MASTER THESIS

The Impact of the Inclusion of Social Dimensions on Decision-Making in the Dutch Heat Transition: an Empirical Study

Engineering and Policy Analysis
Technology, Policy and Management
TU Delft

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29-9-2022

The Impact of the Inclusion of Social Dimensions on Decision-Making in the Dutch Heat Transition: an Empirical Study

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Engineering and Policy Analysis**

Faculty of Technology, Policy and Management

by

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To be defended in public on **29 September 2022**

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EXECUTIVE SUMMARY

We find ourselves at a crossroads, and without immediate and deep emissions reductions, limiting global warming to 1.5 degrees Celsius will be impossible (Intergovernmental Panel on Climate Change (IPCC), 2022). In the Netherlands, the national government aims to reduce greenhouse gas emissions by 55% by 2030, compared to 1990 and aims to be climate neutral by 2050 (Rijksoverheid, n.d.-b). For the Netherlands to achieve these climate targets, Dutch municipalities have been delegated the crucial task of the heat transition where natural gas in the built environment needs to be replaced by sustainable heating alternatives (Rijksdienst voor Ondernemend Nederland, 2017).

Prior research reveals that the Dutch energy transition and policy documents are often techno-economic centred and hardly stress citizens' central role (Haarbosch et al., 2021). However, it remains a thoroughly social affair as changes in energy technologies are accompanied by societal ramifications (Miller & Richter, 2014). In this research, social aspects are defined as aspects that concern the people, their transactions, and relationships within the energy system (adopted from: (Krumm et al., 2022)). Two categories of social aspects are considered: public support and energy justice. First, researchers argue that the exclusion of social aspects can undermine public support and impede energy policy implementation (Kallbekken et al., 2011) and repeal (Yektansani & Azizi, 2021). Then, there are also risks involved if energy justice (distributional, recognition-based, and procedural justice) is excluded in energy policy, such as deteriorating energy affordability (Williams & Doyon, 2019). Despite the importance of social aspects, they have not yet received the necessary attention (Grafakos et al., 2017) and are rarely incorporated in energy policy (Miller & Richter, 2014).

So far, a considerable amount of academic research in the energy field remains in the theoretical realm (Jenkins et al., 2020). Accordingly, examining whether social information impacts policymakers' decisions in the heat transition is essential. Not only to examine how policymakers make decisions in complex contexts but also how they make decisions in a context of trade-offs among competing objectives. Especially since research suggests that our moral systems are ill-equipped to deal with the complexity of modern-day issues (Markowitz & Shariff, 2012; Sovacool & Dworkin, 2015), consequently, the following main research question was formulated:

"What is the impact of including social information in the information provided for decision-making processes on the social responsibility of policymakers' decisions for the heat transition?"

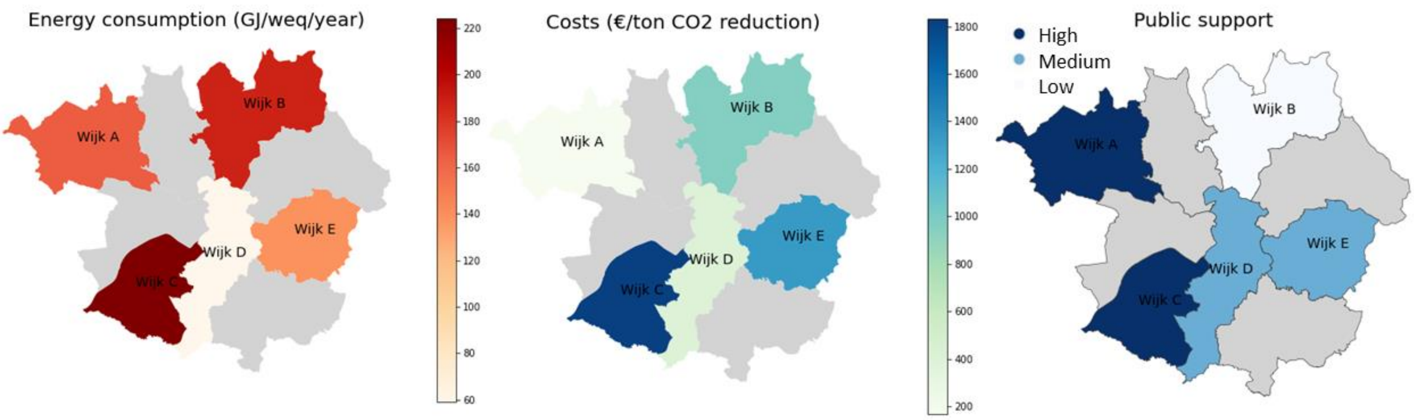
The study deployed a convergent parallel design where qualitative interviews were used to expand on the quantitative findings of the survey experiment. The experiment took on a 1x2 between-subjects design where participants were randomly allocated to one of two conditions: group A: exposure to only technical and economic information, and group B: exposure to technical, economic and social information.

To set up the experiment, it was essential to establish the relevant techno-economic and social indicators for heat transition decision-making. Information in the experiment was displayed through indicators. This research used indicators to describe the links between energy use and human activity (Schipper et al., 2001) and communicate energy issues data to policymakers (Vera et al., 2007). With a document analysis, literature review, and expert interviews, the relevant indicators were narrowed down to four technical, two economic and five social indicators. The

following indicators were selected whilst accounting for data availability and minimisation of the cognitive burden of policymakers:

- Technical: energy consumption, energy label, year of construction of buildings in the built environment
- Economic: costs of disconnecting a neighbourhood from natural gas
- Social: public support, energy poverty (distributional justice), public participation (procedural justice)

Various indicators were combined to construct four scenarios (the figure below depicts scenario 1). In each scenario, policymakers were presented with the following story problem: "*Please indicate the order in which you would disconnect the five neighbourhoods from natural gas, with 1 being the neighbourhood you would disconnect first and 5 being the neighbourhood you would disconnect last*". Where group A had to rank the five neighbourhoods based on only technical and economic indicators, group B based the ranking on technical, economic and social information. This study deployed a Mann-Whitney U test to determine whether there were differences between the two groups (Laerd Statistics, 2015). In this research, this translates to whether groups A and B differ in ranking.



Depiction of scenario 1 for group B with technical, economic and social indicators (left shows the energy consumption; centre shows the costs; right shows public support)

The results of this study indicated that the inclusion of social aspects leads to more socially responsible decisions in the heat transition for nine out of 20 neighbourhoods. This result means that neighbourhoods with specific social characteristics are prioritised more than after including this information. These results support the ideas of Sovacool and Dworkin (2015) that the concept of energy justice is interesting to use as a support for a decision-making tool to aid energy planners. Finally, this finding disagrees with Amer et al. (2020), who indicate that policymakers would probably find the quantification of social challenges in energy models useless. Following this, a practical implication of these findings would be to include and quantify more social indicators in energy models to increase the social responsibility of decisions in the heat transition.

Nonetheless, there was also a case in which the addition of social information led to a less socially responsible decision. This unforeseen finding occurred in the scenario where information about energy poverty was added to information about energy consumption and costs. The hypothesis was that neighbourhoods with low shares of energy poverty would be prioritized less (ranked lower). However, unexpectedly, neighbourhoods that scored lowest in energy poverty obtained a higher priority after including this information, possibly due to the following reasons. Firstly, the lack of information about the ratio of social housing to private homeowners in the experiment.

During the interviews, policymakers indicate that they find areas with social housing easier to approach as they can communicate with the housing corporation instead of each homeowner. Thus, if policymakers had information about the ratio of rented compared to privately owned houses in a neighbourhood, then the value of the energy poverty information would also increase. Secondly, the interviewed policymakers indicated that the neighbourhood-implementation plans (WUP, the next step in the heat transition) and energy poverty programs run parallel. Perhaps these parallel plans induced unexpected results as policymakers are already tackling energy poverty problems through these plans, therefore attaching less value to the energy poverty information in light of the "conventional" heat transition plans. However, these remain speculations, and further research is needed to confirm these theories.

Then, this study finds that policymakers often think in extremes when considering social information. For example, neighbourhoods with high public participation or support were prioritised more. This result suggests that Dutch policymakers attach importance to social information for heat transition decision-making and can be explained as follows: human decision-making has been discovered to systematically violate axioms of logic, known as cognitive biases (Tversky & Kahneman, 1974). One of these cognitive biases is the availability bias, defined as people overestimating the probability of occurrences that come to mind easily (Tversky & Kahneman, 1973). This may be why memories of extreme occasions impact people's decisions more substantially than moderate events (Ludvig et al., 2014). Strikingly, this violation of axioms of logic was not structural. There were cases in which extreme favourable social conditions did not lead to significant differences between groups A and B, e.g. policymakers were reluctant to prioritise neighbourhood A with high consumption and costs despite it having high public support.

Another interesting finding of this study is that many policymakers (and therefore municipalities) seemed to have diverging approaches to the heat transition. This result became apparent through the many unique rankings in the rankings distribution. Underlying these differences could be personal (educational background, professional experience and personal values) or organisational (integral municipal collaboration) characteristics. Therefore, future studies should research personal characteristics of what motivates individuals to adopt more socially responsible approaches. As for organisational characteristics, it might be interesting to examine whether policymakers of other municipal departments approach the heat transition the same way. Prior research found that it is essential to design policies across sectors and actors to convert trade-offs into synergies (Scherer et al., 2018); therefore, this research extension can help provide insights into how the energy policy design across municipal departments can lead to more social heat transition decision-making.

Finally, this research can be replicated by adjusting the presentation of the information for decision-making. Lorenz et al. (2015) found that even within a reasonably comparable group of local practitioners, there are differences in comprehension and preferences for information visualisation. Thus, as an extension of this research, it is possible to display the information in a table format, information about energy labels can be displayed in the form of a bubble chart, or techno-economic information can be displayed in bivariate choropleths. These new representations can be interesting to see whether decisions change if the same information is shown differently and which display of information or visuals leads to more social(ly responsible) decisions. Additionally, this research could provide insights into the preferred ways for policymakers to communicate information. Policymakers can then use their preferred (and comprehendible) information as food for thought during stakeholder meetings.

ACKNOWLEDGEMENTS

This thesis is possibly the most challenging thing I have done. My journey has been a long one; there were many times when the task seemed impossible both on an academic and personal front. It is an absolute pleasure to have reached this moment which has been made possible and bearable with the help of a few exceptional individuals along the way.

First and foremost, I would like to express my sincere gratitude to my first supervisor, Trivik Verma, for his guidance, invaluable feedback, and kindness. He taught me to believe in my abilities and was there for discussions about things I was unsure about. My heartfelt thanks to Devin Diran for his thought-provoking questions and insights. His unwavering support and professional expertise have enlightened my way of writing this thesis.

My heartfelt thanks to David Paulus for his excellent advice. I am incredibly grateful for his encouragement throughout the process. Thank you to my chair Gerdien de Vries, Lydia Geijtenbeek and Gerdien van de Vreede for your valuable feedback, comments and suggestions. Furthermore, a special thanks to all participants in the survey experiment and interviews for their participation and engagement in the study. Thank you for expressing your insights and thoughts so eloquently.

My deepest appreciation goes to my friends. As the witnesses of the whole process of my writing this thesis, they have been incredibly patient in listening to my struggles. I want to thank them for their unconditional support and encouragement.

Finally, I would like to thank my parents and sister. No words can truly express my indebtedness to them. I will be forever grateful for their never-ending faith in me; without them, none of this would have been possible.

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1. INTRODUCTION

1.1 PROBLEM CONTEXT

Problem background

We find ourselves at a crossroads, and without immediate and deep emissions reductions, limiting global warming to 1.5 degrees Celsius will be impossible (Intergovernmental Panel on Climate Change (IPCC), 2022). The international community previously adopted a legally binding international treaty, also known as the Paris Agreement, on 12 December 2015 to achieve this ambitious target (United Nations Framework Convention on Climate Change (UNFCCC), n.d.). In the Netherlands, the national government aims to reduce greenhouse gas emissions by 55% by 2030, compared to 1990 and aims to be climate neutral by 2050 (Rijksoverheid, n.d.-b). To meet these climate targets, we need to accelerate the energy transition. The energy transition refers to the shift of the global energy system from fossil-based to renewable energy sources (International Renewable Energy Agency (IRENA), n.d.). The Dutch government put the so-called 'heat transition' into place to aid this transition, where natural gas in the industry, built environment and agricultural sector needs to be replaced by sustainable heating alternatives (Rijksdienst voor Ondernemend Nederland, 2017). A critical target of the heat transition is to supply 1.5 million existing residential homes with sustainable heating by 2030 (Rijksoverheid, 2019).

The Dutch heat transition

The national government delegated this transition's crucial task and responsibility to the local governments due to the local character of the heat supply. For this purpose, the government expected municipalities to draw up a plan by the end of 2021, the so-called "Transition Vision Heat" (hereinafter TvW), detailing the heating alternatives considered for those neighbourhoods where the transition is planned before 2030 (Rijksoverheid, 2019). From the document analysis of twelve TvWs (see Appendix A), it becomes clear that techno-economic assumptions dominate municipalities' choices in the heat transition. This analysis shows that many municipalities validate their findings with the aid of the Netherlands Environmental Assessment Agency's (PBL) Start Analysis. The Start Analysis is a tool based on a techno-economic analysis of costs and impacts of the various techniques to heat the built environment without natural gas developed by the Dutch government to aid municipalities in the heat transition (PBL, 2020b).

Furthermore, a detailed analysis of Dutch energy policy documents into the dominant narratives revealed that the expected future within these documents was often anticipated to be technical and economic by nature (Haarbosch et al., 2021) (see Figure 1.1). Haarbosch et al. (2021) also find that the strategic future is a social one in which the success of the transition depends on citizens. However, Haarbosch et al. (2021) uncovered that policy documents hardly stress the citizens' central role in the desired (environmental) and expected future narratives. They concluded that goals were already set, and the social aspects were barely considered (Haarbosch et al., 2021).

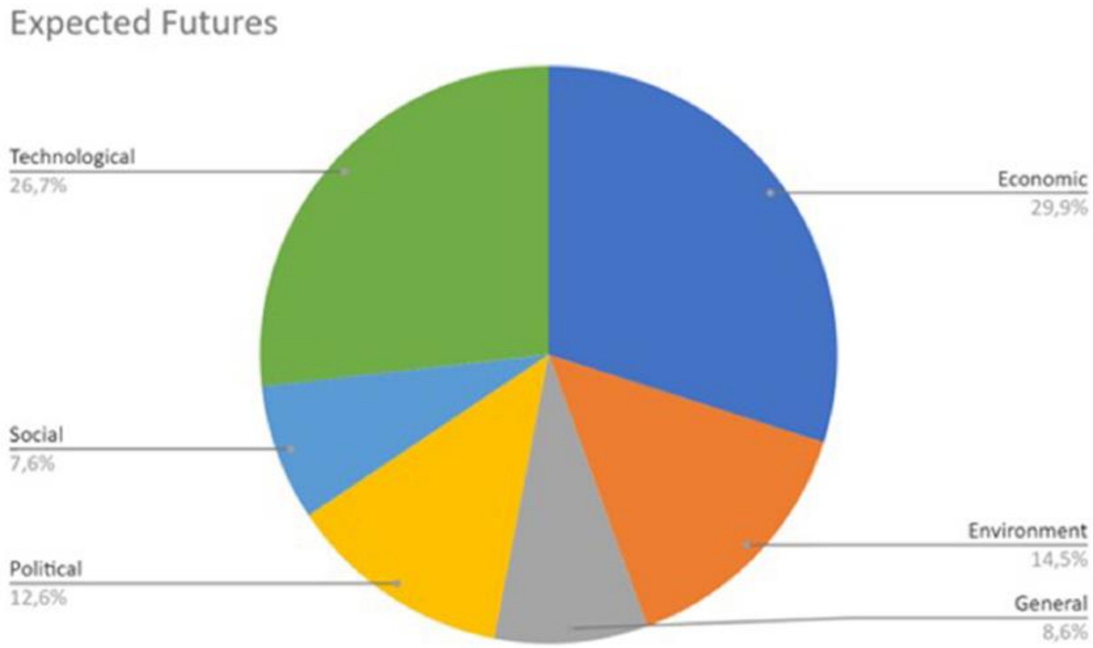


Figure 1.1 Visualizing the different types of expected futures based on a narrative analysis of Dutch energy policy documents. Reprinted from "A Mismatch in Future Narratives? A Comparative Analysis Between Energy Futures in Policy and of Citizens", by Haarbosch et al., 2021, *Frontiers in Sustainable Cities, 41*, Copyright 2021 by Frontiers in Sustainable Cities Inc.

The lack of social dimensions (public support and energy justice) within the transition

Energy transitions are thoroughly social affairs, as changes in energy technologies accompany societal ramifications (Miller & Richter, 2014), such as jobs created in energy industries or energy access (Laird, 2013). In this research, social aspects are defined as aspects that concern the people, their transactions, and relationships within the energy system (adopted from: (Krumm et al., 2022)). Two categories of social aspects are considered: public support and energy justice.

The first social aspect considered in this research is public support. Public support has to do with the transactions and relationships of people within the energy systems. Research shows that many socioeconomic determinants underlie the attitudes of citizens' sustainable energy behaviour (Frederiks et al., 2015) and support for policies and system changes (Steg et al., 2021). The lack of consideration of the social facets, such as public support, can lead to impediments to energy policy implementation (Kallbekken et al., 2011), opposition, protests or even policy repeal (Yektansani & Azizi, 2021).

The second social aspect considered in this study is energy justice. Energy justice relates to the social outcomes for people within the energy system. Changes in energy technologies reshape social values and relationships, which then can contribute to reinforcing unequal distributions (Miller et al., 2013). The consequence of unequal distributions raises normative questions to do with energy justice. Sovacool and Dworkin (2015) state that it is a mistake to only consider techno-economic dimensions, without assessing the social element of energy justice. At the core of energy justice is a research area that tries to apply the principles of social justice to energy policy (McCauley et al., 2013). Sovacool (2014) defines energy justice as follows: "*energy justice … recognises that energy needs to be included within the list of things we prize; how we distribute the benefits and burdens of energy systems is pre-eminently a concern for any society that aspires to be fair*". Not only does the idea of energy justice inclusion stem from more top-down decision-making, e.g. "Clean Energy for All" policy from European Commission (European Commission, 2019), there are also risks accompanied with the exclusion of the three tenets of energy justice.

Jenkins et al. (2016) define three tenets of energy justice: distribution, recognition, and procedure. Distributional justice concerns exploring where energy injustices emerge (Jenkins et al., 2016). For instance, the distributional burden of rising energy prices is questioned by energy poverty studies (Boardman, 2013). Straver et al. (2020) underline the importance of considering energy justice facets as the falling behind of households in the energy transition risks undermining public support for the energy transition. Additionally, the exclusion of distributional justice considerations can lead to deteriorating availability and affordability of energy (Williams & Doyon, 2019). From the document analysis of the TvWs (Appendix A), it becomes evident that much remains unclear on how municipalities will deal with problems of energy poverty that can arise from the heat transition task.

Recognition-based justice encourages investigating which parts of society are ignored or underrepresented. This form of justice emphasises acknowledging divergent perspectives rooted in social and cultural differences (Fraser, 1999). The lack of recognition-based justice can lead to the exclusion of marginalised voices from stakeholder decision-making (Williams & Doyon, 2019).

Finally, procedural justice concerns access to decision-making processes. Warren and McFadyen (2010) show that creating a sense of community ownership in wind farm development can generate new acceptance processes. However, excluding procedural justice can result in sub-optimal decisions due to excluding knowledge from non-experts (Williams & Doyon, 2019). Klabbers (2020) highlights that although the inclusion of residents in the Dutch transition is a priority for municipalities, it remains a theoretical policy with little execution for some municipalities. She finds that sometimes the focus is more on convincing them of the ideas of the municipality instead of participation, as these processes are cost- and labour-intensive.

It is possible to conclude that excluding social aspects (public support and energy justice) in the heat transition can have undesired societal consequences. Despite the importance of social aspects, they have not yet received the necessary attention (Grafakos et al., 2017) and are rarely incorporated in energy policy (Miller & Richter, 2014). Additionally, policymakers need to recognise energy justice problems and move towards more "justice aware" energy policy (Sovacool et al., 2017). Jenkins et al. (2020) reveal that, although current research has merit, there is growing recognition that academic research in the field of energy justice is disconnected from "real-world" practice. Integrating the social dimension with natural sciences is essential for expanding the scientific reach from academic to policy (Smith & Gilbert, 2018). It is crucial to proactively go beyond stating academic outputs and suggest how they might realistically translate to practice to enhance the impact of energy literature.

Decision-making under complex environments

It becomes evident that there is a need to include the social dimension in energy decision-making and move away from the theoretical realm to examine academic outputs in the real world. As local policymakers lead the Dutch heat transition, they are pivotal. However, local policymakers are often an under-researched group of information users (Demeritt & Langdon, 2004; Porter et al., 2015) and rarely studied directly in empirical studies (Kwiatkowski, 2016), but the effects can be profound (Cairney & Kwiatkowski, 2017).

Amer et al. (2020) indicate that policymakers would "probably" find the quantification of social challenges in energy models "not useful". However, Cairney and Kwiatkowski (2017) underline that policy studies are essential to highlight how individual behaviour occurs in complex policymaking environments. These environments often contain socioeconomic contexts to which policymakers must respond, even if these are difficult to comprehend or control fully (Cairney & Weible, 2017; Heikkila & Cairney, 2018). Costa-Campi et al. (2017) express that the energy sector is undergoing a critical period characterised by challenges related to social dimensions: environmental sustainability (e.g. greenhouse gas mitigation), security of energy supply (e.g. reliability of supply), and economic sustainability (e.g. affordable energy). When designing energy policies, one of the challenges remains that these have to be designed in a context of trade-offs among competing objectives (Costa-Campi et al., 2017). Additionally, researchers argue that our moral systems are ill-equipped to deal with the complexity of modern-day energy issues (Markowitz & Shariff, 2012; Sovacool & Dworkin, 2015). Consequently, questions arise on how policymakers' decisions change when social aspects are included in the heat transition decision-making process.

1.2 KNOWLEDGE GAP

This literature overview reveals gaps in understanding of the relationship of, on the one hand, the inclusion of social information for the heat transition decision-making process and, on the other hand, local policymakers' decisions. There is no systematic study yet, into whether the inclusion of social information in heat transition decision-making leads to more social(ly responsible) decisions by local Dutch policymakers, how it impacts their behaviour and how they make trade-offs, thus identifying a crucial knowledge gap. This research aims to address this gap by evaluating the impact of including social information in the information provided for the decision-making process on decisions made by local Dutch policymakers for the heat transition. This study will examine whether policymakers' decisions become more social(ly responsible) when positioned in a complex policymaking environment with an experiment. In other words, do policymakers attach value and weight to social dimensions of decisions? This analysis will be complemented with quotes from interviews to provide insights into the thoughts and trade-offs of policymakers when faced with these complex decisions.

1.3 RESEARCH QUESTIONS

The literature overview reveals that at-present Dutch policymakers continuously depend on a techno-economic understanding for their decisions in the heat transition, whilst the social dimension is arguably equally important. The lack of consideration of social facets can impede policy implementation, undermining public support and deteriorating energy availability. As policymakers must respond to such contexts, they are ill-equipped to manage modern-day energy issues and often must make trade-offs when designing energy policies. Consequently, questions arise on how policymakers' decisions change after social information inclusion.

The main research question addressed in this study is the following:

"What is the impact of including social information in the information provided for decision-making processes on the social responsibility of policymakers' decisions for the heat transition?"

1.3.1 Sub-research question 1

What are relevant technical, economic and social indicators in the decision-making about the heat transition?

There must be an overview of relevant technical, economic and social indicators to empirically assess the effects of including social information in the information provided for decision-making processes on policymakers' decisions. In this study, indicators are a tool to describe the links between energy use and human activity (Schipper et al., 2001) and communicate energy issues data to policymakers (Vera et al., 2007). These indicators provide better insight into the factors that affect the energy transition, e.g. energy consumption and energy justice.

Since policymakers were already using the Start Analysis, a tool with a techno-economic basis, technical and economic indicators are considered. Besides technical and economic indicators, only social indicators are considered to minimise the cognitive burden on policymakers. Researchers find that although humans consume information in nature (Huynh et al., 2007; Saxena & Lamest, 2018), it is only possible to process and comprehend small doses of information at a time (Mahdi et al., 2020). Thus, this study considers only these three themes of indicators.

I will conduct desk and literature research to create an overview of all available technical, economic and social indicators, whereafter, I will solidify the relevant ones through expert interviews. Current research into existing heat transition models from the Dutch professional practice reveals many potential indicators (Henrich et al., 2021; Netbeheer Nederland, n.d.-b). In addition, research into existing energy transition models from international academic practice can also aid in expanding knowledge and understanding of indicators, e.g. articles by Bouw et al. (2021) and Krumm et al. (2022). The comprehensive list of indicators from Dutch professional and international academic practice provides insights into most indicators. Out of all indicators, I will select a few based on expert consultation and data availability to use in subsequent parts of this study.

1.3.2 Sub-research question 2

How can the technical, economic and social indicators be effectively operationalised and included in information provision?

Sub-research question 1 yields the relevant techno-economic and social indicators for decision-making in the heat transition. These indicators need to be effectively operationalised to make them actionable and usable for empirical experiments. In the operationalisation of the indicators, the indicators stemming from the expert interviews are evaluated on their data availability whilst accounting for many other relevant aspects, such as effectively conveying indicator information. In this process, a select number of indicators is appointed to ensure information conciseness and minimise cognitive burden during the experiment. Subsequently, I will use these indicators to construct scenarios for the experiment.

1.3.3 Sub-research question 3

What are the effects of combining technical, economic and social information on the social responsibility of policymakers' decisions in the heat transition, and how are trade-offs made?

This question is closer to answering the crux of the main research question. Answering sub-research questions 1 and 2 yields a concrete empirical experiment. The experiment will be conducted by nesting the experiment within a survey, resulting in the deployment of a survey experiment within this research. This experiment enables this study to examine the relationship between, on the one hand, the inclusion of social information for the heat transition decision-making process and, on the other hand, local policymakers' decisions. When designing energy policies, one of the main challenges remains the design in the context of trade-offs among competing goals, e.g. environmental sustainability vs economic sustainability (Costa-Campi et al., 2017). However, Sovacool and Dworkin (2015) state that our moral systems are ill-equipped to deal with the complexity of modern-day energy issues. Researchers identify various reasons for the failure of the human moral judgement system concerning modern-day energy issues. Analytical reasoning about moral issues of energy tends to be slow and cognitively demanding (Markowitz & Shariff, 2012). Policymakers are constantly faced with bounded rationality as they are under continual pressure to reach decisions (Botterill & Hindmoor, 2012). Additionally, Cairney (2012) demonstrates that individuals typically pay attention to one policy problem at a time. The constraints of cognitive complexity and bounded rationality that policymakers face in the decision-making of modern-day energy issues make it interesting to research trade-offs of competing objectives. Policy studies have an added value as these can show how individual behaviour occurs in complex policymaking environments (Cairney & Kwiatkowski, 2017); this environment would be one in which modern-day energy issues are situated. In this study, the experiment examines whether including social information in the heat transition leads to more social(ly responsible) decisions and what trade-offs policymakers made.

The experiment aims to test four hypotheses. In short, policymakers will receive information about the heat transition within a few neighbourhoods through choropleth maps (2D geo-spatial visualisations), which are characterised by a specific indicator. Based on the information, policymakers have to decide in which order they would disconnect the five displayed neighbourhoods (A, B, C, D and E) from natural gas, with one being the highest priority (first to disconnect) and five being the lowest priority (last to disconnect). For example, if the ranking were B – A – D – E – C, neighbourhood B would be disconnected from natural gas first, then neighbourhood A, etc. Subsequent sections (2 and 4) include a more elaborate discussion of the experimental set-up. Subsections 1.3.3.1 through 1.3.3.4 will discuss the hypotheses that the experiment will test.

1.3.3.1 Hypothesis 1

Hypothesis 1 reads: *Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.*

These specific indicators are combined to examine the effects of including an indicator of public support when the participant has information about the energy consumption of the residents and the costs. Public support is measured through the indicator "the willingness of residents to make their homes more provided they recoup their investment". Policies are successful only when there is broad support from those affected and involved (Radtke & Scherhaufer, 2022). Furthermore, Kallbekken et al. (2011) find that the lack of public support can impede energy policy implementation, opposition, protests and even policy repeal (Yektansani & Azizi, 2021). Thus, I hypothesise that policymakers will prioritise neighbourhoods with higher levels of public support after being added to the existing information about energy consumption and costs.

1.3.3.2 Hypothesis 2

Hypothesis 2 reads: *Neighbourhoods with higher (/lower) shares of energy poverty obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.*

These specific indicators are combined to examine the effects of including an indicator of energy poverty when the participant has information about the energy consumption of the residents and the costs. Energy poverty is measured through the "the share of low-income and high energy consumption" indicator. Energy poverty is considered in light of the first energy justice tenet, distributional justice, which relates to affordability (Sovacool et al., 2017). They define affordability as: "*people deserve sufficient energy resources of high quality*". The concept of energy poverty implies that the affordability of energy and energy services need to be respected (Shyu, 2021). Straver et al. (2020) find that public support for the energy transition could be undermined if a portion of households falls behind in the energy transition. Thus, I hypothesise that policymakers will prioritise neighbourhoods with higher levels of energy poverty after being added to the existing information about energy consumption and costs.

1.3.3.3 Hypothesis 3

Hypothesis 3 reads: *Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy labels and costs.*

Hypothesis 3 is similar to hypothesis 1 but differs in the technical indicator. Instead of energy consumption, this hypothesis researches the effect on energy labels after including public support information. These specific indicators are combined to examine the effects of including an indicator of public support when the participant has information about the energy labels and the costs. Public support is measured through the indicator "the willingness of residents to make their homes more provided they recoup their investment". Policies are successful only when there is broad support from those affected and involved (Radtke & Scherhaufer, 2022). Furthermore, Kallbekken et al. (2011) find that the lack of public support can impede energy policy implementation, opposition, protests and even policy repeal (Yektansani & Azizi, 2021). Thus, I hypothesise that policymakers will prioritise neighbourhoods with higher levels of public support after being added to the existing information about energy labels and costs.

1.3.3.4 Hypothesis 4

Hypothesis 4 reads: *Neighbourhoods with higher (/lower) shares of public participation obtain a higher (/lower) priority in decision-making when this information is added to the existing information about the year of construction and costs.*

These specific indicators are combined to examine the effects of including an indicator of public participation when the participant has information about the year of construction and the costs. Public participation is measured through the indicator "the share of households members of a sustainable neighbourhood initiative". Public participation is considered in light of energy justice. One of the core tenets in the energy justice literature encompasses procedural justice, which focuses on who is included in the decision-making processes of energy and aims to ensure that energy procedures are fair and inclusive of all who choose to participate (Carley & Konisky, 2020). Due process is essential for broader community involvement and participation (Sovacool & Dworkin, 2015). Energy justice literature considers local knowledge critical; therefore, seeking the inclusion of the affected public is of utmost importance (Jenkins et al., 2016). Additionally, Renn et al. (2013) argue that the transformation of such a complex system requires intensive public participation to overcome difficulties that emerge during the transformation. Similarly, Greening and Bernow (2004) find that the active involvement of stakeholders in decision-making processes will increase their confidence in the outcome. Thus, I hypothesise that policymakers will prioritise neighbourhoods with higher shares of public participation after being added to the existing information about the year of construction and costs.

1.4 SOCIETAL AND ACADEMIC RELEVANCE

The outcome of this thesis is twofold. It aims to address a scientific and societal objective.

1.4.1 Scientific relevance

Though energy transitions are thoroughly social affairs (Miller & Richter, 2014), social aspects of the transition have not yet received the necessary attention (Grafakos et al., 2017) and are rarely incorporated in energy policy (Miller & Richter, 2014). The literature revealed that there is no systematic study yet, into whether the inclusion of social information in heat transition decision-making leads to more social(ly responsible) decisions by local Dutch policymakers, how it impacts their individual behaviour and how they make trade-offs. This thesis aims to address this gap by integrating social dimensions with natural sciences to expand the scientific reach from academic to policy (Smith & Gilbert, 2018).

1.4.2 Societal relevance

From the document analysis of twelve TvWs (see Appendix A), it becomes clear that techno-economic assumptions dominate municipalities' choices in the heat transition. Haarbosch et al. (2021) uncovered that Dutch policy documents hardly stress the citizens' central role in the desired (environmental) and expected future narratives. They concluded that goals were already set, and the social aspects were barely considered (Haarbosch et al., 2021). In the same way, Klabbers (2020) highlights that although the inclusion of residents is a priority for municipalities, it remains a theoretical policy with little execution for some municipalities. This thesis aims to contribute to this societal debate by researching policymakers' approaches to the heat transition and providing insights into heat transition decisions. Additionally, potential shifts in decision-making due to social information inclusion can result in a call for more socially responsible energy decision-making and open discussions about energy justice in decision-making among policymakers, society and academics.

1.5 THESIS OUTLINES

Figure 1.2 outlines this thesis. Section 2 (Research design and methodology) discusses the research design and various methods deployed in this research. Subsequently, section 3 (Techno-economic and social indicators) aims to answer sub-research question 1, where I interview two experts in the field of the Dutch energy transition to identify relevant indicators for heat transition decision-making processes. At the end of this section, I identified a list of relevant techno-economic and social indicators. This list of indicators forms the input of Section 4 (Experimental setup and procedure). This section details the implementation of the empirical experiment: how I operationalise the indicator and design the experiment, who the participants are and how the data are collected. Section 4 answers sub-research question 2 and results in the survey experiment. Section 5 (Results) hereafter will provide a quantitative and qualitative analysis of the collected data and simultaneously answer sub-research question 3. Then, section 6 (Discussion) reviews the research and connects the findings to the literature. Finally, section 7

(Conclusion and Recommendations) summarises the key findings, answers the main research question and identifies opportunities for future research.

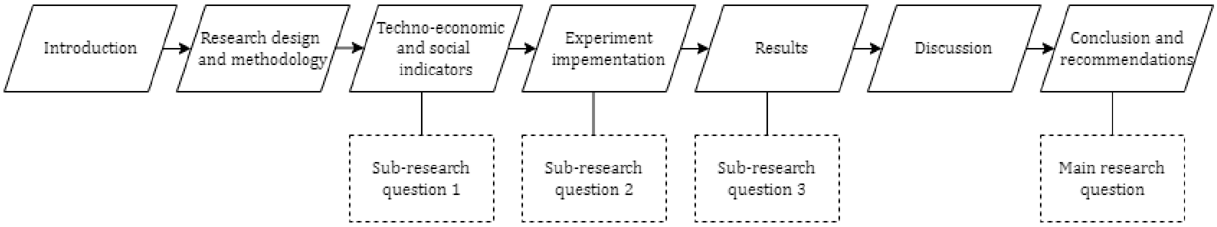


Figure 1.2. Outline of the thesis

2. RESEARCH DESIGN AND METHODOLOGY

This section describes the mixed-methods research design in subsection 2.1, whereafter I detail the various methods deployed in this study in subsection 2.2.

2.1 RESEARCH DESIGN: CONVERGENT PARALLEL DESIGN

This research deploys a mixed-methods approach. A mixed-methods approach is defined as a type of research in which quantitative and qualitative research methods are used to answer the research questions (Tashakkori & Teddlie, 2003). More specifically, this study will deploy a convergent parallel design. Morse (1991) defines the underlying rationale of this design as "to obtain different but complementary data on the same topic" (Morse, 1991). Patton (1990) states that this design is used to bring together the various advantages and nonoverlapping disadvantages of quantitative methods (large sample size, trends, and generalization) with those of qualitative methods (small sample size, details, and in-depth insights). One of the reasons to use this design is if the researcher wants to expand quantitative results with qualitative data (Creswell & Plano Clark, 2011). Both quantitative and qualitative data collection takes place at the same time, making it an efficient design (Creswell & Plano Clark, 2011).

There are different variants of the convergent design. The variant used in this research is the validating quantitative data model (see Figure 2.1). Researchers use this model when they want to validate and expand on the quantitative findings from a questionnaire by including open-ended qualitative questions (Creswell & Plano Clark, 2011). However, open-ended qualitative survey questions often lead to larger item non-response (Reja et al., 2003). Therefore, I set up this research as follows: 1) the experiment will be nested in a survey, and the survey experiment will be sent out to a large group of subjects to collect the qualitative response, and 2) I will interview a small group of subjects about their thoughts during the experiment. With this design, researchers hope to identify interesting quotes to validate and expand the quantitative survey findings (Creswell & Plano Clark, 2011).

One pitfall of mixed methods research is that the replication is considered difficult, especially replicating qualitative data is considered problematic (Jick, 1979). Thus, caution and careful documentation are needed to alleviate the severity of the limitation in case other researchers want to replicate this study.

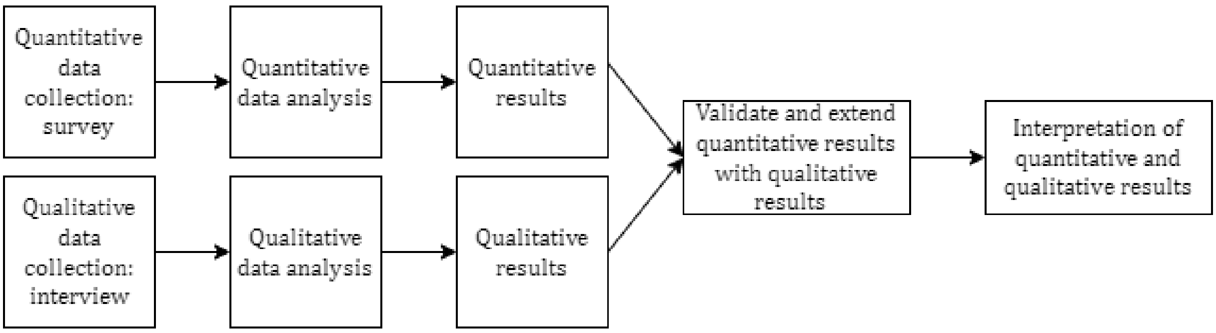


Figure 2.1 Research design: convergent data validation variant

2.2 METHODOLOGY

This subsection describes the research methods deployed in this research: 1) literature research and expert interviews, 2) an experiment, and 3) policymaker interviews. For every method, I detail the purpose, necessary data and tools. First, I describe the literature research and expert interview performed to establish the knowledge gap and relevant indicators for the experiment in subsection 2.2.1. Subsection 2.2.2 describes the experiment in detail. Finally, subsection 2.2.3 details information about the policymakers' interviews.

2.2.1 Literature research and expert interviews

To answer the first sub-research question: *"What are relevant technical, economic and social indicators in the decision-making about the heat transition?"* it is essential to gain insight into the available indicators for the experiment. For this, various grey literature in the form of documents by Netbeheer Nederland (n.d.-b) on various models used by Dutch professional practice for the heat transition will be studied. In addition, I will analyse international academic literature to determine the relevant indicators used in the energy transition abroad. From these documents and articles, a few models will be chosen to analyse in more detail.

Subsequently, to establish the relevance of the indicators for the experiment, I will interview two experts operating in the energy field. Table 2.1 details the information about the function of the interviewed experts and the duration of the interview. The interviews will serve as a way to identify the most relevant indicators, as including too much information can give rise to complexity. Appendices B and C include the consent form and the expert interview protocol outline.

Table 2.1 List of interviewed experts

Interview participant	Function	Duration interview
Expert 1	Data advisor in the energy transition	27:33
Expert 2	Researcher and advisor in the energy transition	31:15

2.2.2 Experiment

Subsection 2.2.2 describes the second method deployed in this research: the experiment. Before the experiment is set up, a few steps of data operationalisation must be considered (described in subsection 2.2.2.1). Subsection 2.2.2.2 describes the experiment by outlining the between-subject design and the participants. Then, subsection 2.2.2.3 specifies the survey experiment. Finally, subsection 2.2.2.4 will provide insights into the data collection and inferential analysis procedures.

2.2.2.1 Steps before the experiment

After establishing the relevant indicators, it is possible to start answering the second sub-research question: "*How can the technical, economic and social indicators be effectively operationalised and included in information provision?"*. For this purpose, the literature will be studied on how to incorporate techno-economic and social information to increase uptake and effectiveness. Subsequently, I will collect data on these indicators from Statistics Netherlands, the Association of Netherlands Municipalities (from now on VNG), and PBL. Subsequently, these data will be operationalised by transforming the quantitative data into information that policymakers can use to make heat transition decisions about specific neighbourhoods. For the operationalisation, I will deploy Python (version 3.7.9), which is defined as "an interpreted, object-oriented, high-level programming language" (Python, n.d.). I use Python to transform quantitative indicator data into visualisations to aid decision-making in the operationalisation. Padilla et al. (2018) define visualisation as a visual depiction of data intended to effectively communicate information and enhance audience comprehension (Alhadad, 2018). Eberhard (2021) finds that visualisation can enhance decision quality, confidence and speed. Section 4 provides an elaborate explanation of the operationalisation.

As data from a Dutch municipality will be used, these data will be made "anonymous", meaning that the participants will not recognize or trace from which municipality or neighbourhood the data originate. The underlying reason is to prevent any bias and preconceived ideas that the subjects associated with the specific municipal area. Section 4 discusses the operationalisation of the relevant indicators in detail.

2.2.2.2 Between-subject design and participants

Then, to answer part of the third sub-research question: "*What are the effects of combining technical, economic and social information on the social responsibility of policymakers' decisions in the heat transition, and how are trade-offs made?*", an experiment will be set up. The operationalised indicators lay the foundation of the experiment that examines the relationship between, on the one hand, the inclusion of social information for the heat transition decision-making process and, on the other hand, local policymakers' decisions.

According to Allen (2017), a between-subject design is often used in communication experiments to examine how different messages affect subjects. Thus, for the experiment, I will set up a between-subjects design in which subjects will be assigned to different conditions where each subject will be randomly exposed to only one situation (Allen, 2017) (see figure 2.2). More specifically, this research takes on a 1x2 between-subjects design, which means this design includes one independent variable of two levels (the inclusion or exclusion of social information). The dependent variable is a ranked variable that concerns a decision about the heat transition – the order in which the policymaker plans to disconnect the various neighbourhoods from natural gas.

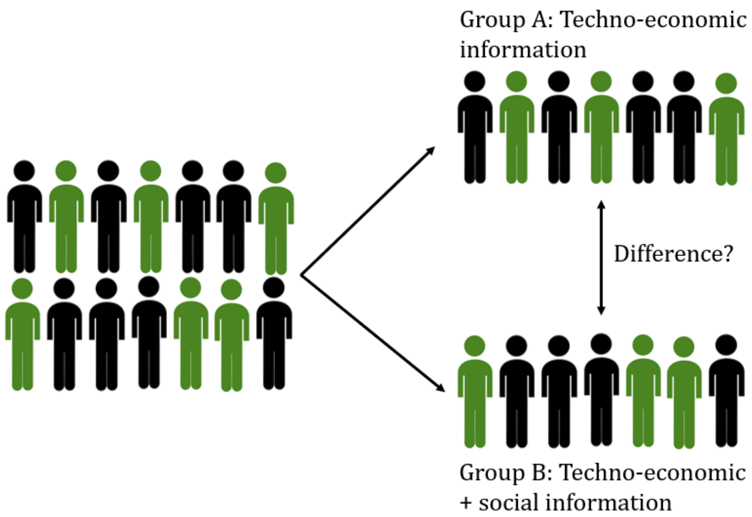


Figure 2.2 Conceptual design between-subjects design.

As the national government delegated the task of the heat transition to the municipalities, the subjects in this study comprise local Dutch policy-makers involved in the heat transition. The experiment will assign the participants to different conditions using probability sampling, which entails the random selection of the sample. Probability sampling is of utmost importance as this reduces systematic group differences introduced in a between-subject design (Allen, 2017). Thus, participants will be allocated to one of two similar online survey experiments set up using the online survey tool Qualtrics. According to Comley (1997), an advantage of surveys set up online is that these will be completed and returned relatively quickly.

Whilst one survey experiment contains merely operationalised techno-economic information for policymakers to base their decision on, the second survey experiment contains both techno-economic as well as social information. From here on, the experimental group presented with only techno-economic information (first survey experiment) will be referred to as group A. In contrast, the group presented with both techno-economic and social information (second survey experiment), will be referred to as group B.

2.2.2.3 Survey experiment

The survey experiment (also called 'survey' within this study) will be organized into a few sections. First, it will introduce the purpose of the study and outline information about ethical standards and safe data processing. The second section continues with personal questions about the participant to identify the right population for the experiment.

Hereafter, I present the policymakers with the following story problem: "*Please indicate the order in which you would disconnect the neighbourhoods below from natural gas, with 1 being the neighbourhood you would disconnect first and 5 being the neighbourhood you would disconnect last.*". For instance, if the ranking of neighbourhoods A, B, C, D, and E is 1, 2, 3, 4, and 5, then the participant prioritises neighbourhood A the most.

In this decision situation, group A will rank the neighbourhoods based on merely techno-economic information, whereas group B will rank neighbourhoods based on both techno-economic and social information. In subsequent survey sections, I will incorporate exit questions, such as: "*To what extent do you consider your decision socially responsible?*". The final survey section leaves room for remarks. Appendix E provides more details on the entire survey experiment.

2.2.2.4 Data collection and inferential analysis procedures

The survey will take approximately 10 – 15 minutes to complete and will be distributed through a mailing list. I will establish a mailing list by collecting e-mail addresses from 1) policymakers mentioned in the colophon of the TvWs, and 2) webpages of municipalities that list policymakers involved in the energy transition. The mailing list includes 114 e-mails, of which 107 are for the survey and seven for an interview. Additionally, the survey will also be distributed through LinkedIn. The survey will be open for four weeks, from July 11th 2022 to August 9th 2022.

After collecting all data, I will analyse it using the statistical software SPSS (International Business Machines Corporation (IBM), n.d.). In SPSS, I will perform the Mann-Whitney U test, a rank-based nonparametric test intended to determine whether there are differences between two groups on an ordinal dependent variable (Laerd Statistics, 2015). In this study, the test will be used to determine whether there are differences in the ranking of the neighbourhoods (ordinal dependent variable) between groups A and B.

As the survey distribution happens over the summer, it is anticipated that the number of collected responses will remain relatively low since policymakers will likely be on holiday. Consequently, the survey will be distributed through LinkedIn to collect additional non-policymaker responses to mitigate the risk of not collecting enough responses from policymakers. Contrary to the email, more participants will have access to it.

2.2.3 Policymaker interviews

Finally, to complement the experiment's findings, the policymaker interviews are also intended to answer sub-research question 3. From the established list of heat transition involved policymakers, the majority were approached to participate in the survey experiment. I kept a few emails separate from this list to contact for an interview (see table 2.2). In the email, the policymaker can find a consent form (see Appendix F) to ensure the interview adheres to ethical standards. These interviews are exploratory. Exploratory interviews provide a broad perspective, and as the research progresses, the results crystallize (Stebbins, 2001). The first part of this study will mainly focus on using quantitative data; therefore, the exploratory interviews can offer a more refined and nuanced perception (Flick, 2018). The primary purpose of conducting the exploratory interviews is to provide more in-depth insights into policymakers' thought processes and trade-offs when combining the technical, economic and social information for the heat transition.

After the interviews are conducted, recorded and transcribed, these data will be analysed for quotes. To ensure correct interpretations of interviewees' answers, I will send the results to all respondents for feedback and validation. Appendix G details the outline of the interview protocol.

Table 2.2 List of interviewed policymakers

Interview participant	**Function within municipality**	**Duration interview**
Participant 1 (PM1)	Advisor energy transition	43:23
Participant 2 (PM2)	Project manager energy and heat	48:40
Participant 3 (PM3)	Policy advisor energy	48:08
Participant 4 (PM4)	Policy advisor environment	52:23
Participant 5 (PM5)	Program manager sustainability	46:29

3. TECHNO-ECONOMIC AND SOCIAL INDICATORS

This section analyses tools and models used to aid decision-making processes in heat and energy transitions. In the course of this examination, I aim to provide an answer to the first subquestion: *"What are the relevant techno-economic and social indicators to consider for decision-making processes about the heat transition?"*. Firstly, I select the tools and models outlined in subsections 1.3.1, whereafter the indicators used in the models and tools are distributed into four themes of indicators: economic, technical, environmental, and social. Subsection 1.3.2 discusses each of these themes in more detail. Then, subsection 1.3.3 familiarizes itself with potential social indicators outside the current realm of models and tools. Finally, I answer the first subquestion in subsection 1.3.4 by consulting experts on the relevancy of the various identified indicators.

3.1 DESCRIPTION OF EXISTING TOOLS AND MODELS

This subsection discusses tools and models from Dutch professional practice (subsection 3.1.1) and international academic practice (subsection 3.1.2) to identify practical tools and models.

3.1.1 Description of tools and models from the Dutch professional practice

I examine tools and models used to aid decision-making processes in the Dutch heat transition to determine the indicators used in consecutive steps of this research. Quantitative analytic tools are commonly used to synthesise available evidence (Atkinson et al., 2015). Models are an abstraction of reality used to analyse complex systems (Wainwright & Mulligan, 2013). They are used to reduce the complexity of systems specifically tailored to the problem the researcher wants to solve (Müller et al., 2011).

Netbeheer Nederland developed the toolkit "Energietransitierekenmodellen", in which they provide an overview of the multitude of Dutch models and tools available for the heat transition. The toolkit aims to aid municipalities, housing corporations and energy cooperatives in swiftly and effectively tackling their energy issues (Netbeheer Nederland, n.d.-b). The toolkit provides an overview of 29 tools and models, which are narrowed down to a smaller selection based on various criteria (Netbeheer Nederland, n.d.-a). Of the 29 tools and models, six have been chosen based on the following criteria:

- Geographical scale: all data needs to be available on a neighbourhood level.
- Output visualisation: the output must be available in a 2D spatial representation, otherwise known as maps. Through their exploratory study into using energy models in practice, Amer et al. (2020) found that municipalities work with modelling results rather than models themselves, implying that 2D spatial representation should suffice for the output visualisation.
- Information about the model: there needs to be a website explaining the model.
- Target group: only selected models with government-oriented target groups.

The remaining models and tools include Cegoia, Eta, Pico, Transform and Vesta. I added a tool developed by the VNG to this selection: DEGO, a data provision tool for the energy transition in the Dutch built environment (VNG, n.d.-b). Table 3.1 provides an overview of these alongside information about their developer, target group and objective. I collected information on the indicators for these models and tools through an overview on Netbeheer Nederland (Netbeheer Nederland, 2017, 2018, 2021a, 2021b, 2021c, 2021d), corresponding developers' user manuals (Meyer & van de Poll, 2021; PBL, 2021; VNG, n.d.-b), and another master thesis (van Berkel, 2019).

Subsequently, these categories are categorised into four main themes: economic, technical, environmental and social. These themes are discussed extensively in the following subsections.

Table 3.1 Overview of existing tools and models Dutch professional practice with the corresponding developer, target group and objective that aid in decision-making about the heat transition

Model or tool	**Developer**	**Target group**	**Objective**
Cegoia	CE Delft (Netbeheer Nederland, 2021a)	Policymakers and practitioners (Netbeheer Nederland, 2021a)	To provide insights into the potential developments of the heat supply on a neighbourhood level (Netbeheer Nederland, 2021a).
Energie Transitie Atlas (ETA)	Over Morgen (Netbeheer Nederland, 2018)	Local and regional governments, energy companies and housing corporations (Netbeheer Nederland, 2018)	To aid in decision-making about the energy transition, Over Morgen asks three questions: where are we now? Where are we going? What are the opportunities? (Netbeheer Nederland, 2018).
PICO*	Geodan, TNO, Alliander, NRG301/Waifer, Ecofys, and Esri Nederland (Netbeheer Nederland, 2021b)	(Lower level) governments, network operators, property owners, housing corporations, residents' collectives and energy suppliers (Netbeheer Nederland, 2021b).	To accelerate the energy transition by providing insights into opportunities to make the energy supply of specific areas more sustainable (Netbeheer Nederland, 2021b).
Transform	Accenture, AIT, Macomi (Netbeheer Nederland, 2017).	Local policymakers (Netbeheer Nederland, 2017).	To support decision-makers in examining energy information to determine the most optimal and robust plans (Netbeheer Nederland, 2017).
Vesta Mais	PBL (Netbeheer Nederland, 2021d).	National and lower-level governments, energy companies and other organisations (Netbeheer Nederland, 2021d).	To explore the measures and options to reduce energy usage and carbon emissions up to 2050 (Netbeheer Nederland, 2021d).
DEGO	VNG (VNG, n.d.-b).	Local government (VNG, n.d.-b)	To support municipalities in their work with data in the heat transition (VNG, n.d.-b)

** **Note**: PICO has been terminated as a freely accessible service (PICO, n.d.) but is still included in the analysis as it still provides insights into the foundation of factors used in models and tools for the heat transition.*

3.1.2 Description of tools and models from academic practice

I also analysed models outside the Netherlands to broaden the perception of available indicators. Bouw et al. (2021) reviewed models used in the built environment on a local scale from international academic practice. Similarly, Krumm et al. (2022) examined energy models on integrating social aspects. I examined a selection of the models analysed by Bouw et al. (2021) and Krumm et al. (2022), focusing on the heat sector. In addition, I chose models that focus on simulation rather than optimisation as we still find ourselves in a relatively exploratory phase of the transition in the Netherlands. Table 3.2 provides an overview of the selected models alongside information about their developer, target group and objective. For these models and tools, I collected information on the indicators through a comprehensive overview of models in academic practice provided by Bouw et al. (2021) and complemented by Krumm et al. (2022).

Table 3.2 Overview of existing tools and models from academic practice with the corresponding developer, target group and objective that aid in decision-making about the energy transition

Model or tool	**Developer**	**Target group**	**Objective**
EnergyPLAN	Sustainable Energy Planning Research Group at Aalborg University, Denmark (Aalborg University, n.d.-b)	Primarily national governments, already used in multiple countries such as Germany, Denmark, and Ireland, but also for regional and local government (Lund et al., 2021)	Assist national energy planning strategies by analysing the energy, environmental, and economic impact of various energy strategies to compare a palette of options for the energy system (Aalborg University, n.d.-c; Lund et al., 2021)
TRNSYS	University of Wisconsin-Madison, U.S. (Bouw et al., 2021)	Not specified	The modular structured model is used for analysing single-project, local community systems (Bouw et al., 2021)
H2RES	Instituto Superior Técnico, Portugal; University of Zagreb, Kroatia (Bouw et al., 2021)	Not specified	Simulates the integration of renewable energy into energy systems, specifically to increase the integration of renewable sources into energy systems on islands (Connolly et al., 2010) and to minimise the yearly operation and simulation costs (Aalborg University, n.d.-a)

To analyse these models, Bouw et al. (2021) built a list of evaluation criteria to classify the various types of models. This list considers the built environment on a neighbourhood scale and examines building characteristics, the physical context surrounding buildings, social context and usability of the model. The researchers came up with the following list of ten characteristics: 1) energy potential, 2) energy demand, 3) end-user characteristics, 4) infrastructure and storage, 5) system costs and benefits, 6) energy-saving measures, 7) system boundaries, 8) output, 9) interface, and 10) flexibility of measures (Bouw et al., 2021).

As this list contains characteristics outside the scope of this research (e.g. user-friendliness of the model), I omitted some from the further in-depth analysis. The following five characteristics were excluded: energy potential, infrastructure and storage, system boundaries, interface and flexibility of measures, leaving us with energy demand, end-user characteristics, system costs and benefits, energy-saving measures and output as the remaining themes. These can be understood as follows:

- Energy demand: energy demand concerns demand patterns. More specifically, local energy models require more detailed demand data. Furthermore, assumptions about future developments of energy demand needs are required too (Bouw et al., 2021).
- End-user characteristics: end-user characteristics concern the social dimension of the transition. Social indicators such as the age, socioeconomic status, financial capacity, norms and value of residents determine the implementation success of the system (Bouw et al., 2021).
- System costs and benefits: system costs and benefits concern the total system costs. It is crucial to differentiate costs and benefits for different stakeholder groups on a smaller scale as it supports multi-stakeholder decision-making processes (Bouw et al., 2021).
- Energy-saving measures: Bouw et al. (2021) consider energy-saving measures. Related to the energy-saving measures are building characteristics. The building characteristics determine the technology options, and the exclusion of these characteristics leads to non-realistic outcomes, according to Bouw et al. (2021).
- Output: Finally, the output characteristic covers the purpose of implementing specific targets, e.g. $CO2$ emission or costs and benefits per stakeholder of the system as a whole (Bouw et al., 2021).

These characteristics are, in essence, similar to the layout used before. For instance, the characteristic "system costs and benefits" closely resembles an economic theme. Thus, I categorise the parameters (also known as indicators) found by Bouw et al. (2021) under system costs and benefits under economic indicators in subsection 1.3.2. Table 3.3 provides an overview of the classification of the characteristics established by Bouw et al. (2021) within the themes of this research.

Table 3.3 Overview of the classification of the characteristics by Bouw et al. (2021) within the themes of this research

Characteristic by Bouw et al. (2021)	**Theme**
Energy demand	Environmental
End-user characteristics	Social
System costs and benefits	Economic
Energy-saving measures	Technical
Output	Environmental, Economic

In the consecutive in-depth analysis, I extensively discuss the four themes and their corresponding indicators found in the models in Tables 3.2 and 3.3.

3.2 INDICATORS USED IN MODELS FOR ENERGY AND HEAT TRANSITION MODELS

This subsection describes the various technical (subsection 3.2.1), economic (subsection 3.2.2), environmental (subsection 3.2.3), and social indicators (subsection 3.2.4) included in the existing models specified in Tables 3.2 and 3.3.

3.2.1 Economic indicators

Research into models for the heat transition by Hoppe et al. (2016) revealed that most existing models often centre around energy's technical and economic dimensions. From a series of interviews with heat transition model developers executed by van Berkel (2019), she concludes that many experts acknowledge that economic factors are important in the models they develop or deploy (van Berkel, 2019). The emphasis on economic indicators also comes to light when examining the tools and models discussed in table 3.4: almost all models and tools considered use either one or multiple economic indicators.

Most of these indicators are costs related to the infrastructure, investment or operations, which are considered by models from both academic and professional practice (see table 3.4). Another curious observation from table 3.4 is that DEGO does not consider economic indicators. An underlying reason is that the intended use for the data is for open data application and does not contain any interpretation (VNG, n.d.-a). Where other models were intended for advisory purposes, the information provided in DEGO cannot be used instead of advice (VNG, n.d.-a).

Moreover, models consider more detailed economic indicators than "affordability", a reoccurring indicator in the TvWs. As municipalities base many of the conclusions of the TvWs on model calculations, it is not unlikely that these affordability indicators are an aggregation of various economic indicators considered in these professional practice models. Finally, table 3.4 also shows many other costs considered mainly by models from academic practice. These include fuel costs, building efficiency costs and electricity prices.

In the current heat transition, the "affordability" indicator that many Dutch municipalities consider manifests itself in the lowest national costs, based on PBL's Vesta Mais model. The lowest costs are calculated for every municipality neighbourhood, and the cost amount depends on the chosen strategy. As policymakers are expected to determine how to disconnect neighbourhoods from natural gas, the Vesta Mais model includes five strategies to move forward: 1) all homes and buildings are equipped with an individual electric heat pump, 2) all homes and buildings are connected to a new district heating grid that provides heat at medium temperature, 3) all homes and buildings are connected to a district heating grid that provides heat at low temperature, 4) all homes and buildings are heated with green gas (combined with electric heat pumps), and 5) all homes and buildings are heated with hydrogen through a modified natural gas grid (combined with hybrid heat pump) (PBL, n.d.). Thus upon deciding which strategy to implement, municipal policymakers can account for the costs. These strategies can differ for each neighbourhood.

Table 3.4 Overview of economic indicators considered in tools and models

Model or tool → Indicator ↓	Energy PLAN	TRNSYS *	H2RES	Cegoia	ETA**	PICO**	Transform	Vesta Mais	DEGO
Economic		■			■	■			
Infrastructural costs	■						■	■	
Investment costs	■		■	■			■	■	
(Financial) benefits								■	
Operation (and maintenance) costs	■		■	■					
Fuel costs	■								
Building efficiency costs	■								
Electricity price			■						

** **Note**: TRNSYS considers system costs but provides no details on these costs (Bouw et al., 2021).*

*****Note**: The description of Netbeheer Nederland states that PICO (Netbeheer Nederland, 2021b) and ETA (Netbeheer Nederland, 2018) have outputs that are financial indicators, but since they do not specify which economic indicators form the outputs; I marked the overall category.*

3.2.2 Technical indicators

Not only economic indicators are prominent in heat transition models, but technical indicators are also prominent (Hoppe et al., 2016) (see table 3.5). This phenomenon has not only been confirmed in this analysis but also model descriptions. For instance, the report on Vesta Mais states: *"Vesta MAIS is a technical-economic model that has been developed to gain insight into the possible transition paths of the heat supply in the built environment in the longer term."* (PBL, 2021).

Table 3.5 Overview of technical indicators considered in tools and models

Model or tool → Indicator ↓	Energy PLAN	TRNSYS*	H2RES	Cegoia	ETA	PICO	Transform	Vesta Mais	DEGO
Technical									
Energy label				■		■		■	■
Type of building/building features		■		■		■	■		■
Building density						■	■		
Renewable energy (share)			■		■		■	■	
Key register Addresses and Buildings (BAG)				■	■	■		■	
Energy consumption	■	■	■	■	■	■	■	■	■

** **Note**: The building features referred to are building efficiency (Bouw et al., 2021)*

3.2.3 Environmental indicators

Environmental indicators are also common in models as the transition needs to be sustainable. Table 3.6 provides an overview of the environmental indicators considered in tools and models. Even though one of the interviewees in van Berkel's research argued that CO2 emission reduction needs to be considered the most important as it is the reason for this fundamental systemic change (van Berkel, 2019), not all models consider CO2 emissions.

Table 3.6 Overview of environmental indicators considered in the tools and models

Model or tool → Indicator ↓	**Energy PLAN**	**TRNSYS**	**H2RES**	**Cegoia**	**ETA**	**PICO**	**Transform**	**Vesta Mais**	**DEGO**
Environmental									
CO2 emissions									
Energy balance/ energy load									

3.2.4 Social indicators

Some models include the social dimension of the heat transition, which table 3.7 exhibits. Interestingly, some models do not consider social indicators or consider them secondary. For instance, the user manual for the CEGOIA model states: "*If the costs of different techniques are relatively close to each other, the differences fall within the uncertainty margin. In such a case, other reasons, such as social or political considerations, may be decisive. If the costs are relatively far apart, a neighbourhood clearly prefers a technique from a cost point of view.*" (Meyer & van de Poll, 2021).

Furthermore, the social indicator remains vague in some models, e.g. PBL's Vesta Mais. The description simply states the inclusion of socioeconomic characteristics but does not detail the exact indicator. Finally, some models consider indicators such as employment through discussing the model output (Krumm et al., 2022).

In the research by van Berkel (2019), one of the experts mentions that potential social and political factors to include are the sustainability ambitions of a municipality, the presence of local sustainability initiatives, or voting behaviour. Another expert mentioned (the CEGOIA model) incorporating employment and affordability – measured by a neighbourhood's mean house value to the household income into future models. If data are available, these indicators are also interesting to consider.

Another interesting finding is that the lack of social indicators adopted for the Dutch heat transition is not uncommon in international energy transition models. Bouw et al. (2021) find that none of the three selected models used in academic practice includes social indicators (in Bouw et al. (2021), referred to as end-user characteristics). However, Krumm et al. (2022) find that EnergyPLAN does include some social indicators to predict energy demand patterns. It seems that there is no consensus on the definition of social indicators. This study adheres to the previously defined social aspects to manage this issue: "*social aspects are defined as aspects that concern the people, their transactions, and relationships within the energy system (adopted from: (Krumm et al., 2022))*". Additionally, the expert interviews are used to validate the use of social indicators.

Table 3.7 Overview of social indicators considered in the tools and models

Model or tool → Indicator ↓	Energy PLAN	TRNSYS	H2RES	Cegoia	ETA	PICO	Transform	Vesta Mais	DEGO
Social									
Socioeconomic characteristics (e.g. income, household size)									
Low income, high gas use									
Employment									

3.3 Other potential social factors

Outside existing academic and professional models and tools, other literature and projects provide insights into potential social indicators to consider in consecutive research steps. An interesting source of potential social indicators is the project Miranda by Statistics Netherlands and the Dutch research institute TNO. Both parties joined to research citizens' willingness to contribute to the energy transition in this research. Based on various existing surveys (e.g. belevingenonderzoek 2020, het WoON onderzoek 2018), Dutch demographic characteristics (e.g. income, gender, age, level of education), property characteristics and energy consumption, Statistics Netherlands and TNO determined the willingness to contribute to the Dutch energy transition. This willingness to contribute manifested itself into two different factors: 1) the willingness of an individual to make their home more sustainable, provided that they recoup their investment, and 2) an individual has no intention/does not know how to/considers it too expensive/has not had the opportunity to invest in a more sustainable home yet. These form interesting social factors to consider for the transition.

3.4 Relevant indicators for heat transition decision-making processes

This subsection provides an overview of the relevant indicators for decision-making processes based on previous research on indicators (see Appendix D for a complete overview) and two expert interviews. The interviews showed that four technical, two economic and five social indicators remained. These are outlined below and described in more detail. Subsection 3.4.1 defines the techno-economic indicators, and subsection 3.4.2 delineates the social indicators.

3.4.1 Selected techno-economic indicators

The interviewed experts considered several technical and economic indicators relevant to the experiment. These are listed and additional comments (if necessary) below:

- Year of construction of the built environment (expert 1).
- Energy consumption (experts 1 and 2).
- Type of buildings (experts 1 and 2).
- The energy label of the built environment (expert 2). An energy label depicts a home's energy efficiency (Rijksoverheid, n.d.-a).
- National costs/lowest costs (experts 1 and 2).
- Income and savings of people (expert 2).

3.4.2 Selected social indicators

As defined earlier, social indicators concern the people, their transactions, and relationships within the energy system. Within the study, two categories of social indicators are considered: public support and energy justice. The interviewed experts considered several social indicators relevant to the experiment. These are defined below:

- The willingness of an individual to make their home more sustainable provided that they recoup their investment (expert 1). This indicator is a social indicator as it concerns people's transactions within the energy system and is considered within the category of public support. This indicator is interpreted as an indicator of public support.
- An individual has no intention/does not know how to/considers it too expensive/has not had the opportunity to invest in a more sustainable home yet (expert 1). This indicator is a social indicator as it concerns people's transactions within the energy system and is considered within the category of public support.
- Distribution rental, owner-occupied residencies, and people's savings (expert 1). This is a social indicator concerning people's transactions within the energy system.
- Energy poverty indicator (expert 1). According to expert 1, there are two indicators to do with energy poverty provided by the VNG: 1) the share of households with a high energy quota (8% or more of their income is spent on energy), and 2) there is the share of households with a low-income (lowest 25%) and high gas consumption (highest 50%). (S)he states that the latter indicator is most robust in light of the recent rising gas prices. Therefore the latter indicator is considered the energy poverty indicator. This indicator is a social indicator as it concerns people's transactions within the energy system and is considered within the category of energy justice and, more specifically, distributional justice. This indicator is interpreted as an indicator of energy poverty.
- Sustainable neighbourhood initiatives (expert 2). More specifically, the presence of more sustainable neighbourhood initiatives will result in a positive impact (and therefore more social(ly responsible) decisions) as Greening and Bernow (2004) find that the active involvement of stakeholders in decision-making processes will increase their confidence in the outcome. This indicator is a social indicator as it concerns people's relationships within the energy system and is considered within the category of energy justice and, more specifically, procedural justice. This indicator is interpreted as an indicator of public participation.

3.5 SYNTHESIS INDICATORS

This section aimed to answer the first sub-research question: *"What are the relevant techno-economic and social indicators to consider for decision-making about the heat transition?"*. To answer this question, I analysed models and tools used in both Dutch professional practice for the heat transition as well as international academic models for the energy transition. From the model analysis, I conclude a pattern within all models used for heat transition decision-making: a dominant techno-economic approach. Not only models from Dutch professional practice lack social indicators, but this is also standard practice observed in international academic models. I included additional research into social factors to compensate for the lack of social indicators.

Along with all previous indicators identified in the models, these were considered. This comprehensive list of indicators was then presented to a group of experts, who established a ranking to identify the most relevant indicators for consecutive research steps. These indicators included: four technical, two economic and five social indicators.

4. EXPERIMENTAL SETUP AND PROCEDURE

This section describes the data collection procedure and experimental setup. In this section, I aim to answer the second subquestion: “*How can the technical, economic and social indicators be effectively operationalised and included in information provision?*”. Firstly, subsection 4.1 details the data collection procedure. Subsequently, subsection 4.2 explains the operationalisation of the experiment, which involves operationalising and combining indicators to construct scenarios. Subsection 4.2 also specifies the survey experiment. Finally, subsection 4.3 synthesises this section and aims to provide an answer to subquestion 2.

4.1 DATA COLLECTION

This study collected data by distributing the survey experiment through two different channels. Firstly, through the mailing list consisting of e-mail addresses from policymakers mentioned in the colophon of the TVWs. The mailing list included 114 e-mails, of which 107 were for the survey and seven requesting an interview. Secondly, I created a post on LinkedIn to collect survey responses. In the week of July 29th, I sent out a reminder. The survey was open for four weeks, from July 11th 2022, to August 9th 2022, collecting 65 responses. Of these 65 responses, 42 completed the survey, of which 39 were policymakers and three non-policymakers. A 66% completion rate suggests that the survey may have been too long.

4.2 EXPERIMENT OPERATIONALISATION

This subsection dives into the operationalisation of the experiment. Before setting up the experiment, subsection 4.1.1 discusses various choices and justifications for indicator operationalisation. Hereafter, subsection 4.1.2 details the experiment by choosing a few indicators to reduce the complexity and constructing scenarios for the experiment. Finally, subsection 4.1.3 provides an overview of the survey experiment.

4.2.1 Indicator operationalisation

Through their exploratory study into energy models in practice, Amer et al. (2020) found that municipalities work with modelling results rather than models themselves, implying that 2D geospatial representation, otherwise known as choropleth maps, should suffice for the output visualisation. According to Slocum & Egberts (1993), choropleth maps can be used to present lower aggregate levels (municipal data), which allows policymakers to analyse disparities between neighbourhoods (Wolffenbuttel, 2020). VNG’s DEGO exemplifies such data representation in the current municipal decision-making process for the heat transition (see figure 4.1). DEGO visualises the necessary data for the heat transition in the form of maps, which can be downloaded for each municipality.

Figure 4.1 Screenshot example of choropleth use in current heat transition decision-making, exemplified through the year of construction indicator displayed for neighbourhoods of The Hague. (Source: VNG (n.d.))

Geo-spatial data constitute two components: 1) descriptive content in the form of attributes that characterise a specific spatial entity, and 2) a spatial component displayed through coordinates (Juergens, 2020b). Concerning figure 4.1, component one, the attribute refers to the year of construction, whereas component two ensures the proper display of the component by connecting the coordinates to the attribute. If one distinguishes geospatial data based on source and nature, then two kinds of data models of the rest world can be identified: raster and vector data models (Juergens, 2020a; Pászto et al., 2020). Where vector data represents real-world data through polygons, points or lines, raster data uses several raster cells to represent these objects. Due to the experiment's decision variable (ranking neighbourhoods), this research uses vector data to display neighbourhoods using polygons.

As the policymakers rank five neighbourhoods based on two to three maps, the maps must have the same projection. This way, there will not be any misinterpretations due to distortion errors due to different projections (Juergens, 2020a). For this reason, I display the same maps in every decision situation. This similarity is demonstrated in figure 4.9, where all three maps display the same area and are the same size.

Then, there is the classification method of choropleth maps. For choropleth maps, many options influence the resulting choropleth (Kraak & Ormeling, 2020), such as the number of classes, the class limits and the colour scheme (Brewer, 2005). However, as the neighbourhood scale allows for a specific value, there is no need to consider different classes. Schiewe (2019) argues that it is essential to create choropleths so that an effective and intuitive comparison of colour values between different regions is possible. Subsection 4.2.2.1 underlines the reasoning behind every indicator's colour scheme, of which figure 4.2 (right) depicts an example.

The chosen neighbourhoods were purposely nested in a different setting, which means that the neighbourhoods depicted in the experiment were regions outside of the Dutch context, while most data were tailored to neighbourhoods in The Hague. This context aids in avoiding confirmation bias. Confirmation bias is when information that supports what we already believe is given excessive weight (Cairney & Kwiatkowski, 2017). For example, I took the data on energy consumption of specific neighbourhoods in The Hague and plotted the data on an empty map (see figure 4.2). On the left figure in figure 4.2, I displayed the energy consumption in the city of The Hague for five neighbourhoods. Each neighbourhood is then projected onto a different and unfamiliar map on the right. From figure 4.2, it is possible to observe that the neighbourhoods align, e.g. neighbourhood C is the neighbourhood with the highest consumption in both figures.

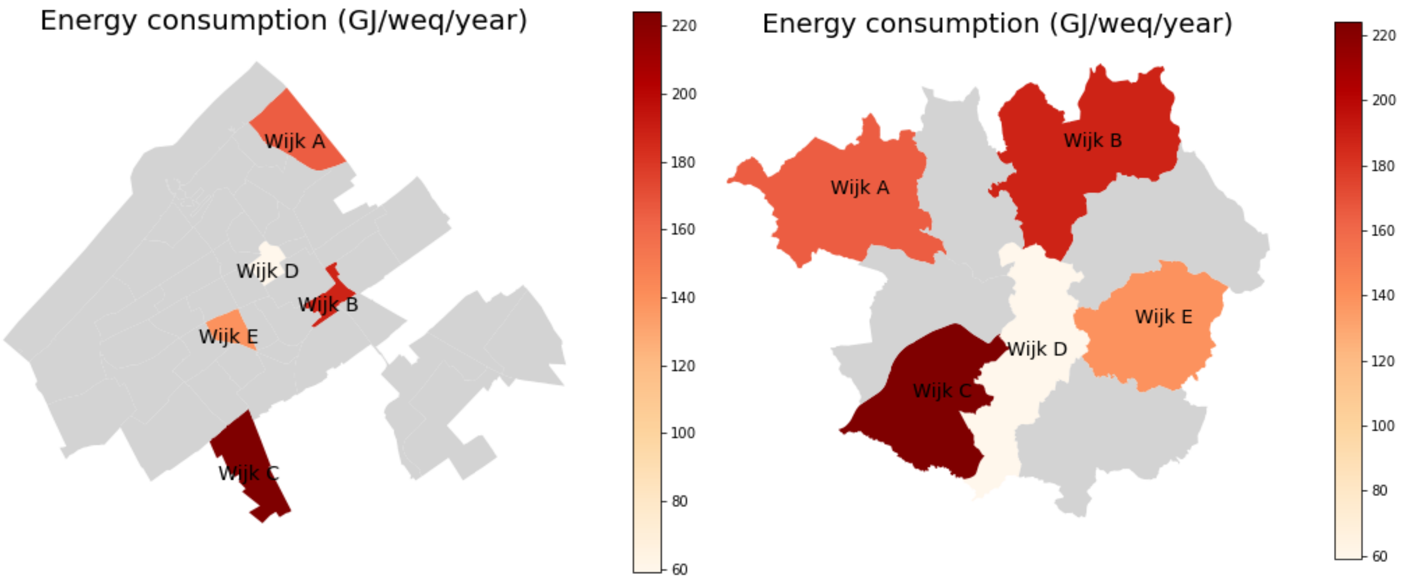


Figure 4.2 Energy consumption in The Hague (left) projected on a different, unfamiliar map (right)

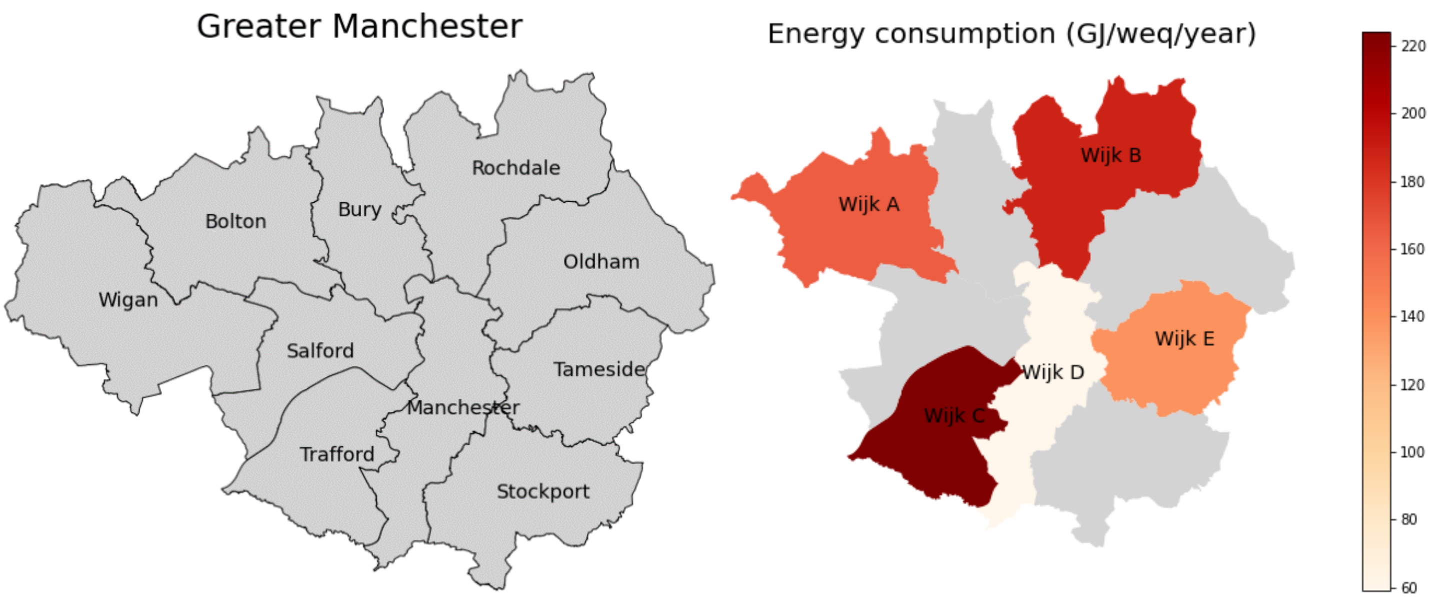


Figure 4.3 Empty map of Local UK Authority District Greater Manchester (left) that has been modified and filled with energy consumption data in five neighbourhoods (right).

These different and unfamiliar maps are of various Local Authority Districts of the United Kingdom (Office for National Statistics, 2022). On the left, figure 4.3 depicts the district of Greater

Manchester, on which the energy consumption data of The Hague is projected (see the right figure in figure 4.3). For example, the energy consumption data of neighbourhood A is depicted in the Bolton area of Greater Manchester. Since Dutch policymakers are likely unfamiliar with these districts, this new context allows for avoiding their bias about The Hague's neighbourhoods.

4.2.2 Scenarios

This subsection highlights the pathway to the construction of the scenarios. Subsection 4.2.2.1 underlines the indicator and data choices that lay the foundation of the experiment, whereafter, subsection 4.2.2.2 details which indicators are combined to construct scenarios. Finally, subsection 4.2.2.3 provides insights into the neighbourhood choices.

4.2.2.1 Indicator and data choices

As became clear from section 3, several technical, economic and social indicators were relevant to consider for the experiment. Juergens (2020b) argues that real-world object representation needs some form of simplification to reduce the natural world's complexity. Therefore, a selection of the used indicators is depicted in table 4.1. I selected the final indicators based on three requirements:

1. Data availability and quantifiability.
2. Concise synthesis of information. Although human beings are natural informavores (Huynh et al., 2007; Saxena & Lamest, 2018), it is only possible to process and comprehend small doses of information at a time (Mahdi et al., 2020). Similarly, Cairney and Kwiatkowski (2017) argue that it is crucial not to bombard policymakers with information. Providing them with a concise synthesis of information minimizes their cognitive burden.
3. For social indicators: the indicators need to relate to people, their transactions, and relationships within the energy system.

Table 4.1 Indicators and their corresponding data sources.

Theme	Indicator	Unit	Data source
Technical	Energy consumption	Gigajoule / weq* / year	(PBL, 2020a)
	Energy label	%	(PBL, 2020a)
	Year of construction	%	(PBL, 2020a)
Economic	Costs	€ / ton CO_2 reduction	(PBL, 2020a)
Social	Public support (The willingness of an individual to make their home more sustainable provided that they recoup their investment)	-**	(Statistics Netherlands, 2022)
	Energy poverty (Share of low-income households with high gas consumption)	%	(Statistics Netherlands, 2021)
	Public participation (Share of households members of a sustainable neighbourhood initiative)	%	-***

** Residential equivalent (weq): one weq equals 130m² of floor area of a commercial building in the utility sector. This measure allows meaningful examination of residential and commercial buildings.*
*** For the public support indicator, there is no unit. This variable is measured in high, medium and low.*
**** For this indicator, no data sources were available; however, as a sustainable neighbourhood initiative is an essential social indicator for public participation and no data were available on the public participation indicator, these have been fabricated to examine the effects of inclusion in decision-making information.*

After I collected the data on the selected indicators, I retrieved these for the municipality of The Hague specifically. Two folders with csv files and two excel files were loaded into a Jupyter Notebook, an open-source web application to develop Python notebooks, code, and data (Jupyter, n.d.). These files were cleaned and made practical for the following steps. Links to these files can be found in the Jupyter Notebook, uploaded to the repository. Finally, I plotted these cleaned data on maps of Local Authority Districts of the United Kingdom (Office for National Statistics, 2022).

4.2.2.1.1 Technical and economic data

The folders maps with csv-files retrieved from PBL (2020a) contained the indicators for every neighbourhood (buurt) in table 4.1. The first folder includes information on the built environment in The Hague; the other one contains information on the heat transition strategy for The Hague's neighbourhoods (see links in Jupyter Notebook). The data and data cleaning process of these techno-economic indicators is described below.

Energy consumption

PBL uses the energy consumption of the year 2019. PBL differentiates between various forms of energy consumption: space heating, hot water, ventilation, cooling, and appliances and light (PBL, 2020a). These various forms have been aggregated for this research, and I considered the total energy consumption. Finally, the data were aggregated for higher scale neighbourhoods, so-called Dutch wijken, instead of buurten, primarily because decisions about the heat transition concern wijken. According to Broto and Baker (2018), choropleth maps are the favoured maps to depict energy consumption with pre-given administrative units. Brewer et al. (1997) found that people prefer colour maps over monochrome maps. In light of these colour maps, Harrower and Brewer (2003) state that sequential colour schemes imply order and best correspond to representing data that ranges from low-to-high values on an ordinal scale or numerical scale. Therefore, figure 4.4 depicts the energy consumption on a coloured choropleth with a sequential colour scheme.

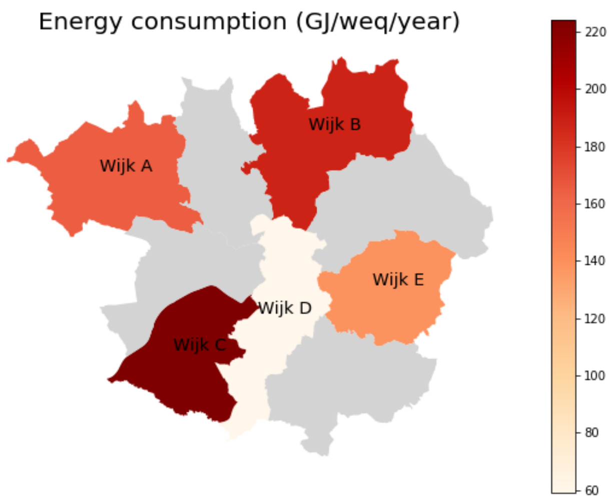


Figure 4.4 Energy consumption exemplified

Energy label

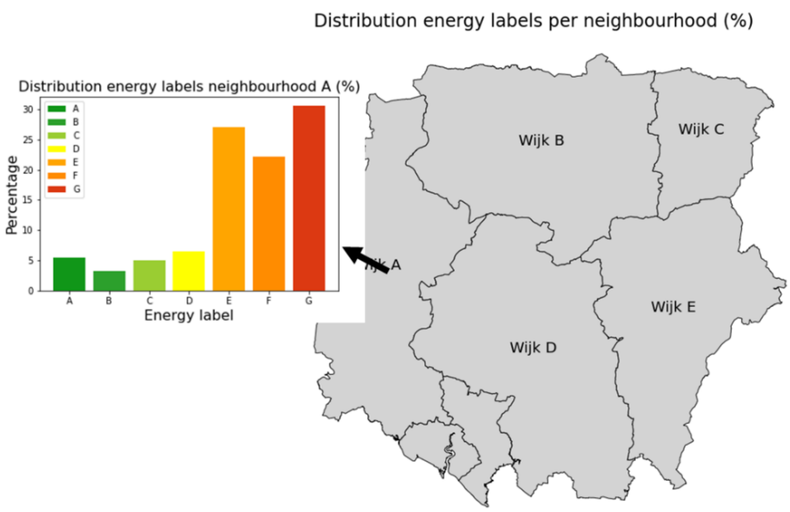


Figure 4.5 Energy label exemplified

In the csv files, PBL included information on the energy labels of residential buildings (PBL, 2020a). These labels are categorised into seven levels: A, B, C, D, E, F, and G (from best to worst). The data were aggregated for higher scale neighbourhoods, so-called Dutch wijken, instead of buurten, primarily because decisions about the heat transition concern wijken.

Energy labels were depicted in a bar chart as energy labels are a categorical variable and each neighbourhood had a different distribution. In figure 4.5, the bars have the same colour scheme as the typical energy labels to increase the participants' intuitiveness. Figure 4.5 depicts the distribution of energy labels for one neighbourhood.

Year of construction

In the csv files, PBL included the year of construction of residential buildings (PBL, 2020a). PBL distinguished between seven categories of buildings: before 1930, 1930-1945, 1946-1964, 1965-1974, 1975-1990, 1990-2005, and 2005-2109. Since the year of construction is a categorical variable, and each neighbourhood has a different distribution, I depicted this indicator with a bar chart. The data were aggregated for higher scale neighbourhoods, so-called Dutch wijken, instead of buurten, primarily because decisions about the heat transition concern wijken. Figure 4.6 depicts the distribution of the year of construction for one neighbourhood.

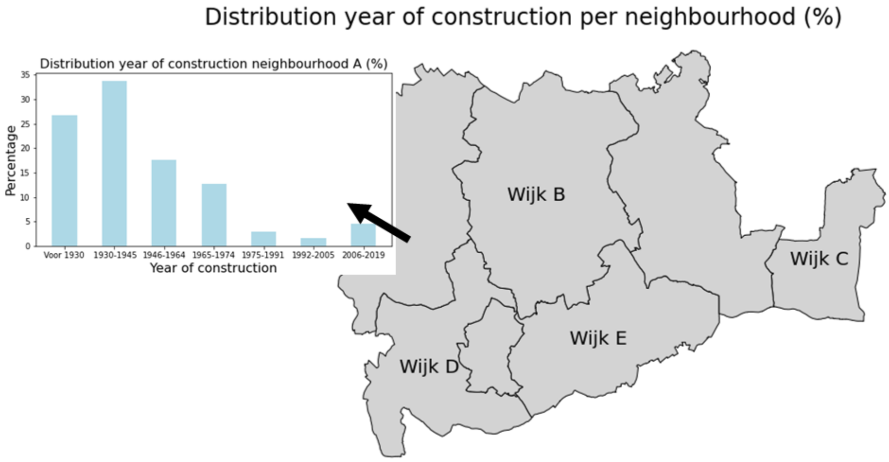


Figure 4.6 Year of construction exemplified

Costs

In terms of the costs, this research uses PBL's strategic analysis, which examined which strategy led to what costs in various neighbourhoods. In this calculation, the costs are those required to implement measures of a specific strategy in 2030 compared to the baseline scenario, regardless of who pays for those costs (PBL, 2020a). PBL uses five strategies, and in this research, PBL establishes the costs by considering the lowest costs of all five strategies for each neighbourhood.

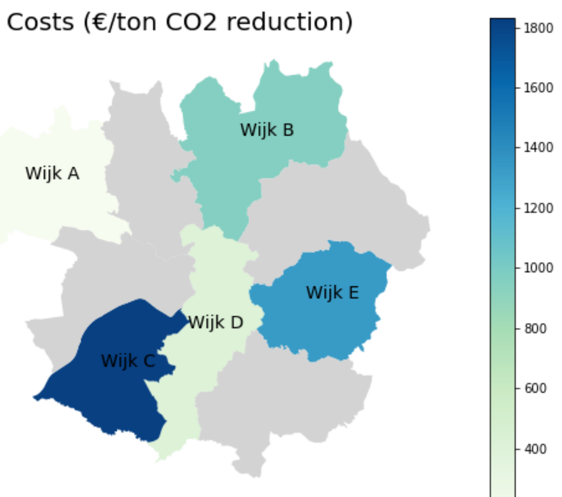


Figure 4.7 Costs exemplified

In establishing the costs, there were two options: 1) total extra costs in 2030 or 2) costs per ton reduction of CO2 (PBL, 2020a). The latter alternative was preferred as it provides insights into the costs and how cost-efficient a strategy is in a neighbourhood. Figure 4.7 depicts the costs with a coloured choropleth with a sequential colour scheme, as 1) research by Brewer et al. (1997) find that people prefer colour maps over monochrome maps, and 2) Harrower and Brewer (2003) state that sequential colour schemes imply order and best correspond representing data that ranges from low-to-high values on an ordinal scale or numerical scale.

4.2.2.1.2 Social data

I retrieved the excel files from Statistics Netherlands (2021, 2022). The first excel file includes information on energy poverty, while the other contains information on public support (see links in the Jupyter Notebook). The following section describes these social indicators' data and the data cleaning process.

The expert interviews in the heat transition made it evident that public participation is a relevant social indicator. More specifically, the presence of more sustainable neighbourhood initiatives will result in a positive impact (and therefore more social(ly responsible) decisions) as Greening and Bernow (2004) find that the active involvement of stakeholders in decision-making processes will increase their confidence in the outcome. However, as several Dutch neighbourhoods already had sustainable neighbourhood initiatives, adding this indicator would not have additional value as it does not differentiate the neighbourhoods. To provide more insights into the effects of participation as a social indicator, I generated fictitious data about public participation (the share of households that are members of a sustainable neighbourhood initiative).

Energy poverty

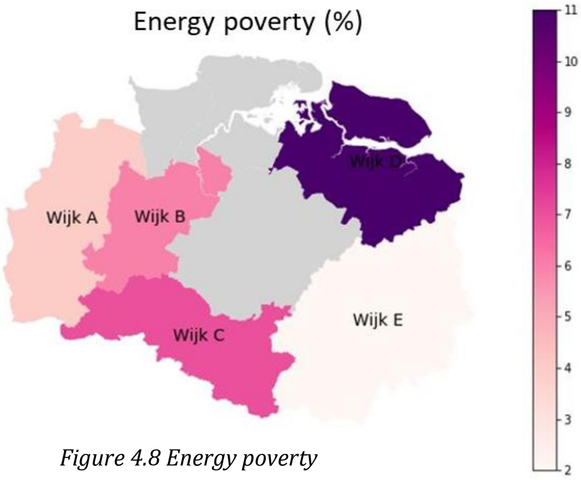


Figure 4.8 Energy poverty

In the excel file, Statistics Netherlands considered the share of households with a low income (lowest 25%) and high gas consumption (highest 50%) or energy poverty. Brewer et al. (1997) find that people prefer colour maps over monochrome maps. Figure 4.8 depicts the energy poverty indicator on a coloured choropleth with a sequential colour scheme. This is because 1) research by Brewer et al. (1997) find that people prefer colour maps over monochrome maps, and 2) Harrower and Brewer (2003) state that sequential colour schemes imply order and best correspond to representing data that ranges from low-to-high values on an ordinal scale or numerical scale.

Public support

Statistics Netherlands categorised the public support indicator into low, medium and high. The data were selected on a neighbourhood level. Brewer et al. (1997) find that people prefer colour maps over monochrome maps. Additionally, Harrower and Brewer (2003) state that, in terms of colour schemes, sequential colour schemes imply order and best correspond to representing data that ranges from low-to-high values on an ordinal scale or numerical scale. Usually, light colours represent low data values, and the darker ones equal more. Thus, in figure 4.9, the public support is plotted on a coloured choropleth with a sequential colour scheme.

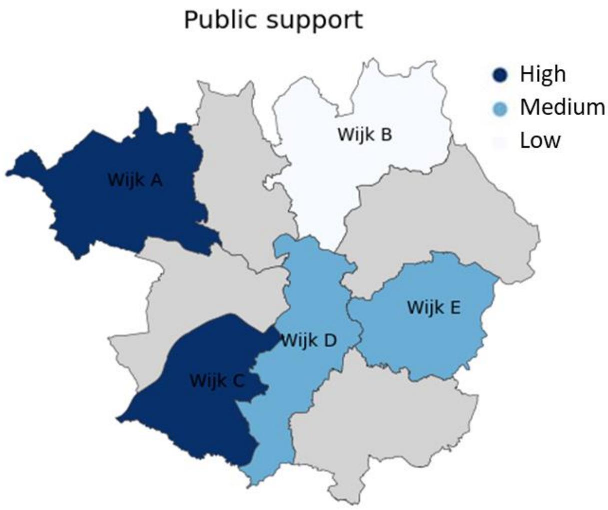


Figure 4.9 Public support

4.2.2.2 Scenario set-up

Various combinations of technical, economic and social indicators were constructed to set up the experiment, referred to as scenarios in table 4.2. In the experiment, there are two groups: group A receives only technical and economic information, and group B receives technical, economic, and social information. I display the information by plotting the indicators on choropleths. Figure 4.10 and 4.11 exemplify scenario 1 for groups A and B.

In setting up the scenarios, the decision variable was the starting point. It is ensured that every scenario includes a technical, economic and social indicator to support the decision-making process. In each scenario, combinations of indicators that provide insights into interesting trade-offs are considered. Table 4.2 depicts the scenarios and corresponding hypotheses. As mentioned in section 2, this research takes on a 1x2 between-subjects design, which means this design includes one independent variable of two levels (the inclusion or exclusion of social information). Essentially, there are four different 1x2 designs depicted in table 4.2. The following sections describe the trade-offs and the reasoning behind the constructed scenarios in table 4.2.

4.2.2.2.1 Scenario 1: Energy consumption, costs and public support

Scenario 1 refers to the indicator combination of energy consumption, costs, and public support. These specific indicators are combined to examine the effects of including an indicator that indicates public support when the participant has information about the energy consumption of the residents and the costs of CO2 reduction. For instance, how will the participant trade-off a low level of public support against a relatively cost-efficient transition in a neighbourhood with high energy consumption?

4.2.2.2.2 Scenario 2: Energy consumption, costs and energy poverty

Scenario 2 refers to the indicator combination of energy consumption, costs, and energy poverty. These specific indicators are combined to examine the effects of including an indicator that indicates energy poverty when the participant has information about the energy consumption of the residents and the costs of CO2 reduction. For instance, how will the participant trade-off a high share of energy poverty against a relatively costly transition in a neighbourhood with low energy consumption?

4.2.2.2.3 Scenario 3: Energy label, costs and public support

Scenario 3 refers to the indicator combination of energy labels, costs, and public support. These specific indicators are combined to examine the effects of including an indicator that indicates public support when the participant has information about the energy labels in a neighbourhood and the costs of CO2 reduction. For instance, how will the participant trade-off a low level of public support against a relatively cost-efficient transition in a neighbourhood with a high share of bad labels?

4.2.2.2.4 Scenario 4: Year of construction, costs and public participation

Scenario 4 refers to the indicator combination of the year of construction, costs, and public participation. These specific indicators are combined to examine the effects of including an indicator that indicates participation when the participant has information about the year of construction of the homes in a neighbourhood and the costs of CO2 reduction. For instance, how will the participant trade off a low share of public participation against a relatively cost-efficient transition in a neighbourhood with a high share of old houses?

Table 4.2 Scenarios and their indicator combinations for the two experimental groups

	Experimental group			
	Group A: technical and economic information		**Group B: technical, economic and social information**	
Scenario	**Technical indicator**	**Economic indicator**	**Social indicator**	**Hypothesis**
1	Energy consumption	Costs	Public support	Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.
2	Energy consumption	Costs	Energy poverty	Neighbourhoods with higher (/lower) shares of energy poverty obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.
3	Energy label	Costs	Public support	Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy labels and costs.
4	Year of construction	Costs	Public participation	Neighbourhoods with higher (/lower) shares of public participation obtain a higher (/lower) priority in decision-making when this information is added to the existing information about the year of construction and costs.

4.2.2.3 Neighbourhood choices

The final step in operationalising the techno-economic and social indicators, and therefore the experiment, is the neighbourhood choices. The neighbourhoods are selected based on the following requirements:

1. Data availability and neighbourhood characteristics. Fewer data were available for some of The Hague's neighbourhoods, leading to exclusion from the experiment. For scenarios 3 and 4, this condition is especially relevant. Some of the neighbourhoods had fewer residential buildings (or less available data) and consequently had less available data on energy labels and year of construction. Thus, neighbourhoods in scenarios 3 and 4 have available data (labels and year of construction) within a similar range.
2. The contrast between the indicators. For group A (see figure 4.10), neighbourhood C has the highest energy consumption, making it the most attractive to prioritise. Simultaneously, neighbourhood C has the highest costs to reduce one ton of CO_2, making it the least attractive to prioritise. Additionally, figure 4.11 depicts that the residents of neighbourhood C are highly willing to make their homes more sustainable, making this a favourite neighbourhood to start in. However, while neighbourhood C shows high public support, it also accompanies high costs. This contrast forces participants to make trade-

offs about the indicators, which remains challenging when designing energy policies (Costa-Campi et al., 2017).

3. Every scenario includes a relatively easy option. For group A (see figure 4.10), neighbourhood A has a relatively high energy consumption whilst having the lowest costs. Furthermore, for group B (see figure 4.11), neighbourhood A also seems to be an attractive option as the residents are highly willing to make their homes more sustainable. This requirement is established to aid participants in easing into the decision.

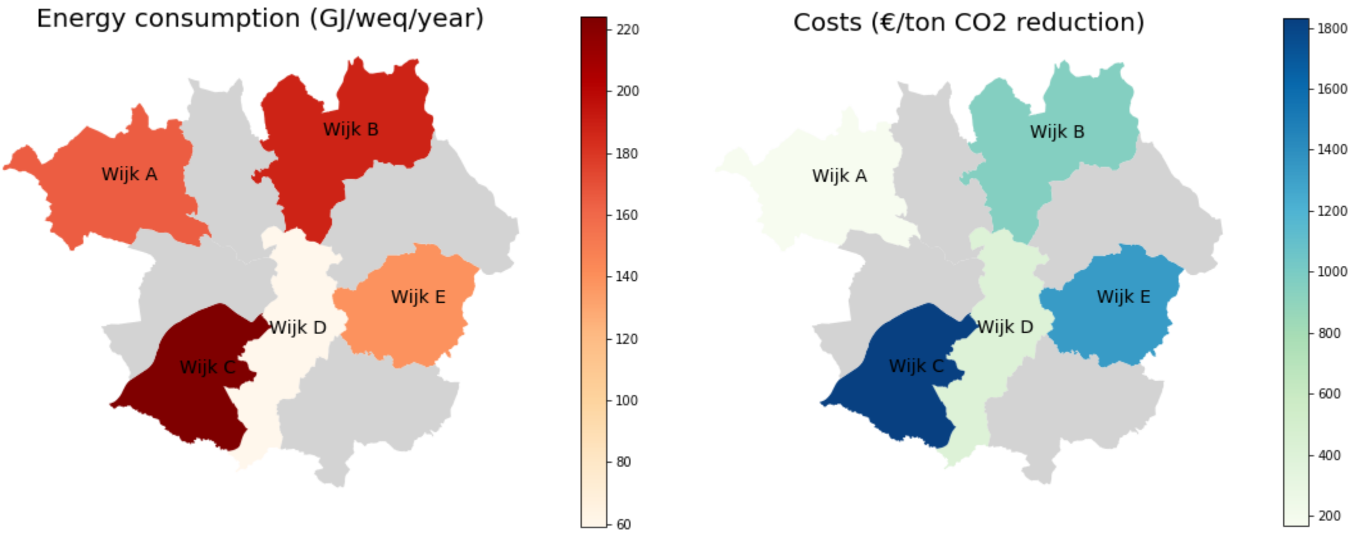


Figure 4.10 Depiction of scenario 1 for group A with only technical and economic indicators (left shows the energy consumption; right shows the costs)

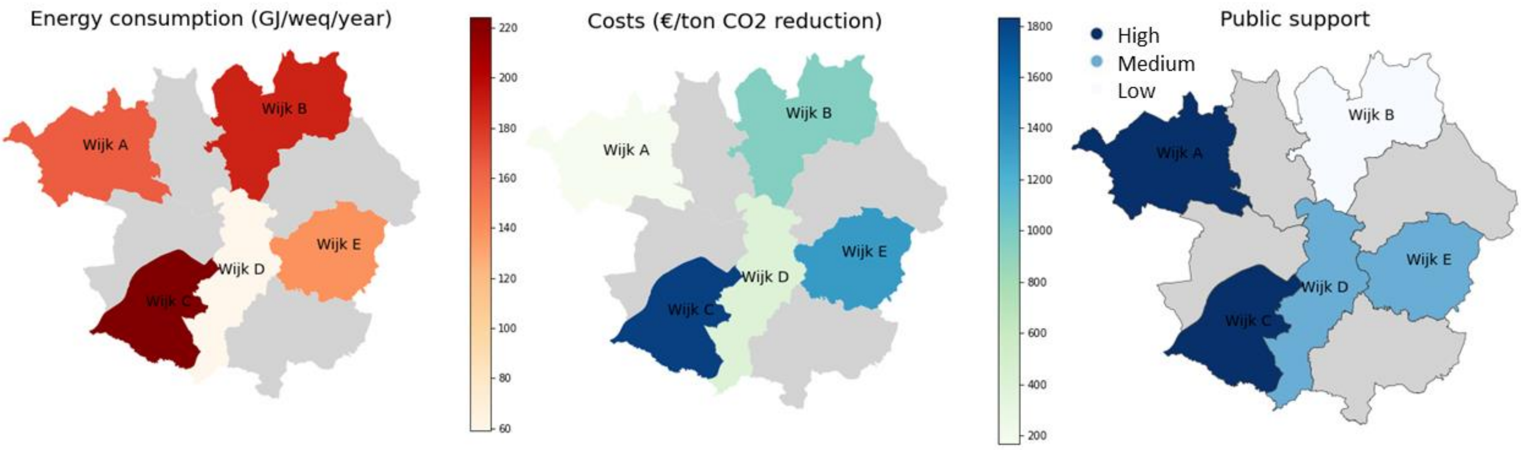


Figure 4.11 Depiction of scenario 1 for group B with technical, economic and social indicators (left shows the energy consumption; centre shows the costs; right shows the public support)

4.2.3 Survey experiment

The experiment was included in an online survey experiment and implemented in Qualtrics (see Appendix E for the detailed survey experiment). Participants first received some general information about the experiment, whereafter, several questions followed about the participants. These questions provide insights into the survey participants – whether they work for municipalities or are involved in the heat transition.

Hereafter the experiment followed, and all participants read the following story problem:

"Imagine the following: You are the head of the department in your municipality responsible for the heat transition. Your decision is final. In the first phase of the heat transition, five neighbourhoods have been selected to be the first to be disconnected from natural gas. For the next phase of the transition, the municipality will determine the order in which this will happen. In the next section, you will receive information about these five neighbourhoods. We ask you to determine the order based on this information."

When filling out the survey, Qualtrics allocated the participants to either one of two experimental conditions. If a participant was presented with question block A containing three scenarios, then he or she belonged to experiment group A. Figure 4.8 depicts an example of a scenario in block A. If Qualtrics presented a participant with question block B containing four scenarios, then he or she belonged to experiment group B. Figure 4.9 depicts an example of a scenario in block B.

Finally, the survey presented the participants with exit questions to provide insights into their thoughts and confidence of the participants in the decisions they made. An example of an exit question includes: "*To what extent do you consider your decision socially responsible?*". By altering between the choropleths and questions, the aim is to alleviate cognitive load (Mayer, 2002; Mayer & Moreno, 2003).

4.3 SYNTHESIS EXPERIMENTAL SETUP

This subsection synthesises this section and aims to answer the following sub-research question: *"How can the technical, economic and social indicators be effectively operationalised and included in information provision?".*

First, this section examined how the indicators can be displayed. Researchers found that municipalities work with modelling results rather than models themselves (Amer et al., 2020), implying that choropleths should suffice to visualise the indicators. A small number of indicators were used to alleviate policymakers' cognitive load. Additionally, the cognitive load has been diminished through the concise synthesis of the information provided. As for the choropleths, these were coloured and deployed a sequential colour scheme, as sequential colour schemes imply order and best correspond to representing data that ranges from low-to-high values on an ordinal scale or numerical scale. Additionally, the choropleths are displayed at the same size in every decision situation to avoid confusion caused by distortion errors resulting from various projections. Finally, the indicators are nested in maps of various Local Authority Districts of the United Kingdom to prevent confirmation bias that policymakers might have towards Dutch neighbourhoods.

Finally, to build a sturdy foundation for the survey experiment, scenarios and neighbourhoods are selected based on enlarging contrasting characteristics to force policymakers to make trade-offs within the experiment. The experiment takes on four times 1x2 between-subjects design, testing four hypotheses in the subsequent section to measure the effects of combining techno-economic and social information. The four scenarios are:

1. Scenario 1: Energy consumption, costs and public support
2. Scenario 2: Energy consumption, costs and energy poverty
3. Scenario 3: Energy label, costs and public support
4. Scenario 4: Year of construction, costs and public participation

5. RESULTS

This section describes the results following the experiment and the interviews with the policymakers. In this section, I aim to answer the third subquestion: "*What are the effects of combining technical, economic and social information on the social responsibility of policymakers' decisions in the heat transition, and how are trade-offs made?*". Firstly, subsection 5.1 details the exploratory data analysis in which I provide an initial picture of the collected data. Subsequently, subsection 5.2 analyses the effects of the inclusion of social information using a Mann-Whitney U test. Finally, subsection 5.3 aims to provide an answer to subquestion 3. Appendix H includes a description of all results. The data from the experiment can be found through 4TU.ResearchData.

5.1 EXPLORATORY DATA ANALYSIS: INITIAL PICTURE

Subsection 5.1 aims to provide an initial picture of the collected data by producing general descriptives in subsection 5.1.1, whereafter subsection 5.1.2 provides additional descriptives on the rankings. Finally, subsection 5.1.3 presents the descriptives of the exit questions.

5.1.1 General descriptives

The survey collected 65 responses, of which 42 were completed. Of these 42 participants, there were 39 Dutch municipal policymakers, of which Qualtrics assigned 21 to group A and 18 to group B. 37 out of 39 participants have worked/currently works in the Dutch heat transition.

Figure 5.1 (left) depicts a bar plot of provinces in which the municipalities of the participants are situated. The sample represents seven out of 12 provinces, ranging from two municipalities in the province of Limburg to ten municipalities in the province of Zuid-Holland. Figure 5.1 (right) also depicts a bar plot of the participants' professional experience duration. From the figure, it is possible to conclude that most participants had two to four years of experience as a policymaker.

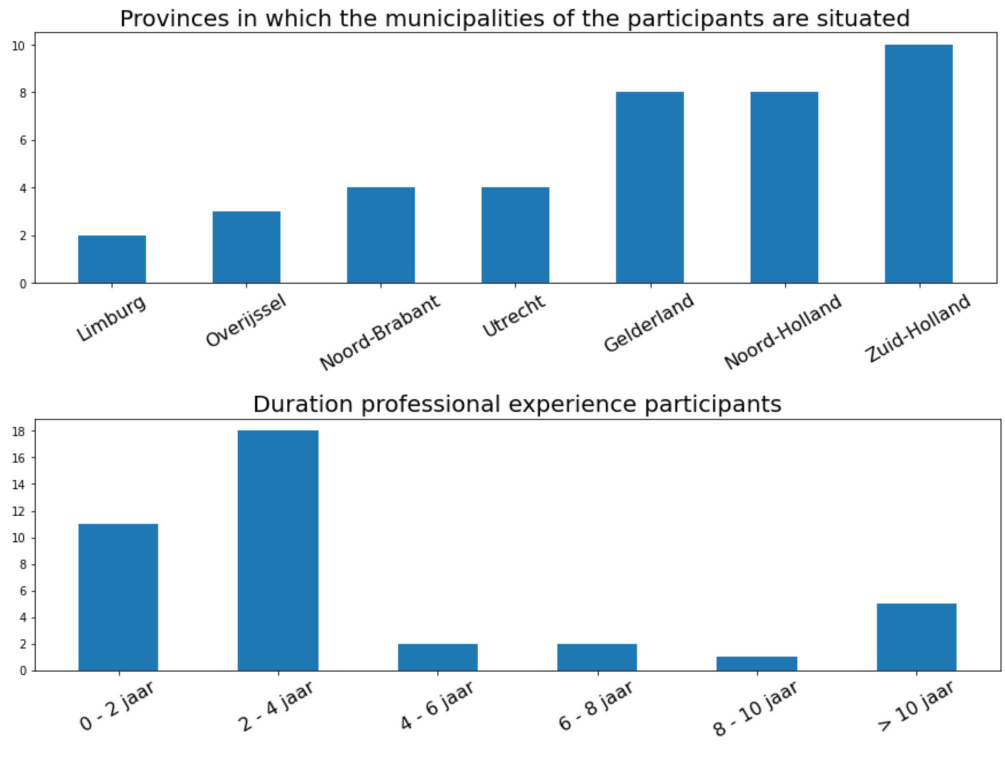


Figure 5.1 Bar plot of the general descriptives (top: provinces in which the municipalities of the participants are situated; bottom: duration of the professional experience of the participants)

5.1.2 Descriptives of the rankings

Based on the information, policymakers had to decide in which order they would disconnect five neighbourhoods (A, B, C, D and E) from natural gas, with one being the highest priority (first to disconnect) and five being the lowest priority (last to disconnect). For example, if the ranking were B – A – D – E – C, neighbourhood B would be disconnected from natural gas first, then neighbourhood A, etc.

Figure 5.2 summarizes the ranks for scenario 1 (energy consumption, costs and public support). On the left, the figure shows the rankings that the survey participants attached to the decision task of disconnecting neighbourhoods from natural gas based on only technical and economic information (group A). For group A, the ranking of C – B – A – E – D was most popular, with seven policymakers concluding this ranking. This statistic means that seven policymakers chose to disconnect neighbourhood C from natural gas first, whereafter they selected neighbourhood B etc.

On the right side of figure 5.2, the figure shows the rankings that the survey participants attached to the decision task of disconnecting neighbourhoods from natural gas based on technical, economic and social information (group B). For group B, the most popular rankings were chosen only twice. The multiple stand-alone rankings and lower number of common rankings in group B suggest a higher complexity and difficulty of group B's ranking task than in group A. This suggests that including social information in addition to techno-economic information adds complexity to the decision task. Appendix H details the ranks for scenarios 2, 3 and 4.

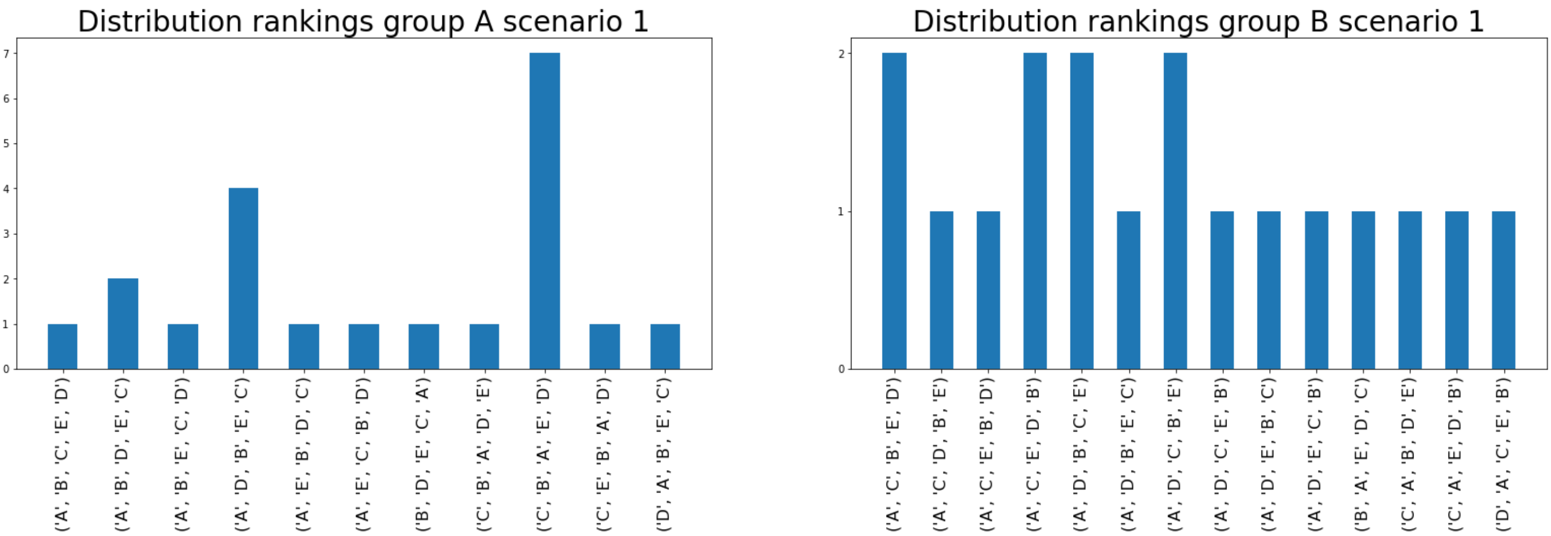


Figure 5.2 Distribution of the rankings of scenario 1 with group A displayed on the left and group B displayed on the right.

Figure 5.3 summarizes the frequency of every rank for every neighbourhood for scenario 1 for group A (top row) and group B (bottom row). For instance, the first graph on the first row shows the frequency of how often neighbourhood A had been ranked first, second, third, etc. by the survey participants. The graph shows that, in scenario 1, ten participants in group A ranked neighbourhood A first, one ranked neighbourhood A second, eight ranked neighbourhood A third, one ranked neighbourhood A fourth and one ranked neighbourhood A fifth.

Figure 5.3 shows that, where ten policymakers in group A chose to prioritise neighbourhood A first, 14 policymakers in group B chose to prioritise neighbourhood A, suggesting the added social information might be compelling to prioritise neighbourhood A in scenario 1. Appendix H details the distribution of the ranks for every neighbourhood for scenarios 2, 3 and 4.

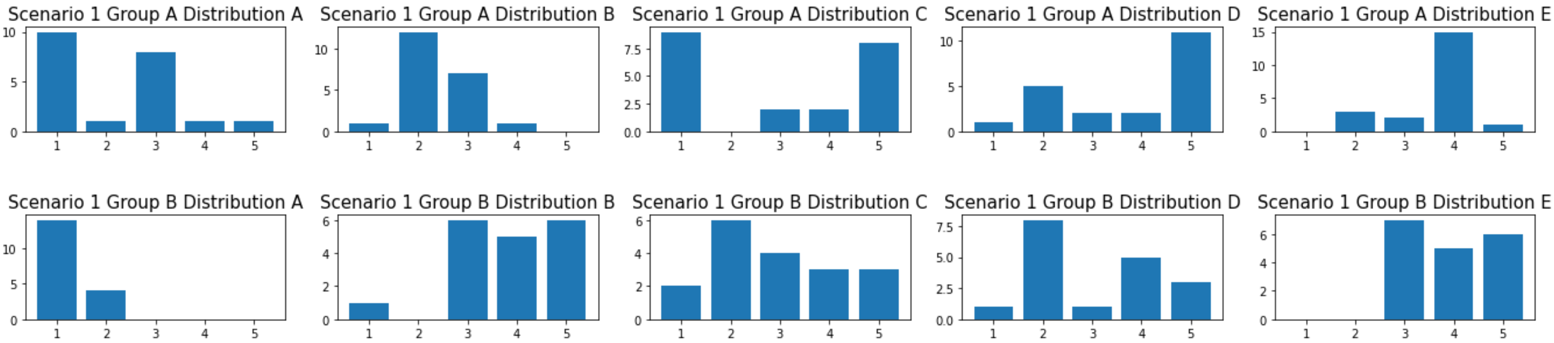


Figure 5.3 Distribution of the rankings of scenario 1 for all neighbourhoods with group A displayed on the top row and group B displayed on the bottom row.

5.1.3 Descriptives of the exit-questions

Figures 5.4 through 5.6 present the descriptives of exit questions that both groups answered. Appendix H details the analysis of the exit questions unique to each group.

These were the statistics for the statement "*I am confident in my decision on the neighbourhood orders*": Mean A = 4.48, Mean B = 5.0, SD A = 4.31, SD B = 4.64). From these statistics and figure 5.4, it is possible to conclude that the confidence level of both groups is reasonably similar but slightly higher in group B. However, the data also suggest a greater dispersion in group B than in group A.

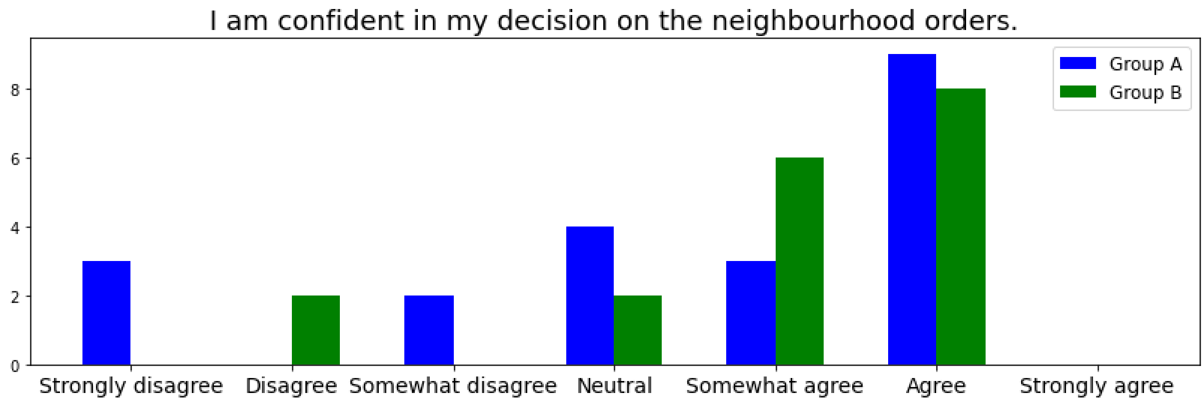


Figure 5.4 Descriptives of exit question: "I am confident in my decision on the neighbourhood orders."

These were the statistics for the statement "*I made a socially responsible and just decision in the ordering of the neighbourhoods*": Mean A = 4.14, Mean B = 5.01, SD A = 4.06, SD B = 4.64). From these statistics and figure 5.5, it is possible to conclude that where the majority of group A agrees with the statement, on average, more participants in group B agree. This initial statistic could be explained by the fact that group B received social information and group A did not, which also suggests that participants of group A seemed to be aware of the lack of this information. However, the data also suggest a greater dispersion in group B than in group A.

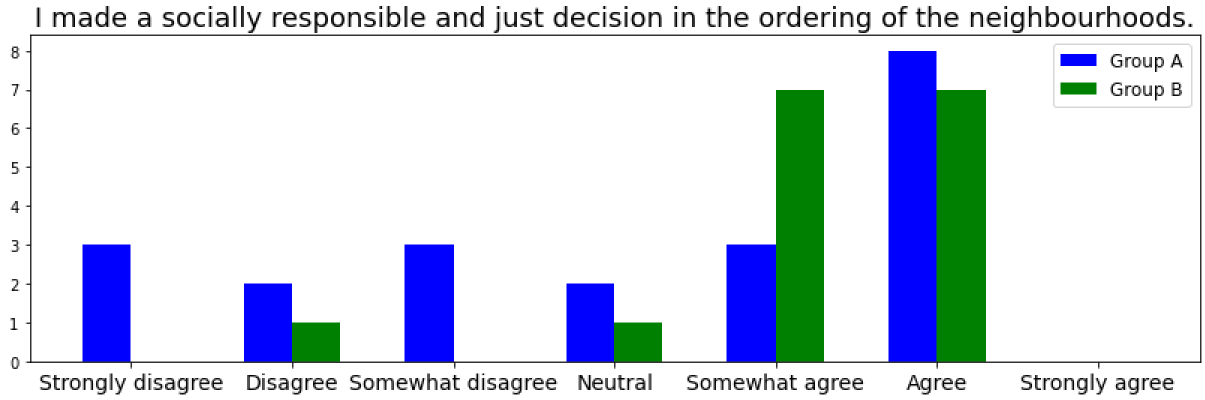


Figure 5.5 Descriptives of exit question: "I made a socially responsible and just decision in the ordering of the neighbourhoods."

Finally, these were the statistics for the statement "*I found it difficult to order the neighbourhoods*": Mean A = 5.0, Mean B = 5.38, SD A = 4.72, SD B = 5.06). These statistics and figure 5.6 show that most participants from both groups found the survey experiment difficult, and there is a minimal difference on average between both groups. Participants also clarified this when they provided comments and feedback on the last survey question. This statistic could have to do with the task at hand, the available information or the lack of information presented for the decision-making task.

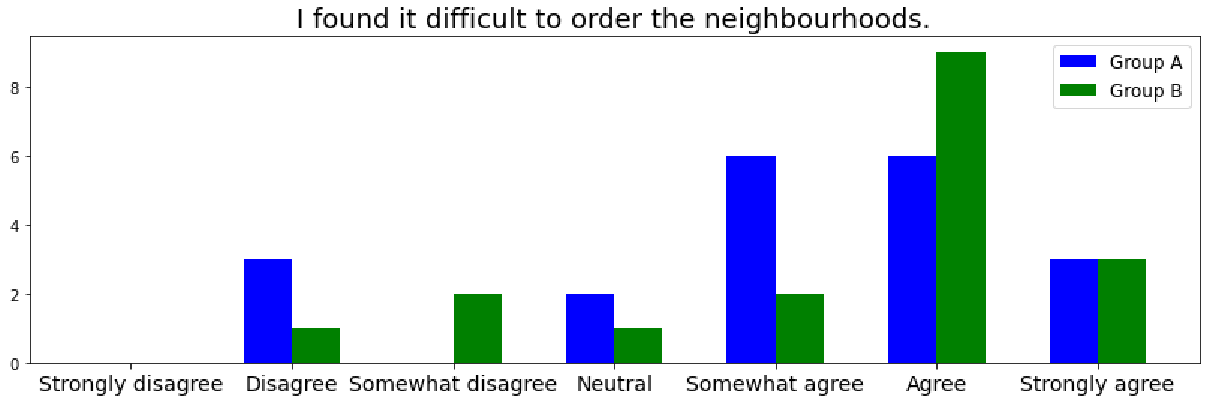


Figure 5.6 Descriptives of exit question: "I found it difficult to order the neighbourhoods"

5.2 INFERENTIAL ANALYSIS: EFFECTS OF INCLUSION OF SOCIAL INFORMATION

Subsection 5.2 examines the effects of including social information through inferential analysis. Additionally, these effects will be elaborated upon with insights from the interviews with policymakers. Subsection 5.2.1 explains the statistical test for this analysis, the Mann-Whitney U test, whereafter subsection 5.2.2 describes the procedures prior to statistical testing. Then subsection 5.2.3 reports the results from the Mann-Whitney U test for each scenario.

5.2.1 Mann-Whitney U test

Subsection 5.2.1 discusses the Mann-Whitney U test by providing a description and requirements of the test in subsection 5.2.1.1, whereafter subsection 5.2.1.2 outlines the U statistic of the Mann-Whitney U test.

5.2.1.1 The Mann-Whitney U test

The data for inferential analysis have a few characteristics. First, the final sample totalled 39 participants, of which 21 were in group A and 18 in group B. In the experiment, I asked participants to rank five neighbourhoods (A, B, C, D, and E) from one to five based on the information they received, with one being the neighbourhood to be disconnected from natural gas first and five last. This ranking is the dependent variable and of ordinal level of measurement. An ordinal scale allows ordering attributes and making statements such as "a is greater than b" (Kemp & Grace, 2021). In this study, it means that one neighbourhood will be disconnected before another. Second, the independent variable concerns whether a survey participant belongs to group A (techno-economic) or B (techno-economic and social). A Mann-Whitney U test has been deployed to research how the ranking (dependent variable) differs between groups A and B (dependent variable).

The Mann-Whitney U test is a rank-based nonparametric test used to determine whether there are differences between two groups on an ordinal dependent variable (Laerd Statistics, 2015). Research often includes two groups with only a few participants. In that case, the researcher cannot state that these groups come from a normal population (Mann & Whitney, 1947). In these cases, researchers can deploy the Mann-Whitney U test. According to McKnight and Najab (2010), the Mann-Whitney U test does not require the collected data to have a particular distribution. Therefore, there is no need to consider the normal distribution assumption.

Despite waiving the normal distribution assumption, there are four requirements to run a Mann-Whitney U test (Laerd Statistics, 2015; Nachar, 2008), three of which relate to the design of the experiment, whilst the last reflects the nature of the data:

1. The dependent variable is measured at the ordinal level. This research measures neighbourhood ranking, an ordinal variable.
2. The independent variable consists of two categorical, independent groups. Since there are two groups, A and B, this assumption has also been satisfied.
3. Observations are independent, implying no relationship exists between the observations in each group or between the groups themselves. This requirement has been satisfied because Qualtrics assigned all survey participants randomly to one of the groups. Additionally, participants could only fill out the survey once.
4. The distribution of the scores has either the same or a different shape. If the distributions have the same shape upon evaluation, then the Mann-Whitney U test is used to interpret whether there are differences in the medians of groups A and B; otherwise, the test determines whether there are differences in the distributions of the two groups. Subsection 5.2.3 evaluates the distributions. Figure 5.7 depicts an example of the distribution of the rankings for neighbourhood A in scenario 1 (energy consumption, costs and public support). Ffor distributions of the remaining neighbourhoods, see Appendix H.

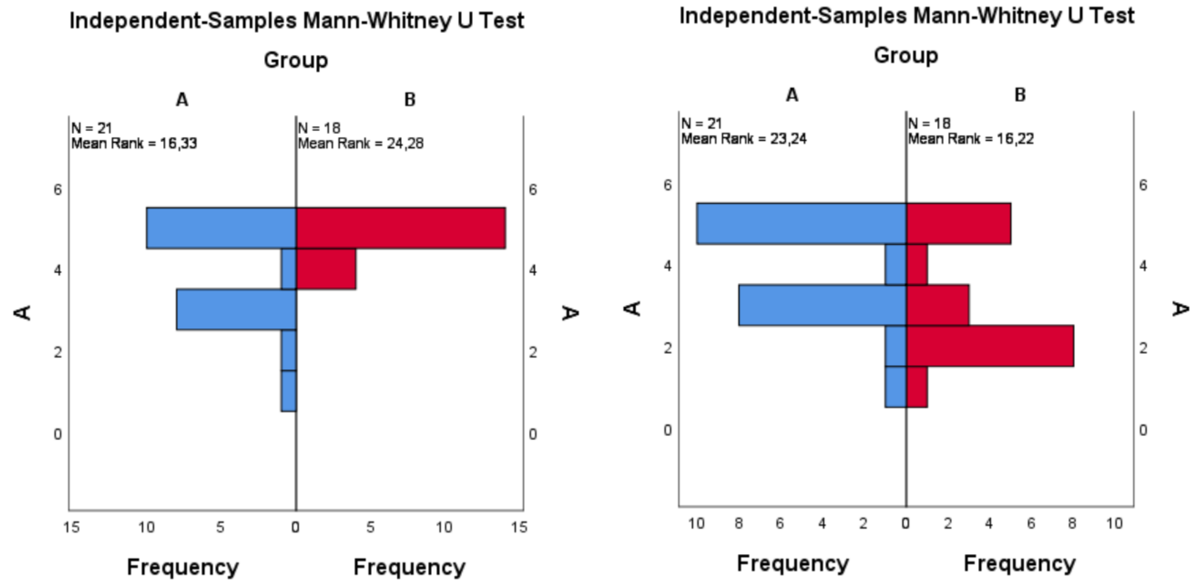


Figure 5.7 Distribution of the ranking of neighbourhood A for groups A and B for scenario 1 (left) and scenario 2 (right)

As the data satisfy all four requirements, a Mann-Whitney U test was performed in SPSS.

5.2.1.2 U statistic

First and foremost, the Mann-Whitney U calculates an U statistic for each group. The U statistic is the number of times observations from one sample precede or follow observations when all scores from one group are placed in ascending order (see example in table 5.1). This statistic can be calculated using the following equation (Nachar, 2008):

- For group A: $Ux = nx \cdot ny + \left(\frac{nx \cdot (nx+1)}{2}\right) - Rx$ (1)
- For group B: $Uy = nx \cdot ny + \left(\frac{ny \cdot (ny+1)}{2}\right) - Ry$ (2)

where nx and ny are the number of observations for each group, and Rx and Ry are the sums of the ranks assigned to each group. In table 5.1, I provided an example of the calculation of the U statistics for this research.

Table 5.1 Example calculation U statistic Mann-Whitney U test

Group	Neighbourhood A ranking	Adjusted value*	Rank	Rank sum (R)	U statistic
A	1	5	6.5	= 6.5 + 3.5 + 1 = 11	$= 3 \cdot 4 + \left(\frac{3 \cdot (3+1)}{2}\right) - 11 = 7$
A	3	3	3.5		
A	5	1	1		
B	1	5	6.5	= 6.5 + 3.5 + 5 + 2 = 17	$= 3 \cdot 4 + \left(\frac{4 \cdot (4+1)}{2}\right) - 17 = 5$
B	3	3	3.5		
B	2	4	5		
B	4	2	2		

** This column shows the adjusted value of the original neighbourhood ranking in the example. The reasoning is as follows: the original neighbourhood ranking is depicted in the second column. For the first participant (first row), this means that (s)he ranked neighbourhood A first to disconnect from natural gas. However, a neighbourhood ranking of 1 would lead to a rank of 1, leading to a lower rank sum and lower mean rank. A lower mean rank equals less priority (van den Berg, n.d.). Thus, a ranking of 1 for neighbourhood A needs to be adjusted to a higher value, which means that the adjusted value becomes 5.*

With these two U statistics, the z-value can be calculated using the following equations (3-6):

- $U = \min(Ux, Uy) = \min(7,5) = 5$ (3)

The expected value of U:

- $\mu U = \frac{nx \cdot ny}{2} = \frac{3 \cdot 4}{2} = 6$ (4)

An assumption of the Mann-Whitney U test is one of continuity, where the data must be unique. Nonetheless, in reality, equal measurements are often observed because of imprecise measurements. In these cases, it is necessary to calculate both U by allocating half of the tied ranks to the first group and half of the tied ranks to the second group's values. Then, the equation becomes for the standard error becomes (Nachar, 2008):

The standard error (if tied ranks occur):

- $\sigma U = \sqrt{\frac{nx \cdot ny}{n(n-1)}\left(\frac{n^3-n}{12} - \sum_{j=1}^{g} \frac{tj^3-tj}{12}\right)} = 7.714$ (5)

where g = number of tied ranks and tj = the number of times rank j appears.

z-value

- $z = \frac{U - \mu U}{\sigma \mathrm{U}} = \frac{5-6}{7.714} = -0.130$ (6)

Hereafter, the z-value is used to calculate the p-value. The p-value will determine whether there is a significant difference in ranking between groups A and B.

5.2.2 Procedure

Subsection 5.2.2 describes the procedures tied to the Mann-Whitney U test by explaining the data preparation procedure in subsection 5.2.2.1, whereafter subsection 5.2.2.2 provides additional information on the test in SPSS.

5.2.2.1 Data preparation

Before running the Mann-Whitney U, I prepared the data in Jupyter Notebook as the data were not ready. There were two steps involved in the data preparation.

First, the data were filtered only to retain the answers of policymakers. The survey collected 42 completed responses. From these 42 surveys, there are 39 policymakers and three non-policymakers. Initially, responses of non-policymakers were collected to compensate for a potential lack of responses. However, one of the advantages of the Mann-Whitney U is that it allows for small samples of participants (five to 20 subjects) (Nachar, 2008). Even with a small size sample of between 10 to 20 observations, the Mann-Whitney U test has approximately 95% of the Student's T-test statistical power, its parametric counterpart (Landers, 1981). Thus, the final sample size included policymakers solely to preserve the results' authenticity. Of the 39 policymakers, 21 were distributed to group A and 18 to group B.

The second data preparation step related to the inherent characteristics of the Mann-Whitney U test. The experiment asked participants to rank neighbourhoods in which they would connect neighbourhoods A, B, C, D, and E from natural gas. For instance, if the ranking of neighbourhoods A, B, C, D, and E is 1, 2, 3, 4, and 5, then the participant prioritises neighbourhood A the most. This is also the way Qualtrics registered the ranking. However, a neighbourhood rank of 1 would lead to a lower mean rank. A lower mean rank equals less priority (van den Berg, n.d.). Thus, if A is valued highest, this is not reflected in the ranking value of 1. Therefore, I recoded the priority. In the case of the example, A would receive a score of 5 instead of 1 after recoding.

Finally, I uploaded the resulting excel file in SPSS for statistical testing. While performing the statistical tests, SPSS tested assumption four for every scenario and every neighbourhood. Subsection 5.2.3 and Appendix H discuss these.

5.2.2.2 Mann-Whitney U test in SPSS

According to Nachar (2008), SPSS distinguishes large and small data samples for the Mann-Whitney U test. For large data samples, SPSS returns an asymptotic significance (*Asymp. Sig. (2-tailed)*) which bases the significance level on the normal distribution of the statistical test. Whereas, for small and poorly distributed data samples, SPSS generates an exact significance (*Exact Sig. (2-tailed)*) which bases the significance level on a statistical test's exact distribution. Researchers should use the exact significance when encountering small, sparse, poorly balanced samples with many tied ranks. Therefore, the analysis uses the *Exact Sig. (2-tailed)* to conclude.

5.2.3 Effects of the inclusion of social information

Subsection 5.2.3 discusses the effects of including social information next to techno-economic information. Subsections 5.2.3.1, 5.2.3.2, 5.2.3.3, and 5.2.3.4 discuss each of the four scenarios.

5.2.3.1 Scenario 1: Energy consumption, costs and public support

I ran a Mann-Whitney U test to determine if there were differences in neighbourhood rankings between groups A (N = 21) and B (N = 18). Distributions of the rankings for all neighbourhoods (A, B, C, D, and E) for groups A and B were dissimilar, as assessed by visual inspection (see Appendix H).

Table 5.2 provides an overview of the statistics for each neighbourhood in scenario 1. For scenario 1, the general hypothesis was: <u>Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.</u>

Following this hypothesis, it is expected that the neighbourhood ranking shifts (after social information inclusion) in a way that reflects the value of the social indicator. This hypothesis translates to neighbourhood B (low public support) ranking significantly lower after social information inclusion and neighbourhood A and C (high public support) ranking significantly higher after inclusion. As for neighbourhoods D and E (medium public support), these could go in either direction. To make substantial claims about the general hypothesis, I test the following specific hypothesis for scenario 1 for each neighbourhood:

- H0: The distribution of scores for groups A and B in scenario 1 are equal. This means that adding information about public support to existing decision-making information about energy consumption and costs **does not lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

Table 5.2 Statistics Mann-Whitney U test scenario 1

Statistic → Neighbourhood ↓	**Mean rank A***	**Mean rank B**	**U**	**z**	**p (exact sig (2-sided))**	**Decision****
A	16.33	24.28	266.0	2.494	0.030	Reject H0
B	26.62	12.28	50.00	-4.067	0.000	Reject H0
C	20.05	19.94	188.0	-0.029	0.989	Retain H0
D	17.05	23.44	251.0	1.830	0.083	Retain H0
E	21.17	18.64	164.5	-0.750	0.494	Retain H0

**The Mean rank is calculated by Rank sum (see table 5.1) / nA.*
***The cells marked in green are neighbourhoods for which the null hypothesis is rejected, and the alternative hypothesis is accepted.*

Scenario 1 (Energy consumption, costs and public support): Rejected H0

The overall conclusion is that the hypothesis for scenario 1 must be rejected. This means that not all neighbourhoods with higher levels of public support obtain higher priority in decision-making after this information is added to the existing information about energy consumption and costs. However, it does remain true for neighbourhoods A and B (see table 5.2).

- For neighbourhoods A and B in scenario 1: H0 is rejected. Thus, for neighbourhoods A and B, adding information about public support to existing decision-making information about energy consumption and costs **does lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

For instance, the participants receiving information about public support (group B) ranked neighbourhood A (with high public support) higher than the participants without this information (group A). Group B also ranked neighbourhood B (with low public support) lower than participants of group A (see figure 5.8). These patterns are in line with the thought process of PM1.

PM1 ranked the neighbourhoods in the order of B – A – C – E – D before being presented with additional social information. (S)he starts with neighbourhood B because of its relatively high consumption and low costs, whereafter PM1 prioritises neighbourhood A because of its medium consumption and reasonably low costs. Hereafter, (s)he continues with neighbourhood C. Neighbourhood C consumes the most energy but costs the most. (S)he states: "[…] *let's gain some positivity first in neighbourhoods B and A.*" Then, neighbourhood E and neighbourhood D last because: "*I think neighbourhood D does not consume and cost that much; therefore, I believe neighbourhood D is doing pretty well.*" From this, it is possible to conclude that policymakers trade off techno-economic indicators and prioritise specific neighbourhoods to obtain positivity and confidence. Finally, neighbourhoods such as D with favourable conditions (e.g., low consumption and low costs) are considered not urgent and therefore not prioritised.

Afterwards, with the inclusion of social information, PM1 ranks the neighbourhoods as A – C – B – E – D after. Concerning neighbourhood A, (s)he said: "*Neighbourhood A still consumes a decent amount of energy, does not cost as much and has a high public support*", which causes its increase in rank. Then, concerning neighbourhood B (s)he said: "*Neighbourhood B does not feel like it so much. So, neighbourhood B is in third place, because if it turns out that neighbourhood A and neighbourhood C succeeded, then I think neighbourhood B might become a darker colour.*" Often, policymakers mention that they start in relatively easy neighbourhoods to gain trust and confidence to tackle more ambitious and problematic neighbourhoods. In this case, neighbourhood B might be seen as more problematic regarding public support.

Scenario 1 (Energy consumption, costs and public support): Retained H0

- For neighbourhoods C, D, and E in scenario 1: H0 is retained. Thus, for neighbourhoods C, D and E, adding information about public support to existing decision-making information about energy consumption and costs **does not lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

Despite its extreme value, the rankings for neighbourhood C did not statistically significantly differ between groups A and B, suggesting that the high public support of residents does not have an impact. After receiving the social information, PM5 says: "*C is probably also complex, so even though people are willing, maybe it is not feasible at all*". Thus, perhaps the complexity faced in neighbourhood C (high consumption and high costs) makes it too ambitious, and despite the high public support, policymakers are reluctant to prioritise it.

As mentioned before, neighbourhoods D and E had medium public support, which means these could go in either direction, according to the hypothesis. For instance, after receiving information about the public support, PM5 states: "*Well, we often tend to think in extremes, you often see that in analyses. So those areas where the colours hang around in the middle, those are not the neighbourhoods you are going to start.*". Following this statement, PM5 ordered the neighbourhoods A – B – C – E – D / D – E after including the public support indicator. With the initial ranking of A – B – E – C – D, both neighbourhoods D and E's rankings seem to remain the same or worsen. The following comment of PM1 can explain this: "*I think neighbourhood D does not consume and cost that much; therefore, I believe neighbourhood D is doing pretty well.*" Thus, the fact that there is medium public support is trivial as neighbourhood D can probably manage on its own making it a less urgent neighbourhood to prioritise. It is possible to conclude whether the null hypothesis is retained or rejected also depends on the ranking before the inclusion of social information. If a neighbourhood is already acknowledged as unproblematic and non-urgent, then adding favourable social information will likely be trivial.

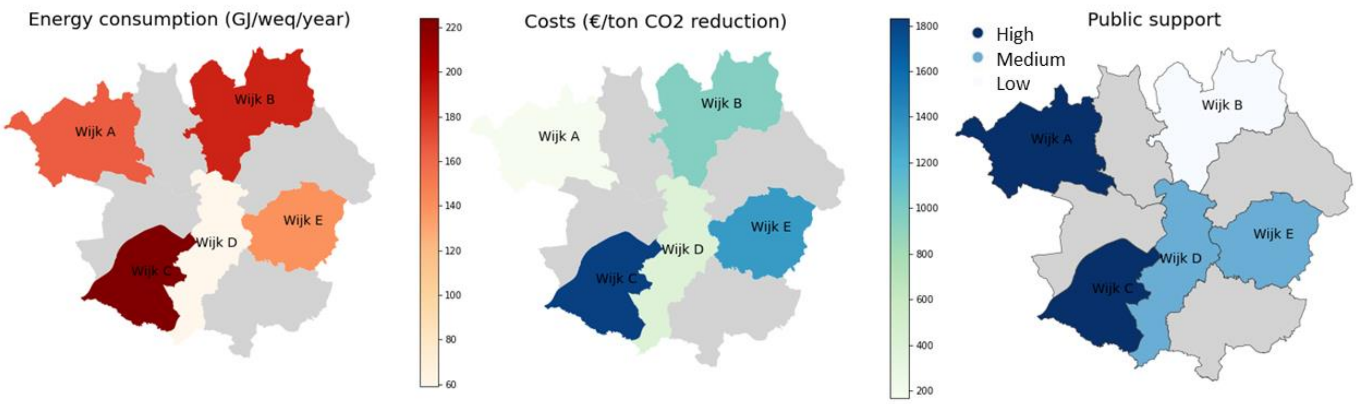


Figure 5.8 Depiction of scenario 1 for group B with technical, economic and social indicators (left shows the energy consumption; centre shows the costs; right shows the public support)

5.2.3.2 Scenario 2: Energy consumption, costs and energy poverty

I ran a Mann-Whitney U test to determine if there were differences in neighbourhood rankings between groups A (N = 21) and B (N = 18). Distributions of the rankings for all neighbourhoods

(A, B, C, D, and E) for groups A and B were dissimilar, as assessed by visual inspection (see Appendix H).

For scenario 2, the general hypothesis was: <u>Neighbourhoods with higher (/lower) shares of energy poverty obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.</u>

Following this hypothesis, it is expected that the neighbourhood ranking shifts (after social information inclusion) in a way that reflects the value of the social indicator. This translates to neighbourhood E (low energy poverty) ranking significantly lower after inclusion of social information and neighbourhood D (high energy poverty) ranking significantly higher after inclusion. As for neighbourhoods A, B and C (medium energy poverty), these could go in either direction. To make substantial claims about the general hypothesis, I test the following specific hypothesis for scenario 2 for each neighbourhood:

- H0: The distribution of scores for groups A and B in scenario 2 are equal. This means that adding information about energy poverty to existing decision-making information about energy consumption and costs **does not lead** to a higher priority in case of higher shares of energy poverty.

Table 5.3 Statistics Mann-Whitney U test scenario 2

Statistic → Neighbourhood ↓	**Mean rank A***	**Mean rank B**	**U**	**z**	**p (asymptotic sig (2-sided))**	**Decision****
A	23.24	16.22	121.0	-2.010	0.057	Retain H0
B	14.81	26.06	298.0	3.297	0.002	Reject H0
C	23.12	16.36	123.5	-1.984	0.065	Retain H0
D	18.52	21.72	220.0	0.915	0.394	Retain H0
E	15.52	25.22	283.0	2.827	0.007	Reject H0

**The Mean rank is calculated by Rank sum (see table 5.1) / nA.*
***The cells marked in green are neighbourhoods for which the null hypothesis is rejected, and the alternative hypothesis is accepted.*

Scenario 2 (Energy consumption, costs and energy poverty): Rejected H0

The overall conclusion is that the hypothesis for scenario 2 must be rejected. This means that not all neighbourhoods with higher shares of energy poverty support obtain higher priority in decision-making after this information is added to the existing information about energy consumption and costs. However, it only remains valid for neighbourhood B (see table 5.3).

- For neighbourhoods B and E in scenario 2: H0 is rejected. Thus, for neighbourhood B adding information about energy poverty to existing decision-making information about energy consumption and costs **does lead** to a higher priority in case of higher shares of energy poverty. Interestingly, H0 is rejected for neighbourhood E, but the effect is reversed.

For instance, the participants receiving information about the share of energy poverty (group B) ranked neighbourhood B (with a relatively high share) higher than the participants without this information (group A) (see figure 5.9). Interestingly, participants 2 (PM2) and 3 (PM3) ranked neighbourhood B the same or worse in both situations. Though the difference among participants from groups A and B is significant, in which neighbourhood B gains more priority from group B, PM 2 and 3 underline that this is not always the case. From this, it is possible to conclude that even faced with the same problem and task, the approaches of the Dutch policymakers remain diverse.

Unexpectedly, the rankings of neighbourhood E were statistically higher for group B than group A. Though, in line with H0 for scenario 2, it is not in line with the hypothesis which anticipated a lower priority for neighbourhood E, as it scores lowest on the share energy poverty. Where neighbourhood E ranked lower in group A (Mean rank = 15.52) compared to other neighbourhoods, it ranked significantly higher in group B (Mean rank = 25.22) than other neighbourhoods. Though the difference among participants from groups A and B is significant, in which neighbourhood E gains more priority from group B, PM 2 and 3 underline that this is not always the case. It can only be speculated that perhaps the low value (an extreme value) of the social indicator in neighbourhood E prompts policymakers to prioritise it to use it as an example neighbourhood.

Another possible reason for the unexpected difference in the ranking of neighbourhood E is that many municipalities now have energy poverty plans parallel to their heat transition plans. Participant 4 (PM4) says about these plans: "*On the one hand, energy poverty is part of the energy transition because you are addressing the same problem, and you could also make a large impact. [...] Ultimately, the WUPs will still be focused on a local area. With energy poverty, the people who experience it are spread all over the municipality. It is not like you can point to one neighbourhood and say this is where they live. I would still say these (WUPs and energy poverty plans) are two different parts.*" This statement indicates parallelism between these neighbourhood-implementation plans (Dutch: wijkuitvoeringsplannen, WUPs) and energy poverty plans. Perhaps these parallel plans induced unexpected results as policymakers will already tackle problems of energy poverty through other plans, attaching less value to the energy poverty information in light of the heat transition.

Final speculation about the surprising results concerns the ratio of social to private housing in the neighbourhoods. One survey participant mentions that people who experience energy poverty often live in social housing, whereas energy poverty among homeowners tends to be dispersed throughout the city. Because policymakers find it easier to communicate with the housing corporation as a representative instead of individual homeowners, this information on energy poverty may remain trivial without a ratio of social to private housing.

Scenario 2 (Energy consumption, costs and energy poverty): Retained H0

- For neighbourhoods A, C, and D in scenario 2: H0 is retained. Thus, for neighbourhoods A, C, and D, adding information about energy poverty to existing decision-making information about energy consumption and costs **does not lead** to a higher priority in case of higher shares of energy poverty.

As mentioned before, neighbourhood D had a high energy poverty public support, so it was expected that this neighbourhood would have a higher priority after social information inclusion. However, there is little difference in the mean rank of neighbourhood D (Mean rank A = 18.52, Mean rank B = 21.72) after the inclusion of social information. A reason could be that neighbourhood D was already perceived as favourable. For example, PM3 stated the following about neighbourhood D: "[…] *Then I would say neighbourhood D requires relatively little effort because of the low energy consumption.* […] *Well, then you gained some experience with easier* *neighbourhoods (neighbourhood A and D), so then I believe you also have more striking power to achieve that in a more complex neighbourhood where you need more investments.*” As neighbourhood D had favourable techno-economic conditions initially, some policymakers used neighbourhood D as an “example neighbourhood” and prioritised this neighbourhood. For those policymakers, the high share of energy poverty in neighbourhood D can be considered convenient as it enforces their initial thoughts on the prioritisation of neighbourhood D.

As mentioned before, neighbourhoods A and C had medium energy poverty, which means these could go in either direction according to the hypothesis. From table 5.3, it is possible to conclude that neighbourhoods A (Mean rank A = 23.24), C (Mean rank A = 23.12) and D (Mean rank = 18.52) were highest in priority before receiving social information (in comparison with neighbourhood B and E). For instance, PM3 ranked the neighbourhoods A – D – C – B – E before obtaining information about the social indicator. However, after receiving social information, these three neighbourhoods seemed to shift from the top three highest priorities to the top three lowest priorities. For neighbourhoods A and C, these differences are relatively significant but not substantial enough to conclude a statistically significant difference. Perhaps expanding the sample size of the survey will lead to different results. According to Peers (2006), the sample size of a study can impact the detection of significant differences, correlations or interactions. Larger samples generally lead to smaller P values (Whitley & Ball, 2002), and therefore it is hypothesised that larger sample size will lead to a higher probability of statistically significant results for neighbourhoods A and C.

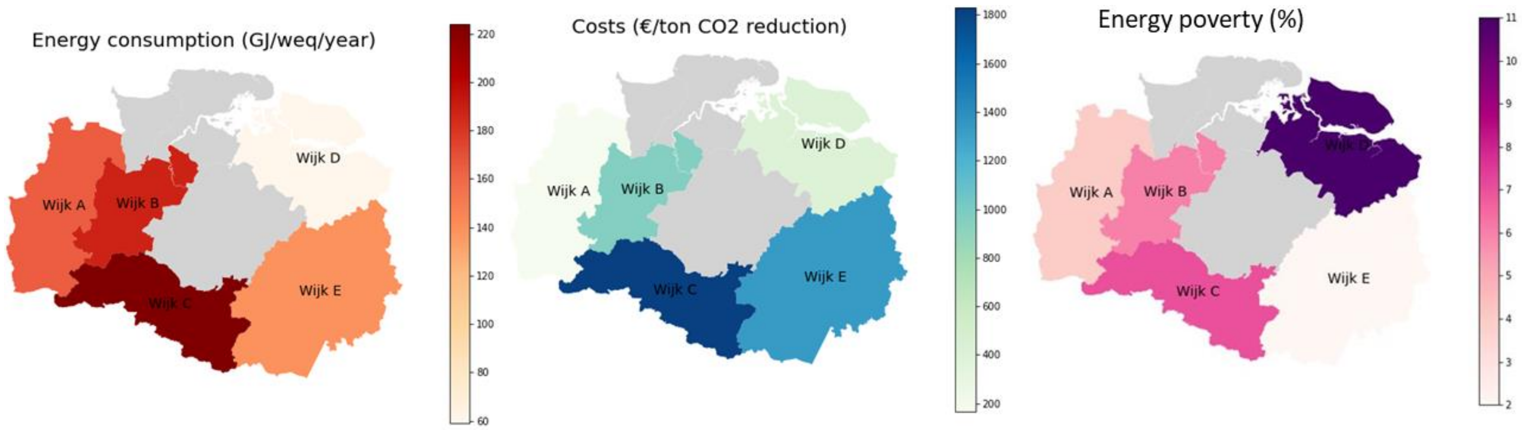


Figure 5.9 Depiction of scenario 2 for group B with technical, economic and social indicators (left shows the energy consumption; centre shows the costs; right shows the share of energy poverty)

5.2.3.3 Scenario 3: Energy label, costs, and public support

I ran a Mann-Whitney U test to determine if there were differences in neighbourhood rankings between groups A (N = 21) and B (N = 18). Distributions of the rankings for all neighbourhoods (A, B, C, D, and E) for groups A and B were dissimilar, as assessed by visual inspection (see Appendix H).

For scenario 3, the general hypothesis was: <u>Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy labels and costs.</u>

Following this hypothesis, it is expected that the neighbourhood ranking shifts (after social information inclusion) in a way that reflects the value of the social indicator. This translates to neighbourhood B (low public support) ranking significantly lower after inclusion of social information, and neighbourhoods A and C (high public support) ranking significantly higher after inclusion. As for neighbourhoods D and E (medium public support), these could go in either direction. To make substantial claims about the general hypothesis, I test the following specific hypothesis for scenario 3 for each neighbourhood:

- H0: The distribution of scores for groups A and B in scenario 3 are equal. This means that adding information about public support to existing decision-making information about energy labels and costs **does not lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

Table 5.4 Statistics Mann-Whitney U test scenario 3

Statistic → Neighbourhood ↓	Mean rank A*	Mean rank B	U	z	p (asymptotic sig (2-sided))	Decision**
A	16.67	23.89	259.0	2.050	0.049	Reject H0
B	25.71	13.33	69.00	-3.614	0.000	Reject H0
C	16.79	23.75	256.5	2.114	0.057	Retain H0
D	22.05	17.61	146.0	-1.284	0.234	Retain H0
E	23.45	15.97	116.5	-2.183	0.040	Reject H0

**The Mean rank is calculated by Rank sum (see table 5.1) / nA.*
***The cells marked in green are neighbourhoods for which the null hypothesis is rejected, and the alternative hypothesis is accepted.*

Scenario 3 (Energy label, costs, and public support): Rejected H0

The overall conclusion is that the hypothesis for scenario 3 must be rejected. This means that not all neighbourhoods with higher levels of public support obtain higher priority in decision-making after this information is added to the existing information about energy labels and costs. However, it does remain true for neighbourhoods A, B and E (see table 5.4).

- For neighbourhoods A, B and E in scenario 3: H0 is rejected. Thus, for neighbourhoods A and B, adding information about public support to existing decision-making information about energy labels and costs **does lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

For instance, the participants receiving information about public support (group B) ranked neighbourhood A (with high public support) higher than the participants without this information (group A). Group B also ranked neighbourhood B (with low public support) lower than participants of group A (see figure 5.10).

This pattern is in line with the thought process of PM2. PM2 ranked the neighbourhoods in the order of D – E – B – A – C before social information. (S)he starts with neighbourhood D due to the combination of poor labels and lowest costs; whereafter PM2 continues with neighbourhood D due to its poor labels and relatively low cost. Hereafter (s)he proceeds with neighbourhood B because of the average labels and costs. Finally, PM2 ends the ranking with neighbourhoods A and C. However, PM2's ranking seems to change substantially after being presented with social information. Her/his ranking changes to A – C – D – E – B. Additionally, (s)he even says: "*Public support is just as important as the technical and economic indicator.*" From the ranking, it might even be argued that the participant takes it as the principal starting point, considering it even more important than the other indicators. Where the social information seems to change the entire order for PM2, this is not the case for all survey participants.

Contrary to PM2 (and the majority of the survey participants), PM3 gave neighbourhood B a lower ranking before (rank 3) compared to after (rank 1) receiving social information. Their ranking before was D – A – B – E – C, which converted into B – D – E – C – A. (S)he argued the latter ranking as follows: "*In reality, we have done it his way, we start in neighbourhood B, which is relatively interesting from a technical, financial point of view, but the public support and involvement of residents are relatively low, but if it sets up well there and it succeeds there, then we can do it relatively easy in neighbourhoods D and A for example.*" In comparison, other participants have argued to take on a relatively easy neighbourhood first to gain confidence, PM3 favours tackling one of the most challenging neighbourhoods. From this, it is also possible to conclude that participants (and therefore municipalities) have different views on tackling the ordering of the neighbourhoods and making different trade-offs.

Interestingly, the rankings of neighbourhood E were statistically higher for group A than group B. In line with the majority of the survey participants, PM4 also ranked neighbourhood E higher before the inclusion of social information. Neighbourhood E received significant priority in the ranking due to the high share of poor G-labels. However, after adding social information, neighbourhoods A and D suddenly seem more favourable. This is likely because neighbourhood A's residents had higher public support than E, and neighbourhood D had similar labels to E, the same level of public support, but lower costs. This result suggests that the inclusion of social information has favourable effects on the priority of specific neighbourhoods, but the effect depends on the techno-economic information of the neighbourhood.

Before receiving social information, PM2 prioritised E because of its "*bad labels and medium costs";* however, (s)he obtains information about the public support, neighbourhoods A, C, and D are prioritised. Thus, once again, it depends on the previous situation. As PM5 argued earlier, we often think in extremes; perhaps the medium score on public support, neighbourhood E's initial priority, and its high/low score of the public support of other neighbourhoods resulted in a statistically significant difference between group A and B for which the mean rank of group A was higher.

Scenario 3 (Energy label, costs, and public support): Retained H0

- For neighbourhoods C and D in scenario 3: H0 is retained. Thus, for neighbourhoods C and D, adding information about public support to existing decision-making information about energy labels and costs **does not lead** to a higher priority in case of higher levels of public support (and lower priority in case of lower levels).

Why did the hypothesis remain untrue for neighbourhood C? There could be several grounds for this. For instance, concerning neighbourhood C PM4 argued the following: "*I believe neighbourhood C needs least help. [...] C should be the easiest to disconnect from natural gas as a municipality*." After including social information, PM4 repeats him/herself: "*Neighbourhood C last (again), because they need the least help*". Thus, where neighbourhood C has favourable techno-economic conditions initially, most policymakers do not prioritise this self-reliant neighbourhood. After participants receive information about the high public support of residents in neighbourhood C, this picture of self-reliance is enforced and makes the neighbourhood less of a priority. However, when examining table 5.4, neighbourhood C seemed to be among the later neighbourhoods to be prioritised (Mean rank A = 16.79) and ranked higher after (Mean rank B = 23.75). Besides, the p-value was 0.057, meaning the difference was substantial enough to conclude a statistically significant difference. Perhaps expanding the population of the survey will lead to different results.

As mentioned before, neighbourhood D had medium public support, which means that these could go in either direction according to the hypothesis. PM 3 and 4 initially prioritised neighbourhood D due to its poor labels and high cost-effectiveness. However, this seemed to be different for the survey participants. According to table 5.4, neighbourhood D remained in the middle rank (third) for groups A and B. This result suggests that public support had little impact on the priority of neighbourhood D, perhaps because of the average value, as policymakers often think in extremes.

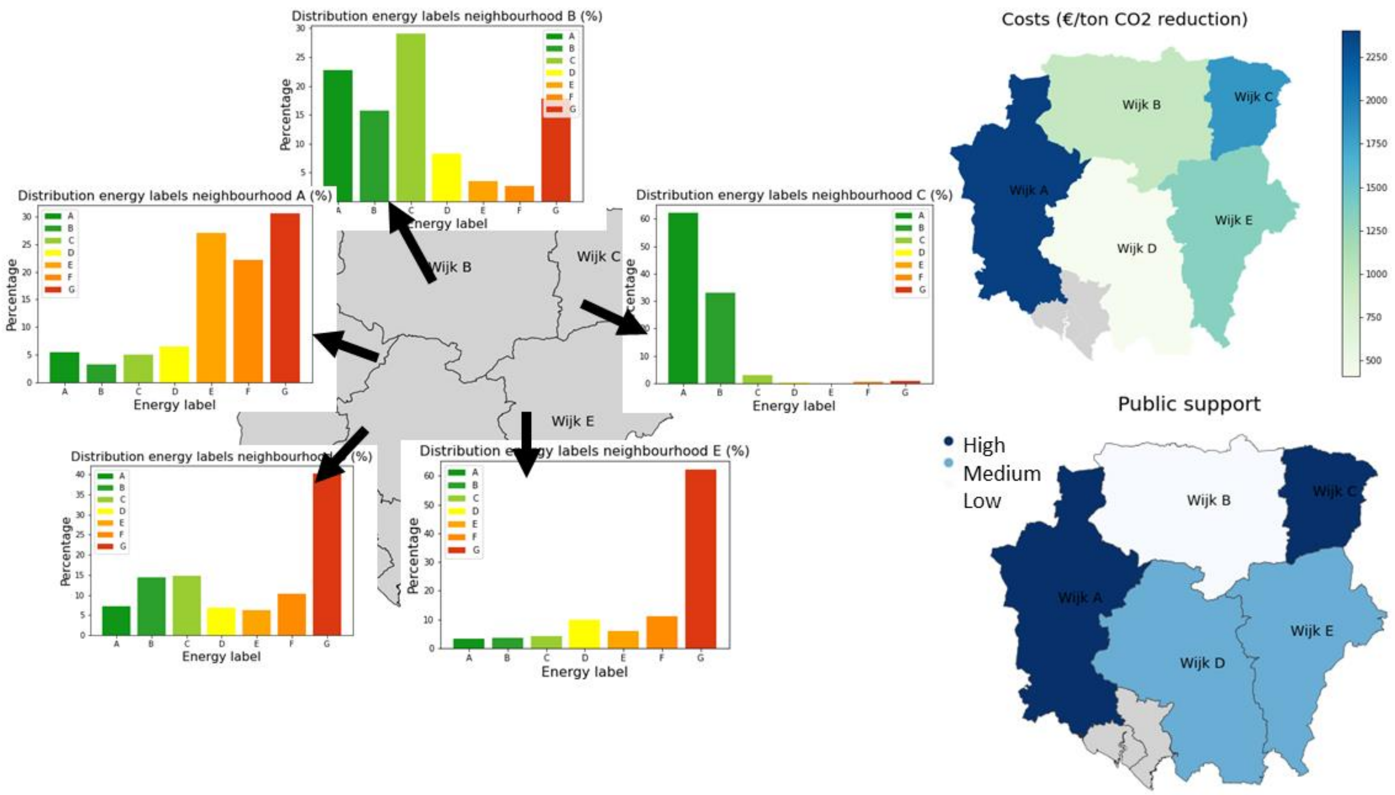


Figure 5.10 Depiction of scenario 3 for group B with technical, economic and social indicators (left shows the distribution of energy labels; centre shows the costs; right shows public support)

5.2.3.4 Scenario 4: Year of construction, costs and public participation

I ran a Mann-Whitney U test to determine if there were differences in neighbourhood rankings between groups A (N = 21) and B (N = 18). Distributions of the rankings for all neighbourhoods (A, B, C, D, and E) for groups A and B were dissimilar, as assessed by visual inspection (see Appendix H).

For scenario 4, the general hypothesis was: <u>Neighbourhoods with higher (/lower) shares of public participation obtain a higher (/lower) priority in decision-making when this information is added to the existing information about the year of construction and costs.</u>

Following this hypothesis, it is expected that the neighbourhood ranking shifts (after social information inclusion) in a way that reflects the value of the social indicator. This translates to neighbourhood B (low public participation) ranking significantly lower after inclusion of social information and neighbourhood A (high public participation) ranking significantly higher after inclusion. As for neighbourhoods C, D and E (medium public participation), these could go in either direction. To make substantial claims about the general hypothesis, I test the following specific hypothesis for scenario 4 for each neighbourhood:

- H0: The distribution of scores for groups A and B in scenario 4 are equal. This means that adding information about public participation to existing decision-making information about the year of construction and costs **does not lead** to a higher priority in case of higher shares of public participation (and lower priority in case of lower shares).

Table 5.5 Statistics Mann-Whitney U test scenario 4

Statistic → Neighbourhood ↓	Mean rank A*	Mean rank B	U	z	p (asymptotic sig (2-sided))	Decision**
A	15.79	24.92	277.5	2.560	0.011	Reject H0
B	24.83	14.36	87.50	-3.013	0.003	Reject H0
C	21.05	18.78	167.0	-0.646	0.549	Retain H0
D	18.69	21.53	216.5	0.906	0.443	Retain H0
E	22.14	17.50	144.0	-1.305	0.213	Retain H0

**The Mean rank is calculated by Rank sum (see table 5.1) / nA.*
**The cells marked in green are neighbourhoods for which the null hypothesis is rejected, and the alternative hypothesis is accepted.*

Scenario 4 (Year of construction, costs and public participation): Rejected H0

The overall conclusion is that the hypothesis for scenario 4 must be rejected. This means that not all neighbourhoods with higher levels of public participation obtain higher priority in decision-making after this information is added to the existing information about the year of construction and costs. However, it does remain true for neighbourhoods A and B (see table 5.5).

- For neighbourhoods A and B in scenario 4: H0 is rejected. Thus, for neighbourhoods A and B, adding information about public participation to existing decision-making information about the year of construction and costs **does lead** to a higher priority in case of higher shares of public participation (and lower priority in case of lower shares).

For instance, the participants receiving information about the share of public participation (group B) ranked neighbourhood A (with a high share) higher than the participants without this information (group A). Group B also ranked neighbourhood B (with a low share) lower than participants of group A (see figure 5.11).

This result is in line with the thoughts of PM4. PM4 ranked the neighbourhoods in the order of D – B – A – E – C before receiving any information about the share of public participation. (S)he starts with neighbourhood D because: "*Neighbourhoods A and D have many buildings with older constructions and so does B partly, those are the neighbourhoods that need it more. […]neighbourhood D seems attractive because D costs little, and you could make great improvements*." Afterwards, PM 4 moves to B and then A for the same reasons as D. Finally, (s)he puts E and C at the bottom of their list since these are considered relatively self-sufficient. Upon receiving social information, (s)he adjusts their ranking to D – A – B – E – C. Interestingly, in PM4's ranking, only neighbourhoods A and B have shifted.

Scenario 4 (Year of construction, costs and public participation): Retained H0

- For neighbourhoods C, D and E in scenario 4: H0 is retained. Thus, for neighbourhoods C, D and E, adding information about public participation to existing decision-making information about the year of construction and costs **does not lead** to a higher priority in case of higher shares of public participation (and lower priority in case of lower shares).

As mentioned before, neighbourhoods D and E had medium public support, which means these could go in either direction, according to the hypothesis. PM5 stated that we often think in extremes, and neighbourhoods with average values are often not the neighbourhoods in which policymakers tend to start. The values of the share of public participation for neighbourhoods C, D and E tend to be in the middle. Before receiving information about the share of public participation, PM4 said: "*Therefore, the question is to what extent should you then actively help the neighbourhoods E and C, maybe it is enough to start a campaign there informing residents on how to insulate their homes […], perhaps you will see a large part will already pick it up themselves.*" Neighbourhoods C and E seem to have favourable techno-economic conditions and are thus seen as less urgent. Therefore, the inclusion of the "medium" values of the share does not seem rigorous enough to impact PM4's ranking of these two neighbourhoods.

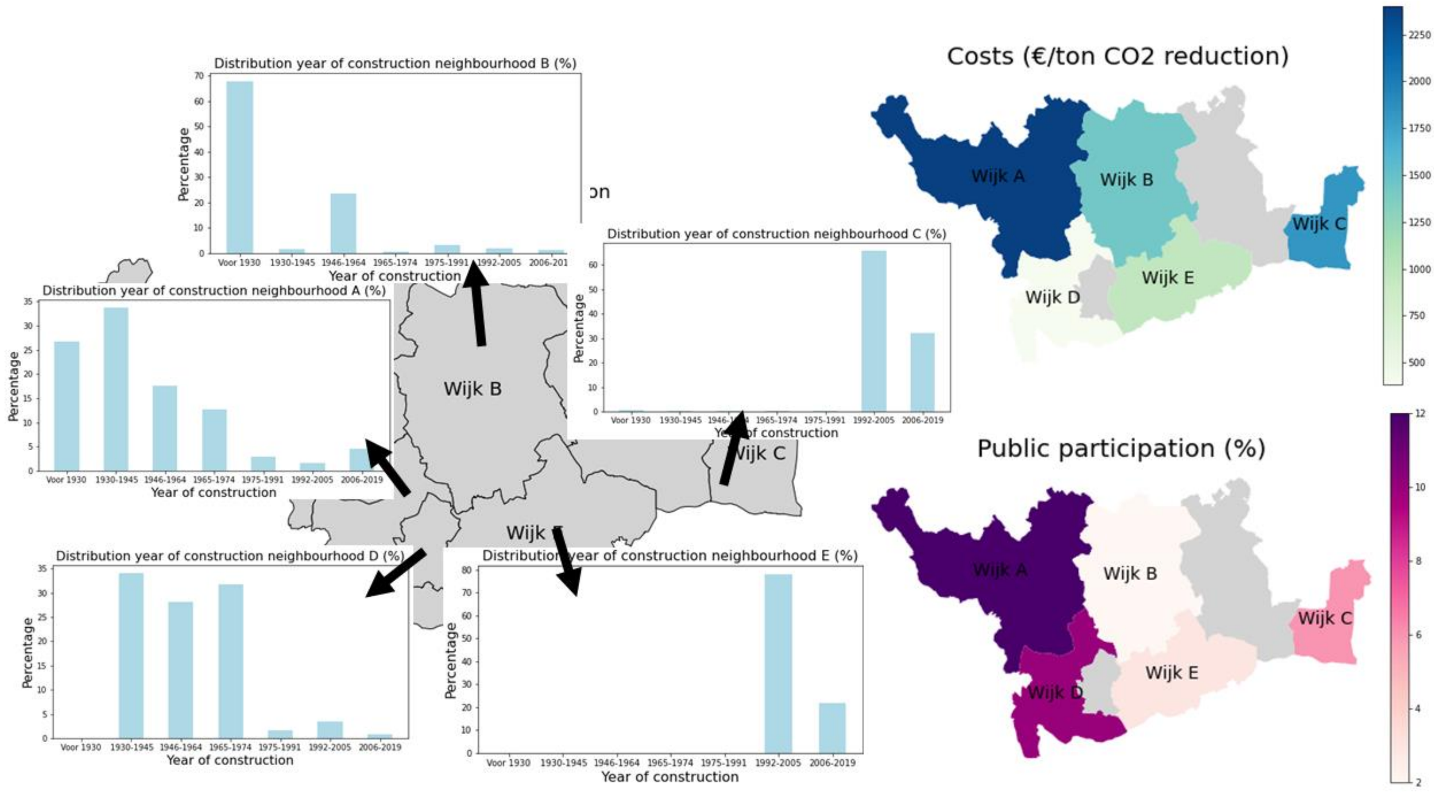


Figure 5.11 Depiction of scenario 4 for group B with a technical, economic and social indicator (left shows the distribution of year of construction; top right shows the costs; right shows public participation)

5.3 SYNTHESIS RESULTS

Section 5 aimed to answer the following sub-research question: "*What are the effects of combining technical, economic and social information on the social responsibility of policymakers' decisions in the heat transition, and how are trade-offs made?*" To answer this research sub-research question, I performed a Mann-Whitney U test. Table 5.6 provides an overview of the four hypotheses tested with the non-parametric test and their corresponding overall and neighbourhood-specific decisions. The analysis of these results was complemented with answers from policymakers in the interviews.

From table 5.6, it is possible to conclude that policymakers' decisions in the heat transition experiment are more socially responsible for nine out of 20 neighbourhoods after the inclusion of social information. Below is a series of explanations that might provide insight into the results of the inferential analysis.

Firstly, it is possible to conclude that policymakers (and therefore municipalities) approached the experiment differently, each in their own way. Initially, this became clear through the many unique rankings in the distribution of the rankings in both the survey experiment and the interviews. Several reasons could explain the difference in approach of each municipality. Personal characteristics could underlie these differences since factors such as educational background, professional experience and personal values vary for each policymaker. Additionally, organisational aspects of the transition could have influenced policymakers' decisions in the experiment. For instance, larger municipalities could benefit more from assistance and insights from other municipal departments, resulting in more comprehensive perspectives on the heat transition than smaller municipalities. The advantage of diverging approaches is that it creates an ideal learning environment where (similar) municipalities can exchange information and learn from each other.

This diverging perspective was exemplified by prioritising neighbourhoods with certain "favourable" techno-economic conditions. For instance, neighbourhood A has a low energy consumption and low costs. Some policymakers would first tackle such a relatively easy neighbourhood to gain trust and confidence to tackle more ambitious and problematic neighbourhoods. In this process, policymakers also anticipate that their plans and actions in one neighbourhood will affect other neighbourhoods (if performed successfully). One participant believed that after the successful disconnection of some neighbourhoods, the public support in a neighbourhood (with low public support) would increase. However, others argue that such relatively easy neighbourhoods are self-sufficient and do not need to be prioritised.

Another instance is when one of the policymakers decided to prioritise a neighbourhood with favourable techno-economic prospects but low public support. The argument was that if it succeeds in this neighbourhood, other neighbourhoods become easier. For this participant, their reasoning was coloured by what they are familiar with since their municipality is met with a similar situation in reality. As became clear from the interviews, these diverging approaches are standard practices that happen in reality. From the interviews, it became clear that every municipality has a different approach to the next steps of the heat transition, establishing the WUPs.

Furthermore, one of the policymakers stated that policymakers often tend to think in extremes and that neighbourhoods with "medium" values are often not the ones that people decide to prioritise. This statement proved to be true for hypotheses 1, 3 and 4. Firstly, for these hypotheses, policymakers attach value to either high or low public support, but the medium values seem trivial. Some policymakers, such as PM 2, adjusted their order entirely upon receiving information about the social indicator. (S)he argued that the social indicator was equally crucial to the technical and economic indicators. Similarly, policymakers attach more value to a high or low share of public participation. Difficulty navigating medium values of social indicators seems to be the overall observed pattern.

Interestingly enough, the pattern of thinking in extreme values did not occur in scenario 2 (energy consumption, costs and energy poverty) generated puzzling results. For instance, neighbourhood D encountered the highest share of energy poverty but did not gain more priority. Additionally, neighbourhood E faced the lowest share of energy poverty rose significantly in priority. It could only be speculated that perhaps the low value (an extreme value) of the social indicator prompts policymakers to prioritise it to use it as an example neighbourhood. Another possible reason is that many municipalities have energy poverty plans parallel to their WUPs. Since these existing energy poverty plans are often perceived as separate from their heat transition plans, the social indicator of the share of energy poverty could be seen as "trivial" information. In other words, disconnecting neighbourhoods from natural gas and relieving energy poverty are considered two different problems for which there are different approaches and resources, and therefore this scenario induced unexpected results. Finally, it could likely be connected to the lack of information about the ratio of social housing to private homeowners. Policymakers find areas with social housing easier to approach as they can communicate with the housing corporation instead of each homeowner.

However, there have also been two cases where the extreme value seemed trivial. In one of the scenarios, neighbourhood C faced enormous complexity, and even favourable social conditions seemed inadequate to increase its priority significantly. The reluctance to prioritise a particularly complex neighbourhood in techno-economic terms is also a typical pattern observed in the experiment. In the other scenario, neighbourhood C, with favourable techno-economic conditions (e.g., a high percentage of new residencies and medium costs) was believed to be reasonably self-sufficient. Thus, neighbourhood C ranked last. After receiving information about high public support in the neighbourhood, this picture of self-reliance might be enforced.

Finally, it also happened that the mean ranks between groups A and B were substantial for four of the neighbourhoods, but the p-value remained on the brink of statistical significance. Perhaps replicating this research with a larger sample size would lead to different results as larger sample sizes generally lead to smaller P values, increasing the probability of statistically significant results.

Table 5.6 Overview of four hypotheses with their corresponding overall and neighbourhood-specific decisions

Hypothesis	Overall decision	Neighbourhood-specific decision	
1. Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.	Reject	A	True
		B	True
		C	Untrue
		D	Untrue
		E	Untrue
2. Neighbourhoods with higher (/lower) shares of energy poverty obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy consumption and costs.	Reject	A	Untrue
		B	True
		C	Untrue
		D	Untrue
		E	True
3. Neighbourhoods with higher (/lower) levels of public support obtain a higher (/lower) priority in decision-making when this information is added to the existing information about energy labels and costs.	Reject	A	True
		B	True
		C	Untrue
		D	Untrue
		E	True
4. Neighbourhoods with higher (/lower) shares of public participation obtain a higher (/lower) priority in decision-making when this information is added to the existing information about the year of construction and costs.	Reject	A	True
		B	True
		C	Untrue
		D	Untrue
		E	Untrue

6. DISCUSSION

This section elaborates on the results of this study and places them in light of the scientific literature in subsection 6.1. Hereafter, subsection 6.2 discusses the limitations of the various components of the research.

6.1 FINDINGS

In light of the lack of the disconnect of academic research of social dimensions from real-world practice (Jenkins et al., 2020), this study aimed to proactively set up an experiment to integrate the academic field with real-world practice. This study set up a between-subjects experiment researching the relationship of, on the one hand, the inclusion of social information for the heat transition decision-making process and, on the other hand, Dutch local policymakers' decisions. The experiment randomly assigned the local policymakers to one of two experimental groups: groups A and B. Group A was exposed to only technical and economic information, but group B received technical, economic, and social information. In the experiment, experiment participants were presented with the following story problem: "*Please indicate the order in which you would disconnect the neighbourhoods below from natural gas, with 1 being the neighbourhood you would disconnect first and 5 being the neighbourhood you would disconnect last*". For instance, if the ranking of neighbourhoods A, B, C, D, and E is 1, 2, 3, 4, and 5, then the participant prioritises neighbourhood A the most. There were a total of four scenarios.

The results of this study indicate that the inclusion of information about social aspects impacts policymakers' decisions in the heat transition, although these decisions only become more socially responsible for nine out of 20 neighbourhoods. These results support the ideas of Sovacool and Dworkin (2015) that the concept of energy justice is interesting to use as a support for a decision-making tool to aid energy planners in making more informed choices. Finally, the main findings of this study disagree with Amer et al. (2020), who indicate that policymakers would probably find the quantification of social challenges in energy models not useful. Following this, a practical implication of these findings would be to include and quantify more social indicators in energy models.

Nonetheless, there was also a case in which the addition of social information led to a less socially responsible decision. This occurred in scenario 2, where information about energy poverty was added to energy consumption and costs. These findings were somewhat challenging to explain and left many unanswered questions. Neighbourhoods with the highest share of energy poverty did not receive more priority, so adding social information did not lead to a more socially responsible decision. Perhaps this is because energy poverty is often observed in social housing, which is often situated in the same areas, whereas energy poverty amongst homeowners tends to be dispersed. Policymakers find areas with social housing easier to approach as they can communicate with the housing corporation instead of each homeowner. Thus, it is speculated that the additional information on the ratio of social to private housing next to the energy poverty indicator would have likely made a difference. At last, it seems possible that the results are due to the fact that many municipalities now have energy poverty plans parallel to their WUPs, making them two separate programs. This can give policymakers reason to view this information more lightly. However, these are mere speculations.

A second essential finding concerns the divergent approaches of the surveyed and interviewed policymakers (and therefore municipalities) in the decision experiment about the heat transition (and therefore the heat transition). This became clear through the many unique rankings in the distribution of the rankings in both the survey experiment as well as the interviews. Several reasons could explain the difference in approach of each municipality. Personal characteristics could underlie these differences since factors such as educational background, professional experience and personal values vary for each policymaker. Additionally, organisational aspects of the transition could have influenced policymakers' decisions in the experiment. For instance, larger municipalities could benefit more from assistance and insights from other municipal departments, resulting in more comprehensive perspectives on the heat transition than smaller municipalities. The advantage of diverging approaches is that it creates an ideal learning environment where (similar) municipalities can exchange information and learn from each other.

This diverging perspective was exemplified by prioritising neighbourhoods with certain "favourable" techno-economic conditions. For instance, neighbourhood A has a low energy consumption and low costs. Some policymakers would first tackle such a relatively easy neighbourhood to gain trust and confidence to tackle more ambitious and problematic neighbourhoods. In this process, policymakers also anticipate that their plans and actions in one neighbourhood will affect other neighbourhoods (if performed successfully). One participant believed that after the successful disconnection of some neighbourhoods, the public support in a neighbourhood (with low public support) would increase. However, others argue that such relatively easy neighbourhoods are self-sufficient and do not need to be prioritised. In the prioritisation of these neighbourhoods, politics also plays a role. Some survey respondents acknowledge the role of the City Council and political environment to agree with the plans, which might also be the reason underlying the disconnection of the relatively easy neighbourhoods first. The interconnectedness of the political and energy system is also a pattern observed in the literature (Abramsky, 2010).

Furthermore, this study found that policymakers often think in extremes when considering social information, as stated by one of the interviewed policymakers. For instance, in scenario 1, in which information about public participation was added to energy consumption and costs, neighbourhoods with high levels of public participation obtained a higher priority in group B (after the inclusion of social information). Accordingly, in scenario 1, neighbourhoods with low levels of public participation obtained lower priority in group B. Conversely, neighbourhoods with medium levels of public participation did not obtain higher nor lower priority in group B. This result can be explained as follows: human decision-making has been discovered to systematically violate axioms of logic, known as cognitive biases (Tversky & Kahneman, 1974). One of these cognitive biases is the availability bias, defined as people overestimating the probability of occurrences that come to mind easily (Tversky & Kahneman, 1973). This may be why memories of extreme occasions impact people's decisions more substantially than moderate events (Ludvig et al., 2014).

Nonetheless, there were also cases in which extreme values of social information did not result in statistically significant differences between groups A and B. Policymakers were reluctant to prioritise neighbourhoods with high public support because of their techno-economic character (high consumption and high costs). It seems that the complexity faced in the neighbourhood made it too ambitious to prioritise, suggesting that techno-economic information plays a more prominent role in this case.

6.2 LIMITATIONS

This subsection discusses the various limitations concerning the research design and methodology (subsection 6.2.1), data (subsection 6.2.2), the response of the experiment (subsection 6.2.3), interview sample size (subsection 6.2.4), design and content of the survey (subsection 6.2.5), and Mann-Whitney U test (subsection 6.2.6).

6.2.1 Limitations regarding research design and methodology

The primary experimental approach in this study was a between-subject research design, where each participant was exposed to one of the treatments (Allen, 2017). In the experiment, participants were randomly assigned to either group A (only techno-economic information) or group B (techno-economic and social information). Charness et al. (2012) explain that between-subject designs often deviate from reality and can fail to identify actual patterns. This tendency to fail is especially true when real-world problems are posed within a between-subject, but choices about decisions may be considered within a within-subjects design. For instance, decisions about the heat transition may start off as situations in which policymakers are only equipped with relevant techno-economic information, but information streams are reasonably dynamic and constantly evolving.

An additional limitation of the between-subject design concerns the statistical power as each experimental group only provides one independent data point. Therefore bigger sample sizes are often necessary to compare two groups. However, if researchers want to compare even more groups, then trade-offs must be made between statistical power and the number of treatments to test (Charness et al., 2012). In case of a large sample size in the future, more treatments can be tested by varying information presentation (e.g., table form or bivariate choropleths).

Furthermore, as discussed in section 2, this study uses a convergent parallel design that researchers use to expand on the quantitative findings from a questionnaire. In the case of a convergent parallel design, the quantitative data collection and analysis phase and the qualitative data collection and analysis phase take place simultaneously. However, this simultaneous data collection and analysis complicates the explanation of unexpected (quantitative) results (e.g., results of scenario 2 (energy consumption, costs and energy poverty). Thus, an explanatory sequential design may be more fitting in case of future replication of this research. In this design, researchers start with the quantitative data collection, whereafter the analysis follows. The second and qualitative phase of the research follows after the results of the quantitative phase (Creswell & Plano Clark, 2011). This approach leaves room for the researcher to interpret the results from the survey experiment, tailor their questions based on these quantitative results, and gain better insights behind surprising and unexpected research results.

As opposed to the experiment, part of the exploratory interviews of policymakers took on an approach resembling a within-subject design. A within-subject design exposes each participant to more than one treatment, and causal evaluations can be obtained by analysing how participant behaviour changes after the treatment (Allen, 2017). In the interviews, participants were asked to rank the neighbourhoods before and after they received social information. One limitation of within-subject designs is known as the "demand effect", in which participants interpret the intentions of the experiment and change to satisfy these perceived intentions (Rosenthal, 1976; White, 1977). The demand effect could develop as follows in the interview: after obtaining the social information, the participant intentionally changes the ranking because (s)he believes this is the purpose of the experiment or the socially desirable answer.

6.2.2 Limitations regarding data

Finally, there were limitations surrounding the available data. For instance, one interviewed expert mentioned that sustainable initiatives are interesting to consider as a social indicator. Even though some municipal websites provide the number of active sustainable initiatives within the municipality, there is no structural data available on the number of (active) members or households or the frequency of gatherings. Currently, policymakers enter the neighbourhood and communicate with residents and initiatives; however, an overview and structural data would ease this process.

6.2.3 Limitations regarding the response of the experiment

Firstly, the response rate of the survey remained relatively low. After emailing 107 policymakers and setting up a LinkedIn post, 65 responses seem relatively low. It is likely due to the timing of the research schedule (the research took place during the summer holiday). In the future, it is recommended to set out surveys for specific target groups, such as policymakers, during working months to increase the response rate.

Then, merely 66% of the respondents who opened the survey completed the survey. A reason underlying this low completion rate could be the complexity experienced by the participants, which relates to issues related to the survey content voiced by survey participants and interviewed policymakers. Firstly, participants from both the experiment and interviews expressed the need for additional information. Survey and interview participants indicate a need for more data (both groups) and information regarding social aspects (group A), possible techniques, and renovation plans and state that it depends on politics. To reduce the cognitive load, only the necessary information was considered. Future research should provide additional necessary information to see whether additional information increases the completion rate. Additionally, researchers find that, in the absence of an interviewer to support participants in how to answer questions, the respondents will seek such information themselves (Schwarz, 1995; Schwarz et al., 1991). Future replications of the research could look into whether the presence of research explaining the content of the experiment leads to an increase in the completion rate.

Another reason for the low completion rate could be the lack of progress indicator. The benefit of such a progress indicator is that it updates survey participants on their process and should motivate them to complete the survey (Couper et al., 2001). As the progress bar in Qualtrics experienced problems after adding the randomising function, this has been left out of the survey. It is possible that some quit the survey close to the end. Future replications of the research could look into whether implementing a progress bar would increase the completion rate.

6.2.4 Limitations regarding interview sample size

Contrary to quantitative research methods, the sample size in qualitative research methods is often smaller due to its objective of obtaining an in-depth understanding of a phenomenon. In-depth interviews are not as concerned with generalisation (Dworkin, 2012). However, in the process of choosing a suitable sample size, there is practical uncertainty involved (Vasileiou et al., 2018). Many scholars argue that saturation is most important when examining the sample size (Mason, 2010), which is the point at which data collection does not reveal new theoretical insights (Dworkin, 2012). Therefore, I would argue that the sample size of five interviewed policymakers in this study is relatively small as I believe saturation has yet to be achieved. Interviews will still generate new insights as many municipalities have diverging approaches.

This notion is supported by the fact that most Dutch municipalities have their own approach and perspective on how to approach the heat transition. However, due to time constraints and the research schedule (the research took place during the summer holiday period), this would have been unavoidable. In the future, more Dutch policymakers could be interviewed to the point where saturation is achieved.

6.2.5 Limitations regarding the design and content of the survey experiment

There are also limitations concerning the design of the survey. The considerable growth of mobile phones that can be used to fill in surveys has presented survey researchers with new challenges (Mavletova, 2013). Essentially, the survey experiment in this study was designed to be taken on computers, as filling out the survey on mobile phones distorted the figures presented. Despite the recommendation on the introductory page of the survey to use a computer to fill in the survey, participants might not always have followed this advice.

Then, there are also critiques surrounding the decision in question (ranking the order in which neighbourhoods are disconnected from natural gas). One respondent remarks that disconnecting natural gas is a means to save CO2; however, CO2 reduction is also possible by properly insulating homes with a high consumption or wrong energy label without immediately disconnecting them from the grid. Often this is still expensive. However, this respondent filled in the survey based on the decision variable "disconnecting them from natural gas". Contrary to this respondent, others have considered most CO2 reduction as a starting point. The different approaches and interpretations of the decision variable have probably impacted the results of this study.

6.2.6 Limitations regarding the Mann-Whitney U test

In this study, the overall sample size of the experiment was N=39, with N=21 in group A and N=18 in group B. Robert et al. (1999) state that the Mann-Whitney U test can give wrongfully significant results, and according to Zimmerman (1987), inequality of variances can have distinct effects on the significance and the probability of Type I errors (when a null hypothesis is wrongly rejected) if sample sizes differ. It is possible that the overall sample size and the difference in the sample size of groups A and B caused a decrease in predictive power and an increase in Type I errors. However, due to time constraints and the research schedule (the research took place during the summer holiday period), this small sample size was anticipated. For future replication of this research, it is essential to increase the overall sample size and maintain equal group sizes to increase the power of the Mann-Whitney U test and reduce the number of Type I errors.

7. CONCLUSION AND RECOMMENDATIONS

This section concludes the research by re-iterating the purpose of the study and concisely providing an answer to the main research question in subsection 7.1. Hereafter, subsection 7.2 dives into recommendations for future research.

7.1 CONCLUSION

Dutch municipalities have been delegated the crucial task of the heat transition where natural gas in the built environment needs to be replaced by sustainable heating alternatives. However, it has become clear that the approach to this transition has been largely techno-economic centred whilst it remains a thoroughly social affair. Researchers argue that the exclusion of social aspects can undermine public support and lead to impediments to energy policy implementation and other risks such as deteriorating energy affordability. Additionally, considerable academic research in the energy field remains in the theoretical realm. Accordingly, examining whether social information impacts policymakers' decisions in the heat transition is essential. Not only to examine how policymakers make decisions in complex contexts but also how they make decisions in a context of trade-offs among competing objectives, especially since research suggests that our moral systems are ill-equipped to deal with the complexity of modern-day issues. Consequently, the following main research question was formulated:

"What is the impact of including social information in the information provided for decision-making processes on the social responsibility of policymakers' decisions for the heat transition?"

This study set up a between-subjects experiment where group A was exposed to only technical and economic information to measure the effect of social information inclusion in the information provided for decision-making processes on policymakers' decisions for the heat transition. In contrast, group B received technical, economic, and social information. The information was presented in the form of coloured choropleths. After establishing the relevant indicators and scenarios, the experiment was set up, which asked policymakers to order the neighbourhoods in the order in which they would disconnect these from natural gas. The data were collected among Dutch policymakers, and finally, four hypotheses were analysed with a Mann-Whitney U test.

The results indicate that for almost half the neighbourhoods (nine out of 20), social information affects policymakers' decisions regarding the heat transition. In these nine neighbourhoods, adding a social indicator causes a shift in prioritisation of the neighbourhoods and decisions to become more social(ly responsible). For example, neighbourhoods with high public participation or public support were prioritised more. This result suggests the importance that Dutch policymakers attach to social information for decision-making for the heat transition. However, as became clear from the interviews, the data are almost nonexistent, and data collection processes remain labour-intensive and ineffective as not many residents show input.

Strikingly, most of these nine neighbourhoods had "extreme" social values, e.g., either noticeably high or low. In case of the exceptions where extreme values seemed to be trivial, neighbourhoods seemed to be faced with either 1) enormous complex techno-economic conditions that even favourable social conditions seemed to be inadequate to increase significance, or 2) such favourable techno-economic conditions that the neighbourhood was believed to be self-sufficient enough.

Nonetheless, there was also a case in which the addition of social information led to a less socially responsible decision. This occurred in scenario 2, where information about energy poverty was added to information about energy consumption and costs. These findings were somewhat challenging to explain and left many unanswered questions. The hypothesis was that neighbourhoods with shares of low energy poverty would be prioritized less; however, unexpectedly, neighbourhoods that scored lowest in energy poverty obtained a higher priority after including this information. It seems possible that these results could be due to several reasons. Firstly, the lack of information about the ratio of social housing to private homeowners. During the interviews, policymakers indicate that they find areas with social housing easier to approach as they can communicate with the housing corporation instead of each homeowner. Thus, if policymakers had information about the ratio of rented compared to privately owned houses in a neighbourhood, then the value of information about energy poverty would also increase. Secondly, the interviewed policymakers indicated that the neighbourhood-implementation plans and energy poverty programs run parallel. Perhaps these parallel plans induced unexpected results as policymakers will already tackle problems of energy poverty through other plans, attaching less value to the energy poverty information in light of the heat transition. However, these remain speculations, and further research is needed into the inclusion of energy poverty considerations next to techno-economic information.

7.2 RECOMMENDATIONS

First, as the research indicates that extreme values of social factors of public participation and public support are essential for heat transition decision-making, more research is needed into these indicators. During the interviews, many policymakers indicate that they struggle with the involvement of residents and enlarging public participation. Currently, municipalities organise activities and inform the public, but this approach remains untargeted, and residents' attendance rate remains low. Therefore, future research should research which social factors increase residents' participation or public support so policymakers can use these data meaningfully. Consequently, this can lead to more socially responsible decision-making in the heat transition. This recommendation is consistent with what Bouw et al. (2021) found. They state that there is a lack of understanding of which factors should be included to represent the social context adequately. Future research should therefore research which social factors cause residents to partake in sustainable energy initiatives or are associated with high public support for the heat transition to construct individual household profiles. Interviewed policymakers indicate that even neighbourhood-level seems to be too aggregated.

Furthermore, this study demonstrated that many policymakers (and therefore municipalities) seemed to have diverging approaches to the heat transition. As this could depend on personal (educational background, professional experience, personal values) or organisational (municipality size) characteristics, this study can be deepened and replicated in various ways. Firstly, future studies should research various characteristics of the deciding individual. This recommendation is consistent with Perlaviciute et al. (2018), who state that it is essential to research what motivates critical stakeholders to adopt more socially responsible approaches. Additionally, research into the municipality (e.g., area size or heating strategy) may be interesting. Municipalities with an all-electric strategy might think differently about how to trade off social indicators with techno-economic ones than those with a district heating strategy. Within the municipality, it might be interesting to examine whether other municipal departments approach the situation in question the same. One of the policymakers stated that integral design for the energy transition, e.g. it is crucial also to include policymakers from the public space department. Stafford-Smith et al. (2017) argue that it is essential to design policies across sectors and actors to convert trade-offs into synergies (Scherer et al., 2018). Therefore, the perspective of policymakers of other municipal departments might generate interesting complementary insights.

Finally, this research can be replicated by adjusting the presentation of the information for decision-making. Lorenz et al. (2015) found that even within a reasonably comparable group of local practitioners, there are differences in comprehension and preferences for information visualisation. Thus, as an extension of this research, it is possible to display the information in a table format, information about energy labels can be displayed in the form of a bubble chart, or techno-economic information can be displayed in bivariate choropleths. This extension can be interesting to see whether decisions change if the same information is shown differently and which display of information or visuals leads to more social(ly responsible) decisions. Additionally, this research can provide insights into the preferred display of information and provide policymakers with ways to communicate in which they are most comfortable. Policymakers can then use their preferred (and comprehendible) information as food for thought during stakeholder meetings.

BIBLIOGRAPHY

Aalborg University. (n.d.-a). *H2RES*. Retrieved 17-05-2022 from https://www.energyplan.eu/othertools/island/h2res/

Aalborg University. (n.d.-b). *Introduction*. Retrieved 17-05-2022 from https://www.energyplan.eu/

Aalborg University. (n.d.-c). *Introduction to EnergyPLAN*. Retrieved 17-05-2022 from https://www.energyplan.eu/training/introduction/

Abramsky, K. (2010). *Sparking a worldwide energy revolution: Social struggles in the transition to a post-petrol world*. AK Press.

Alhadad, S. S. (2018). Visualizing data to support judgement, inference, and decision making in learning analytics: Insights from cognitive psychology and visualization science. *Journal of Learning Analytics*, *5*(2), 60–85-60–85.

Allen, M. (2017). *The SAGE encyclopedia of communication research methods*. SAGE publications.

Amer, S. B., Gregg, J. S., Sperling, K., & Drysdale, D. (2020). Too complicated and impractical? An exploratory study on the role of energy system models in municipal decision-making processes in Denmark. *Energy Research & Social Science*, *70*, 101673.

Atkinson, J.-A., Page, A., Wells, R., Milat, A., & Wilson, A. (2015). A modelling tool for policy analysis to support the design of efficient and effective policy responses for complex public health problems. *Implementation Science*, *10*(1), 1-9.

Boardman, B. (2013). *Fixing fuel poverty: challenges and solutions*. Routledge.

Botterill, L. C., & Hindmoor, A. (2012). Turtles all the way down: Bounded rationality in an evidence-based age. *Policy Studies*, *33*(5), 367-379.

Bouw, K., Noorman, K. J., Wiekens, C. J., & Faaij, A. (2021). Local energy planning in the built environment: An analysis of model characteristics. *Renewable and Sustainable Energy Reviews*, *144*, 111030.

Brewer, C. A. (2005). Designing better maps. *A Guide for GIS Users*, *1*.

Brewer, C. A., MacEachren, A. M., Pickle, L. W., & Herrmann, D. (1997). Mapping mortality: Evaluating color schemes for choropleth maps. *Annals of the Association of American Geographers*, *87*(3), 411-438.

Broto, V. C., & Baker, L. (2018). Spatial adventures in energy studies: An introduction to the special issue. *Energy Research & Social Science*, *36*, 1-10.

Buckingham, S., & Kulcur, R. (2009). Gendered geographies of environmental injustice. *Antipode*, *41*(4), 659-683.

Cairney, P. (2012). *Understanding Public Policy: Theories and Issues*. Palgrave Macmillan.

Cairney, P., & Kwiatkowski, R. (2017). How to communicate effectively with policymakers: combine insights from psychology and policy studies. *Palgrave Communications*, *3*(1), 1-8.

Cairney, P., & Weible, C. M. (2017). The new policy sciences: Combining the cognitive science of choice, multiple theories of context, and basic and applied analysis. *Policy Sciences*, *50*(4), 619-627.

Carley, S., & Konisky, D. M. (2020). The justice and equity implications of the clean energy transition. *Nature Energy*, *5*(8), 569-577.

Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of economic behavior & organization*, *81*(1), 1-8.

Comley, P. (1997). The use of the Internet as a data collection tool. ESOMAR Annual Conference, Edinburgh,

Connolly, D., Lund, H., Mathiesen, B. V., & Leahy, M. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy*, *87*(4), 1059-1082.

Costa-Campi, M. T., del Rio, P., & Trujillo-Baute, E. (2017). Trade-offs in energy and environmental policy. In (Vol. 104, pp. 415-418): Elsevier.

Couper, M. P., Traugott, M. W., & Lamias, M. J. (2001). Web survey design and administration. *Public opinion quarterly*, *65*(2), 230-253.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and Conducting Mixed Methods Research* (2nd ed.). SAGE.
Demeritt, D., & Langdon, D. (2004). The UK Climate Change Programme and communication with local authorities. *Global environmental change*, *14*(4), 325-336.
Dworkin, S. L. (2012). Sample size policy for qualitative studies using in-depth interviews. In (Vol. 41, pp. 1319-1320): Springer.
Eberhard, K. (2021). The effects of visualization on judgment and decision-making: a systematic literature review. *Management Review Quarterly*, 1-48.
ECW. (n.d.-a). *Aan de slag met de Leidraad*. Retrieved 15-04-2022 from https://www.expertisecentrumwarmte.nl/themas/de+leidraad/aan+de+slag+met+de+leidraad/default.aspx
ECW. (n.d.-b). *De Leidraad*. Retrieved 13-04-2022 from https://www.expertisecentrumwarmte.nl/themas/de+leidraad/default.aspx
European Commission. (2019). *Clean energy for all Europeans*. Retrieved from https://op.europa.eu/en/publication-detail/-/publication/b4e46873-7528-11e9-9f05-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=null&WT.ria_f=3608&WT.ria_ev=search
Flick, U. (2018). *An introduction to qualitative research*. sage.
Fraser, N. (1999). Social justice in the age of identity politics: Redistribution, recognition, and participation. *Culture and economy after the cultural turn*, *1*, 25-52.
Fraser, N. (2009). Social justice in the age of identity politics. *Geographic thought: A praxis perspective*, *72*, 91.
Frederiks, E. R., Stenner, K., & Hobman, E. V. (2015). The socio-demographic and psychological predictors of residential energy consumption: A comprehensive review. *Energies*, *8*(1), 573-609. https://doi.org/10.3390/en8010573
Gemeente Amsterdam. (2021). *Transitievisie Warmte Amsterdam*. https://overmorgen.nl/wp-content/uploads/2020/09/tvw-amsterdam.pdf
Gemeente Den Haag. (2022). *Transitievisie Warmte Den Haag*. Retrieved 14-4-2022 from https://denhaag.raadsinformatie.nl/document/11234823/1#search=%22RIS311707%22
Gemeente Gemert-Bakel. (2021). *Transitievisie Warmte 1.0*. Retrieved 19-04-2022 from https://www.gemert-bakel.nl/sites/default/files/20210923-Ontwerp-TVW-Gemert-Bakel-versie-1.0.pdf
Gemeente Noordenveld. (2021). *Warmtevisie Noordenveld*. https://noordenveld.nl/file/4550/download#:~:text=Noordenveld%20stelt%20een%20plan%20op,in%20Noordenveld%20aardgasvrij%20te%20maken.
Gemeente Oostzaan. (2021). *Wonen in Oostzaan zonder aardgas*. Retrieved 19-04-2022 from https://oostzaan.bestuurlijkeinformatie.nl/Agenda/Document/2ec785ca-5e75-41cc-9330-6c67452b22da?documentId=45d06182-6622-47a2-8fff-7ea5a8972e16&agendaItemId=be63d1ac-de8d-4a75-8ba2-37a9a3e43037
Gemeente Rotterdam. (2021). *Rotterdam aardgasvrij*. Retrieved 14-04-2022 from https://duurzaam010.nl/app/uploads/2021/06/Rotterdamse-Transitievisie-Warmte-1.pdf
Gemeente Scherpenzeel. (2021). *Transitievisie Warmte Scherpenzeel*. Retrieved 19-04-2022 from https://www.duurzaamscherpenzeel.nl/_flysystem/media/20211025-transitievisie-warmte-scherpenzeel.pdf
Gemeente Utrecht. (2021a). *Naar een CO2-vrije warmtevoorziening in 2050 Transitievisie Warmte deel I*. Retrieved 14-04-2022 from https://utrecht.bestuurlijkeinformatie.nl/Agenda/Document/13b91c41-cc55-4bb5-a0c5-45e6239ebbca?documentId=78aa14a3-8a5d-4616-b69e-24261acc7ea8&agendaItemId=ee8eea6c-93ba-42f4-8300-4b201890174b
Gemeente Utrecht. (2021b). *Naar een CO2-vrije warmtevoorziening in 2050 Transitievisie Warmte deel II*. Retrieved 14-04-2022 from https://utrecht.bestuurlijkeinformatie.nl/Agenda/Document/3a2786ca-2d0e-4f6f-

9ea1-44910d7cacb9?documentId=c0cb8b88-47e3-4cb3-b094-7f428e030fb4&agendaItemId=ac50ce1e-ddb2-49cb-b4d3-40de429f40b1
Gemeente Vaals. (2021). *Transitievisie Warmte Gemeente Vaals*. Retrieved 19-04-2022 from https://www.vaals.nl/data/downloadables/7/2/7/transitievisie-warmte-gemeente-vaals-2022-2030-versie-10.pdf
Gemeente Valkenswaard. (2021). *Transitievisie Warmte Valkenswaard*. Retrieved 19-04-2022 from https://www.bereikbaarvalkenswaard.nl/in-valkenswaard/documenten_43265/item/transitievisie-warmte_97237.html
Gemeente Waddinxveen. (2021). *Transitievisie Warmte Waddinxveen*. Retrieved 19-04-2022 from https://www.waddinxveen.nl/_flysystem/media/transitievisie-warmte-waddinxveen.pdf
Grafakos, S., Enseñado, E. M., & Flamos, A. (2017). Developing an integrated sustainability and resilience framework of indicators for the assessment of low-carbon energy technologies at the local level. *International Journal of Sustainable Energy*, *36*(10), 945-971.
Greening, L. A., & Bernow, S. (2004). Design of coordinated energy and environmental policies: use of multi-criteria decision-making. *Energy policy*, *32*(6), 721-735.
Haarbosch, S. W., Kaufmann, M., & Veenman, S. (2021). A Mismatch in Future Narratives? A Comparative Analysis Between Energy Futures in Policy and of Citizens. *Frontiers in Sustainable Cities*, 41.
Harrower, M., & Brewer, C. A. (2003). ColorBrewer. org: an online tool for selecting colour schemes for maps. *The Cartographic Journal*, *40*(1), 27-37.
Heikkila, T., & Cairney, P. (2018). Comparison of theories of the policy process. *Theories of the policy process*, 363-389.
Henrich, B. A., Hoppe, T., Diran, D., & Lukszo, Z. (2021). The use of energy models in local heating transition decision making: Insights from ten municipalities in the Netherlands. *Energies*, *14*(2), 423. https://doi.org/10.3390/en14020423
Hoppe, T., Coenen, F., & van den Berg, M. (2016). Illustrating the use of concepts from the discipline of policy studies in energy research: An explorative literature review. *Energy Research & Social Science*, *21*, 12-32.
Huygen, A., & Diran, D. (2020). *Criteria bij de besluitvorming rond een duurzame warmtevoorziening* (TNO 2020 R10832). https://repository.tno.nl//islandora/object/uuid:f74272d9-3b12-4fbf-bc3d-9e7a716c4455
Huynh, D. F., Karger, D. R., & Miller, R. C. (2007). Exhibit: lightweight structured data publishing. Proceedings of the 16th international conference on World Wide Web,
Intergovernmental Panel on Climate Change (IPCC). (2022). *Climate Change 2022 - Mitigation of Climate Change*. https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf
International Business Machines Corporation (IBM). (n.d.). *IBM SPSS Statistics*. Retrieved 08-08-2022 from https://www.ibm.com/products/spss-statistics
International Renewable Energy Agency (IRENA). (n.d.). *Energy Transition*. Retrieved 07-04-2022 from https://www.irena.org/energytransition#:~:text=The%20energy%20transition%20is%20a,emissions%20to%20limit%20climate%20change
Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, *11*, 174-182. https://doi.org/10.1016/j.erss.2015.10.004
Jenkins, K. E., Stephens, J. C., Reames, T. G., & Hernández, D. (2020). Towards impactful energy justice research: transforming the power of academic engagement. *Energy Research & Social Science*, *67*, 101510. https://doi.org/10.1016/j.erss.2020.101510
Jick, T. D. (1979). Mixing qualitative and quantitative methods: Triangulation in action. *Administrative science quarterly*, *24*(4), 602-611. https://doi.org/10.2307/2392366
Juergens, C. (2020a). Digital data literacy in an economic world: geo-spatial data literacy aspects. *ISPRS International Journal of Geo-Information*, *9*(6), 373.

Juergens, C. (2020b). Trustworthy COVID-19 mapping: Geo-spatial data literacy aspects of choropleth maps. *KN-journal of cartography and geographic information*, *70*(4), 155-161.
Jupyter. (n.d.). *About Us: Project Jupyter's origins and governance*. Retrieved 27-07-2022 from https://jupyter.org/
Kallbekken, S., Kroll, S., & Cherry, T. L. (2011). Do you not like Pigou, or do you not understand him? Tax aversion and revenue recycling in the lab. *Journal of Environmental Economics and Management*, *62*(1), 53-64.
Kemp, S., & Grace, R. C. (2021). Using ordinal scales in psychology. *Methods in Psychology*, *5*, 100054.
Klabbers, S. (2020). *Strengthening decision-making in the heat transition - A study on how to include non-techno-economic criteria into the decision-making process for the heat transition in the Netherlands* Utrecht University]. https://studenttheses.uu.nl/handle/20.500.12932/38146
Kraak, M.-J., & Ormeling, F. (2020). *Cartography: visualization of geospatial data*. CRC Press.
Krumm, A., Süsser, D., & Blechinger, P. (2022). Modelling social aspects of the energy transition: What is the current representation of social factors in energy models? *Energy*, *239*, 121706.
Kwiatkowski, R. (2016). Mind games. *House Magazine*, *8*, 34-35.
Laerd Statistics. (2015). *Mann-Whitney U test using SPSS Statistics. Statistical tutorials and software guides.* . Retrieved 08-08-2022 from https://statistics.laerd.com/
Laird, F. N. (2013). Against transitions? Uncovering conflicts in changing energy systems. *Science as Culture*, *22*(2), 149-156.
Landers, J. (1981). Quantification in history, topic 4: Hypothesis testing II - differing central tendency. *John Landers*.
Lorenz, S., Dessai, S., Forster, P. M., & Paavola, J. (2015). Tailoring the visual communication of climate projections for local adaptation practitioners in Germany and the UK. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *373*(2055), 20140457. https://doi.org/10.1098/rsta.2014.0457
Ludvig, E. A., Madan, C. R., & Spetch, M. L. (2014). Extreme outcomes sway risky decisions from experience. *Journal of Behavioral Decision Making*, *27*(2), 146-156.
Lund, H., Thellufsen, J. Z., Østergaard, P. A., Sorknæs, P., Skov, I. R., & Mathiesen, B. V. (2021). EnergyPLAN–Advanced analysis of smart energy systems. *Smart Energy*, *1*, 100007.
Mahdi, M. N., Ahmad, A. R., Ismail, R., Subhi, M. A., Abdulrazzaq, M. M., & Qassim, Q. S. (2020). Information overload: the effects of large amounts of information. 2020 1st. Information Technology To Enhance e-learning and Other Application (IT-ELA,
Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The annals of mathematical statistics*, 50-60.
Markowitz, E. M., & Shariff, A. F. (2012). Climate change and moral judgement. *Nature Climate Change*, *2*(4), 243-247.
Mason, M. (2010). Sample size and saturation in PhD studies using qualitative interviews. Forum qualitative Sozialforschung/Forum: qualitative social research,
Mavletova, A. (2013). Data quality in PC and mobile web surveys. *Social Science Computer Review*, *31*(6), 725-743.
Mayer, R. E. (2002). Multimedia learning. In *Psychology of learning and motivation* (Vol. 41, pp. 85-139). Elsevier.
Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational psychologist*, *38*(1), 43-52.
McCauley, D. A., Heffron, R. J., Stephan, H., & Jenkins, K. (2013). Advancing energy justice: the triumvirate of tenets. *International Energy Law Review*, *32*(3), 107-110.
McKnight, P. E., & Najab, J. (2010). Mann-Whitney U Test. *The Corsini encyclopedia of psychology*, 1-1.
Meyer, M., & van de Poll, F. (2021). *CEGOIA Gebruikershandleiding*. https://ce.nl/wp-content/uploads/2021/04/CE_Delft_CEGOIA_gebruikershandleiding_2.0.pdf

Miller, C. A., Iles, A., & Jones, C. F. (2013). The social dimensions of energy transitions. *Science as Culture*, *22*(2), 135-148.

Miller, C. A., & Richter, J. (2014). Social planning for energy transitions. *Current Sustainable/Renewable Energy Reports*, *1*(3), 77-84.

Morse, J. M. (1991). Approaches to qualitative-quantitative methodological triangulation. *Nursing research*, *40*(2), 120-123.

Müller, F., Breckling, B., Jopp, F., & Reuter, H. (2011). What are the general conditions under which ecological models can be applied? In *Modelling complex ecological dynamics* (pp. 13-28). Springer.

Nachar, N. (2008). The Mann-Whitney U: A test for assessing whether two independent samples come from the same distribution. *Tutorials in quantitative Methods for Psychology*, *4*(1), 13-20.

Netbeheer Nederland. (2017). *Transform*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_2b858576f9.pdf

Netbeheer Nederland. (2018). *Energie Transitie Atlas (ETA)*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_c769f55771.PDF

Netbeheer Nederland. (2021a). *CEGOIA*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_bf9465dbdb.pdf

Netbeheer Nederland. (2021b). *Pico*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_39d3f1091b.pdf

Netbeheer Nederland. (2021c). *Pien*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_fef8a7b997.pdf

Netbeheer Nederland. (2021d). *Vesta Mais*. Retrieved 28-03-2022 from https://www.netbeheernederland.nl/_upload/Files/Rekenmodellen_21_6819e2a4f0.pdf

Netbeheer Nederland. (n.d.-a). *Keuzehulp Energietransitie Rekenmodellen*. Retrieved 31-03-2022 from https://etrm.nl/

Netbeheer Nederland. (n.d.-b). *Rekenmodellen*. Retrieved 30-03-2022 from https://www.netbeheernederland.nl/dossiers/rekenmodellen-21

Office for National Statistics. (2022). *Local Authority Districts (December 2021) GB BFC*. Retrieved 22-06-2022 from https://geoportal.statistics.gov.uk/datasets/ons::local-authority-districts-december-2021-gb-bfc/about

Padilla, L. M., Creem-Regehr, S. H., Hegarty, M., & Stefanucci, J. K. (2018). Decision making with visualizations: a cognitive framework across disciplines. *Cognitive research: principles and implications*, *3*(1), 1-25.

Pászto, V., Jürgens, C., Tominc, P., & Burian, J. (2020). *Spationomy: Spatial Exploration of Economic Data and Methods of Interdisciplinary Analytics*. Springer Nature.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, inc.

PBL. (2020a). *Gemeenterapportages*. Retrieved 20-06-2022 from https://themasites.pbl.nl/leidraad-warmte/2020/#

PBL. (2020b). *Startanalyse aardgasvrije buurten 2020 - Gemeenterapport toelichting bij resultaten*. Retrieved 22-08-2022 from https://www.pbl.nl/publicaties/startanalyse-aardgasvrije-buurten-2020

PBL. (2021). *Functioneel Ontwerp Vesta MAIS 5.0*. Retrieved 04-05-2022 from https://www.pbl.nl/publicaties/functioneel-ontwerp-vesta-mais-50

PBL. (n.d.). *Strategieën en varianten*. Retrieved 12-09-2022 from https://themasites.pbl.nl/leidraad-warmte/2020/#

Peers, I. (2006). *Statistical analysis for education and psychology researchers: Tools for researchers in education and psychology*. Routledge.

Perlaviciute, G., Steg, L., Contzen, N., Roeser, S., & Huijts, N. (2018). Emotional responses to energy projects: Insights for responsible decision making in a sustainable energy transition. *Sustainability*, *10*(7), 2526.

PICO. (n.d.). *PICO stopt als vrij toegankelijke dienst*. Retrieved 04-05-2022 from https://pico.geodan.nl/pico/index.html

Porter, J. J., Demeritt, D., & Dessai, S. (2015). The right stuff? Informing adaptation to climate change in British local government. *Global environmental change*, *35*, 411-422.

Python. (n.d.). *What is Python? Executive Summary*. Retrieved 06-09-2022 from https://www.python.org/doc/essays/blurb/

Radtke, J., & Scherhaufer, P. (2022). A social science perspective on conflicts in the energy transition: An introduction to the special issue. *Utilities Policy*, *78*, 101396.

Reed, M. S., Vella, S., Challies, E., De Vente, J., Frewer, L., Hohenwallner‐Ries, D., Huber, T., Neumann, R. K., Oughton, E. A., & Sidoli del Ceno, J. (2018). A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration ecology*, *26*, S7-S17.

Reja, U., Manfreda, K. L., Hlebec, V., & Vehovar, V. (2003). Open-ended vs. close-ended questions in web questionnaires. *Developments in applied statistics*, *19*(1), 159-177.

Renn, O., Kock, W., Schweizer, P.-J., Bovet, J., Benighaus, C., Scheel, O., & Schroter, R. (2013). Public participation within the german energiewende. policies and guidelines for planning processes/Die offentlichkeit an der energiewende beteiligen: grundsatze und leitlinien fur planungsvorhaben. *GAIA-Ecological Perspectives for Science and Society*, *22*(4), 279-281.

Rijksdienst voor Ondernemend Nederland. (2017). *Samen aan de slag met aardgasvrij, inspiratie voor gemeenten*. Utrecht, The Netherlands Retrieved from https://www.rvo.nl/sites/default/files/2017/12/Start%20Aardgasvrij_inspiratie%20voor%20gemeenten.pdf

Rijksoverheid. (2019). *Klimaatakkoord*. Retrieved 20-12-2021 from https://www.rijksoverheid.nl/documenten/rapporten/2019/06/28/klimaatakkoord

Rijksoverheid. (n.d.-a). *Energielabel woning*. Retrieved 22-07-2022 from https://www.rijksoverheid.nl/onderwerpen/energielabel-woningen-en-gebouwen/energielabel-woning#:~:text=Een%20energielabel%20laat%20zien%20hoe,een%20nieuwe%20woning%20laten%20bouwen.

Rijksoverheid. (n.d.-b). *Voortgang klimaatdoelen*. Rijksoverheid. Retrieved 21-12-2021 from https://www.rijksoverheid.nl/onderwerpen/klimaatverandering/voortgang-klimaat doelen

Robert, C. P., Casella, G., & Casella, G. (1999). *Monte Carlo statistical methods* (Vol. 2). Springer.

Rosenthal, R. (1976). Experimenter effects in behavioral research.

Saxena, D., & Lamest, M. (2018). Information overload and coping strategies in the big data context: Evidence from the hospitality sector. *Journal of Information Science*, *44*(3), 287-297.

Scherer, L., Behrens, P., de Koning, A., Heijungs, R., Sprecher, B., & Tukker, A. (2018). Trade-offs between social and environmental Sustainable Development Goals. *Environmental science & policy*, *90*, 65-72.

Schiewe, J. (2019). Empirical studies on the visual perception of spatial patterns in choropleth maps. *KN-journal of cartography and geographic information*, *69*(3), 217-228.

Schipper, L., Unander, F., Murtishaw, S., & Ting, M. (2001). Indicators of energy use and carbon emmissions: Explaining the energy economy link. *Annual Review of Environment and Resources*, *26*, 49.

Schlosberg, D. (2003). The justice of environmental justice: Reconciling equity, recognition, and participation in a political movement in A. Light and A. De‐Shalit, moral and political reasoning in environmental practice. In: London: MIT Press.

Shyu, C.-W. (2021). A framework for 'right to energy'to meet UN SDG7: Policy implications to meet basic human energy needs, eradicate energy poverty, enhance energy justice, and uphold energy democracy. *Energy Research & Social Science*, *79*, 102199.

Simcock, N. (2016). Procedural justice and the implementation of community wind energy projects: A case study from South Yorkshire, UK. *Land Use Policy*, *59*, 467-477.
Smith, H., & Gilbert, C. (2018). Communication Barriers and Lessons Learned in Energy Policy. *Sustainability*, *10*(2), 449.
Sovacool, B. K. (2014). What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Research & Social Science*, *1*, 1-29. https://doi.org/10.1016/j.erss.2014.02.003
Sovacool, B. K., Burke, M., Baker, L., Kotikalapudi, C. K., & Wlokas, H. (2017). New frontiers and conceptual frameworks for energy justice. *Energy policy*, *105*, 677-691. https://doi.org/10.1016/j.enpol.2017.03.005
Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. *Applied Energy*, *142*, 435-444. https://doi.org/10.1016/j.apenergy.2015.01.002
Stafford-Smith, M., Griggs, D., Gaffney, O., Ullah, F., Reyers, B., Kanie, N., Stigson, B., Shrivastava, P., Leach, M., & O'Connell, D. (2017). Integration: the key to implementing the Sustainable Development Goals. *Sustainability science*, *12*(6), 911-919.
Statistics Netherlands. (2021). *Energie-indicatoren naar regio, 2018*. Retrieved 20-06-2022 from https://www.cbs.nl/nl-nl/maatwerk/2021/02/energie-indicatoren-naar-regio-2018
Statistics Netherlands. (2022). *Bereidheid energietransitiemaatregelen 2018*. Retrieved 13-06-2022 from https://www.cbs.nl/nl-nl/maatwerk/2022/26/bereidheid-energietransitiemaatregelen-2018
Stebbins, R. A. (2001). *Exploratory research in the social sciences* (Vol. 48). Sage.
Steg, L., Perlaviciute, G., Sovacool, B. K., Bonaiuto, M., Diekmann, A., Filippini, M., Hindriks, F., Bergstad, C. J., Matthies, E., & Matti, S. (2021). A Research agenda to better understand the human dimensions of energy transitions. *Frontiers in psychology*, 2421. https://doi.org/10.3389/fpsyg.2021.672776
Straver, K., Mulder, P., Middlemiss, L., Hesselman, M., Feenstra, M., & Herrero, S. T. (2020). *Energiearmoede en de energitransitie*. https://www.tno.nl/nl/aandachtsgebieden/energietransitie/roadmaps/systeemtransitie/de-sociale-aspecten-van-de-energietransitie/energiearmoede/
Tashakkori, A., & Teddlie, C. (2003). Issues and dilemmas in teaching research methods courses in social and behavioural sciences: US perspective. *International journal of social research methodology*, *6*(1), 61-77.
Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive psychology*, *5*(2), 207-232.
Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *science*, *185*(4157), 1124-1131.
United Nations Framework Convention on Climate Change (UNFCCC). (n.d.). *The Paris Agreement*. United Nations Framework Convention on Climate Change (UNFCCC). Retrieved 09-11-2021 from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
van Berkel, P. (2019). *Realising a just transition to gas-free heating in the Dutch social housing sector - Integration of energy poverty considerations into decision-making* Wageningen University]. Wageningen.
van den Berg, R. G. (n.d.). *SPSS Mann-Whitney Test - Simple Example* Retrieved 15-09-2022 from https://www.spss-tutorials.com/spss-mann-whitney-test-simple-example/
Vasileiou, K., Barnett, J., Thorpe, S., & Young, T. (2018). Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. *BMC medical research methodology*, *18*(1), 1-18.
Vera, I., Langlois, L., & Rogner, H. (2007). Indicators for sustainable energy development. *Energy Indicators for Sustainable Development: Country Studies on Brazil, Cuba, Lithuania Mexico, Russian Federation, Slovakia and Thailand, pg*, 5-16.

VNG. (n.d.-a). *Data bron omschrijving*. Retrieved 04-05-2022 from https://commondatafactory.nl/docs/metadata
VNG. (n.d.-b). *Energietransitie Gebouwde Omgeving Datavoorziening VNG Realisatie*. Retrieved 03-05-2022 from https://dego.vng.nl/?tab=gebouw&label=topo&layer=layer0#16.5/52.087049/4.308188
Wainwright, J., & Mulligan, M. (2013). *Environmental modelling: finding simplicity in complexity*. John Wiley & Sons.
Walker, G. (2009). Beyond distribution and proximity: exploring the multiple spatialities of environmental justice. *Antipode*, *41*(4), 614-636.
Walker, G., & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. *Energy policy*, *49*, 69-75.
Warren, C. R., & McFadyen, M. (2010). Does community ownership affect public attitudes to wind energy? A case study from south-west Scotland. *Land Use Policy*, *27*(2), 204-213.
White, R. A. (1977). The influence of experimenter motivation, attitudes, and methods of handling subjects on psi test results. *Handbook of parapsychology*, 273-301.
Whitley, E., & Ball, J. (2002). Statistics review 4: sample size calculations. *Critical care*, *6*(4), 1-7.
Williams, S., & Doyon, A. (2019). Justice in energy transitions. *Environmental Innovation and Societal Transitions*, *31*, 144-153.
Wolffenbuttel, D. P. J. (2020). *The Energy Transition in the Built Environment: Modelling and Visualising Sustainable Urban Development* Delft University of Technology].
Yektansani, K., & Azizi, S. (2021). Using Machine Learning to Predict Consumers' Environmental Attitudes and Beliefs. https://doi.org/10.22004/ag.econ.313902
Young, I. M. (2002). *Inclusion and democracy*. Oxford University press on demand.
Zimmerman, D. W. (1987). Comparative power of Student t test and Mann-Whitney U test for unequal sample sizes and variances. *The Journal of Experimental Education*, *55*(3), 171-174.

A. APPENDIX A: CURRENT DECISION-MAKING PROCESS IN THE HEAT TRANSITION

This section describes the current decision-making process. First, we detail the national decision-making process in subsection 1.1; whereafter, I describe the local decision-making process from a municipal perspective in subsection 1.2. More specifically, I analyse twelve municipal plans for the heat transition through document analysis. Subsequently, subsection 1.3 describes the decision-making process from a modeller perspective, where I analyse various heat transition models and tools and find relevant themes. Finally, I draw a conclusion in subsection 1.4.

A.1 NATIONAL DECISION-MAKING IN THE HEAT TRANSITION

To aid municipalities in their responsibilities in the heat transition, the national government has developed "the Leidraad". The Leidraad acts as a guiding instrument and consists of two parts: 1) "the Start Analysis" (Startanalyse) developed by PBL Netherlands Environmental Assessment Agency (PBL) and 2) the "Guideline for local analysis" (Handreiking voor de lokale analyse) developed by Heating Expertise Centre (ECW) (ECW, n.d.-b).

The Leidraad states that, in the trade-off of various options, the alternative with the lowest national costs prevails regardless of who may carry the costs (ECW, n.d.-a). However, the financially most competitive option does not necessarily equal the most optimal alternative. In addition, the lowest national costs do not equal societal costs, which consider societal welfare (Huygen & Diran, 2020). Moreover, the Start Analysis deploys PBL's Vesta MAIS model to give municipalities an initial idea of which heat supply options might fit the neighbourhoods. However, the model is based on techno-economic and sustainable indicators (such as national costs, energy demand and CO2 emission) (Huygen & Diran, 2020). These findings highlight the disregard for integrating the societal and social aspects of the heat transition on a national level. Thus, the Leidraad forms an adequate steppingstone for decision-making, but not more than that (Huygen & Diran, 2020).

A.2 LOCAL DECISION-MAKING IN THE HEAT TRANSITION

Municipalities make choices in the heat transition that have long-lasting impacts on the future of their neighbourhoods' heat supply (Huygen & Diran, 2020). In 2021, Dutch municipalities drew up a plan on how they intend to advance the heat transition, the so-called "Transition Vision Heat" (hereinafter TvW). The TvW needs to include details about (1) in which order neighbourhoods will be disconnected from natural gas before 2030, (2) when this disconnection occurs and (3) which heating alternatives are considered for each neighbourhood (Rijksoverheid, 2019). Drawing up this plan proved to be difficult as, to date, few neighbourhoods have been disconnected from natural gas, which makes it difficult to find quality examples (Huygen & Diran, 2020). In current decision-making processes, Dutch municipalities are therefore trying to find their own way and are establishing their own criteria (Huygen & Diran, 2020).

I analyse twelve municipalities through a document analysis to gain more insights into local decision-making in the heat transition. This analysis comprises the four largest, four medium-sized and four small Dutch municipalities. The four largest municipalities include: Amsterdam, Utrecht, Rotterdam and The Hague, the four medium-sized municipalities include: Waddinxveen, Noordenveld, Valkenswaard and Gemert-Bakel, and the four small municipalities include: Scherpenzeel, Alpen-Chaam, Vaals, and Oostzaan. Most of these TvWs (eight out of twelve) were drawn up by consultancy bureaus specialised in the energy transition, such as Over Morgen, Warmte Transitie Makers, Buro Loo, and Driven by Values (see Table A.1). These TvWs are often primarily written by the consultancy.

Table A.1 Overview of which consultancies wrote which TvW

Municipality→ **Consultancy ↓**	**Amsterdam**	**Utrecht**	**Rotterdam**	**The Hague**	**Waddinxveen**	**Noordenveld**	**Valkenswaard**	**Gemert-Bakel**	**Scherpenzeel**	**Alphen-Chaam**	**Vaals**	**Oostzaan**
Municipality		■	■	■						■		
Over Morgen	■											■
Warmte Transitie Makers					■		■	■	■			
Buro Loo						■						
Driven by Values											■	

The analysis revealed that the twelve municipalities had overlapping but diverging criteria and assumptions. I distributed these criteria into economic, technical, environmental, and social dimensions. I discuss each of these themes in the following subsections, and each subsection provides an overview of which municipalities consider which dimension.

a.2.1 Economic dimension

Every municipality considers an economic dimension as a starting point for their decisions in the heat transition. From their research into Dutch policymaking documents about the energy transition, Haarbosch et al. (2021) reveal that policy documents often anticipate future changes from an economic and technical perspective. The TvWs consider three sorts of economic assumptions: 1) lowest national costs, 2) lowest societal costs, and 3) lowest costs for the end-user. Table A.2 depicts which TvWs considered which economic assumptions.

a.2.1.1 Affordability – lowest national costs

In many TvWs, the affordability assumption adheres to the affordability definition set in the Leidraad. As discussed before, the Leidraad considers affordability the lowest national cost (ECW, n.d.-a). However, Huygen and Diran (2020) extensively discuss that the lowest national costs do not necessarily equal the lowest local societal costs. Other factors are considered in considering the lowest local societal costs, e.g. immaterial costs or options that generate the highest added value for society (Huygen & Diran, 2020).

Considering the lowest national costs remains an important theme throughout all TvWs as it is the leading principle considered by the national government (ECW, n.d.-a). Consequently, some municipalities deploy PBL's Start Analysis to validate their findings. For instance, the municipality of Noordenveld started by gathering local information to determine the opportunities for gas-free neighbourhoods, whereafter, it validates its findings by comparing these to the PBL's Start Analysis. The municipality concludes: "*The conclusion is that the possible solutions per neighbourhood in this TvW correspond to the possible solutions suggested by the Start Analysis as the most affordable solution.*" (Gemeente Noordenveld, 2021).

a.2.1.2 Affordability – lowest societal costs

Multiple TvWs associate affordability with the lowest societal costs so that society's total costs remain lowest. In some TvWs, affordability forms the foundation of further calculations and considerations. For instance, Amsterdam's TvW states: "*The financial-technical analysis has determined the heating option based on the lowest societal costs, whereafter these are tested against two other relevant criteria: the availability of sustainable sources and sustainability.*". (Gemeente Amsterdam, 2021).

In some TvWs, such as that of Utrecht, affordability partly determines the robustness of a solution. Utrecht's TvW states: "*Robustness means that the chosen alternative is technically and economically the best solution for the area in the long term.*" (Gemeente Utrecht, 2021b). After researching all of Utrecht's neighbourhoods, it became evident that for 72 neighbourhoods, a district heating system resulted in the lowest societal costs. For these 72 neighbourhoods, the municipality researched the consequences of a scenario in which all buildings insulate to energy level B. Hereafter, Utrecht concludes: "*For 63 neighbourhoods, district heating systems remain the solution with the lowest societal costs. We call these the robust neighbourhoods.*" (Gemeente Utrecht, 2021b).

Another crucial remark that accompanies affordability is the distribution of the costs. All municipalities attach great importance to affordability, but none address how to distribute the costs. The municipality of Amsterdam states: *"The TvW does not address how the lowest costs are distributed fairly and are not about the various instruments that ensure a fair distribution."* (Gemeente Amsterdam, 2021). This topic is addressed in the subsequent subsection of the social dimension.

a.2.1.3 Affordability – lowest costs for the end-user

In the majority of municipalities, affordability also has an additional meaning attached to it: the lowest costs for the end-user. For example, the municipality of Scherpenzeel considers this: *"Affordability is essential. [..] We aim for the lowest total costs for the heating solution and the lowest costs for residents and companies."* (Gemeente Scherpenzeel, 2021). In these cases, the municipalities aim for cost neutrality, which means that the total housing costs should not increase due to the energy transition (Gemeente Amsterdam, 2021). The municipality of Waddinxveen places this definition within an even broader context through the inclusion of more stakeholders: *"The costs must be bearable for all involved (end-users, building owners, authorities, network operators and heat suppliers)."* (Gemeente Waddinxveen, 2021).

Table A.2 Overview of the economic assumptions considered in the TvW by Dutch municipalities

Municipality→ / Assumption ↓	Amsterdam	Utrecht	Rotterdam	The Hague	Waddinxveen	Noordenveld	Valkenswaard	Gemert-Bakel	Scherpenzeel	Alphen-Chaam	Vaals	Oostzaan
Economic												
Affordability (lowest national costs)*					■	■	■	■	■		■	
Affordability (lowest societal costs)*	■	■	■			■				■		■
Affordability (end-user)	■	■	■	■	■	■	■	■	■	■		■

* It seems that in some municipalities they do not distinguish between the term "societal costs" and "national costs", e.g. in TvW of Noordenveld: "*societal (or national) costs are the total costs in the Netherlands of all measures that are necessary to realise a strategy, regardless of who pays those costs.*" (Gemeente Noordenveld, 2021).

a.2.2 Technical dimension

Next to the economic assumptions, every municipality also considers a technical assumption as a starting point for their heat transition decisions. This finding aligns with Haarbosch et al. (2021), who reveal that policy documents often anticipate future changes from an economic and technical perspective. I break these technical assumptions into three types: 1) natural moments (linking opportunities), 2) existing infrastructure and availability of sustainable heating sources, and 3) building properties or similarities of the buildings. Table A.3 depicts which TvWs are considered from the technical dimension.

a.2.2.1 Natural moments and linking opportunities

A technical assumption mentioned by most municipalities is seizing opportunities that arise due to "natural moments", so-called linking opportunities. These linking opportunities include various plans, such as plans to replace old infrastructure, new construction plans, and plans of property owners (Gemeente Den Haag, 2022), but municipalities also gathered information on planned sewer and gas pipeline works (Gemeente Rotterdam, 2021).

In addition, there is also another kind of linking opportunity, which is when municipalities pair the heat transition to tackle other existing problems. In Noordenveld, the municipality aims to combine the heat transition with reducing water nuisance and heat stress (Gemeente Noordenveld, 2021). Rotterdam's TvW includes more examples of linking opportunities: *"We make connections with other tasks in an area as much as possible, such as reducing water nuisance, improving the quality of life, tackling poverty and strengthening the local economy."* (Gemeente Rotterdam, 2021).

It is essential to mention that linking opportunities and affordability are often considered the main criteria. Oostzaan's TvW states: *"It is important to mention that an area does not necessarily need to meet all selection criteria (which were: public support, affordability, linking opportunities, availability of sustainable heating sources and similarity of buildings) to be included in the review. Often, linking opportunities and affordability are leading."* (Gemeente Oostzaan, 2021).

a.2.2.2 Existing infrastructure and availability of sustainable heating sources

Another frequently mentioned technical assumption is existing infrastructure and the availability of sustainable heating sources. Existing infrastructure can refer to existing cables and pipelines for energy (Gemeente Den Haag, 2022). In addition, the presence of sustainable heating sources locally is a relevant determinant (Gemeente Amsterdam, 2021), as these sources shorten energy-transportation distance (Gemeente Den Haag, 2022).

a.2.2.3 Building properties or similarity of the buildings

Many municipalities consider the building properties or similarities of buildings in an area. The characteristics of buildings impact the heat demand, especially older buildings that will require a higher temperature for heating (Gemeente Gemert-Bakel, 2021). Many municipalities underline the importance of insulating buildings to reduce the heat demand. Gemert-Bakel's heat transition strategy for the coming years mainly centres around insulating the built environment as the municipality plans on learning from the experiences of other municipalities (Gemeente Gemert-Bakel, 2021). From Gemert-Bakel's TvW: "*This provides a glimpse into what will happen in the municipality in the coming thirty years to heat the built environment without natural gas. We indicate how we will start saving and insulating in the coming years.*" (Gemeente Gemert-Bakel, 2021). Other building characteristics include construction year (Gemeente Noordenveld, 2021), energy label (Gemeente Scherpenzeel, 2021), building density (Gemeente Vaals, 2021).

Furthermore, some municipalities prefer to tackle neighbourhoods that have similar buildings. That way, there is a clear preference for an alternative, and as a result, redundant infrastructure and, therefore, unnecessary costs can be prevented (Gemeente Oostzaan, 2021). In addition, some municipalities also consider density.

Table A.3 Overview of the technical assumptions considered in the TvW by Dutch municipalities

Municipality→ **Assumption ↓**	**Amsterdam**	**Utrecht**	**Rotterdam**	**The Hague**	**Waddinxveen**	**Noordenveld**	**Valkenswaard**	**Gemert-Bakel**	**Scherpenzeel**	**Alphen-Chaam**	**Vaals**	**Oostzaan**
Technical												
Natural moments and linking opportunities												
Existing infrastructure and availability of sustainable heat sources												
Building properties or similarities of the buildings												

a.2.3 Environmental dimension

The environmental dimension is also standard criteria as a starting point for municipalities' decisions in the heat transition. According to Haarbosch et al. (2021), the environmental dimension is dominant in what is considered a "desired" future within Dutch energy policy documents. This presents dangers as it assumes that citizens are expected to participate because they also share these goals, but often carbon neutrality is not a dominant issue considered by citizens. I divided environmental assumptions into two types: 1) sustainable sources and 2) CO2 emissions. Table A.4 depicts which TvWs considered which environmental assumptions.

a.2.3.1 Sustainable source

Naturally, sustainability is an essential assumption as this underlying red thread of the TvWs. Where the municipality of Utrecht characterises sustainability as: *"a source that provides the heat in the heat network must be sustainable in the long run"* (Gemeente Utrecht, 2021a), Waddinxveen's TvW expresses sustainability as follows: *"good for the environment and climate"* (Gemeente Waddinxveen, 2021).

a.2.3.2 CO2-emission

The municipality of Amsterdam considers CO2 emissions within the realm of environmental assumptions: "*Heat options that lead to savings in CO2 emissions and that prevent a permanent dependence on fossil fuels are given priority over those that do not.*" (Gemeente Amsterdam, 2021). Similarly, in Waddinxveen, exploratory research into the choices of the neighbourhood used two starting points: *"The calculation of the costs and CO2-emission savings of the various technical alternatives."* (Gemeente Noordenveld, 2021).

Table A.4 Overview of the environmental assumptions considered in the TvW by Dutch municipalities

Municipality→ Assumption ↓	**Amsterdam**	**Utrecht**	**Rotterdam**	**The Hague**	**Waddinxveen**	**Noordenveld**	**Valkenswaard**	**Gemert-Bakel**	**Scherpenzeel**	**Alphen-Chaam**	**Vaals**	**Oostzaan**
Environmental												
Sustainable source	■	■	■	■	■	■	■	■	■	■	■	■
CO2 emission	■	■		■	■		■	■	■	■		

a.2.4 Social dimension

Finally, TvWs also consider the social dimensions in the decisions in the heat transition. Haarbosch et al. (2021) state that social dimensions are considered most in the strategic future of energy policy documents as the future success of the transition depends on citizens. I broke these social assumptions into five types: 1) energy justice and energy poverty, 2) public support, local initiatives and participation, 3) transparency, 4) nuisance, and 5) freedom of choice. Table A.5 depicts which TvWs considered which social assumptions.

a.2.4.1 Energy justice and energy poverty

Out of the 12, TvWs analysed, none explicitly mention the concept of energy justice. Implicitly, various pillars of energy justice are detected. The pillars of energy justice include 1) recognition, 2) distribution, and 3) procedure (Jenkins et al., 2016). Subsection 1.2.4.3 discusses recognition and distributive justice in this subsection and explains procedural justice.

Recognition justice refers to the fair representation of individuals, free from physical threats and provided with complete and equal political rights (Schlosberg, 2003); it recognizes the rights and needs of particular groups (Walker & Day, 2012). Recognition justice includes non-recognition (Fraser, 2009). Non-recognition occurs when specific needs of particular social groups are not recognised. The danger of non-recognition is that groups that are not even recognised cannot stress their needs and concerns, which leads to exclusion from their perspective during policy formulation (Young, 2002). To go one step further, this non-recognition can even lead to injustice and loss of beneficial knowledge and values (Jenkins et al., 2016) and could also jeopardize the implementation of the transition (Haarbosch et al., 2021). Haarbosch et al. (2021) state that in many Dutch energy policy documents, citizens' desires are often not considered as they consider different rationales.

Distributive justice represents a call for the even distribution of benefits and burdens on all members of society regardless of individual characteristics (Jenkins et al., 2016), with emphasis on the importance of considering interacting distributional inequalities (Walker & Day, 2012) and focusing on re-distribution to reduce negative consequences and safeguard affordable access to energy (Jenkins et al., 2016). From this analysis, it became clear that TvWs consider affordability on various levels, but it remains unclear how benefits and burdens will be distributed. In addition, Haarbosch et al. (2021) reveal that policy documents often anticipate future changes from an economic perspective, which tends to align more with the anticipated futures of financially wealthy and educated households.

Both recognition and distributive justice are directly related to the concept of energy poverty. From the TvWs, it became evident that merely four out of twelve explicitly address the concept of energy poverty. These TvWs were of Amsterdam, Rotterdam, Vaals, and Valkenswaard. These municipalities acknowledge and recognise their responsibility in tackling this problem. For instance, the TvW of Vaals states: "*Therefore there is a role to monitor and prevent energy poverty.*" (Gemeente Vaals, 2021). Nevertheless, none of these TvWs dives deep into how the municipalities plan to combat the problem of energy poverty. Valkenwaard's TvW states: "*… As a result, energy poverty is lurking for a significant number of households. The TvW does not provide a solution for possible energy poverty.*" (Gemeente Valkenswaard, 2021). Furthermore, the TvW of Amsterdam mentions: "*As a follow-up to this TvW, high-risk regions (for energy poverty) will be mapped out, and it will be discussed how this can be mitigated.*" (Gemeente Amsterdam, 2021).

a.2.4.2 Public support, local initiatives and participation

Many municipalities consider the support of the public to be crucial for the heat transition. For instance, the municipality of Waddinxveen considers "social cohesion in the neighbourhood and attitude towards the transition" (Gemeente Waddinxveen, 2021). Scherpenzeel does not only consider the neighbourhood but also other stakeholders: "*There is support from the majority of residents, companies and other interested parties that are necessary for the realisation.*" (Gemeente Scherpenzeel, 2021).

Some municipalities understand public support as the existence of local energy initiatives. For example, Oostzaan's explanation of public support is: *"Presence of public support in the neighbourhood, in the form of an existing neighbourhood initiative…"* (Gemeente Oostzaan, 2021).

Finally, all TvWs address participation. This is where procedural justice becomes essential. Procedural justice concerns access to decision-making processes and inequitable procedures to engage all stakeholders in a non-discriminatory way (Walker, 2009). Firstly, local knowledge has been a critical motivating factor for public engagement. Then there is disclosing information (Jenkins et al., 2016). There is also the extent to which different stakeholders' opinions and concerns are addressed in the decision-making process (Simcock, 2016). For instance, the TvW of Scherpenzeel states: "*In the development of this TvW, the municipality worked with Stedin (which manages the gas network), Liander (the electric grid manager), housing corporation Woonstede, energy cooperative ValleiEnergie, water authority Vallei and Veluwe and heating company Scherpenzeel. A residents' evening was held for the residents, and a survey could be completed. Together, we made clear what we can already do to use less natural gas, other ways of heating, and what we consider important in the transition."* (Gemeente Scherpenzeel, 2021). I observe a similar collaboration in establishing TvWs in other municipalities, where there seems to be a clear division of stakeholders involved directly and indirectly. In those cases, direct stakeholders include housing corporations, grid managers, and housing corporations, which municipalities include in establishing the TvW. In comparison, municipalities incorporate indirect stakeholders through secondary channels, e.g. surveys and newsletters (Gemeente Gemert-Bakel, 2021). Reed et al. (2018) distinguish different forms of public participation: 1) communication mode, 2) consultation mode, and 3) co-productive mode. A communication mode entails a top-down, one-way information stream from public authorities to the stakeholders; a consultation mode entails stakeholders giving feedback to public authorities about their plans. At last, co-productive mode entails a joint development of goals. From the TvWs, it seems that the municipality takes on a co-productive mode with stakeholders such as housing corporations, and assumes a combination of a communication and consultation mode with the public. Interestingly, Haarbosch et al. (2021) find that often it seemed that goals were already set, and the involvement of citizens seemed to gain importance when it came to the implementation of the transition.

Finally, there is representation in institutions in procedural justice (Jenkins et al., 2016). Unequal representation in a wide range of institutions impact decision (Jenkins et al., 2016). Ensuring better representation provides a more proactive approach to realising justice rather than waiting on the response of affected communities (Buckingham & Kulcur, 2009). Currently, this aspect of equal representation and recognition is still unclear.

a.2.4.3 Transparency

Transparency is also an assumption that is considered necessary. The TvW of Noordenveld reflects this in the following way: "*The choices and outcomes made must be transparent and traceable for the stakeholders and to all residents. They must be able to see their own contribution and insights reflected in the vision and were therefore regularly asked to respond to intermediate products in creative ways."* (Gemeente Noordenveld, 2021). Not only transparency in contribution matters but also in how municipalities establish costs. Utrecht considers this one of its criteria. It defines it as follows: "*it needs to be clear for everyone how the costs for heat are determined.*" (Gemeente Utrecht, 2021a).

a.2.4.4 Nuisance

Multiple municipalities address the problem of nuisance due to the heat transition. Nuisance refers to an infrastructural intervention in public spaces and indoor adjustments that must be made in a house (Gemeente Amsterdam, 2021). In considering this criterium, the municipality of The Hague logically states: "*Heating options that cause less nuisance in a neighbourhood or residence are preferred over ones that cause more nuisance.*" (Gemeente Den Haag, 2022). However, some municipalities cannot guarantee a nuisance-free transition due to choices. An example is the municipality of Amsterdam, as the TvW mentions: *"The heat option that causes the least nuisance is the maintenance of the gas grid. This is, however, not a realistic solution for the majority of Amsterdam. All remaining heat options are accompanied by the residence or neighbourhood's nuisance."* (Gemeente Amsterdam, 2021). Thus, Amsterdam does not consider nuisance in determining the heat options but does account for nuisance in the consecutive phases. The municipality aims to consider linking opportunities to minimise nuisance (Gemeente Amsterdam, 2021).

a.2.4.5 Freedom of choice

Finally, there is the freedom of choice as a social assumption. Huygen and Diran (2020) state that users value the possibility of making their own choices and do not want to be forced to make a choice. From research in Germany, it became evident that the tariffs for heat networks were lower in areas where consumers could choose between a district heating system or another option. Apparently, consumer choices force companies to stay sharp as they aim to consider these choices (Huygen & Diran, 2020). However, municipalities realise this is not a realistic option, which poses a dilemma. As the responsible party for the heat transition, the municipality has difficulty finding a balance between the extent and the way it wants to navigate the realisation of the preferred option for the neighbourhood (Gemeente Amsterdam, 2021). To date, the municipalities do not possess legal instruments to impose the actions detailed in this and future TvWs (Gemeente Amsterdam, 2021). The municipality of Noordenveld recognises this constraint: *"Residents should have freedom of choice to choose their own alternative. Simultaneously, the freedom of choice should not become too restrictive: action is needed. Therefore, the freedom of choice may be limited with a neighbourhood-based approach. For now, the basic principle remains that no one is forced to switch off natural gas."* (Gemeente Noordenveld, 2021).

The municipality of Utrecht sees freedom of choice as a secondary criterium: "*Besides these four conditions (sustainability, affordability, reliability and transparency), there are two other values: open net and freedom of choice. […] We find these last two values important, but these should not come at the expense of the four conditions above."* (Gemeente Utrecht, 2021a).

Table A.5 Overview of the social assumptions considered in the TvW by Dutch municipalities

Municipality→ Assumption ↓	**Amsterdam**	**Utrecht**	**Rotterdam**	**The Hague**	**Waddinxveen**	**Noordenveld**	**Valkenswaard**	**Gemert-Bakel**	**Scherpenzeel**	**Alphen-Chaam**	**Vaals**	**Oostzaan**
Social												
Energy justice and energy poverty*	■		■				■				■	
Public support, local initiatives and participation	■	■	■	■	■	■	■	■	■	■	■	■
Transparency	■	■			■	■	■	■				
Nuisance	■	■	■	■	■		■	■				
Freedom of choice	■	■		■	■	■	■					■

** Since none of the TvWs discusses the concept of energy justice, the highlighted cells refer to the discussion of energy poverty*

A.3 Conclusion

From the document analysis of the TvWs, we conclude that there is a similar through-line within all TvWs, where a few main patterns can be identified. First, economic and technical assumptions dominate the choices that municipalities make in the heat transition. This finding also becomes evident through validation of the findings with the help of PBL's Start Analysis, in which the starting point is the lowest national costs, an economic assumption. In addition, this pattern seems to return in the overall energy transition, as Haarbosch et al. (2021) reveal similar findings in their research into Dutch energy policy documents.

Another important finding is that all municipalities consider environmental dimensions necessary, but citizens often do not attach the same importance to this dimension (Haarbosch et al., 2021). Municipalities are highly dependent on citizens for a successful heat transition, which presents some dangers. This dependency is also what makes the social dimension of great importance. The exclusion of this dimension can lead to injustices that could jeopardise policy implementation. From the TvWs, it remains unclear how policymakers are planning to tackle energy justice and energy poverty problems. In addition, it seems that TvWs consider other social assumptions, but those are difficult to guarantee. Furthermore, Haarbosch et al. (2021) find that often it seemed that goals were already set, and the involvement of citizens seemed to gain importance when it came to the implementation of the transition. All in all, we see that the emphasis in this phase of the transition is on techno-economic dimensions, pushing the social dimension to the background where much still remains unclear.

B. APPENDIX B: CONSENT FORM EXPERTS

Beste participant,

Bedankt voor uw deelname aan dit interview. Dit onderzoek wordt uitgevoerd als onderdeel van de TU Delft in samenwerking met TNO en CBS. Het doel van dit onderzoek is om meer inzichten te krijgen in de besluitvorming omtrent de warmtetransitie. De warmtetransitie is een grote opgave waarbij er rekening moet worden gehouden met verscheidene dimensies (denk hierbij aan technische dimensies, maar bijvoorbeeld ook economische dimensies). Met dit interview willen we graag aanvullende inzichten verschaffen in de besluiten die beleidsmakers maken wanneer sociale informatie wordt toegevoegd aan techno-economische informatie.

Om de toevoeging van sociale informatie te onderzoeken, wil ik graag eerst de basis leggen waarbij ik inzichten wil krijgen in de belangrijkste indicatoren voor besluiten in de warmtetransitie. Hiervoor wil ik u graag interviewen. Het interview zal ongeveer 30 minuten duren.

Om ervoor te zorgen dat het onderzoek voldoet aan de ethische richtlijnen van de TU Delft, vraag ik u het onderstaande formulier in te vullen.

Vraag	Ja	Nee
1. Ik heb de informatie over het onderzoek gedateerd [*DD/MM/YYYY*] gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	☐	☐
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	☐	☐
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent: • Het interview wordt opgenomen en een video-opname wordt opgeslagen in de OneDrive van de TU Delft. • Het interview wordt samengevat en geanonimiseerd. • De video-recording zal een maand na het afronden van de scriptie worden vernietigd.	☐	☐
4. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. Ik begrijp dat bij potentiele re-identificatie mijn naam gelinkt kan worden aan de uitspraken die ik tijdens dit interview doe.	☐	☐
5. Ik begrijp dat binnen de Algemene verordering gegevensbescherming (AVG) een deel van deze persoonlijk identificeerbare onderzoeksdata als gevoelig wordt beschouwd, namelijk: mijn naam, de organisatie waarvoor ik werk en mijn werkfunctie.	☐	☐

6. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: • Het interview wordt geanonimiseerd en samengevat ipv een directe transcriptie • Opslag van video-opname op de OneDrive van de TU Delft, waartoe alleen het onderzoeksteam (onderzoeker en haar supervisors vanuit de TU Delft) toegang tot heeft.	☐	☐
7. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam, de organisatie waarvoor ik werk en werkfunctie, niet gedeeld worden buiten het studieteam.	☐	☐
8. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op 29-10-2022.	☐	☐
9. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor de publicatie van een scriptieonderzoek.	☐	☐
10. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	☐	☐
11. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages gelinkt aan mijn naam te quoten in resulterende producten.	☐	☐

Handtekeningen

______________________ ______________________ _______

Naam deelnemer Handtekening Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

______________________ ________________ _______

Naam onderzoeker Handtekening Datum

C. APPENDIX C: INTERVIEW PROTOCOL EXPERTS

- Naam:
- Functie:
  - Duur in de functie:
- Interview nummer:

Introductie

Allereerst wil ik u bedanken dat u mee wilt werken aan dit interview. Voor mijn scriptie onderzoek ik de effecten van het opnemen van sociale informatie in besluitvormingsinformatie op de beslissingen die beleidsmakers nemen voor de warmtetransitie. Om dit effect te meten ben ik van plan een experiment op te zetten met twee groepen: groep A en B. Waar groep A alleen techno-economische informatie krijgt, krijgt groep B zowel techno-economische als sociale informatie. Met dit experiment wil ik nagaan of de beslissingen van groep B socialer en/of sociaal verantwoordelijker worden.

Nu ben ik op een punt aanbeland waarop ik moet beslissen welke informatie ik aan de groepen A en B willen laten zien om een beslissing te kunnen nemen. De informatie wil ik weergeven op 2D geografische kaarten: één kaart is gebaseerd op een techno-economische indicator, en één kaart is gebaseerd op een sociale indicator. Hierbij besluiten ze over het volgende: rangschik in welke volgorde je de getoonde buurten van aardgas zou af laten gaan.

Organisatorisch

- Vindt u het goed dat het interview wordt opgenomen?
- Vindt u het goed als uw naam wordt gekoppeld aan het interview of wilt u liever anoniem deelnemen?
- De informatie uit dit interview kan mogelijk worden opgenomen in de vorm van quotes. Ik zal deze eerst aan u voorleggen voordat de scriptie wordt gepubliceerd.

Vragen

Vraag 1: Wat zijn drie technische indicatoren die u essentieel vindt voor de besluitvorming in de warmtetransitie?

- Hoe zit het met *verwijs naar de lijst*?

Vraag 2: Wat zijn drie economische indicatoren die u essentieel vindt voor de besluitvorming in de warmtetransitie?

- Hoe zit het met *verwijs naar de lijst*?

Vraag 3: Wat zijn volgens u drie sociale indicatoren die essentieel zijn voor de besluitvorming bij de warmtetransitie?

Vraag 4: Als u het thema energierechtvaardigheid in uw achterhoofd houdt, wat zijn dan relevante sociale indicatoren in de warmtetransitie?

- Hoe zit het met *verwijs naar de lijst*?

D. APPENDIX D: LIST OF INDICATORS

Appendix D depicts the potential indicators identified from the document analysis and literature review as a foundation for the expert interviews.

Technical

- Energy label
- Year of construction
- Building density
- Share of installed PV
- Share of installed heat pumps
- Energy consumption

Economic

- Investment costs
- Benefits
- Electricity price
- National costs

Social

- Socio-economic/demographic characteristics (income, household size)
  - Income
  - Household size
  - Education level
  - Age
- Generated employment
- Sustainability ambitions of a municipality
- Voting behaviour
- Energy justice/energy poverty
  - Affordability (= based on neighbourhood's mean house value to household income)
  - Presence of local sustainability initiatives
  - Low income, high gas use
  - Energy quota (= share of a household that spends 8% or more of their income on their energy bill)
  - Financial capacity (= financial assets of private homeowners)
- Public support (Statistics Netherlands research)
  - Individual intends to invest in a more sustainable home, provided it pays off
  - Individual has no intention/does not know how to/considers it too expensive/has not had the opportunity to invest in a more sustainable home yet

E. APPENDIX E: SURVEY EXPERIMENT

Appendix E describes the survey experiment. The survey experiment exists in two parts, with the opening statement and generic questions (e.1) and the scenarios and exit questions (e.2).

E.1 OPENING STATEMENT AND GENERIC QUESTIONS

Besluitvorming in de warmtetransitie

Het invullen van deze enquête duurt ongeveer 10-15 minuten

Over deze enquête

De warmtetransitie is een grote opgave waarbij er rekening moet worden gehouden met verscheidene dimensies (denk hierbij aan technische dimensies, maar bijvoorbeeld ook economische dimensies). Met dit online experiment, willen we graag meer inzichten verschaffen in de besluiten die beleidsmakers maken in de warmtetransitie.

Deze enquête bestaat uit drie onderdelen:

- Een aantal vragen over uw rol in de warmtetransitie
- Een aantal (drie of vier) scenario's waarin u beslissingen moet maken over de warmtetransitie
- Een aantal exit vragen

Participatie

Er zijn geen goede of foute antwoorden in het experiment. Participatie is volledig vrijwillig en u kunt zich elk moment terugtrekken zonder reden op te geven of contact met ons opnemen na het invullen van de enquête indien u uw data wil verwijderen.

Anonimiteit en ethische verwerking van uw data

De data uit dit onderzoek kunnen worden gebruikt voor publicatiedoeleinde. De enquête voldoet aan de ethische eisen gesteld door de Technische Universiteit Delft. U kunt hier meer informatie vinden over de ethische evaluatie. Uw ingediende respons zal anoniem verwerkt en opgeslagen worden. Locatiedata en persoonlijk identificeerbare data worden niet opgeslagen.

Organisatie

Deze enquête maakt deel uit van een master thesis over besluitvorming in de warmtetransitie, uitgevoerd aan de TU Delft in samenwerking met TNO en CBS. Indien u vragen of opmerkingen heeft, kunt u contact opnemen met: l.hu-6@student.tudelft.nl.

Nota bene

Deze enquête kan het best worden ingevuld op de laptop of de computer.

Bedankt voor uw participatie. Klik op 'volgende' om de enquête te starten. Hiermee geeft u tevens toestemming voor het anoniem opslaan en verwerken van uw antwoorden.

Vraag 1: Werkt u bij een gemeente in Nederland?

- Ja
- Nee

Vraag 2: In welke provincie is uw gemeente gesitueerd?

- Groningen
- Friesland
- Drenthe
- Overijssel
- Gelderland
- Utrecht
- Noord-Brabant
- Limburg
- Noord-Holland
- Zuid-Holland
- Zeeland
- Flevoland
- Zeg ik liever niet

Vraag 3: Hoe groot is uw gemeente?

- <20.000 inwoners
- 20.000 – 50.000 inwoners
- 50.000 – 100.000 inwoners
- 100.000 – 250.000 inwoners
- > 250.000 inwoners
- Zeg ik liever niet

Vraag 4: Werkt u of heeft u meegewerkt aan de warmtetransitie in uw gemeente?

- Ja
- Nee

Vraag 5: Werkt u of heeft u meegewerkt aan de duurzaamheid en/of energietransitie in uw gemeente?

- Ja
- Nee

Vraag 6: Hoelang heeft u gewerkt/werkt u al in deze positie bij uw gemeente?

- 0 – 2 jaar
- 2 – 4 jaar
- 4 – 6 jaar
- 6 – 8 jaar
- 8 – 10 jaar
- > 10 jaar

Vraag 7: Geef aan in hoeverre u het eens bent met de volgende stelling:

	Zeer oneens	Oneens	Een beetje oneens	Neutraal	Een beetje mee eens	Mee eens	Zeer mee eens	Weet ik niet
Ik voel mij comfortabel met het gebruiken van data	O	O	O	O	O	O	O	O

E.2 Scenarios and exit questions

Stelt u zich voor...

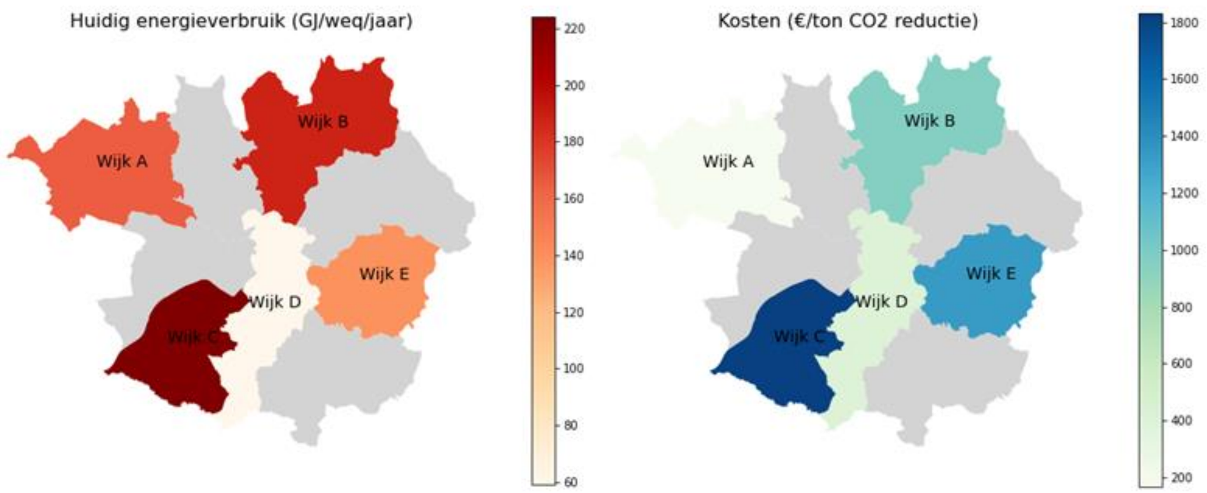
U staat aan het hoofd van de afdeling in uw gemeente die verantwoordelijk is voor de warmtetransitie. Uw besluit is doorslaggevend. In de eerste fase van de warmtetransitie zijn er vijf wijken uitgekozen die als eerst van het aardgas af gaan. Voor de komende fase van de warmtetransitie bepaalt de gemeente de volgorde waarop dat gebeurt. U krijgt in het volgende onderdeel informatie over deze vijf wijken. We vragen u om op basis van deze informatie de volgorde te bepalen.

e.2.1.1 Group A: Techno-economic group

Scenario 1/3

Vraag 8: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.

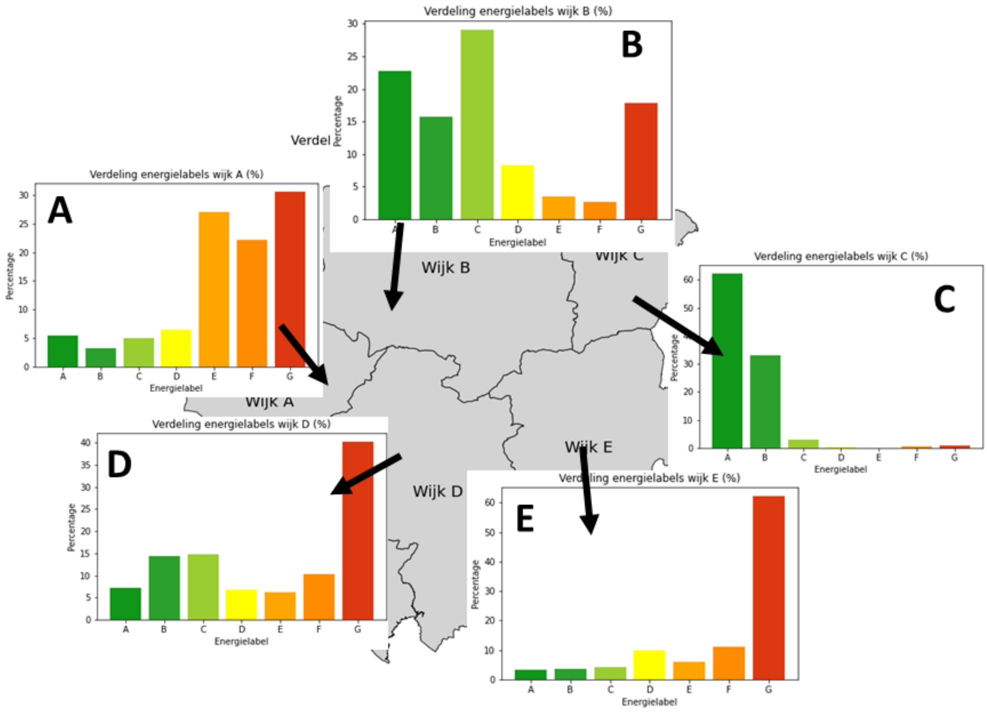


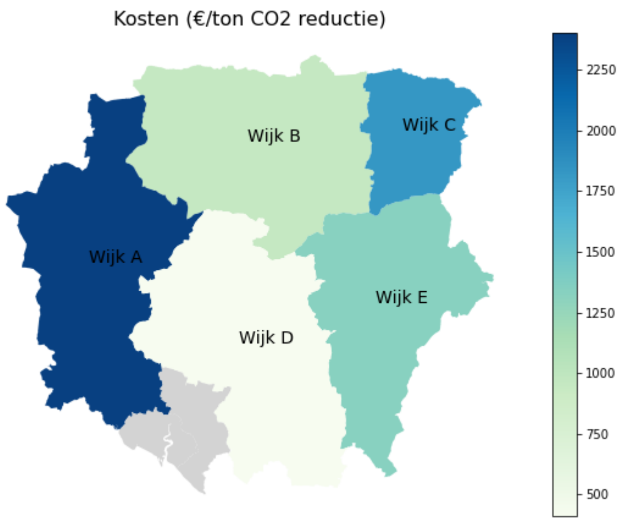
- Huidig energieverbruik (GJ/weq/jaar) = het huidige energieverbruik wordt gemeten in gigajoule per woningequivalent per jaar waarbij ruimteverwarming, warmtetapwater, ventilatie, en apparaten en licht in beschouwing worden genomen.
- Kosten (€/ton CO2 reductie/jaar) = de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.

Scenario 2/3

Vraag 9: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.



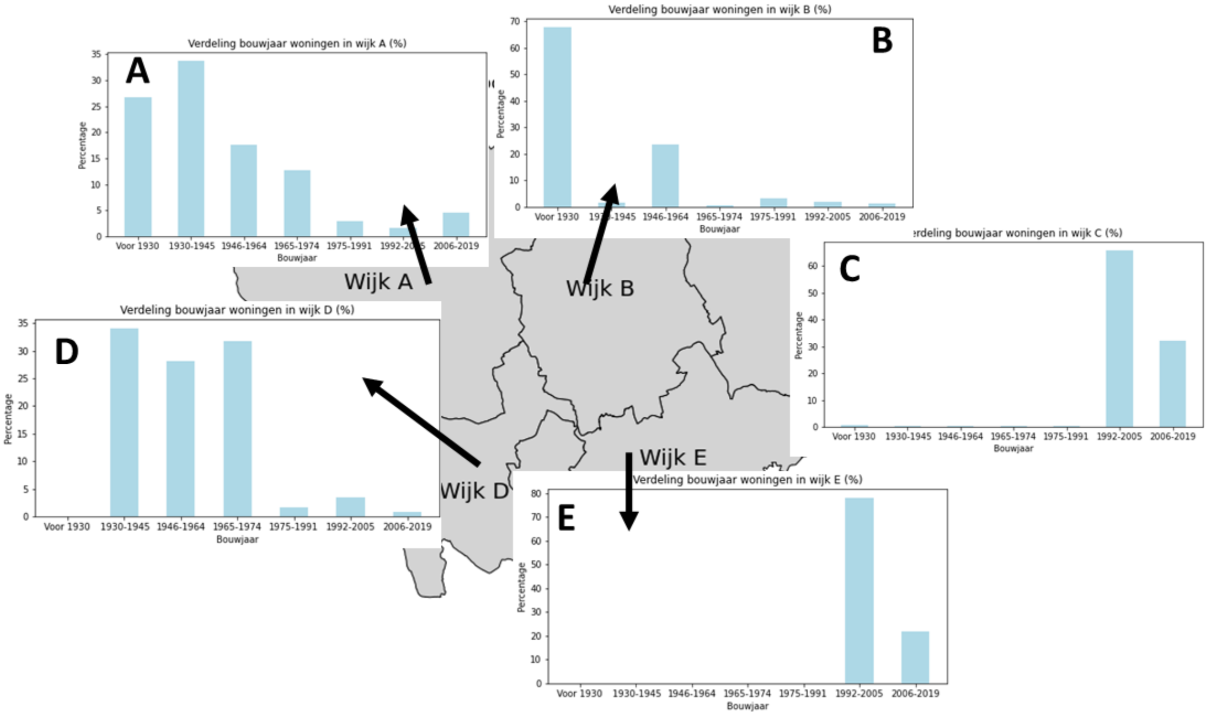


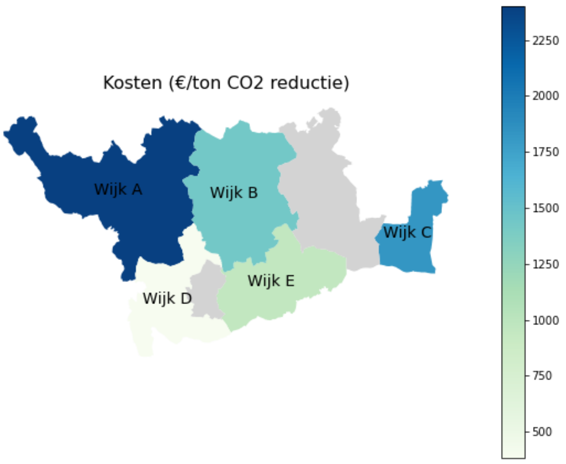
- Verdeling energielabels woningen per wijk (%): is de verdeling van energielabels van de woningen (geen bedrijfsgebouwen ed.) per wijk weergeven in percentages.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.

Scenario 3/3

Vraag 10: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.





- Verdeling bouwjaren woningen per wijk (%): is de verdeling van bouwjaren van de woningen (geen bedrijfsgebouwen ed.) per wijk weergeven in percentages.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.

Vraag 11: Heeft u gedurende de enquête sociale informatie waargenomen? (Met sociale informatie wordt informatie bedoeld die betrekking heeft op mensen, hun interacties en relaties binnen het energiesysteem)

- Ja
- Nee
- Weet ik niet

Vraag 12: Geef aan in hoeverre u het eens bent met de volgende stelling:

	Zeer oneens	Oneens	Een beetje oneens	Neutraal	Een beetje mee eens	Mee eens	Zeer mee eens	Weet ik niet
Ik heb vertrouwen in mijn beslissing over de rangschikking van de wijken.	0	0	0	0	0	0	0	0
Ik heb een sociaal verantwoordelijke en rechtvaardige beslissing gemaakt in de rangschikking van de wijken.	0	0	0	0	0	0	0	0
Ik vond het maken van de beslissing in de rangschikking van de wijken lastig.	0	0	0	0	0	0	0	0
De beschikbare informatie ondersteunt mij voldoende in de besluitvorming in de warmtetransitie.	0	0	0	0	0	0	0	0
Sociale informatie was even belangrijk geweest voor mijn besluitvorming in de warmtetransitie.	0	0	0	0	0	0	0	0

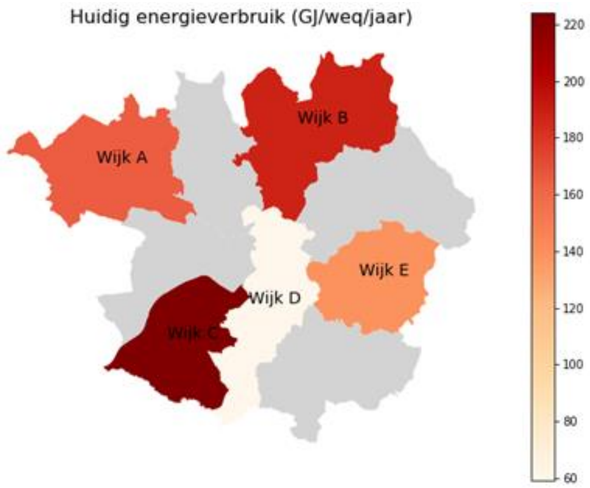
Vraag 13: Heeft u nog vragen of opmerkingen over deze enquête?

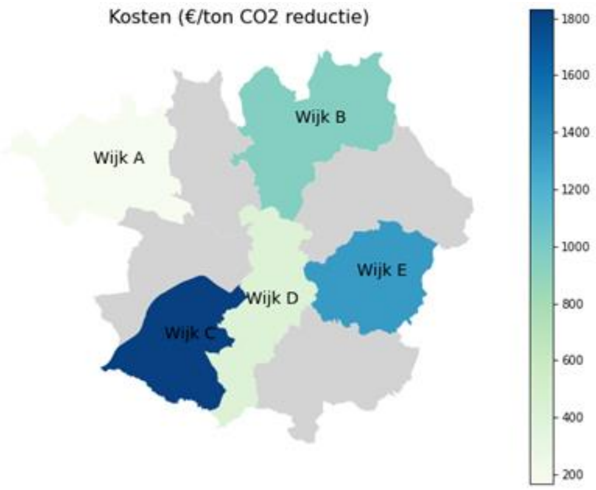
e.2.1.2 Group B: Techno-economic and social group

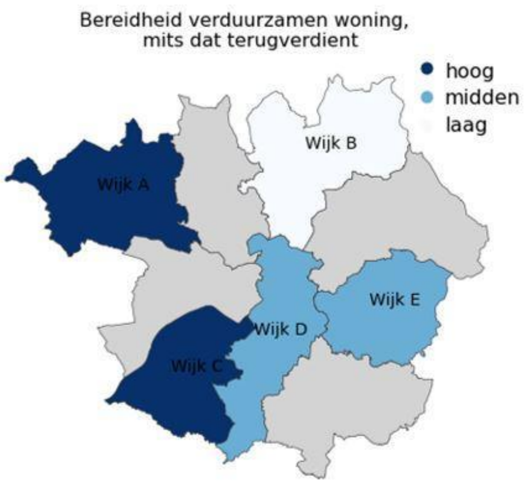
Scenario 1/4

Vraag 14: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.





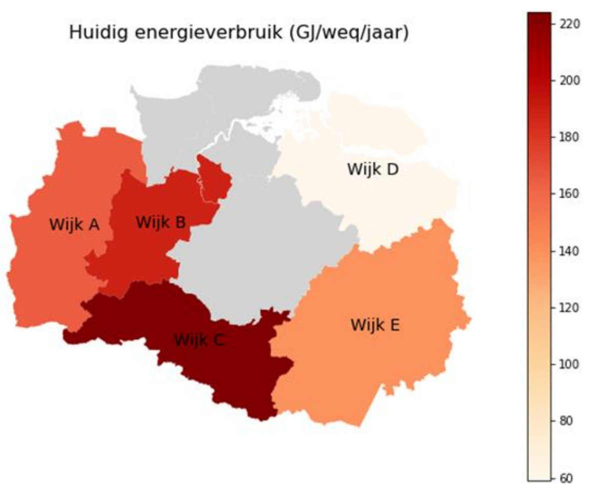


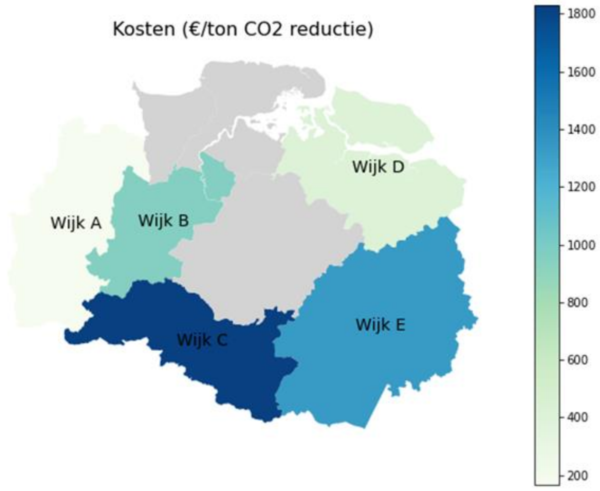
- Huidig energieverbruik (GJ/weq/jaar): refereert naar het huidige energieverbruik dat wordt gemeten in gigajoule per woningequivalent per jaar waarbij ruimteverwarming, warmtetapwater, ventilatie, en apparaten en licht in beschouwing worden genomen.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.
- Bereidheid verduurzamen woning, mits dat terugverdient: de houding van mensen in een wijk tegenover het verduurzamen van een woning, mits dat terugverdient. Indien dit hoog is, dan houdt dit in dat de welwillendheid in de wijk hoog is om te investeren in een zuinigere woning mits dat terugverdient. U kunt hier meer informatie vinden over de totstandkoming van de indicator. Voor deze indicator kunt u ervan uitgaan dat u in staat bent de maatregelen voor het terugverdienen in te voeren.

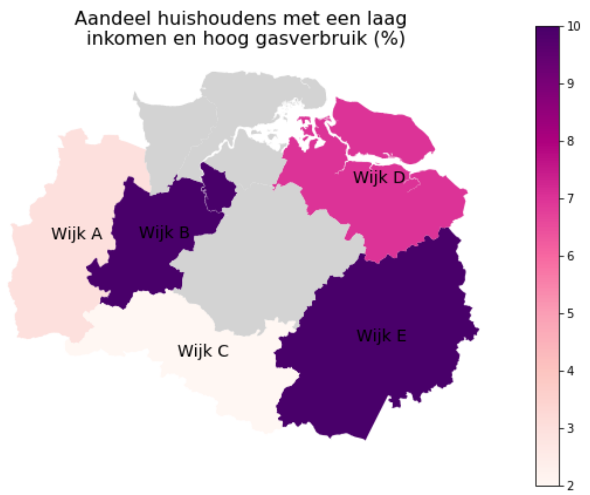
Scenario 2/4

Vraag 15: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.





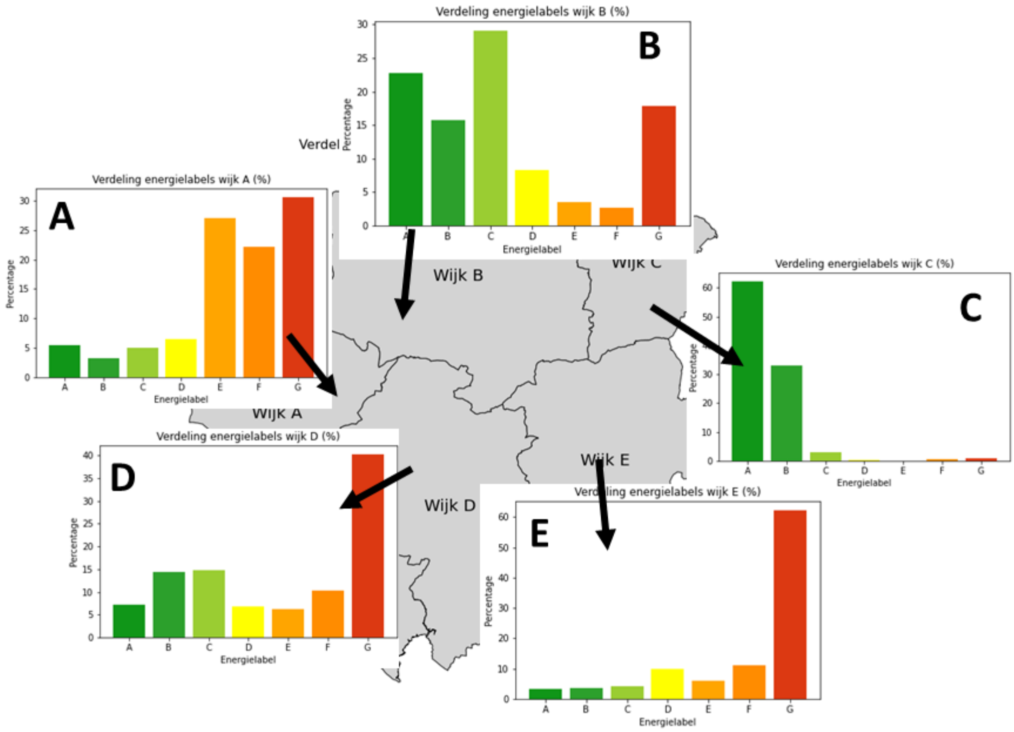


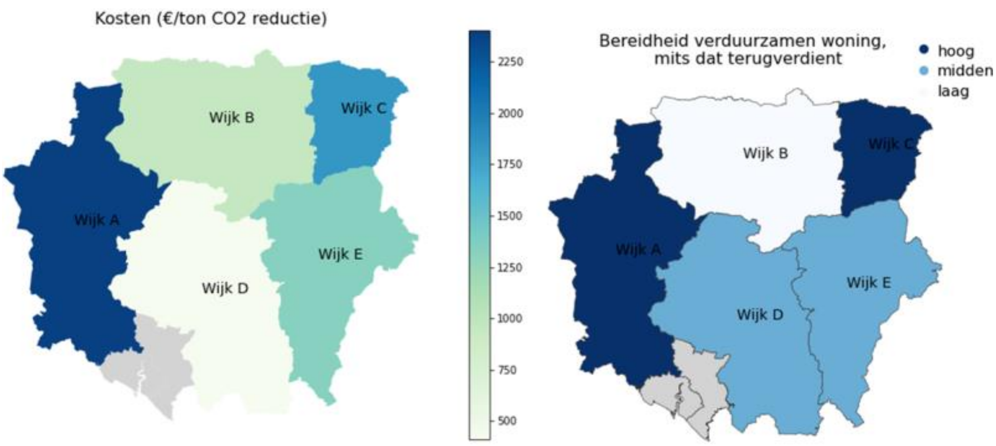
- Huidig energieverbruik (GJ/weq/jaar): refereert naar het huidige energieverbruik dat wordt gemeten in gigajoule per woningequivalent per jaar waarbij ruimteverwarming, warmtetapwater, ventilatie, en apparaten en licht in beschouwing worden genomen.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.
- Aandeel huishoudens met een laag inkomen en hoog gasverbruik: geeft het percentage huishoudens in een wijk weer dat een laag inkomen en hoog gasverbruik heeft. Een huishouden wordt meegerekend als het in de laagste 25% inkomens valt en tegelijkertijd een gasverbruik heeft dat in de hoogste 50% valt.

Scenario 3/4

Vraag 16: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.



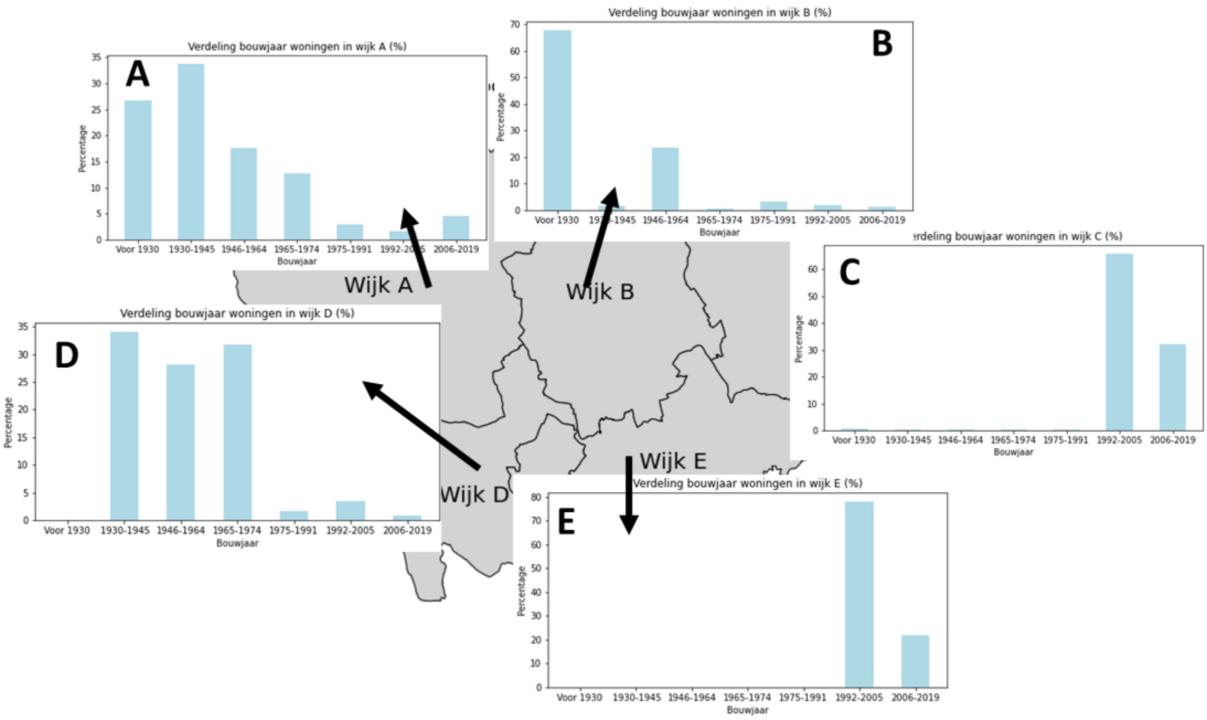


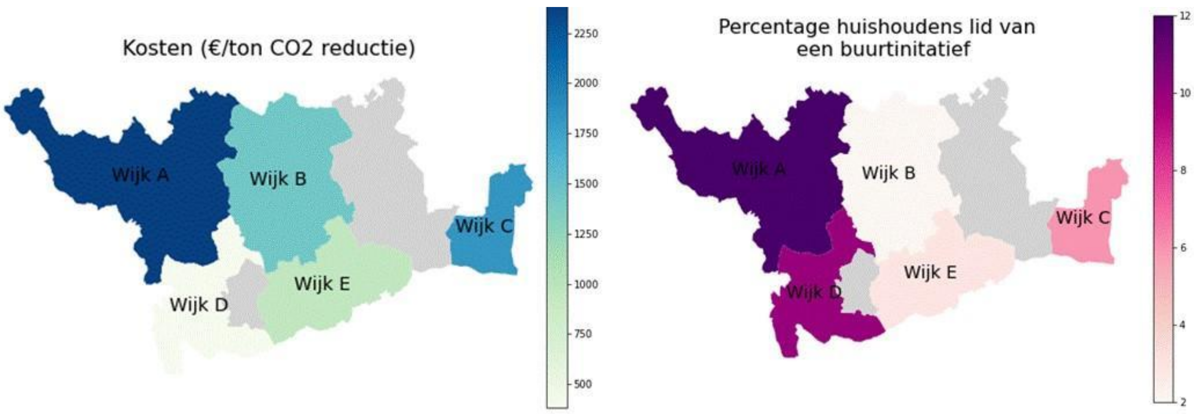
- Verdeling energielabels woningen per wijk (%): is de verdeling van energielabels van de woningen (geen bedrijfsgebouwen ed.) per wijk weergeven in percentages.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.
- Bereidheid verduurzamen woning, mits dat terugverdient: de houding van mensen in een wijk tegenover het verduurzamen van een woning, mits dat terugverdient. Indien dit hoog is, dan houdt dit in dat de welwillendheid in de wijk hoog is om te investeren in een zuinigere woning mits dat terugverdient. U kunt hier meer informatie vinden over de totstandkoming van de indicator. Voor deze indicator kunt u ervan uitgaan dat u in staat bent de maatregelen voor het terugverdienen in te voeren.

Scenario 4/4

Vraag 17: Op basis van de informatie over het huidige energieverbruik en de kosten voor de warmtetransitie vragen wij u de volgende beslissing te nemen: geef aan in welke volgorde u de onderstaande wijken van het aardgas zou afhalen, waarbij 1 de wijk is die u als **eerst** van het gas af zou halen en 5 de wijk is die u het **laatst** van het gas af zou halen.

Let op: hierbij past u de volgorde aan door te schuiven.





- Verdeling bouwjaren woningen per wijk (%): is de verdeling van bouwjaren van de woningen (geen bedrijfsgebouwen ed.) per wijk weergeven in percentages.
- Kosten (€/ton CO2 reductie/jaar): refereert naar de kosten die nodig zijn om alle maatregelen uit te voeren (minus de baten van energiebesparing), ongeacht wie de kosten betaalt.
- Percentage huishoudens lid van een buurtinitatief: geeft het percentage huishoudens in een wijk weer dat lid is van een buurtinitatief waarbij duurzaamheid centraal staat.

Vraag 19: Heeft u gedurende de enquête sociale informatie waargenomen? (Met sociale informatie wordt informatie bedoeld die betrekking heeft op mensen, hun interacties en relaties binnen het energiesysteem)

- Ja
- Nee
- Weet ik niet

Vraag 20: Geef aan in hoeverre u het eens bent met de volgende stelling:

	Zeer oneens	Oneens	Een beetje oneens	Neutraal	Een beetje mee eens	Mee eens	Zeer mee eens	Weet ik niet
Ik heb vertrouwen in mijn beslissing over de rangschikking van de wijken.	0	0	0	0	0	0	0	0
Ik heb een sociaal verantwoordelijke en rechtvaardige beslissing gemaakt in de rangschikking van de wijken.	0	0	0	0	0	0	0	0
Ik vond het maken van de beslissing in de rangschikking van de wijken lastig.	0	0	0	0	0	0	0	0
Het toevoegen van sociale informatie ondersteunt mij in de besluitvorming van de warmtetransitie.	0	0	0	0	0	0	0	0
Het toevoegen van sociale informatie is noodzakelijk om tot goede besluiten te komen in de warmtetransitie.	0	0	0	0	0	0	0	0
Het toevoegen van sociale informatie aan technische en economische informatie maakt de besluitvorming complexer.	0	0	0	0	0	0	0	0

Vraag 21: Heeft u nog vragen of opmerkingen over deze enquête?

F. APPENDIX F: CONSENT FORM POLICYMAKERS

Beste participant,

Bedankt voor uw deelname aan dit interview. Dit onderzoek wordt uitgevoerd als onderdeel van de TU Delft in samenwerking met TNO en CBS. Het doel van dit onderzoek is om meer inzichten te krijgen in de besluitvorming omtrent de warmtetransitie. De warmtetransitie is een grote opgave waarbij er rekening moet worden gehouden met verscheidene dimensies (denk hierbij aan technische dimensies, maar bijvoorbeeld ook economische dimensies). In dit onderzoek ligt de nadruk op het meenemen de sociale dimensie als aanvulling op de technische en economische dimensie. Met dit interview willen we graag aanvullende inzichten verschaffen in de besluiten die beleidsmakers maken en dit interview dient als ondersteuning van de enquête. Het interview zal ongeveer 45 minuten duren.

Om ervoor te zorgen dat het onderzoek voldoet aan de ethische richtlijnen van de TU Delft, vraag ik u het onderstaande formulier in te vullen.

Vraag	Ja	Nee
1. Ik heb de informatie over het onderzoek gedateerd [*DD/MM/YYYY*] gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.		
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.		
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent: • Het interview wordt opgenomen en een video-opname wordt opgeslagen in de OneDrive van de TU Delft. • Het interview wordt samengevat en geanonimiseerd. • De video-recording zal een maand na het afronden van de scriptie worden vernietigd.		
4. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. Ik begrijp dat bij potentiele re-identificatie mijn naam gelinkt kan worden aan de uitspraken die ik tijdens dit interview doe.		
5. Ik begrijp dat binnen de Algemene verordering gegevensbescherming (AVG) een deel van deze persoonlijk identificeerbare onderzoeksdata als gevoelig wordt beschouwd, namelijk: mijn naam, de gemeente en mijn werkfunctie.		
6. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk:	☐	

• Het interview wordt geanonimiseerd en samengevat ipv een directe transcriptie • Opslag van video-opname op de OneDrive van de TU Delft, waartoe alleen het onderzoeksteam (onderzoeker en haar supervisors vanuit de TU Delft) toegang tot heeft.		
7. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam, gemeente en werkfunctie, niet gedeeld worden buiten het studieteam.		
8. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op 29-10-2022.		
9. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor de publicatie van een scriptieonderzoek.		
10. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.		
11. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages gelinkt aan mijn naam te quoten in resulterende producten.		

Handtekeningen

______________________ _____________________ _______

Naam deelnemer Handtekening Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

______________________ ________________ _______

Naam onderzoeker Handtekening Datum

G. APPENDIX G: INTERVIEW PROTOCOL POLICYMAKERS

- Naam:
- Interview nummer:
- Grootte gemeente:

Introductie

Allereerst hartelijk dank dat u mee wilt werken aan dit interview. Ik heb u uitgenodigd omdat u betrokken bent in de warmtetransitie/energietransitie van uw gemeente en ik denk dat uw expertise mijn onderzoek kan verrijken. Het doel van dit interview is om meer inzichten te krijgen in de besluitvormingsprocessen rondom de warmtetransitie, waarbij de informatievoorziening centraal staat. Hierbij wordt nadruk gelegd op sociale informatie, waarmee informatie wordt bedoeld die betrekking heeft op mensen, hun interacties en relaties binnen het energiesysteem. Dit herkent u misschien ook wel als “zachte data”.

Organisatorisch

- Het interview zal ongeveer 45 minuten duren.
- Vindt u het goed dat het interview wordt opgenomen?
- De informatie uit dit interview kan mogelijk worden opgenomen in de vorm van quotes. Deze zullen anoniem worden verwerkt. Ik zal deze eerst aan u voorleggen voordat de scriptie wordt gepubliceerd.

Interview vragen

<u>Deel 1: Algemene vragen over het huidig besluitvormingsproces van de warmtetransitie en de sociale informatievoorziening</u>

1) Kunt u kort uw functie bij de gemeente beschrijven en uitleggen hoe uw werkzaamheden betrekking hebben tot de warmtetransitie?

- Hoelang werkt u al in deze rol?
- Wat is de visie van de gemeente omtrent de warmtetransitie? (ambities, doelen)
  - Welke besluiten worden er op dit moment genomen en welke moeten er nog worden genomen?
  - Hoe ziet het proces van zo’n besluit eruit?
  - Welke kennisgebrekken zijn er op dit moment? (zachte data – informatie over de bewoners)

2) Hoe ziet de informatievoorziening van deze besluitvormingsprocessen eruit? (specifiek op het stuk warmtetransitie indien mogelijk, bijv. opstellen van de transitievisie warmte of wijkuitvoeringsplannen)

- Waar komt de informatie vandaan (onderscheid tussen harde en zachte data)?
- In hoeverre past de informatie voldoende bij de kennis die u nodig heeft om de vraagstukken op te lossen?
  - Waar zou u nog meer inzichten over willen hebben? (zachte data)
- Wat zijn nu de grootste uitdagingen als het gaat om de informatie die u nodig heeft voor de besluitvorming?

   - Barrières in de toepassing van de data? (Of zij bepaalde strategieën hebben/oplossingen zien)
   - Te veel? Te weinig? Te complex? Niet genoeg?

Deel 2: Over de experimenten

3) **Haal een van de kaarten tevoorschijn** Kun u mij meenemen in het denkproces bij het bepalen van de rangorde?

- Waarom?
- Welke trade-offs maakt u?
- Als je met de rangschikking besluiten maakt, wat betekent dit voor jou?

4) In de huidige warmtetransitie, welke factoren/indicatoren zijn volgens u belangrijk? (verschil per gemeente?) (indien tijd)

Deel 3: Exit-vragen

5) Herkent u het maken van deze trade-offs ook in de werkelijkheid?

- Te herkennen in afwegingskader?

6) Heeft u nog andere vragen of opmerkingen die niet aan bod zijn gekomen, maar die u graag wil uitspreken?

H. APPENDIX H: RESULTS

Appendix H illustrates the descriptive results in H.1, H.2 and H3 and the distribution of the samples for the Mann-Whitney U test in H.4, as discussed in section 5.

H.1 DISTRIBUTION OF RANKINGS PER GROUP PER SCENARIO

Figure H.1 summarizes the ranks for scenario 2 (energy consumption, costs and energy poverty). for group A (left) and group B (right). For group A, the ranking of C-B-A-E-D was most popular, with seven policymakers concluding this ranking, whereas the most popular rankings of group B were chosen two times at most. The multiple stand-alone rankings and lower number of common rankings in group B suggest a higher complexity and difficulty of the ranking task of group B compared to group A.

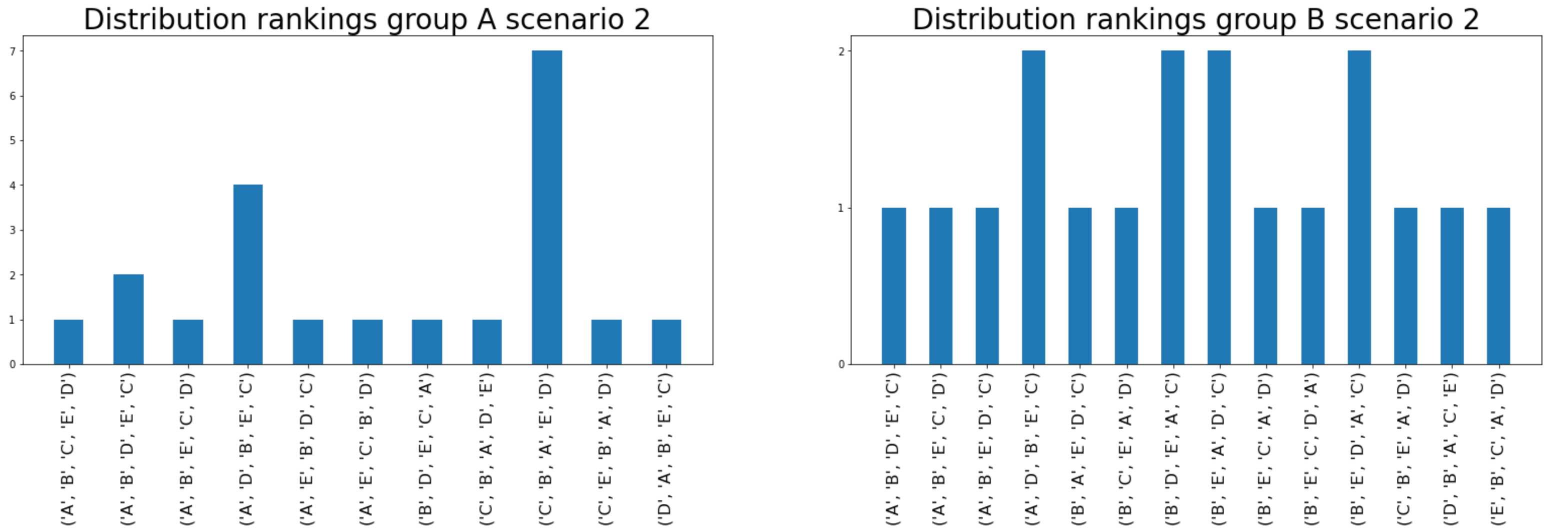


Figure H.1 Distribution of the rankings of scenario 2 with group A displayed on the left and group B displayed on the right.

Figure H.2 summarizes the ranks for scenario 3 (energy label, costs, and public support) for group A (left) and group B (right). For group A, the ranking of A-E-D-B-C was most popular, with four policymakers concluding this ranking. Interestingly, the highest number of rankings (A-D-E-B-C) is also chosen four times, and the most popular ranking in group A does not differ much from the most popular ranking in group B, suggesting the inclusion of social information did not change the priority much in these four cases.

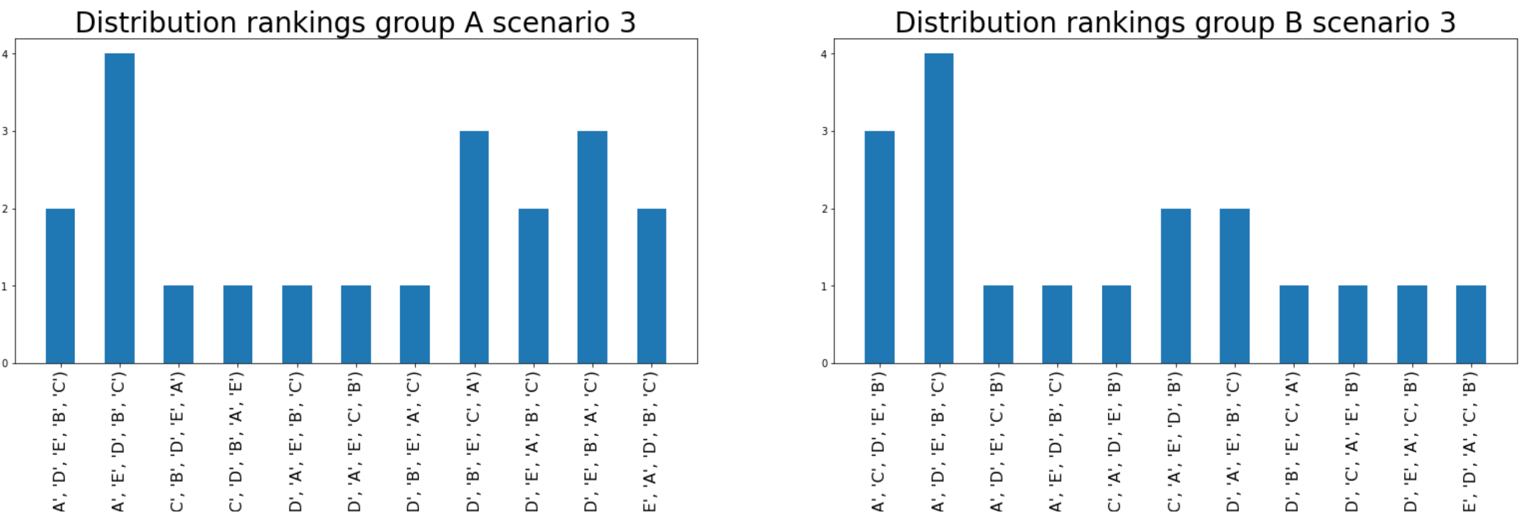


Figure H.2 Distribution of the rankings of scenario 3 with group A displayed on the left and group B displayed on the right.

Figure H.3 summarizes the ranks for scenario 4 (year of construction, costs and public participation) for group A (left) and group B (right). For group A, the ranking of D-E-B-C-A was most popular, with seven policymakers concluding this ranking, whereas the most popular rankings of group B were chosen three times at most. The multiple stand-alone rankings and lower number of common rankings in group B suggest a higher complexity and difficulty of the ranking task of group B compared to group A.

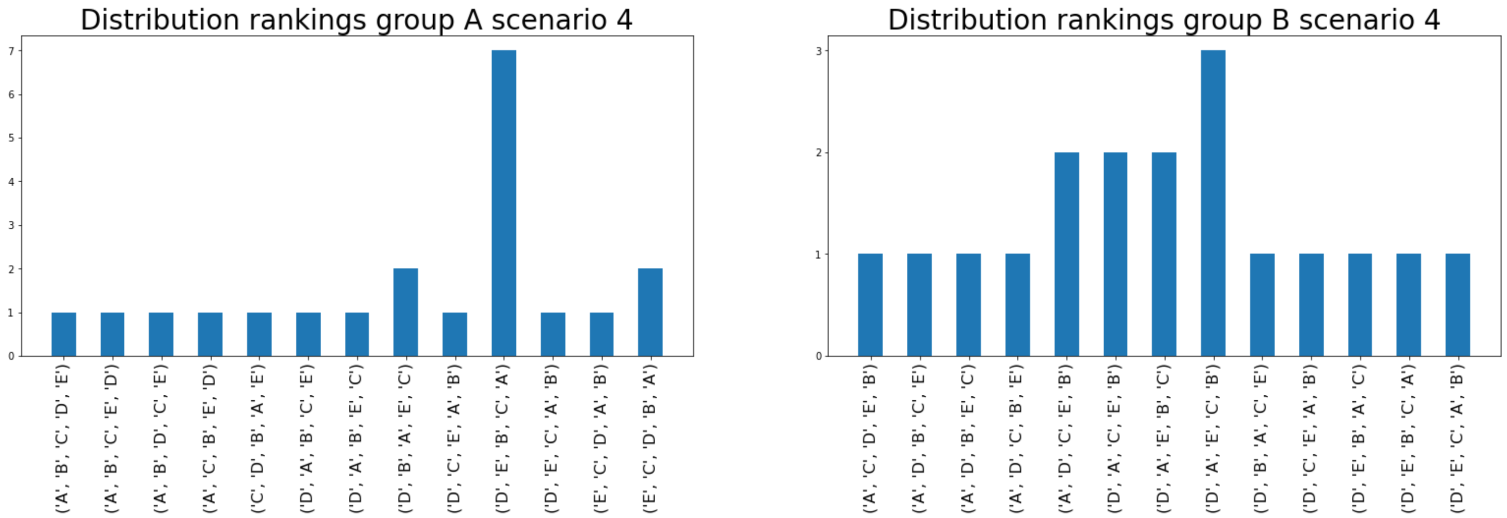


Figure H.3 Distribution of the rankings of scenario 4 with group A displayed on the left and group B displayed on the right.

H.2 DISTRIBUTION OF RANKINGS OF SCENARIOS FOR ALL NEIGHBOURHOODS

Figure H.4 summarizes the frequency of every rank for every neighbourhood for scenario 2 (energy consumption, costs and energy poverty) for group A (top row) and group B (bottom row). For instance, figure H.4 shows that, where ten policymakers in group A chose to prioritise neighbourhood A first, five policymakers in group B chose to prioritise neighbourhood A, suggesting the added social information might lead to a less compelling case to prioritise neighbourhood A.

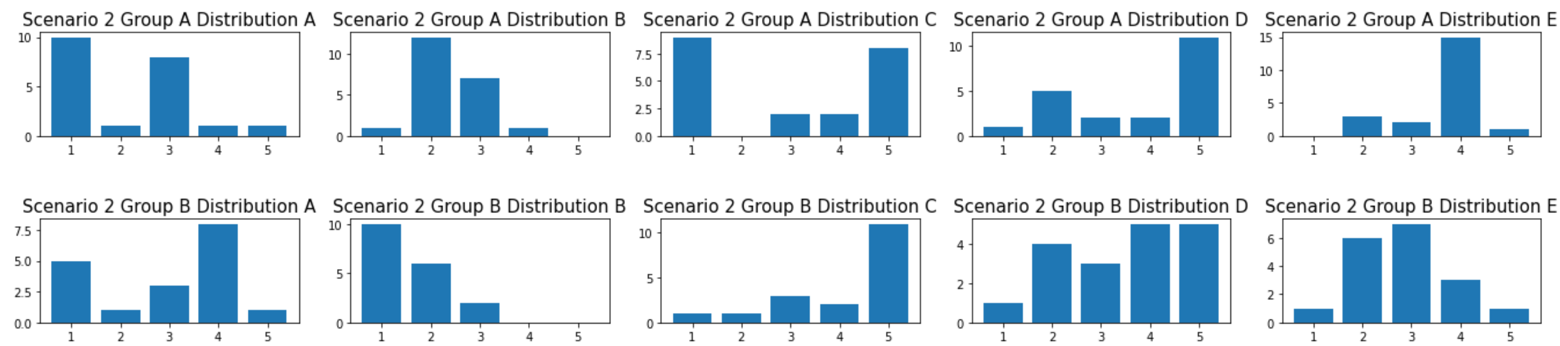


Figure H.4 Distribution of the rankings of scenario 2 for all neighbourhoods with group A displayed on the top row and group B displayed on the bottom row.

Figure H.5 summarizes the frequency of every rank for every neighbourhood for scenario 3 (energy label, costs, and public support) for group A (top row) and group B (bottom row). For instance, figure H.5 shows that, where six policymakers in group A chose to prioritise neighbourhood A first, eight policymakers in group B chose to prioritise neighbourhood A, suggesting the added social information makes it more interesting to prioritise neighbourhood A.

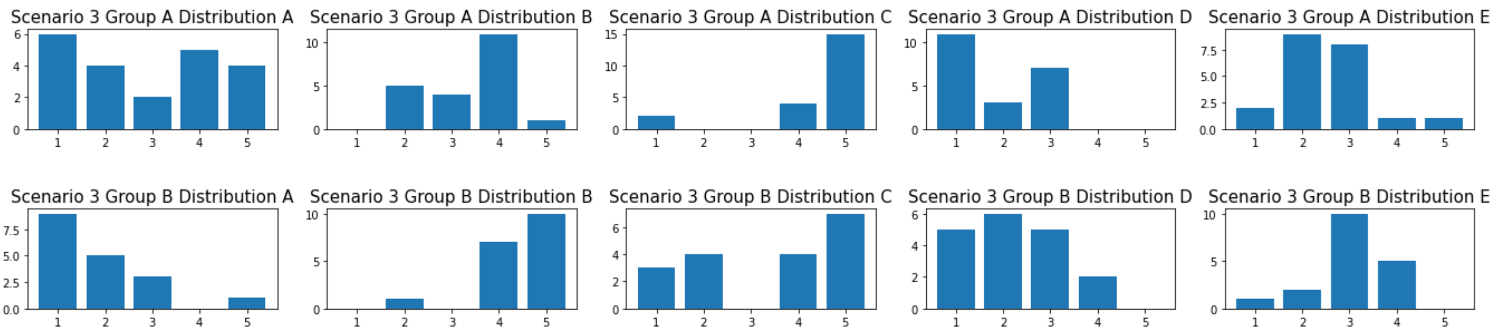


Figure H.6 Distribution of the rankings of scenario 3 for all neighbourhoods with group A displayed on the top row and group B displayed on the bottom row.

Figure H.6 summarizes the frequency of every rank for every neighbourhood for scenario 4 (year of construction, costs and public participation) for group A (top row) and group B (bottom row). For instance, figure H.6 shows that, where four policymakers in group A chose to prioritise neighbourhood A first, six policymakers in group B chose to prioritise neighbourhood A, suggesting the added social information makes it more interesting to prioritise neighbourhood A.

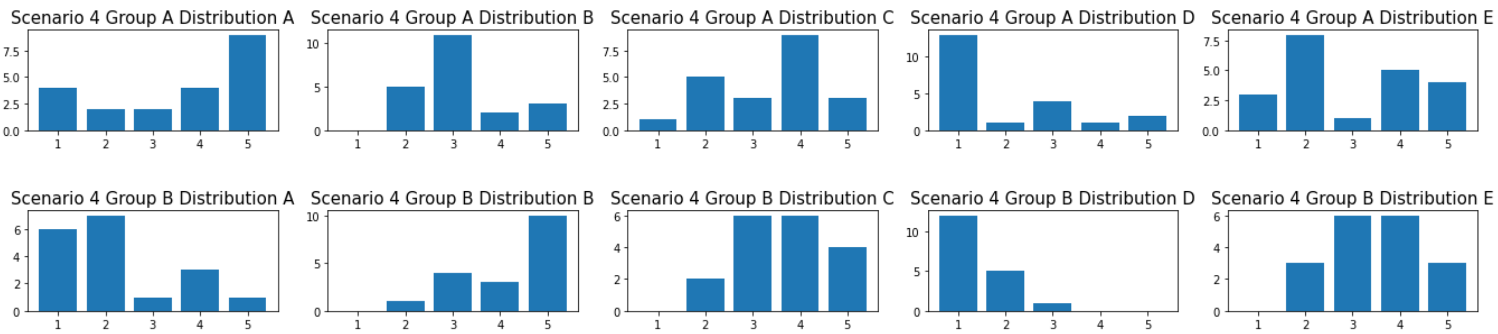


Figure H.5 Distribution of the rankings of scenario 4 for all neighbourhoods with group A displayed on the top row and group B displayed on the bottom row.

H.3 DESCRIPTIVES EXIT-QUESTIONS

Appendix h.3 illustrates the descriptives of the remaining exit questions with the descriptives of group A in h.3.1 and the descriptives of group B in h.3.2.

h.3.1 Descriptives exit-questions group A

From figure H.7, it is possible to conclude that most of the respondents in group A disagree with the statement: "*The available information adequately supports my decision-making in the heat transition*". This result is unsurprising as some respondents indicated they found the information insufficient and incomplete.

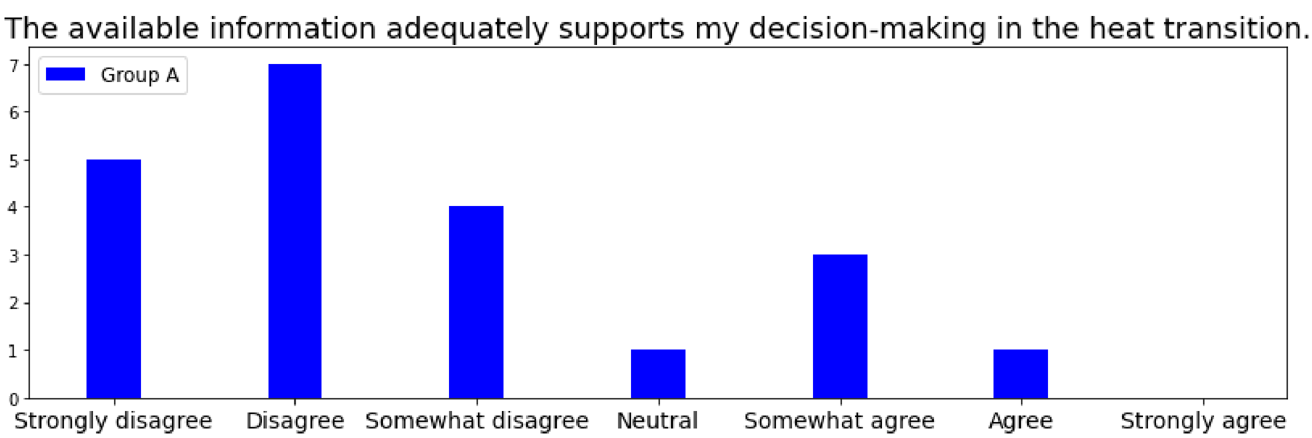


Figure H.7 Descriptives of exit question for group A: "The available information adequately supports my decision-making in the heat transition."

Figure H.8 illustrates that, even though some policymakers in group A are neutral towards the importance of social information for their decision-making process, the majority tends to agree with the statement. Once again, this result is unsurprising as some respondents indicated that additional social information would have been helpful. From the interviews, it becomes clear that social information is often unavailable, and data collection remains a labour-intensive process.

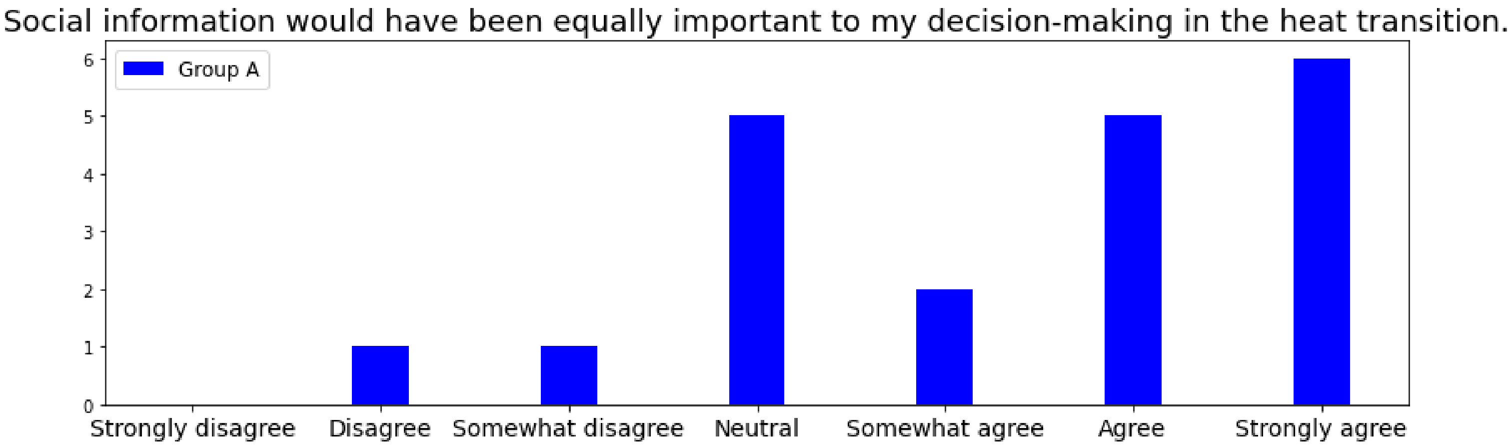


Figure H.8 Descriptives of exit question for group A: " Social information would have been equally important to my decision making in the heat transition."

h.3.2 Descriptives exit-questions group B

From figure H.9, it is possible to conclude that most of the respondents in group B agree with the statement: "*Adding social information supports me in the decision-making of the heat transition.*" This is in line with comments made by policymakers in group A who expressed a need for social information.

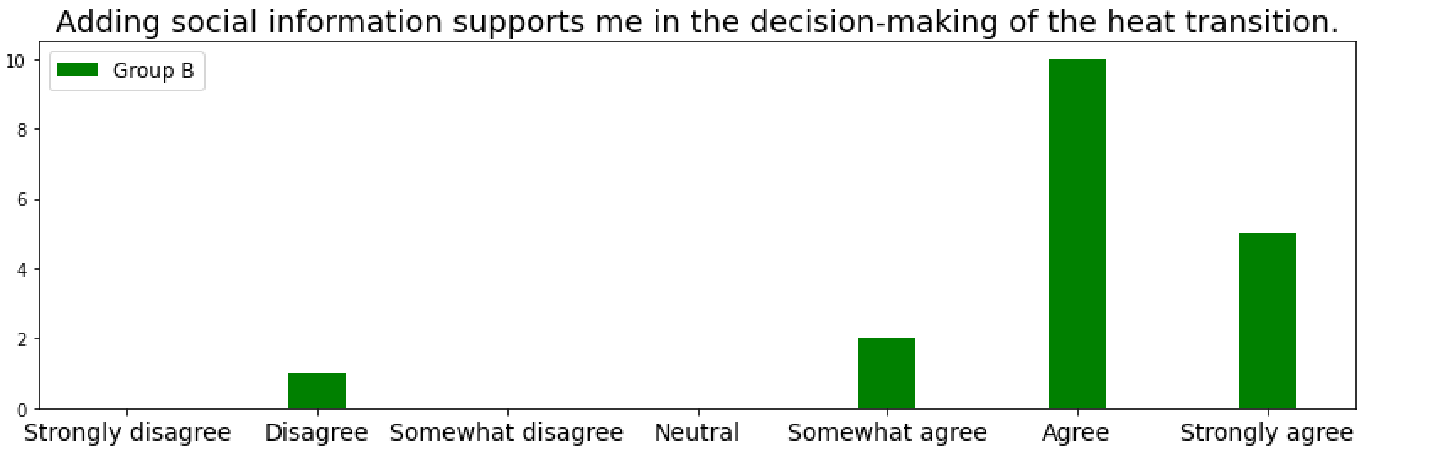


Figure H.9 Descriptives of exit question for group B: " Adding social information supports me in the decision-making of the heat transition."

Figure H.10 seems to illustrate an understanding among policymakers that adding social information is necessary to reach sound decisions in the heat transition. This is somewhat in line with the statistics in figure H.8, where the majority of group A agrees on the importance of social information in the decision-making process.

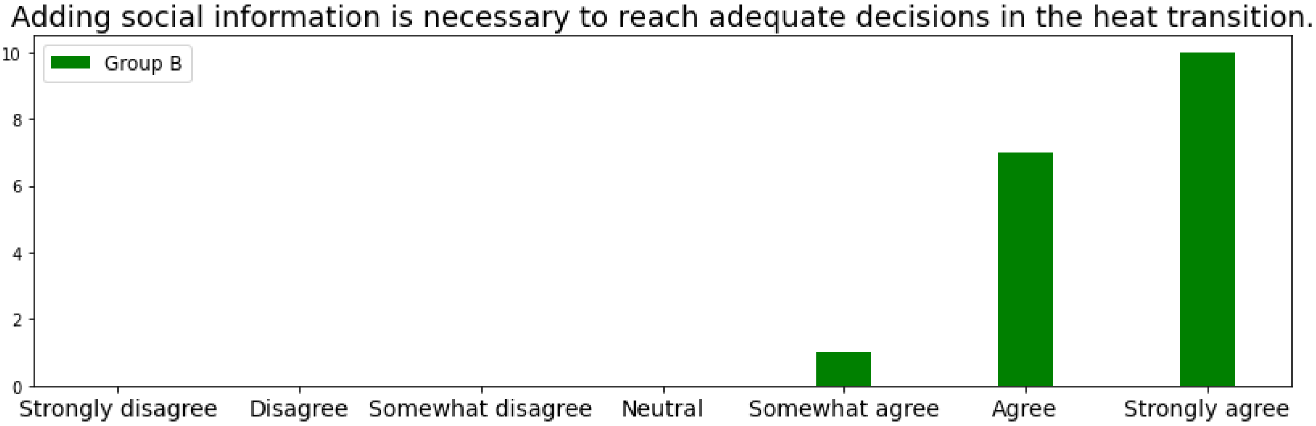


Figure H.10 Descriptives of exit question for group B: " Adding social information is necessary to reach adequate decisions in the heat transition."

On the final exit question, there seems to be somewhat more disagreement. Although the majority of policymakers agree that adding social information to technical and economic information adds complexity, there are also a few policymakers who disagree (figure H.11).

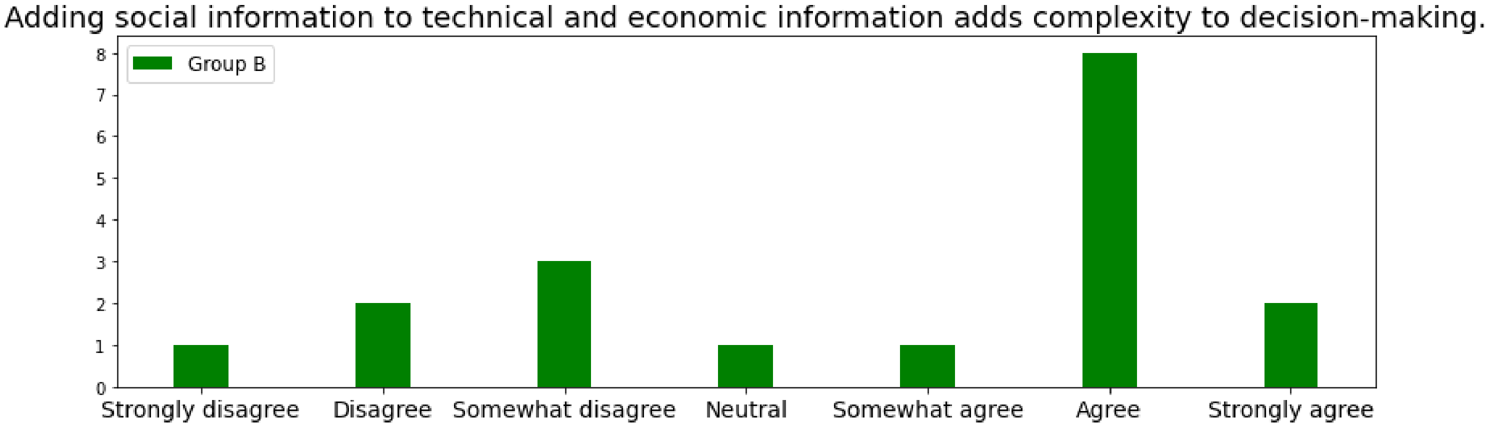


Figure H.11 Descriptives of exit question for group B: " Adding social information to technical and economic information adds complexity to decision-making."

H.4 DISTRIBUTION OF SAMPLES FOR MANN-WHITNEY U TEST

To determine how to interpret the Mann-Whitney U test, distributions of all neighbourhoods for scenario 1 (energy consumption, costs and public support) are depicted in figure H.12. From figure H.12 it can be concluded that the distributions of the rankings for neighbourhoods B, C, D and E are dissimilar for groups A and B.

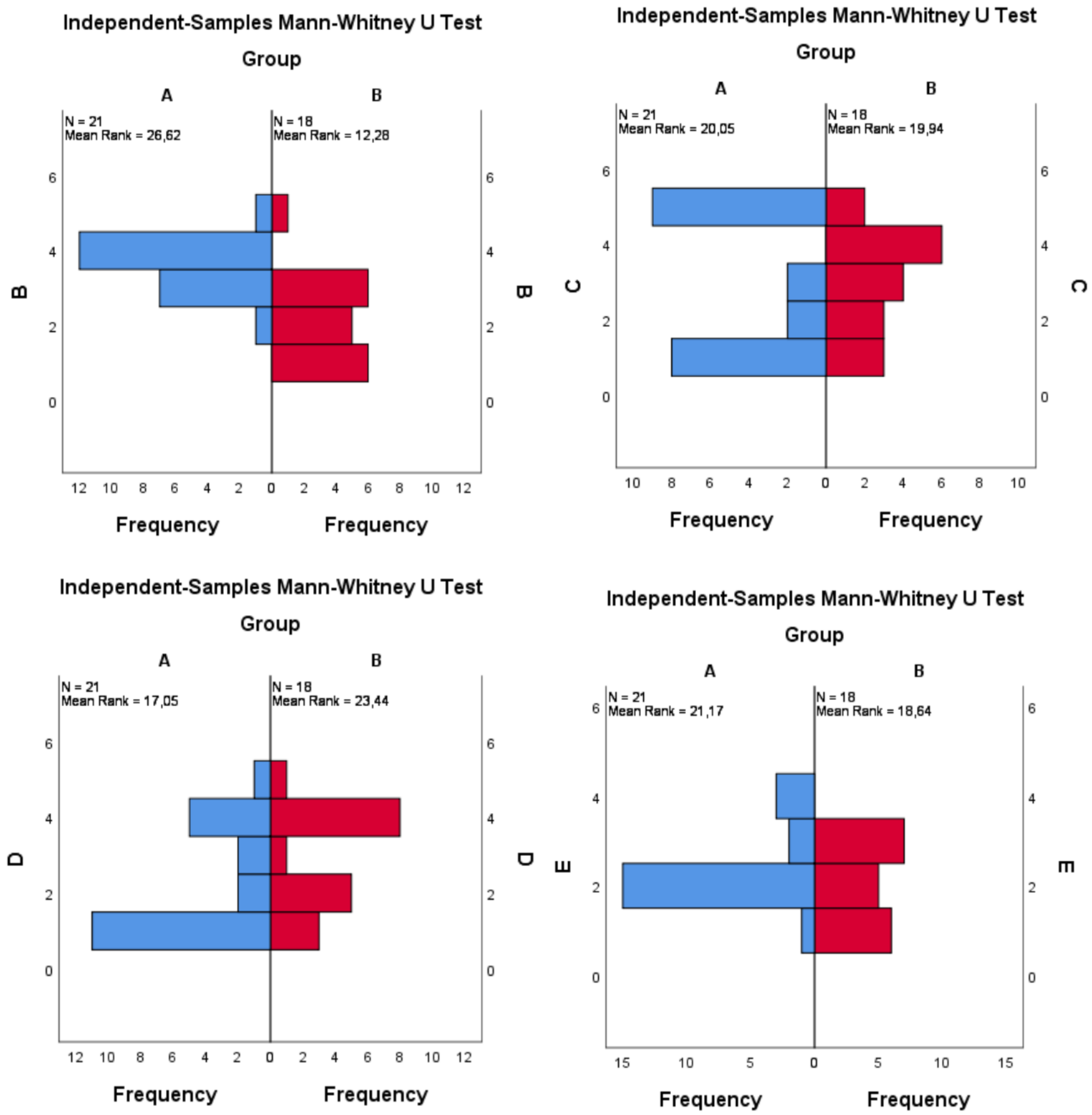


Figure H.12 Scenario 1: distribution of the ranking of scenario 1 for groups A and B (top left: neighbourhood B, top right: neighbourhood C, bottom left: neighbourhood D, and bottom right: neighbourhood E).

To determine how to interpret the Mann-Whitney U test, distributions of all neighbourhoods for scenario 2 (energy consumption, costs and energy poverty) are depicted in figure H.13. From figure H.13 it can be concluded that the distributions of the rankings for neighbourhoods B, C, D and E are dissimilar for groups A and B.

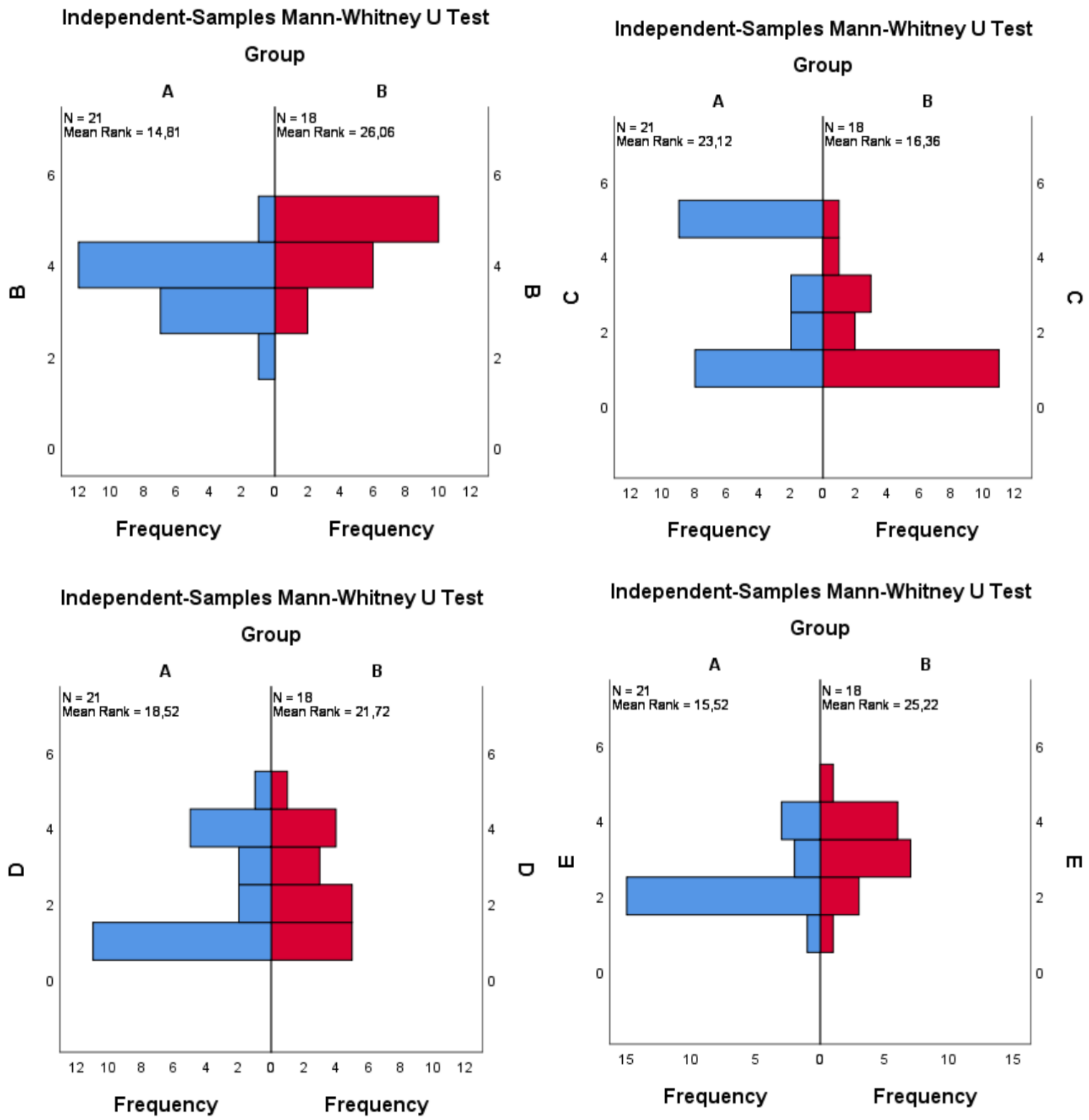


Figure H.13 Scenario 2: distribution of the ranking of scenario 2 for groups A and B (top left: neighbourhood B, top right: neighbourhood C, bottom left: neighbourhood D, and bottom right: neighbourhood E).

To determine how to interpret the Mann-Whitney U test, distributions of all neighbourhoods for scenario 3 (energy label, costs, and public support) are depicted in figure H.14. From figure H.14 it can be concluded that the distributions of the rankings for neighbourhoods B, C, D and E are dissimilar for groups A and B.

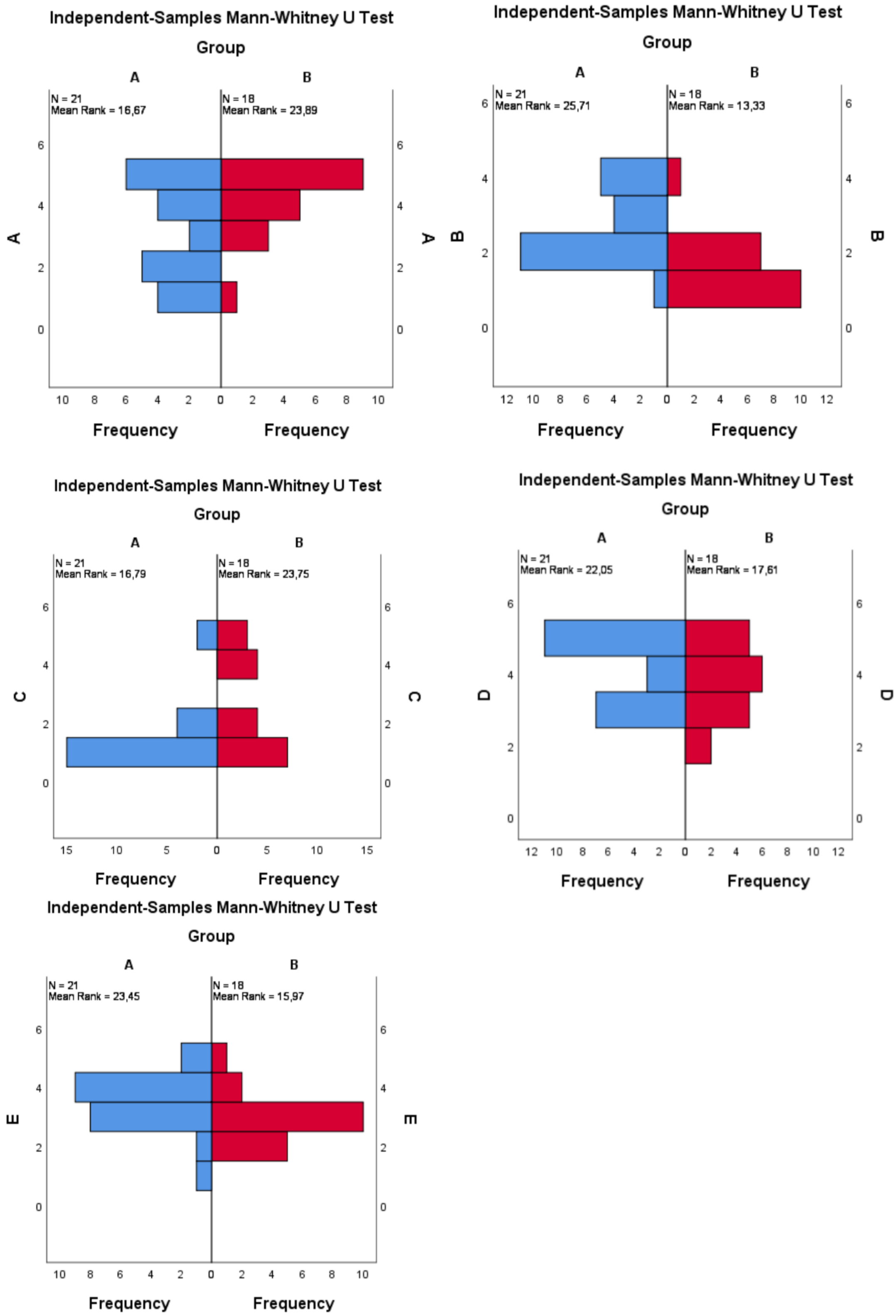


Figure H.14 Scenario 3: distribution of the ranking of scenario 3 for groups A and B (row 1 left: neighbourhood A, row 1 right: neighbourhood B, row 2 left: neighbourhood C, row 2 right: neighbourhood D, and row 3: neighbourhood E).

To determine how to interpret the Mann-Whitney U test, distributions of all neighbourhoods for scenario 4 (year of construction, costs and public participation) are depicted in figure H.15. From figure H.15 it can be concluded that the distributions of the rankings for neighbourhoods B, C, D and E are dissimilar for groups A and B.

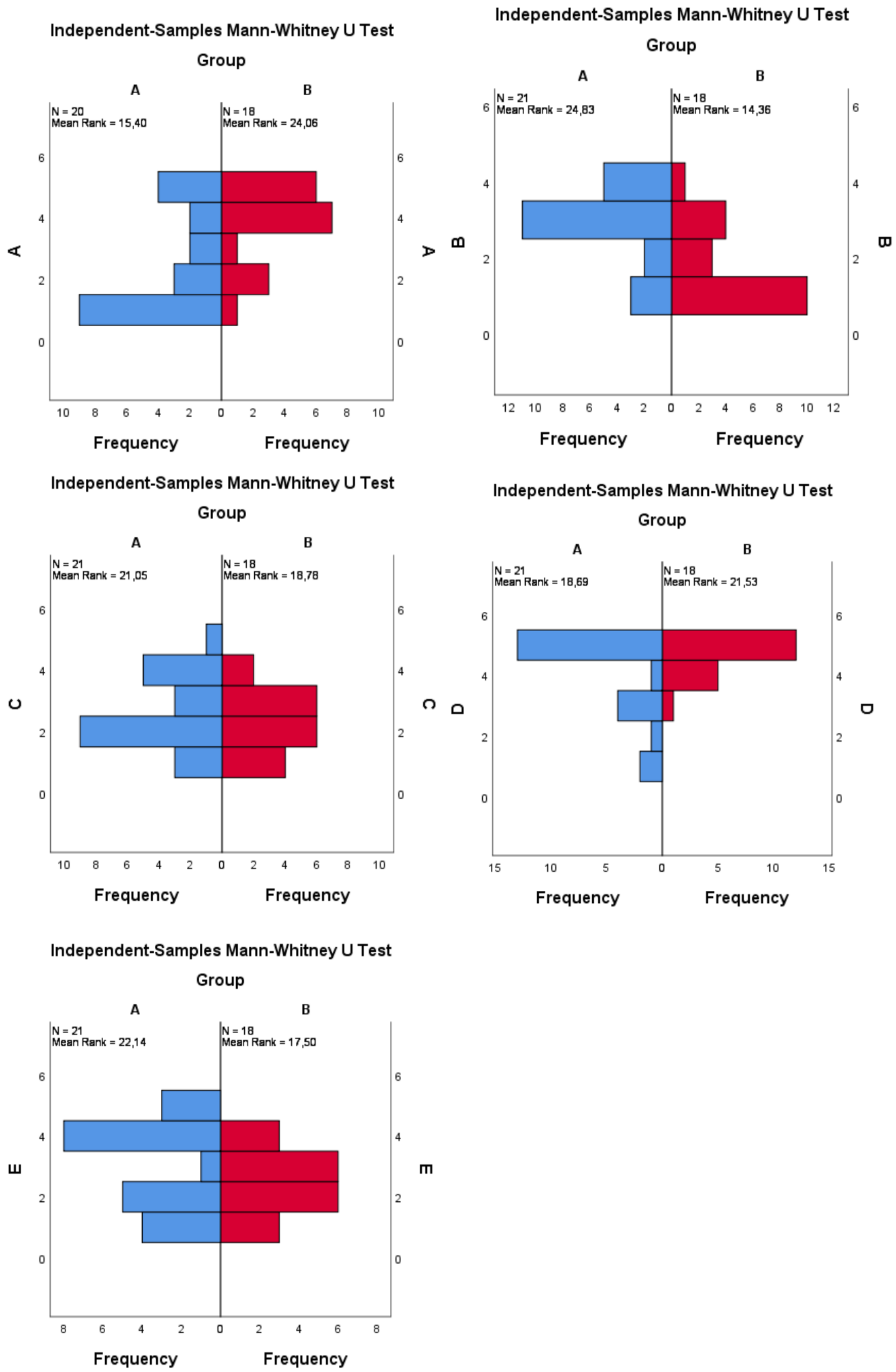


Figure H.15 Scenario 4: distribution of the ranking of scenario 3 for groups A and B (row 1 left: neighbourhood A, row 1 right: neighbourhood B, row 2 left: neighbourhood C, row 2 right: neighbourhood D, and row 3: neighbourhood E).