	0	0	0	2	0	-2	0	0	0	1	-2	1	0	0	0	0			0	0	0	0	0
G2. Low upfront costs and low maintenance costs	0	0	0	-1	-1	2	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0
H. Development of climate change and temperatures																							
H1. Softer winters and hotter summers	-1	1	0	1	-1	0	-2	1	1	0	0	0	0	0	0	0	0	0				0	0
H2. Extreme winters and intense storms during summers	-3	1	2	0	0	0	-3	1	2	0	0	0	-2	2	0	0	0	0				0	0
H3. Negligible rise in temperature	2	-1	-1	0	0	0	2	-1	-1	0	0	0	1	-1	0	0	0	0				0	0
I. Development of community relationship																							
I1. Higher level of community bond	-1	1	0	0	0	0	-1	0	1	0	0	0	-1	1	0	0	0	0	0	0	0		
I2. Lower level of community bond	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0		

Figure 10: Baseline CIB matrix

Importance of 'Comfort'

If the importance of comfort were to develop into not being important, this would have a restricting effect on affordability being fairly important, hence the -1. This means that even though comfort might not be of importance, affordability still might have some level of importance even in the future, so -1 for not at all important as well. On the other hand, if comfort were to develop into being very important, this was interpreted as having a restricting effect on affordability being very important. It was said that one cannot really totally value comfort and have it be very affordable, hence the moderate restricting of -2.

Again, if comfort were to develop to being not at all important, then there might not be a willingness to take on large investments for sustainable heating. On the other hand, if comfort for their household is deemed very important, then larger or smaller investment preferences may coincide with this development.

Lastly, it was said that low maintenance costs slightly effect the living comfort of citizens, as they do not have to exert too much effort in their appliances. A slight promoting effect of +1 is added to descriptor G.

Importance of 'Affordability'

Considering the trade-off that must be made between comfort and affordability, if affordability were to develop into being very important in the heating transition, then comfort cannot coincide completely with this, hence the restricting effect that these developments have.

If affordability were to develop to very important, then larger investment preferences may be restricted as well, hence the -2. On the other hand, citizens with no importance for affordability may still feel no need to solely focus on large investments, and can invest in smaller investments if they want. Hence the +1 for both large and small investments.

Development of investment preferences

Larger investment preferences can positively influence the importance of thermal comfort in home, for both fairly and very important (+1). Smaller preferences still lead to a slight promoting effect on the importance of comfort. On the other hand, if citizens display no interest, it can also weakly restrict how important they find comfort.

Larger investment preferences have a promoting effect on taking high upfront costs, hence the +1 in the relationship with descriptor G1.

Average disposable income

Higher disposable income has a promoting effect to the importance of comfort. For example if one were able to afford more high-end manners of improving thermal insulation within the household. Disposable income similar or lower to the current standard does not necessarily have an effect on how important comfort is found.

Higher disposable income has a restricting effect on the importance of affordability. Considering that current citizens are affluent in Geeridnkhof, the same restricting effect is given to similar levels of disposable income development.

Similar and lower disposable income has a restricting effect on larger investment preferences. Currently, not every citizen is willing to take on larger investments for transitions, hence a -1. Lower disposable income would make this case slightly worse, so -2. On the other hand, a promoting effect is assumed for growth of average disposable income on appetite for larger investments.

It was argued that only if the disposable income of the average household were to increase (or decrease), would this coincide with an increase (decrease) in their environmental concern. This is further elaborated in a study conducted by Bruderer Enzler & Diekmann (2019), that suggests this case. The same study suggests that pro-environmental behavior, and thus community relationships, are also correlated with disposable income. However, this was relationship was found to be weak by interviewees, hence only the use of 1’s.

Development of environmental concern

If citizens express no environmental concern, comfort is still important to a certain extent. However, if the environmental concern grows higher, then in general trade-offs will have to be made for comfort. For example in case of switching from higher radiant heat provision such as natural gas to a lower radiant heat from a heat pump. The same conclusions were drawn for the effect that higher environmental concerns have on the importance of affordability.

Higher environmental concerns were also found to be directly related to the growth of willingness to take on larger investments, hence the +2 on descriptor C. This coincides with the opposite being true for no development of environmental concern. Higher concerns, with higher investment preferences, were also found to likely lead to more spending, and thus a restricting effect on the higher disposable income. Again this was weakly founded, hence a -1.

Development of heating prices

Stability in pricing has a promoting effect to comfort, whereas fluctuating prices have a slightly promoting effect to affordability. Only slight as the neighborhood is considered financially stable enough to handle prices. Stable electricity prices would slightly promote larger and smaller investment preferences for changes within the household, while fluctuating district heating price may only promote smaller investment preferences. Fluctuating district heating prices promotes developing citizens to gain a higher level of environmental concern. Both all-electric and district heating networks promote high upfront costs, hence a slight +1 promoting effect for descriptor G. Lastly, electricity prices have a slight promoting effect to the two more drastic developments in climate change, as opposed to reliance on district heating network.

Development of appliance prices

High upfront costs have a restricting effect on the development of high importance for affordability, and the opposite for low upfront costs. High upfront costs also have a moderately restricting effect on taking smaller investments, hence a -2 for descriptor D2.

Development of climate change and temperatures

Affordability; was met with skepticism from the interviewees, as it can be difficult to predict how climate change affects the importance of affordability. It was suggested for the baseline CIB that affordability is not really important in cases of hotter summers, as citizens are already showing signs of willing to invest in whatever it takes to combat this form of climate change.

Development of community relationship

A higher level of community bond can promote the appetite for larger investments to be made, and vice versa. A higher level of community bond may also slightly raise awareness for environmental concerns (Bruderer Enzler & Diekmann, 2019).

Appendix E: Sensitivity analysis

The base case judgments were introduced in Chapter 5, and are presented again in Figure 11.

	A			B			C			D			E		F		G		H			I	
	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	D3	E1	E2	F1	F2	G1	G2	H1	H2	H3	I1	I2
A. Importance of 'Comfort'																							
A1. Not at all important				-1	-1	2	2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A2. Faily important				0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0	0	0	0	0
A3. Very important				1	1	-2	-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B. Importance of 'Affordability'																							
B1. Not at all important	-2	1	1				-2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B2. Fairly important	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B3. Very important	1	1	-2				2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C. Development of investment preferences																							
C1. No preferences	1	0	-1	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0	0
C2. Small investment preferences	0	-1	1	0	0	0				0	0	0	0	0	0	0	-1	1	0	0	0	0	0
C3. Large investment preferences	-2	1	1	0	0	0				0	0	0	0	0	0	0	1	-1	0	0	0	0	0
D. Average disposable income																							
D1. Similar disposable income	0	0	0	0	1	-1	0	1	-1				0	0	0	0	0	0	0	0	0	0	0
D2. Lower disposable income	0	0	0	-1	0	1	1	1	-2				1	-1	0	0	0	0	0	0	0	-1	1
D3. Higher disposable income	-1	-1	2	1	1	-2	-1	-1	2				-1	1	0	0	0	0	0	0	0	-1	1
E. Development of environmental concern																							
E1. No level of concern	-1	0	1	0	0	0	1	1	-2	0	0	0			0	0	0	0	0	0	0	0	0
E2. Higher level of concern	2	0	-2	1	1	-2	-1	-1	2	0	1	-1			0	0	0	0	0	0	0	0	0
F. Development of heating prices																							
F1. Stable electricity prices	-2	1	1	1	-1	0	-2	1	1	0	0	0	0	0			1	-1	1	1	-2	0	0
F2. Fluctuating district heating prices	0	0	0	1	1	-2	0	1	-1	1	-2	1	-1	1			1	-1	0	0	0	0	0
G. Development of appliance prices																							
G1. Low maintenance costs but high upfront costs	0	0	0	2	0	-2	0	0	0	1	-2	1	0	0	0	0			0	0	0	0	0
G2. Low upfront costs and low maintenance costs	0	0	0	-1	-1	2	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0
H. Development of climate change and temperatures																							
H1. Softer winters and hotter summers	-1	1	0	1	-1	0	-2	1	1	0	0	0	0	0	0	0	0	0				0	0
H2. Extreme winters and intense storms during summers	-3	1	2	0	0	0	-3	1	2	0	0	0	-2	2	0	0	0	0				0	0
H3. Negligible rise in temperature	2	-1	-1	0	0	0	2	-1	-1	0	0	0	1	-1	0	0	0	0				0	0
I. Development of community relationship																							
I1. Higher level of community bond	-1	1	0	0	0	0	-1	0	1	0	0	0	-1	1	0	0	0	0	0	0	0		
I2. Lower level of community bond	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0		

Figure 11: Baseline CIB matrix

Impact of disposable income on the importance of comfort

The rationale in the baseline CIB matrix for this relationship is that only in case of higher disposable income does this have a promoting effect to the importance of comfort. For example if one were able to afford more high-end manners of improving thermal insulation within the household. Disposable income similar or lower to the current standard does not necessarily have an effect on how important comfort is found. The baseline descriptor relationship is given in Table 11.

Table 18: Baseline impact of disposable income on importance of comfort

		Importance of comfort		
		Not at all important	Fairly important	Very important
Disposable income	Similar	0	0	0
	Lower	0	0	0

	Higher	-1	-1	2

It could be argued that even a similar disposable income, considering how affluent most citizens are, is enough to promote comfort being important. It has been noticed by the interviewees that most citizens currently invest in different forms of insulation as their priority is thermal comfort within their household. Furthermore, lower disposable income would perhaps only further the importance of comfort, considering the trade-offs that citizens would have to make in that case. These interpretations of possible judgments are tested in a sensitivity analysis, illustrated in Table 12.

Table 19: SA impact of disposable income on importance of comfort

		Importance of comfort		
		Not at all important	Fairly important	Very important
Disposable income	Similar	-2	1	1
	Lower	-1	1	0
	Higher	-1	-1	2

This change results in 23 consistent scenarios.

Impact of climate change on the importance of affordability

This relationship was met with skepticism from the interviewees, as it can be difficult to predict how climate change affects the importance of affordability. It was suggested for the baseline CIB that affordability is not really important in cases of hotter summers, as citizens are already showing signs of willing to invest in whatever it takes to combat this form of climate change. The baseline relationship is given in Table 13.

Table 20: Baseline impact of climate change on importance of affordability

		Importance of affordability		
		Not at all important	Fairly important	Very important
Climate change	Softer winters	1	-1	0
	Extreme winters	0	0	0
	Negligible	0	0	0

However, it was also suggested that extreme winters could also have the same effect, to a greater extent. If it is increasingly cold in the coming years during winter, then citizens would have to take necessary steps to combat this. Making it affordable could be seen as less relevant in those cases. Therefore, the following adjustment is made to this relationship, illustrated in Table 14.

Table 21: SA impact of climate change on importance of affordability

		Importance of affordability		
		Not at all important	Fairly important	Very important
Climate change	Softer winters	1	-1	0
	Extreme winters	2	1	-3
	Negligible	0	0	0

This change results in 23 consistent scenarios.

Impact of environmental concern on the importance of comfort

The rationale for this relationship is that if citizens express no environmental concern, comfort is still important to a certain extent. However, if the environmental concern grows higher, then in general trade-offs will have to be made for comfort. For example in case of switching from higher radiant heat provision such as natural gas to a lower radiant heat from a heat pump. This relationship is given in Table 15.

Table 22: Baseline impact of environmental concern on importance of comfort

		Importance of comfort		
		Not at all important	Fairly important	Very important
Environmental concern				
	No concern	-1	0	1
	Higher	2	0	-2

It was argued however that even if a trade-off has to be made, most citizens in Geerdinkhof have expressed an unwillingness to completely give up a certain level of comfort. Therefore a higher environmental concern could still mean that comfort is at least fairly important. These changes in the relationship are given in Table 16.

Table 23: SA impact of environmental concern on importance of comfort

		Importance of comfort		
		Not at all important	Fairly important	Very important
Environmental concern				
	No concern	-2	1	1
	Higher	1	1	-2

This change results in 22 consistent scenarios.

Appendix F: All scenarios and their weights

This appendix presents all 23 scenarios generated from the Baseline CIB matrix, and the combinatorial weights calculated. These scenarios are ordered in descending order from highest weigh to lowest. Weights are calculated based on the selections within the ScenarioWizard Tool to filter the "attractor weights" under *Options - Evaluation Options.* **Attractor weights** are the weight of a consistent scenario that indicates the "probability" (loosely used) that a randomly chosen initial scenario will be transformed into this scenario by the CIB succession procedure.

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Scenario No. 1

Weight : 711

Consistency value : 0 Total impact score: 13

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences : C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 2

Weight : 548

Consistency value : 0 Total impact score: 17

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship: I2. Lower level of community bond

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Scenario No. 3

Weight : 540

Consistency value : 0 Total impact score: 9

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 4

Weight : 466

Consistency value : 0 Total impact score: 11

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B2. Fairly important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship: I2. Lower level of community bond

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Scenario No. 5

Weight : 324

Consistency value : 0 Total impact score: 11

A. Importance of 'Comfort' : A1. Not at all important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C1. No preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship: I2. Lower level of community bond

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Scenario No. 6

Weight : 304

Consistency value : 0 Total impact score: 15

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship: I2. Lower level of community bond

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Scenario No. 7

Weight : 155

Consistency value : 0 Total impact score: 13

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B3. Very important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D2. Lower disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 8

Weight : 142

Consistency value : 0 Total impact score: 9

A. Importance of 'Comfort' : A1. Not at all important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C1. No preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 9

Weight : 108

Consistency value : 0 Total impact score: 19

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship : I1. Higher level of community bond

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Scenario No. 10

Weight : 102

Consistency value : 0

Total impact score: 8

A. Importance of 'Comfort' : A1. Not at all important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship: I1. Higher level of community bond

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Scenario No. 11

Weight : 100

Consistency value : 0 Total impact score: 11

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern : E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship: I1. Higher level of community bond

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Scenario No. 12

Weight : 74

Consistency value : 0 Total impact score: 16

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 13

Weight : 72

Consistency value : 0 Total impact score: 17

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 14

Weight : 43

Consistency value : 0 Total impact score: 12

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 15

Weight : 42

Consistency value : 0 Total impact score: 21

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship : I1. Higher level of community bond

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Scenario No. 16

Weight : 41

Consistency value : 0 Total impact score: 19

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I1. Higher level of community bond

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Scenario No. 17

Weight : 31

Consistency value : 0 Total impact score: 7

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B2. Fairly important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 18

Weight : 18

Consistency value : 0 Total impact score: 10

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B3. Very important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D2. Lower disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship: I2. Lower level of community bond

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Scenario No. 19

Weight : 8

Consistency value : 0 Total impact score: 17

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I1. Higher level of community bond

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Scenario No. 20

Weight : 7

Consistency value : 0 Total impact score: 9

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B3. Very important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 21

Weight : 6

Consistency value : 0 Total impact score: 14

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D2. Lower disposable income

E. Development of environmental concern: E1. No level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H1. Softer winters and hotter summers

I. Development of community relationship : I2. Lower level of community bond

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Scenario No. 22

Weight : 6

Consistency value : 0 Total impact score: 11

A. Importance of 'Comfort' : A2. Fairly important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C3. Large investment preferences

D. Average disposable income: D1. Similar disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F2. Fluctuating district heating prices

G. Development of appliance prices: G1. Low maintenance costs but high upfront costs

H. Development of climate change and temperatures: H3. Negligible rise in temperature

I. Development of community relationship: I1. Higher level of community bond

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Scenario No. 23

Weight : 2

Consistency value : 0 Total impact score: 12

A. Importance of 'Comfort' : A3. Very important

B. Importance of 'Affordability': B1. Not at all important

C. Development of investment preferences: C2. Small investment preferences

D. Average disposable income: D2. Lower disposable income

E. Development of environmental concern: E2. Higher level of concern

F. Development of heating prices: F1. Stable electricity prices

G. Development of appliance prices: G2. Low upfront costs and low maintenance costs

H. Development of climate change and temperatures: H2. Extreme winters and intense storms during summers

I. Development of community relationship: I2. Lower level of community bond

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