“It is just too much hassle!”

A stated choice experiment regarding the perception of hassle factors on the decision-making of heat pump adoption by homeowners in the Netherlands

Tormo Jerre Scherer

TU Delft

Photo by Tim Gouw from Unsplash

This page is intentionally left blank

"It is just too much hassle!"

A stated choice experiment regarding the perception of hassle factors on the decision-making of heat pump adoption by homeowners in the Netherlands

Master thesis submitted to Delft University of Technology

in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in **Complex Systems Engineering and Management**

Faculty of Technology, Policy and Management

by

Tormo Scherer

Student number: 4609476

To be defended in public on August 30, 2022

Graduation committee

Chairperson	: Prof. dr. ir. C.G. Chorus, Department of Engineering Systems and Services
First Supervisor	: Dr. G. de Vries, Department of Multi-Actor Systems
Second Supervisor	: Prof. dr. ir. C.G. Chorus, Department of Engineering Systems and Services
Advisor	: Ir. M.C. de Haas, PhD candidate TU Delft

This page is intentionally left blank

Acknowledgements

Writing my master thesis was always something I was dreading. I always thought it would take a tremendous amount of work, it would be a lonely process, you never know if you are doing it correctly and without an interesting topic you will never be able to motivate yourself. Fortunately, this interesting topic gave me many times joy during the process. So, after many hours, and even sometimes too many hours a day, I overcame all barriers by completing this thesis for the master Complex Systems Engineering and Management. Therefore, I would like to thank everybody who surrounded me along my journey and inspired me in these past two years of my study. In particular, I want to express my gratitude to a few people.

First of all, I would like to thank Gerdien de Vries, who introduced me to the field of behavioural economics and helped me explore my topic. I really appreciate your enthusiasm and with it all your guided feedback, which helped me structure my research. Next of I would like to thank Mathijs de Haas for our bi-weekly meetings and advice. Although this was maybe not the topic you had the most expertise about, your methodological perspectives provided valuable insights for me. Moreover, thank you Caspar Chorus for helping me find my topic and set up my graduation committee. Even though you had a busy schedule, you were always available for a quick conversation to steer me in the right direction and motivated me throughout the process. Furthermore, I would like to thank my interviewees for their willingness to provide me with their knowledge. In addition, I want to thank all the respondents of the survey. It was always a pleasure to see a new person giving input and an even bigger one when I saw someone was resharing my survey. For this I specifically want to mention Shima Ebrahimigharehbaghi and all the municipalities who helped me out.

To my dear friends, your endless willingness to let me talk on about my survey, planning and topic, I want to thank you for your patience. I know sometimes it was maybe a bit ‘too much hassle’, but the endless discussions and adventures we pursued were an unimaginable support for me. I am grateful to have done my masters at the Technische Universiteit Delft and for the great friends I have made along the way. Lastly, I would like to thank my family for helping me out in all possible ways and for their confidence in me.

Tormo Scherer
Delft, August 2022

Executive summary

European and Dutch environmental goals prescribe that national emitted CO_2 levels need to be reduced. The Dutch residential heating sector is largely dependent on natural gas. Therefore, the Dutch government chose to transition the whole Dutch residential sector to gas-free living by 2050, to decrease CO_2 levels. Homeowners are responsible themselves for adopting a sustainable heating system, where specifically heat pumps are one of the main proposed solutions. However, renovation rates are not expected to meet their determined goals. Several barriers play a vital role in the decision-making process and are reasons for this lacking uptake, such as technical, financial, institutional, informational and psychological barriers. Research into psychological barriers and their effect is found to be underdeveloped. In order to better understand the decision-making process, this research studied the influence of hassle on the decision-making process of adopting a heat pump by Dutch homeowners. The psychological burden of decision-making is captured in the effect of non-monetary transaction costs or hassles. Hassles can come in the costs of time, effort, complexities, mess, nuisance and uncertainty, which can lead to inaction and delays. Therefore, it has been determined what is perceived as a hassle and to what extent it is a barrier in homeowners' decision-making process.

Through the use of a literature review and interviews, five main hassles were determined which impact the decision-making: ‘length of disruption’, ‘information gathering’, ‘subsidy and loan applications’, ‘finding a contractor’ and ‘neighbour consultation’. Next their influence as a barrier has been examined through discrete choice modelling with the help of a stated-preference choice experiment. An online survey was distributed to Dutch homeowners through two sustainability newsletters and the social media of municipalities and a local political party. In addition, convenience sampling was used to boost the number of respondents. The survey, with 155 complete responses, examined the choices of homeowners between in six choice sets and required them to rate the amount of hassle of each alternative.

The results of this study, for the first time, empirically validated that all five mentioned hassles negatively influence homeowners' decision-making. These influences are best modelled as one combined hassle factor, which explains how much hassle a homeowner sees. This combined factor is perceived as more important than the financial profit a homeowner receives over the lifetime of a heat pump, when traded off against each other. Additionally, a latent class analysis was performed, which found significantly different preferences between two groups of homeowners within the sample. The vast majority is in the first group (81%) and indicated that they prefer a minimal amount of each of the different individual hassles and prefer a large amount of profit. The second group is considerably less sensitive about both aspects. However, high standard errors heavily affect the second group parameter estimates. The determination of the two groups via socio-demographics or dwelling characteristics provided no additional insights.

Additional results showed that how much hassle a homeowner perceives is not solely influenced by the five main hassle factors. The amount of ‘profit’ decreases the overall amount of hassle homeowners see, indicating that context is important for a homeowner. Looking more closely at the perceptions of hassle, differences between conscious and unconscious perceptions can be found. Situational cues can unconsciously affect the relative importance of hassles, making the perceived hassle of a choice possibly different than considered consciously.

The findings of this research show that reducing the five main hassles can be used to speed up the adoption process of heat pumps. Policymakers and businesses can perform interventions to decrease hassle or provide even ‘hassle-free’ alternatives by taking over tasks. The appropriateness of these interventions should be based on the derived willingness to accept values created via the parameter

estimates. These values indicate how much a homeowner is willing to accept for an increase in hassle and can be used the other way around to show the approximate range a homeowner is willing to pay for a decrease in hassle. The use of context differentiations can be used as an additional tool via nudging and sludging to decrease or increase the perceived amount of hassle of choices. However, it must be underlined that the differences between the conscious and unconscious perceptions of hassle by homeowners can give unexpected results of interventions.

This research's overall value provides a better understanding of a barrier rarely considered in homeowners' decision-making. From a societal perspective, these insights can be used to achieve a wanted transition and contribute to reducing the adversities of climate change. Cost-effective interventions, based on the willingness to accept values, can create additional economic impact for businesses.

The findings of this research are subjected to limitations, which can give inaccurate values of hassle on the overall population compared to the sample population used. Additional research can address this limitation by using a representativeness sample and can, based on the hassle-sensitiveness of homeowners, determine effective interventions considering homeowners' context and timing.

Table of content

List of Figures

List of Tables

List of abbreviations

BIC	Bayesian Information Criterion
CBA	Cost-Benefit Analysis
CoSEM	Complex Systems Engineering and Management
DCM	Discrete Choice Models
EER	Energy Efficiency Renovation
HII	Hierarchical Information Integration
KMO	Kaiser-Meyer-Olkin
LCA	Latent Class Analysis
LRS	Likelihood Ratio Statistic
ML	Mixed Logit
MNL	Multinomial Logit
PAF	Principal Axis Factoring
RRM	Random Regret Minimization
RUM	Random Utility Maximisation
SEM	Structural Equation Model

1. Introduction

This chapter provides general information on the problem which this study addresses. It describes background information, the problem itself and its knowledge gaps. Several research questions were composed of scientific and societal relevance. Lastly, the outline of this study is mentioned.

1.1. Background

The European Commission wants to reduce greenhouse gas emissions by 55% in 2030 compared to 1990 to reach climate neutrality by 2050 (European Commission, 2020). To comply with this target, the Dutch government has set a goal to achieve a 95% CO_2 emission reduction by 2050 (Government of the Netherlands, 2019). Residential buildings are roughly responsible for 9% of these CO_2 emissions due to their energy demands (Jansma et al., 2020). The residential sector is thus also an essential part in the energy transition of the Dutch government. Almost 90% of the current residential buildings are connected to the natural gas grid, whereas heating accounts for two-thirds of their energy demand (Jansma et al., 2020; Tigchelaar, van Lidth de Jeude, et al., 2019). This natural gas dependency resulted from a lock-in in the residential sector due to the country's large natural gas reserves in the gas field of Slochteren, in the province of Groningen. The gas extraction became problematic as the population of Groningen experienced seismic activities and as a result had damaged buildings (Boersema, 2021). This untenable situation made the topic of stepping away from natural gas more important. Internationally, natural gas prices increased due to decreased Russian gas supply, because of the war in Ukraine. On top of that, the European Commission launched its climate change strategy, the Green Deal, for reducing CO_2 emissions. All these aspects together increased the importance and urgency of lowering natural gas consumption. Therefore, the Dutch government ordered every municipality to make a specific plan for each neighbourhood to become independent of natural gas (RVO, 2021). This alignment meant stepping away from natural gas heating and moving toward sustainable heating to achieve the Dutch energy goals.

One of the main solutions proposed to go to a sustainable residential heating system is based on heat pumps (RVO, 2017). Heat pumps are heating systems that can heat air and/or water. Different heat pumps exist, but the three main types of heat pumps in the Netherlands are all-electric heat pumps, ventilation heat pumps and hybrid heat pumps. These heat pumps use electricity and temperature differences in the air, ground or water to heat homes. While a hybrid heat pump additionally uses natural gas. For this reason, a hybrid heat pump also needs a gas boiler to heat a home. Natural gas boilers are very common in the Netherlands, making hybrid heat pumps a suitable transition step to complete natural gas independence. Similarly, ventilation heat pumps also need an additional component to heat a complete house (Milieu Centraal, n.d.). A connection to a heat network or electric heater would provide this extra required capacity for ventilation heat pumps. Generally, a house should be well insulated to provide sufficient levels of comfort and not need additional heat. This insulation necessity is hence especially valid for all-electric heat pumps (Kieft et al., 2021). However, for simplicity reasons, this research assumes no differences between any of the heat pump alternatives.

1.2. Problem definition

The envisioned goal of the Netherlands requires a transformation of all houses containing natural gas heating systems into alternatives such as heating by heat pumps. Homeowners in the owner-occupied sector, which are more than half of the total housing sector (CBS, 2021d), are responsible themselves for performing this task. However, large parts of the housing sector still have an average heating profile of level 'C', ranging from A to G, with A being the most energy efficient and G the least energy efficient (Calcasa, 2021; van Dijke, 2019). For the use of a heat pump, it is recommended to have an energy label of at least class 'B' or higher (Kieft et al., 2021). However, it is expected that the renovation rates are not sufficient to meet the predetermined goals (NOS, 2017). So, to increase these numbers, the Dutch government has implemented several interventions such as subsidy schemes (NOS, 2022) and announced the mandatory need from 2026 onwards for new heating systems to be a hybrid heat pump or a more sustainable alternative (Geurts, 2022).

Looking at the reason for the initial lack in uptake, are households aside from a technical change, also susceptible to various non-technical aspects related to the adoption of energy efficiency renovations (EER's). Hence, these renovations are not only a technical challenge but also a financial and social challenge (Jansma et al., 2020; López Rodríguez et al., 2021). Such as high investment costs, unsuitable policy targets and lack of information for households (Du et al., 2022; Tigchelaar, van Lidth de Jeude, et al., 2019). Several scientific articles and reports, therefore, focus on these drivers and barriers of homeowners for carrying out EER's (Du et al., 2022; Ebrahimigharehbaghi et al., 2021; Koning et al., 2020; Stieß & Dunkelberg, 2013; Voskuyl, 2021; Wilson et al., 2015). The use of natural gas for other purposes, such as cooking, is considered not part of this research.

So, aside from the often mentioned technical, financial, institutional and informational barriers for adopting EER's in scientific literature, are behavioural biases or psychological barriers mentioned to a lesser extent. Psychological barriers hinder the adoption of EER as well, as it might question (the effort of) the decision-making (de Vries et al., 2020). Examples include uncertainty, unawareness, lack of trust, habits and a negative attitude towards the heat transition (Drysdale et al., 2019; Jansma et al., 2020; López Rodríguez et al., 2021; Nava-Guerrero et al., 2022; Verplanken & Whitmarsh, 2021). All these barriers make it challenging for municipalities to execute their established visions and programs. Hence, the heat transition in the Netherlands is considered a complex transformation as homeowners' decision-making is influenced by the interactions between actors, technologies and institutions while taking into account multiple criteria simultaneously, such as path dependency and perspectives of homeowners (Nava Guerrero et al., 2019). Understanding this decision-making process can help speed up the heat transition as interventions can be tailor-made to address, overcome or decrease specific barriers.

1.3. Knowledge gap

Efforts to understand this decision-making of homeowners often make use of models to capture this process, such as (differentiations of) Rogers' model of the Innovation Decision Process (Broers et al., 2019; Du et al., 2022; Klockner & Nayum, 2016; Pettifor et al., 2015; Rogers, 2003; Sanguinetti et al., 2021; Wilson et al., 2018) or the CODEC model in Tigchelaar et al. (2019). The psychological burden of decision-making is captured in these models via transaction costs, which shows that decision-making costs play a role in the heat transition and are inevitable (Ebrahimigharehbaghi et al., 2020).

Cost in the form of time, effort, complexities in doing renovations, mess and nuisance, and uncertainties can (collectively) feel like a barrier (de Vries et al., 2020). These non-monetary transaction costs or hassles, as they are sometimes called, can be an important reason for the low uptake of EER's or heat pumps (Snape et al., 2015).

The unclarity regarding hassle relates to which barriers are actually involved in sustainable heating adoption. Hassle is often coupled with inconvenience, and therefore multiple reports started to use this term for implementation problems regarding EER (de Vries & Kooger, 2020; DECC, 2013; Jansma et al., 2020; Koning et al., 2020; Snape et al., 2015; Voskuyl, 2021). The subjectivity what is inconvenient for someone, also impacts hassle. It can be unclear when something is generally perceived as complex or annoying. The empirical evidence towards what, in general, is perceived as hassle is missing, as only limited research towards specific hassle components has been performed. Additionally, due to the subjective nature of hassle, quantitative research would be helpful to gain insights into not only what individuals perceive as hassles but also if there are differences between subgroups. For example, highly educated people perceive knowledge and implementation differently than less-educated groups (Broers et al., 2019).

So, the influence of hassle on an individual's choice to implement an EER or heat pump is mainly unknown. The complex nature of decision-making makes it difficult to understand an individual's decision-making process and the effect of certain specific barriers. A modelling approach to observe these influences seems highly appropriate in order to see what affects homeowners' decision-making. However, the effect of a hassle factor is rarely modelled and the influence of different hassle factors has not yet been part of modelling studies about the decision-making process of homeowners at all, as reviews have shown (Du et al., 2022; Friege & Chappin, 2014; Hesselink & Chappin, 2019; Stadelmann, 2017). The insights of the influences of hassles towards heat pump adoption are considered highly relevant due to the importance of heat pumps in the Dutch heat transition and the expected consequences of hassle. In other words, there is a knowledge gap about what the hassle factor consists of and to what extent it affects the decision-making process of homeowners to adopt a heat pump.

1.4. Research question

Therefore, the main research question of this thesis or research is: *"Which hassle factors are a barrier for Dutch homeowners to adopt a heat pump and to what extent do these factors influence homeowners' decision-making?"*

This question addresses which hassle factors affect a homeowner's decision-making to adopt a heat pump and the severity of these factors. This finding possibly creates insights into ways to accelerate the Dutch heat transition.

The following sub-questions are constructed based on the main research question:

1. *Which hassle factors influence homeowners' adoption of heat pumps?*
2. *How are hassle factors perceived by Dutch homeowners when adopting a heat pump?*
3. *How are hassle factors traded off by Dutch homeowners?*
4. *Which differences among homeowners can be identified based on how they trade off hassle factors?*

1.5. Scientific, societal and master program relevance

Understanding the unknown effect of hassle on the decision-making process poses a great insight into all the related barriers towards heat pump adoption. Empirical analysis of the role of the hassle factor in heat pump adoption in the Netherlands is a first identification step toward the influence of this psychological barrier in the heat transition in general. This case-specific identification gives evidence for the variation in perceptions about barriers to the heat transition, which may vary among (sub)groups or countries and is, therefore, important (Li et al., 2018).

From a societal perspective, this research gives insight into a barrier rarely considered for accelerating the heat transition. Policy recommendations based on this aspect can help determine new ways to stimulate homeowners' behaviour towards sustainable heat alternatives, which consequentially decreases the adversities of climate change. The knowledge about people's trade-offs can help policymakers and businesses make use of someone's value of time for specific (hassle-free) alternatives. The determination of this value can justify interventions to also reach certain hard-to-convince groups in an effort to transform the whole of the Dutch residential heat sector. Simultaneously, it provides an additional economic impact for businesses.

The master Complex Systems Engineering and Management (CoSEM) corresponds to the objective of this study, as the Dutch heating system can be seen as a complex socio-technical system. Decision-making and policymaking are influenced in the heat transition by the many interactions between actors, technologies and institutions (Nava Guerrero et al., 2019). Therefore, analysing the hassle aspect will show the effect of human psychological behaviour as a barrier to the intended system change. The provided analysis creates input for the design of business and policy recommendations as potential intervention mechanisms.

1.6. Report structure

Chapter 2 will focus on the research methodology that uses discrete choice modelling to answer the research questions. In chapter 3, a literature review explores the aspects of hassle from a literature perspective. The design of the choice experiment is explained in chapter 4, based on the conceptual model described at the beginning of this chapter. The preparation steps of the data and the data descriptives are reported in chapter 5. Chapter 6 addresses the different models used to explain the data. These insights are evaluated and discussed in chapter 7, where limitations and recommendations are outlined. The final conclusions of this report are stated in chapter 8.

2. Methodology

This chapter introduces the research approach used to answer the main research question. The main approach is argued for in section 2.1. Subsequently, the different research methods are described and explained how and why they were implemented.

2.1. Choice modelling

A choice modelling approach has been applied to understand homeowners' decision-making behaviour when adopting a heat pump, as mentioned in chapter 1.3 that a modelling approach was deemed highly appropriate. Choice models can be used to determine and explain choices made by an individual when presented with two or more alternatives (Train, 2009).

Discrete choice models (DCM) can mathematically model this choice behaviour of homeowners to describe and explain decisions, using someone's individual trade-offs between alternatives. A homeowner can be faced with a choice between different heat pumps, which differ in their adoption process. The model then analyses a possible causal relationship to see how different attributes, or hassles, in this case, affect a person's choice to adopt a heat pump. Based on these insights, a group's decision-making behaviour can be predicted. This causal relationship makes DCM very suitable for identifying barriers and drivers, and is often used in the research field of energy technology adoption (Du et al., 2022). For example, DCM are widely applied to express household preferences for aspects in EER's (Wilson et al., 2015). However, there have been only a few preliminary attempts to see the effects of an individual hassle factor (Meles et al., 2022; Schleich et al., 2022; Voskuyl, 2021). These attempts mainly focused on the installation time only and not on Dutch homeowners' adoption of heat pumps.

2.2. Identification through a literature review

As hassle factors are rarely researched in modelling studies, the influence of hassle in the decision-making process is analysed in more detail. It has been shown that a literature review provides a good way to create an overview of the existing literature (Webster & Watson, 2002). Therefore, a literature review was used to analyse the aspects related to homeowners' decision-making regarding hassles. A collection of different hassle factors in this decision-making process has also been identified based on scientific articles collected through a structured literature review. The structured literature review was extended from hassle factors for heat pump adoption to the search for hassle factors in energy efficiency renovations or heating technologies due to the limited number of articles for heat pumps only.

The search for scientific articles is performed with the search engine Scopus. By searching through the title, abstract and keywords of articles in the English language, 47 articles were found using the following Boolean operator: *TITLE-ABS-KEY(("homeowner" OR "resident" OR "household" OR ("domestic" AND "consumer")) AND ("heating" OR ("energy" AND "efficiency") OR "heat" OR "thermal") AND (("decision" AND "making" AND "barrier") OR "hassle")).* After selection on suitability, 16 articles were found to mention a hassle factor and identify them as a barrier. Next to the identification of hassle factors are the articles also examined for covariates which could influence these hassle factors.

2.3. Identification through interviews

The selection of the most relevant hassle factors and variables was performed and validated for heat pumps by conducting semi-structured interviews. The results of these interviews were based on the answers to specific questions regarding the relevant factors identified in the literature review and by asking follow-up questions. After contacting several experts, two experts agreed to be interviewed, who either focused on the decision-making of household EER's or their implementation process. These experts from TNO and Klimaatroute, respectively, provided additional insights into this topic of hassle, specifically concerning heat pumps. The choice of two experts with different areas of expertise is based to decrease the chance of finding biased results. Both interviews lasted roughly 45 minutes and were summarized after completion. The summaries were approved by their corresponding actor and are listed in appendix A.

2.4. Stated or revealed preference data

After identifying the most influential hassle factors, homeowners' preferences towards alternatives and attributes will be modelled with a stated preference DCM. The empirical data of DCM can be categorised into revealed preference or stated preference data (Train, 2009). Revealed preference provides data regarding one actual choice in real life, while stated preferences are hypothetical situations.

Revealed preference data can be collected by observation or by asking respondents which choices were made. This data type has a high validity as the choices are actually made. However, revealed data can potentially have multicollinearity or an endogeneity bias, which decreases the models' validity. Here correlation between independent variables occurs (multicollinearity), or there is a correlation between independent variables and the error term (endogeneity bias). Stated preference data can be designed to overcome both problems (Helveston et al., 2018). In that case, the researcher makes hypothetical choice sets, including a complete range of attribute levels that might not be in the current range of revealed preference data. For example, one could create a choice set with an extremely cheap heat pump with much hassle and an expensive alternative with limited hassle. In stated preference data, the participant can also make multiple choices, reducing the number of needed participants to gain statistically significant parameters.

Due to the required time extensity for a search of revealed preference data, it is considered less suitable for the purpose of this research. Stated preference data is, therefore, chosen as more appropriate. Nevertheless, it should be considered that the main drawback of stated preference data is that the participants might respond differently than they would in real life due to its hypothetical nature (Haghani et al., 2021). The reason can be that choices are not felt; they do not want to give or know their real preference and do not have access to perfect information. For these reasons, the external validity of stated preference data is lower than revealed preference data. However, several hypothetical bias mitigation strategies are used to improve the external validity, see chapter 4.5.2.

2.5. Discrete choice modelling

The most dominant decision-making rule for DCM is Random Utility Maximisation (RUM), hence also applied in this study. RUM theory assumes that a person chooses the alternative with the highest total utility. Each attribute of that alternative contributes some level of satisfaction for the decision-maker. The alternative with this highest summated satisfaction or utility will be someone's choice (Train, 2009).

The chosen types of discrete choice models and most common ones are multinomial logit (MNL) models. The mathematical formula is given in equation (1). An MNL model assumes that the utility of a specific alternative is independent of other alternatives and that everyone has the same preferences resulting in the same parameters for all individuals. The error term captures differences in choices due to the randomness of people's choices, unobserved attributes, measurement errors, and taste heterogeneity. However, an MNL model can not explain these errors. The model estimations are done in Apollo, a package of the software RStudio.

$$U_i = V_i + \varepsilon_i = \sum_m \beta_m * x_{im} + \varepsilon_i \quad (1)$$

Where:

$i =$ the alternative, i.e. choice A, choice B

$m =$ the attribute, i.e. profit, information gathering

$U_i =$ the utility of alternative i

$V_i =$ the systematic utility of alternative i

$\varepsilon_i =$ the unobserved utility of alternative i (error term)

$\beta_m =$ the attribute weight for attribute m in alternative i

$x_{im} =$ the attribute level of attribute m in alternative i

2.6. Latent class analysis

Taste heterogeneity are differences in preferences towards attributes. Multiple parameters for an attribute show different preferences for groups within the sample. The identification of those groups is useful to see if some homeowners react differently to hassle factors than others and if interventions are needed to target specific groups to reach higher adoption levels.

A Latent Class Analysis (LCA) can explain this taste heterogeneity by finding homogenous clusters of homeowners within the sample (Vermunt & Magidson, 2002). This used analysis applies a latent class model to see if differences in parameter estimates can be found. Then it creates clusters based on these differences and uses exogenous variables or covariates to predict and describe the cluster membership of homeowners (Vermunt & Magidson, 2002). Examples of possible covariates are age, income and house size. Such covariates can be either active (predictor) variables or inactive (describing) variables. This analysis provides a useful method to see how differences in hassle-sensitiveness can influence decision-making. Compared to other models, such as mixed logit (ML) models, is the benefit of a latent class model that it explains taste heterogeneity rather than just capturing it.

By estimating parsimony models, it is tried to estimate the most taste heterogeneity with the least amount of clusters (Vermunt & Magidson, 2002). As more parameters or clusters can always explain more taste heterogeneity. For the estimation of the model fit and the most appropriate number of classes, the Bayesian Information Criterion (BIC) is used. BIC values allow a more direct visual comparison than the Ben-Akiva and Swait tests or Likelihood Ratio Statistics (LRS). Additionally, the LRS is not appropriate for non-nested models. A lower BIC value indicates that the data is better described with a minimal number of indicators. The formula is given in equation (2). The LCA is performed with the software LatentGold.

$$BIC = -2 * LL_{Final} + k * \ln(n) \quad (2)$$

Where:

LL_{Final} = the Log-Likelihood of the estimated model

k = the amount of parameters

n = the number of observations

3. Literature review

In this chapter, a literature review is provided to explore the effect of hassle on decision-making and determine which aspects can be considered a hassle. Additionally, it is examined if perceptions of hassle can be influenced.

3.1. Rational choices

Rational choice theory assumes that rational decision-makers base their decisions on the costs compared to their benefits in order to make choices that will provide them with the greatest benefits (Heiner, 1983; Zey, 2015). These perceived benefits portray someone's 'true' preferences, which are assumed to be fixed for individuals (Lecouteux, 2016). The decision of heat pump adoption can thus be driven by economic benefits and environmental or social preferences, for example. A way to make a comparison between the costs and benefits of an investment can be with the help of a cost-benefit analysis (CBA). It involves making a list of all costs and benefits and putting them in a monetary term for comparison, while allowing money to be discounted over time to take into account inflation and missed interest. The discount rate can thus be seen as the perceived monetary value of an investment (Hesselink & Chappin, 2019). Together with the similar term, the willingness to pay, which indicates the maximum amount a consumer is willing to pay for a product, service or benefit, it helps to compare all the related factors in monetary terms. These tools are highly used in the economic principle of maximising utility, by considering all information in order to make the best choice considering rational thinking (Lecouteux, 2016). This rationality can be captured with the term 'Homo Economicus', that originates from the neoclassical economic theory and models such as the CBA.

3.2. Irrational choices

Refraining from a heat pump in the case of a negative CBA would seem rational. However, refraining from such an investment, even if it would result in net monetary savings and thus a personal economic optimal situation, would be considered irrational thinking (Hünecke et al., 2019). Failing to behave in someone's own best interest by not purchasing a more energy-efficient heating system creates the energy efficiency gap (Stadelmann, 2017). This energy efficiency gap is thus the difference between the technical and economic potential against actual market adoption (Wilson et al., 2015).

An example related to heat pumps will be if a person says his name is Jonas would not adopt a heat pump even though he found out that the purchasing and instalment of a heat pump would result in profit for him personally over the lifetime of the heat pump, compared to a new version of his old heating system. A reason can be that Jonas does not know someone who can install a heat pump for him. The amount of effort it will take Jonas to search for contractors, call them and make them create invoices is too high for him compared to what he receives for profit due to the installation. Jonas works at a full-time job and does not want to spend his free time arranging a heat pump. He prefers to spend it at the beach with his girlfriend. Jonas' personal discount rate for his free time is high in this example. He prefers to spend it at the beach, not arranging a heat pump. Jonas' discount rate is thus higher than the average rational thinking person's discount rate.

Such a high personal discount rate or implicit discount rate can make a CBA turn from a positive to a negative result. Consequentially these rates lead to the choice not to adopt an investment. These implicit discount rates and/or high personal willingness to pay values are indicators of the existence of the energy efficiency gap (Stadelmann, 2017). Kelly et al. (2016) argue that implicit discount rates can lay from 10% if costs for loans are included to 30% if all other barriers are included, compared to the standard discount rate of around 5%. Therefore, implicit discount rates and personal willingness to pay estimates influence the energy efficiency gap (Schleich et al., 2016; Streimikiene & Balezentis, 2020).

3.3. Behavioural biases

Decision-makers can thus be influenced by other non-monetary drivers and barriers related to investments: 1) preferences such as time and risk; 2) external barriers such as split incentives, lack of capital and information; 3) (ir)rational behaviour such as behavioural biases and bounded rationality (Hesselink & Chappin, 2019; Schleich et al., 2016). These aspects are deviations from the rational acting Homo Economicus and are more similar to the Homo Psychologicus, which also makes decisions based on the above-mentioned influences and is proposed to be a more realistic view of a decision-maker (Lecouteux, 2016; Schillemans & de Vries, 2016). Behavioural biases and bounded rationality are advocated by Herbert Simon, one of the first who claimed that people are influenced by certain (self-)imposed constraints and that people act based on certain heuristics (Simon, 1955). In the case of our example of Jonas, this would be the constraint of minimising the brain capacity and total spending time as he prefers going to the beach more than deciding about heat pumps. This irrational behaviour is not necessarily something negative, as it reduces endless working on activities and can even be functional in some cases. Such as walking in a dark alley at night might be less wise, although it is the fastest route. However, in the context of making decisions about heat pump adoption, it is considered irrational to act based on these psychological barriers, which not necessarily means illogical in a wider context.

This irrational behaviour of preferring short-term costs over long-term costs, hence, having a bias toward the present and neglecting future costs, can be argued as a lack of self-control (Lades et al., 2021; Lecouteux, 2016). In this case, cognitive dissonance (i.e. short-term preferences clash with long-term preferences) repeatedly creates a mental free pass to do the hassles later. This endless delay is also called the intention-behaviour gap. It is debatable if these short-term preferences are always more important than the long-term preference for heating, as the long-term benefits of heating should not be persistently underestimated for our well-being. It can be seen as consistently maximising the "wrong" utility function, as someone's true preference is rarely going to the beach every day and having no heating at all. Therefore, behavioural economics try to include these factors such as emotions, beliefs and cognitive biases to understand how decision-makers actually act instead of how they should act (Thaler & Mullainathan, n.d.).

3.4. A different look at decision-making

In short, the widespread adoption of heat pumps is lacking due to an energy efficiency gap influenced by behavioural aspects that are not included in traditional economic models, which focus solely on costs and benefits. Behavioural aspects are very complex due to the involvement of individuals and their context, which can be a reason why they are often overlooked and underdeveloped in literature (Azizi et al., 2019; Ebrahimigharehbaghi et al., 2022; Gillingham & Palmer, 2014; Huijts et al., 2012). Homeowners act or decide based on their non-standard beliefs and preferences and let (unconsciously) psychological barriers, behavioural biases and heuristics influence their decision (Gifford, 2011; Hoffman & Henn, 2008; Kelly et al., 2016). These behavioural aspects consequently increase implicit discount rates, loss-aversion and non-rational views, leading to delay and inaction toward heat pump adoption.

Lastly, an additional example of non-rational behaviour in the eyes of neoclassical economics is given. Someone, let's call him Jakob, possesses a natural gas boiler which he noticed after a cold shower that it is broken down. He calls up his current mechanic, who is also an installer for heating systems, and asks if they can install a new heating system. The mechanic replies that this is no problem and asks what kind of heating system he wants. Jakob is not aware of current heating systems, nor is he interested in being updated. Therefore, Jakob mentions that his broken natural gas boiler was working well during its lifetime and asks for the same one of a newer model and when they would be able to install it. The mechanic comes the next day and installs a new natural gas boiler. Jakob did not have perfect information as he was unaware of the different possibilities and aspects such as costs, noise or size of the different options. He pursued the decision that involved minimum risks as he knew how his last boiler was working and maximised the preference of minimal hassle by comparing models and waiting for an instalment. This model might have cost him some extra money as other models that were just as good might be cheaper and/or better performing. This example illustrates that one can pursue a decision that involves minimum risks and complications instead of focusing on maximising all his preferences. This theory is called satisficing and is a combination of satisfying certain preferences and sufficing in others instead of maximising all preferences. Simon (1956) explains this as a decision-making strategy that aims for adequate results given someone's cognitive limitations.

3.5. Transaction costs and hassles

Of all the energy retrofit barriers, financial barriers are regarded as the most important ones. However, transaction costs are rated the second most important category of barriers to the energy retrofitting process. These transaction costs describe the cost of going through the decision-making process and can be subjected to subjective interpretation in the case of a non-monetary value (Ebrahimigharehbaghi, 2022). Therefore, non-monetary transaction costs are important in the energy retrofitting decision-making process. However, they are regularly mentioned as overlooked or understudied for homeowners (Ebrahimigharehbaghi et al., 2020; Hünecke et al., 2019; Lades et al., 2021), possibly as they are not considered in a CBA. Hence non-monetary transaction costs, what will be called hassle factors from now on, create sub-optimal decisions and resource allocation when neglected (Ebrahimigharehbaghi et al., 2020).

3.5.1. Hassle during heat pump adoption

Hassle factors are inevitable and unpredictable by nature, these practical problems can be perceived as irritating, frustrating and distressing (de Vries et al., 2020; Ebrahimigharehbaghi et al., 2020; Kanner et al., 1981). When looking at the decision-making process of heat pumps, several hassle factors can be found when using Ebrahimigharehbaghi et al. (2020) model for transaction costs during phases in the energy renovations process, see Figure 1.

In the considering phase, searching for reliable information can pose a barrier when determining a certain heat pump's costs and benefits. The differences in the variety of heat pumps in combination with specific home elements can create difficulties in determining visibility and cost-effectiveness. These stressing aspects can continue in the planning phase when the process needs to be understood and planned for, as it is often perceived as complex as found by de Vries et al. (2020). In the decision phase, searching for a suitable and available contractor can provide frustration. Not everyone knows someone capable of installing a heat pump, while additional constraints such as time planning and trust can make this search more complicated. Typically, no permits need to be requested for heat pumps, but the availability of subsidies or loans for heat pumps can provide problems (Rovers et al., 2021). In the execution phase of Ebrahimigharehbaghi et al. (2020) model, the mess, nuisance and 'uncertainty of about the performance of the installer' can provide hassle. Additional next steps in the experiencing phase can provide new hassles again.

A tendency to postpone these effortful tasks can be considered not uncommon, as signs such as procrastinating, overconfidence and inertia show a present bias for effort (i.e. people postponing an effortful task to the future) (Lades et al., 2021; Sunstein, 2020). This present bias for effort could lead to an intention-behaviour gap, where behaviour does not correspond with the already determined intention to make the investment. These biases show that a perceived or anticipated hassle is also a psychological barrier (de Vries et al., 2020; Klockner & Nayum, 2016; Lades et al., 2021). Hassles are therefore related to psychological barriers such as biases and heuristics, and it is expected to be a large trigger for inaction or delays toward heat pump adoption.

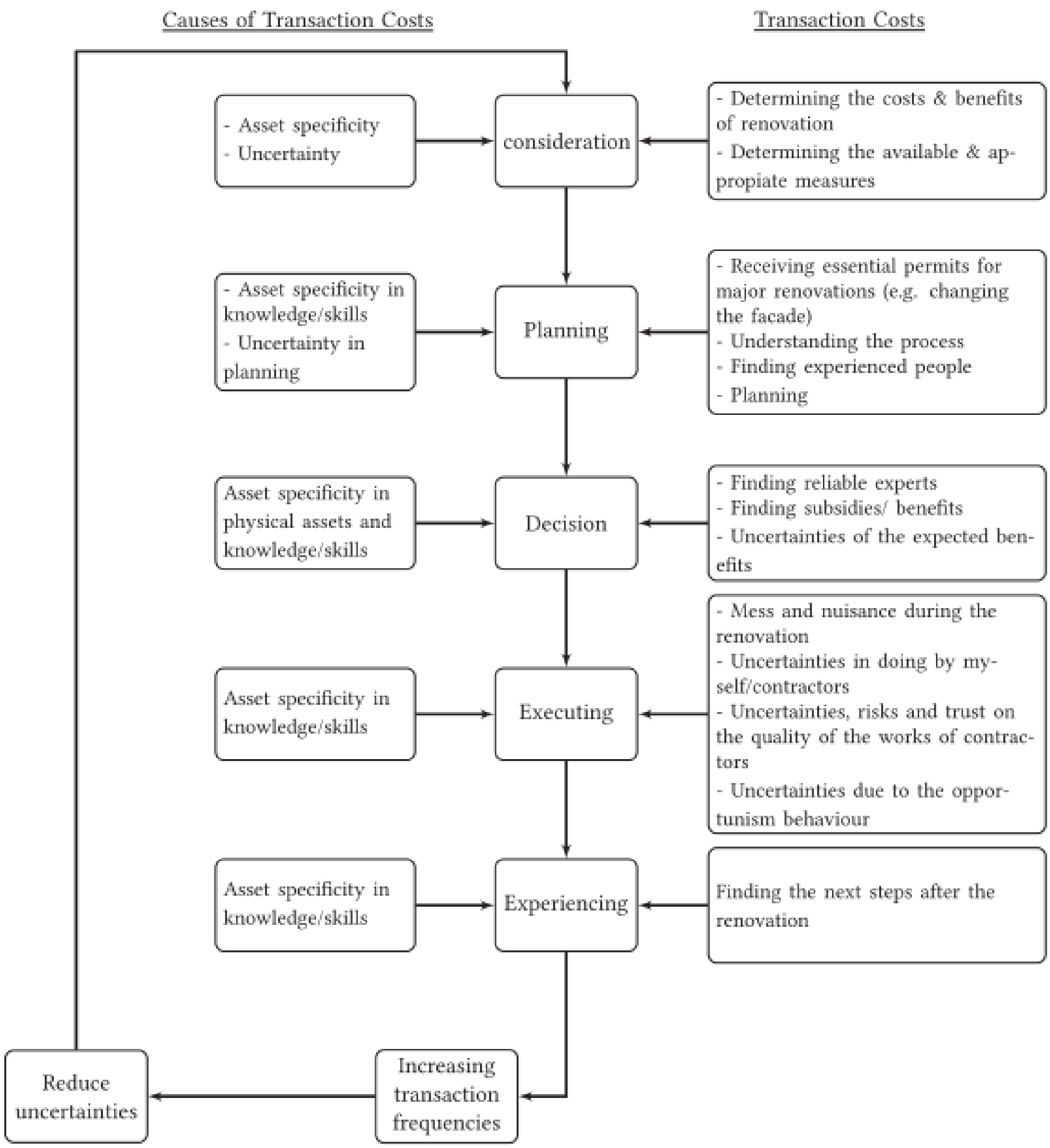


Figure 1. Transaction costs at the different stages of the decision-making process (Ebrahimigharehbaghi et al., 2020)

3.6. Influencing the hassle factor

Decreasing the energy efficiency gap could improve the sustainable heating sector's further increase, reducing the negative externalities associated with the current natural gas heating sector in the Netherlands. Monetary policies alone do not solve the energy efficiency gap, as psychological barriers, such as hassles, are important determinants in the decision-making process. Ossokina et al. (2021)

showed that monetary incentives could provide an increased adoption to some extent, but not enough to convince every household to perform an energy retrofit. Therefore, non-monetary policies such as information provision and complexity reduction are also beneficial in decreasing the transaction costs of decision-making (Ebrahimigharehbaghi et al., 2020). Behavioural literature suggests that in order to reduce transaction costs and the influence of behavioural barriers to follow four main principles: "make it easy", "make it attractive", "make it social", and "make it timely" (Lades et al., 2021, p.5). Reducing transaction costs should thus not be focused on financially changing the choice but rather on minimising the biases and errors created due to bounded rationality. This approach, or libertarian paternalism, is a philosophy that the choice architecture (i.e. how choices are presented) can influence a decision based on playing with these behavioural biases.

3.6.1. Nudge

An application of libertarian paternalism can be nudging, manipulating a choice setting or context in a way that specific (pro-environmental) choices are more likely, while maintaining the freedom of choice (Gillingham et al., 2009; Thaler & Sunstein, 2009; Verplanken & Whitmarsh, 2021). Individuals often make opposing decisions that contradict preferred stated goals, such as the lack of sustainable heating adoption. Nudging can help overcome habits and psychological aspects by exploiting biases and preventing homeowners from making non-sustainable choices (Sunstein, 2020; Verplanken & Whitmarsh, 2021). A rational decision-maker would ignore nudges in the context of heat pumps, as these changes do not influence the direct utility of the costs and benefits. However, choice architects, such as policymakers, governments and businesses, can use nudges as a (heuristic) tool to improve the performance (adoption) among irrational people (Sunstein, 2020).

3.6.2. Sludge

An alternative to nudging is sludging, which focuses on making the choice architecture in a form that leads to the experience of costs or friction (Shahab & Lades, 2021; Sunstein, 2020). Sludge is thus related to creating more friction for an alternative with negative externalities (Sunstein, 2020). These techniques (unintentionally) occur with the application of subsidies for heat pumps. People perceive these as unnecessarily complicated with all the different steps they must undergo (Kraan, 2022; Rovers et al., 2021). However, the degree of experienced hassle is subjective, as the perceived hassle of a task can be different for individuals (Shahab & Lades, 2021). Someone struggling with financial or other worries is subjected to a low bandwidth (Shafir & Mullainathan, 2013). Nudge and sludge can particularly strongly affect people with limited available attention or reduced cognitive functioning due to stress or other aspects (Sunstein, 2020). Therefore it should be applied with caution as it can even be perceived as manipulative and human un-dignifying if done untransparent (Schmidt & Engelen, 2020). Especially caution should be considered if performed on people with a biased mindset, such as a present bias, inertia to alternatives, or simply feeling overwhelmed by too many options (Lades et al., 2021; Sunstein, 2020).

Additionally, policymakers' legitimacy needs to be open for discussion (Lecouteux, 2016). Do governments and policymakers know how to act in the best manner for their citizens? With nudging or sludging, a particular effect is stimulated, but decreasing the negative externalities of natural gas can also increase the negative externalities associated with heat pumps. Certain professions may become obsolete, or unwanted electricity grid reinforcement might be needed. Private and public organisations do not always understand the effect of nudge and sludge, so it requires careful consideration before applying (Schmidt & Engelen, 2020; Sunstein, 2020).

3.7. Hassle factors in scientific literature

Based on the exploratory nature of this research regarding hassle a more in-depth structured literature review is performed, as explained in chapter 2.2. The hassle factor is rarely traced to specific factors in literature. This review aims to provide a better understanding of which barriers the hassle factor is composed of in the heat pump adoption process. See Table 1 for an overview of the found hassle factors. A cross sign in the table indicates that the factor is mentioned as a non-monetary transaction cost barrier in the decision-making process. Extra information about the reviewed papers is mentioned in appendix B. Chapter 4.3 provides additional argumentation if the found factors are applicable for heat pumps and fit the definition of hassle considered in this research. Based on this argumentation, the factors are selected for research in the stated choice experiment.

Table 1. Potential hassle factor according to papers

Factors	Literature																
	Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Disruption of the household	13	x		x	x	x	x	x	x	x		x	x	x	x		x
Finding reliable information	10		x		x		x	x	x	x	x	x		x	x		
Difficult to find/ manage contractor	8		x		x	x	x			x		x		x	x		
Applying for money	6			x		x	x		x	x				x			
Complex process	5						x		x	x				x		x	
Not enough time	4		x				x	x	x								
Burden to make irreversible decision	4						x			x					x	x	
Permit application	4				x		x	x		x							
Too complicated information	3					x			x								x
Clean up loft	2					x								x			
Maintenance	2				x				x								

Where: 1). Meles et al. (2022); 2). Du et al. (2022); 3). Schleich et al. (2022); 4). Sanguinetti et al. (2021); 5). de Vries et al. (2020); 6). Ebrahimigharehbaghi et al. (2020); 7). Chen et al. (2019); 8). Azizi et al. (2019); 9). Ebrahimigharehbaghi et al. (2019); 10). Hesselink & Chappin (2019); 11). Klockner & Nayum (2016); 12). Snape et al. (2015); 13). Pettifor et al. (2015); 14). Wilson et al. (2015); 15). Qiu et al. (2014); 16). Stieß & Dunkelberg (2013).

Disruption of the household is often mentioned as an aspect that results in stress. With three exceptions, all papers of this review consider the inconveniences of a renovation as a barrier or hassle factor. The finding of this barrier is not uncommon, as intruding in someone's home or personal sphere can feel unpleased or even unwanted in general. The additional noise and mess can create agitation towards the process, especially for extended periods (Stieß & Dunkelberg, 2013). This household disturbance can even be distinguished between pre-renovation, during and after renovation. The hassle of clearing out a loft in advance or maintenance work on the heat pump afterwards is mentioned separately, as seen in Table 1.

Managing and finding a reliable contractor can also be a difficult task to perform. In the Netherlands, a household must find a professional mechanic or contractor to perform a renovation or installation if it wants to be eligible for a subsidisation scheme, which saves money. It is therefore assumed that every household applies for this subsidy and hires a contractor. However, almost half of the articles in Table 1 mention managing and finding this contractor as a barrier. Reliable contractors who can perform the intended tasks and have time to perform it are getting rare nowadays. Mechanics for specifically heat pumps in the Netherlands are scarce, resulting in increased waiting times (EenVandaag, 2022; NOS, 2017). Additionally, people have the constraint that they want to trust their contractor in performing his job (Ebrahimigharehbaghi et al., 2020; Sanguinetti et al., 2021). Households want the quality of the contractor's work to be sufficient and need to trust the contractor not to damage or steal objects, as some homeowners give their house keys to the contractor. This subjective interpretation of trust can unnecessarily hinder the search for contractors.

Next to finding someone that can perform a renovation, the choice for the renovated aspects needs to be determined. Finding reliable and suitable information can be challenging due to the overwhelming amount of information on the internet and the lack of tailored information to specific housing conditions. Even direct information from contractors is sometimes considered unclear, as trust in their objectivity or expertise is not always existent (de Vries et al., 2020; Stieß & Dunkelberg, 2013). Therefore, making choices in this process can also feel like a burden due to its complexity. Very similar to this complexity around considering all information, are the barriers of feeling the burden of making an irreversible decision and the potentially overwhelming complexity of the implementation process.

Other factors are concerned with going through the application process for loans and subsidies. Not knowing how, where and what conditions apply to this money can be considered a hassle (DECC, 2011). Specific information must be registered and collected beforehand, and the correct forms and funds must be found. Similarly, this applies to getting a permit application in the Netherlands, which is needed for extensive additional renovations combined with installing a heat pump.

3.8. Hassle predictive covariates

As hassle during the adoption of a heat pump potentially consists of multiple factors, as shown in Table 2, an extra identification step can be made towards exploring which factors are perceived as a hassle. However, this perception can differ among groups (Enpuls, 2018; Thijssen et al., 2020), as different contextual variables can be of an influence (Wilson et al., 2015). Reasons for a different perception of hassle could be similar to perceiving nudges and sludges differently, such as a susceptibility towards biases, heuristics or the presence of low bandwidth (Sunstein, 2020). Different heterogeneous groups can be based on socio-demographics, dwelling characteristics and attitudes, for example (Li et al., 2018; Meles et al., 2022; Schleich et al., 2022; Voskuyl, 2021).

The influence of hassle factors among homeowners adopting a heat pump can differ, so all the papers in Table 1 are reviewed again to find socio-demographic and dwelling covariates that could potentially influence hassle. Table 2 and Table 3 provide an overview of all included socio-demographic and dwelling variables of the reviewed papers, respectively. Chapter 4.4 provides additional argumentation for selecting the covariates based on the expected applicability, similarity and the total number of covariates. For these reasons and the lack of use in scientific papers, no overview of different attitudes influencing decision-making is given.

Table 2 shows that the socio-demographics: age, income, education, gender and household size are cited in half or more of all papers. This inclusion shows their potential information in the energy efficiency decision-making process. However, they are also more generic covariates. The remaining four factors: work situation, household composition, relation status and type of profession, are mentioned to a lesser extent. Potentially, partial information about a household's composition is reflected in the household size and somewhat in a person's relation status. The type of profession is only mentioned once in Sanguinetti et al. (2021). A reason for this could be the specific country, the

US, where self-instalment is more common than in the Netherlands. Someone's work situation could be an indicator of the amount of free time a person has available for the process.

Table 2. Socio-demographics that can influence decision-making, according to papers

Covariates	**Literature**												
	Count	**1**	**2**	**3**	**4**	**6**	**8**	**9**	**11**	**13**	**14**	**15**	**16**
Age	12	x	x	x	x	x	x	x	x	x	x	x	x
Income	11	x	x	x	x	x	x	x		x	x	x	x
Education	10	x	x	x		x	x	x		x	x	x	x
Gender	9	x		x	x		x	x	x	x	x		x
Household size	8	x	x		x	x		x			x	x	x
Work situation	4		x				x		x		x		
Household composition	4					x	x	x		x			
Relation status	2		x				x						
Type of profession	1				x								

Where: 1). Meles et al. (2022); 2). Du et al. (2022); 3). Schleich et al. (2022); 4). Sanguinetti et al. (2021); 6). Ebrahimigharehbaghi et al. (2020); 8). Azizi et al. (2019); 9). Ebrahimigharehbaghi et al. (2019); 11). Klockner & Nayum (2016); 13). Pettifor et al. (2015); 14). Wilson et al. (2015); 15). Qiu et al. (2014); 16). Stieß & Dunkelberg (2013).

Table 3. Dwelling characteristics that can influence decision-making according to papers

Covariates	**Literature**													
	Count	**1**	**2**	**3**	**4**	**6**	**7**	**8**	**9**	**11**	**13**	**14**	**15**	**16**
Construction year	10	x	x		x	x	x	x	x		x	x		x
House size	7	x	x		x		x	x				x	x	
Location	6	x	x	x			x					x	x	
Years of residence	6		x				x	x			x	x	x	
Likely to move	6		x			x	x	x				x	x	
House type	6	x	x			x	x		x	x				
Recent renovation	5		x				x	x					x	x
Ownership type	3	x	x									x		
Heating bill	3	x	x										x	
Current heating system	3			x	x							x		
Age heating system	1				x									
House price	1						x							
Individual meter	1		x											
Consider renovation	1	x												

Where: 1). Meles et al. (2022); 2). Du et al. (2022); 3). Schleich et al. (2022); 4). Sanguinetti et al. (2021); 6). Ebrahimigharehbaghi et al. (2020); 7). Chen et al. (2019); 8). Azizi et al. (2019); 9). Ebrahimigharehbaghi et al. (2019); 11). Klockner & Nayum (2016); 13). Pettifor et al. (2015); 14). Wilson et al. (2015); 15). Qiu et al. (2014); 16). Stieß & Dunkelberg (2013).

There are some noticeable differences with the dwelling characterises included in the researched papers compared to the socio-demographic ones. Aside from construction year, these dwelling characteristics are less often cited in papers than generic variables such as age, gender and income. A difference among the papers can also be noted. Some papers look at a broad range of dwelling characterises while others only consider four or fewer variables. Researchers may not want to exhaust their study participants with too many questions. Additionally, it could also indicate that researchers indirectly assume that these variables do not play a role in explaining taste heterogeneity. The wide variety of variables that are only rarely included in the researched paper hints toward such an explanation.

Aspects of construction year, years of residence, likely to move, recent renovation, age of the heating system and if someone considers a renovation are all related to the timing of the renovation. A household is considered more prone to implement a heat pump when a triggering or salient event occurs (Klockner & Nayum, 2016; Snape et al., 2015; Voskuyl, 2021; Wilson et al., 2015). These events can be the change of household composition, aspects that get broken or are expected to break down in the foreseeable future and combining several adjustments at once. Other variables that try to understand the severity of the needed change, such as house size, house type, heating bill, and current heating system, indicate how much work needs to be done. If several aspects need to be addressed, a household might be more likely to adopt a combined renovation as the overall stress of these aspects is a triggering event. Further research on which salient events can provide such triggers is considered valuable for the heat transition but is outside of this research's scope due to time considerations.

4. Design of the survey

A survey is developed to assess the perception of hassle and its effect on a choice. The main purpose of this survey is to perform a choice experiment, which is elaborated in chapter 4.1. In chapter 4.2, the conceptual model is explained on which the operationalisation of this choice experiment is based. The inclusion of the main attributes and covariables, respectively chapters 4.3 and 4.4, are based on the interviews' results. While in chapter 4.5, the operationalisation of the survey is described. Lastly, the applied distribution method is argued for.

4.1. Choice experiment

In chapter 2.1, the structured literature review provided an extensive overview for the attribute identification of hassle factors. Next to this, additional covariates were identified that could explain taste heterogeneity. This structured way provided a method to account for potential biases that a researcher might have about this topic and gave a wide range of attributes and covariables. This overview also gave a divergence step in understanding the aspects that create a homeowner's utility. However, this review did not result in an unambiguous answer which different hassle factors affect the adoption of heat pumps, as the articles found were not specific for heat pumps. However, in an attempt to not exhaust the respondents in the choice experiment by testing the complete range of found hassle factors and covariates, the use of two expert interviews provided a second divergence step. Too many questions about covariates or too many choices, for that matter, decrease the survey participation and completion rate. When the average time to completion goes up, the willingness to participate in the study decreases. Similarly, being cautious with the number of attributes in the choice experiment results in a coherent set of choices. It was further considered that possible low participation rates and understandability issues might pose a problem. The survey was therefore designed to be suited for almost all of its target audience without needing too much explanation.

4.2. Conceptual model

This study proposes a conceptual model based on an LCA and Hierarchical Information Integration (HII) theory as extensions of a standard stated choice experiment. The conceptual model explains how a homeowner's choice is determined and which (measured) factors influence this choice. Therefore, based on the literature, this model tries to understand how a utility consideration results in the choice of adopting or not adopting a heat pump. The conceptualisation of the model is shown in Figure 2, where the circles resemble the indirectly measured aspects and the squares are the directly measured aspects. In the most standard conceptualisation of a stated choice experiment, the attributes directly affect the expected utility of a decision, such as buying a heat pump.

According to the RUM model, it is assumed that hassle is known by households and taken into account in the expected utility. This assumption is, to a certain degree, contradicting as hassles are not considered in a person's CBA but are expected to influence the behaviour of homeowners. Therefore, it is assumed that after a person's CBA, they create an intention to act. However, hassles are an extra factor that comes after this intention creation (and during the creation of this CBA, by needing to search for information, for example), influencing the total utility of a homeowner. So, the extra mental step of going from an intention to the utility to a choice explains why hassles can be measured in this proposed conceptual model. This assumption is based on the fact that respondents in the choice experiment will be brought aware of the hassle, by stating them as an attribute. This priming makes it suitable to research the extent of the influence of hassles on utility.

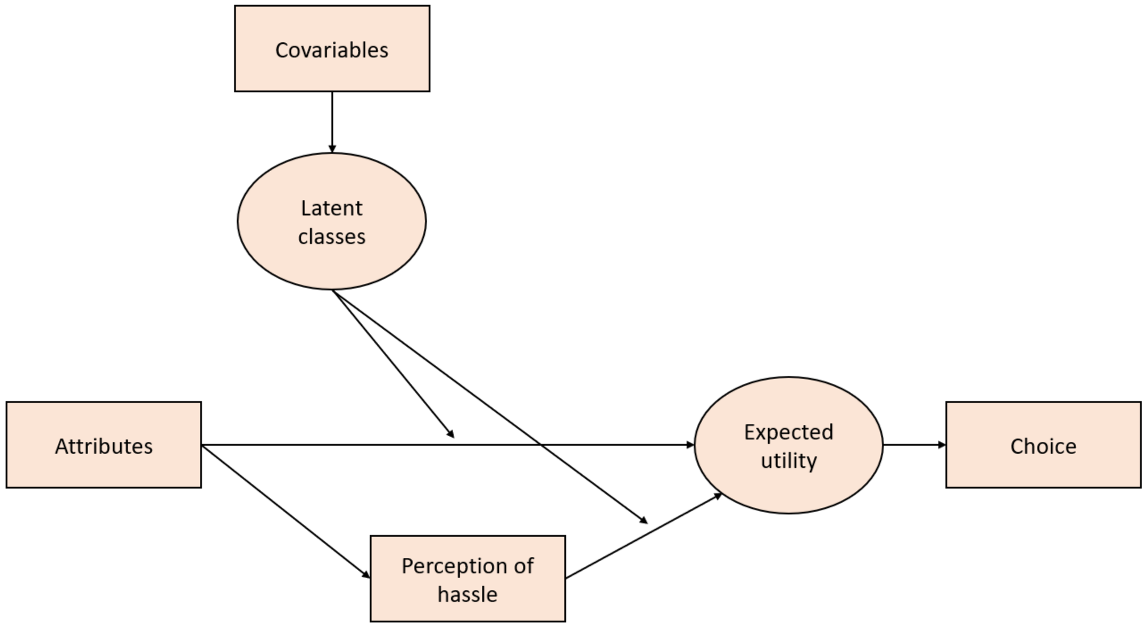


Figure 2. The conceptualisation of the choice model

4.2.1. Influence of covariates

Based on the structured literature review, attributes, such as hassle factors, are expected not solely to influence a homeowner's utility. A latent class analysis finds different parameter estimates for the attributes. These classes can be based on covariables that can explain these classes and could therefore indirectly influence how someone interprets the (hassle) attributes. For example, a full-time employed homeowner might be less attracted to a choice that requires much research time as he is somewhat limited in his free time and cognitive bandwidth.

Personal and dwelling variables are directly measurable aspects, such as age, gender and construction year. Measurable variables can be observed with one single survey question and are assumed to have no measurement error. Attitudes are less reliable measured through one question, so they are measured through multiple indicators. Indicators can be a series of preferences or opinions about several statements, measured through a Likert scale. A factor analysis is used to conjoin multiple indicators to one factor to retain a more reliable variable. An expected attitude regarding the decision to adopt a heat pump can be the degree someone is sustainable orientated, for example. Although no literature review was performed on attitudes that can influence the hassle sensitivity of homeowners, chapter 4.6 lists several questions regarding attitudes included in the survey based on expected sample biases due to the distribution method.

4.2.2. Hierarchical Information Integration theory

According to the HII theory, people are likely to group influential attributes into higher-order constructs when they are confronted with too many influential attributes. These many attributes make it confusing to compare them all with each other, so instead of attributes, higher-order constructs are compared. These higher-order constructs are created by trading off several attributes to form a specific construct evaluation. Therefore, a higher-order construct evaluation measures people's perception of a group of attributes (Molin & Timmermans, 2009). In the context of heat pump adoption, such a higher-order construct evaluation can show if hassle, in general, influences decisions. This broader determination is useful as hassle in literature is grouped and framed as a combined stress factor (de Vries et al., 2020). So, a hassle construct would show if hassle played a role and if the found attributes in literature are also seen as a hassle, affecting a respondent's choice when adopting a heat pump.

The selected attributes can be tested to be part of a hassle factor or not by using this hassle construct. All individual hassle attributes are assumed to indirectly affect the choice to adopt a specific heat pump, as they affect the utility via the hassle construct evaluation. At the same time, the non-hassle attribute is assumed only to affect the utility of adopting a heat pump and not the hassle construct evaluation. An example would be that it is expected that the non-hassle attribute financial profit would not impact the degree of hassle in the hassle construct but would only directly impact the adoption choice. Therefore, to determine all the influences on the construct evaluation, a regression analysis helps to determine what homeowners perceive as a hassle. Secondly, an MNL model determines how the construct evaluation and (the remaining) attributes influence a homeowner's utility. These two analyses can be used to see if there is a difference between what respondents perceive as a hassle compared to how they trade off attributes. Respondents might perceive certain attribute levels as much hassle, but do not base their decision to adopt a heat pump on these aspects (or on hassle at all). This insight will show if respondents behave according to their perception of hassle or if a homeowner's choice is uncoupled from hassle.

4.2.3. HII variants

An HII application in the form of a single experiment with multiple questions is chosen to capture both the indirect effects and possibly also the direct effects of all attributes. The non-hassle attributes can directly affect the utility. However, the hassle attributes, besides their indirect effect, can also directly affect the utility. This extra direct effect is then not captured in the hassle construct evaluation. An example can be that people might perceive information gathering or discussions with people to be a reason for them to reconnect with certain friends and perceive it as a pleasant side aspect. Therefore, this extra effect is not captured in the hassle construct evaluation. The hassle attribute 'information gathering' can hence also have a direct non-hassle effect next to its indirect hassle effect.

The explained conceptual model is extended based on influences from the HII variant developed by Bos et al. (2004). They used the fundamental choice attributes cost and time in their bridging experiment (i.e. the experiment where the different construct evaluations are compared) to trade off their choice constructs evaluation against costs and time. By doing so, they had the opportunity to determine the willingness to pay for a construct. Hence in a similar trend as Bos et al. (2004), all attributes, including those making up the hassle construct, are specified in costs and time. The willingness to pay for each attribute can show how much money people are willing to pay for a decrease in hassle. This insight is useful for creating interventions, as it can determine the effectiveness of interventions. Also, by creating objective indicators, the subjective interpretation of hassle is reduced. Using time indicators for hassles, as hassles are non-monetary, the effort of a particular hassle can be expressed. Time indicators make hassle less sensitive to subjective interpretation compared to mentioning hassles in, for example, Likert scales (Heine et al., 2002). While expressing all hassles in time also helps with comparison among each other. In order to calculate this willingness to pay or more specifically, the value of time, one attribute of the choice experiment needs to have a cost attribute (Streimikiene & Balezentis, 2020). As all hassle attributes are in time, one additional economic factor will be added for the monetary comparison.

4.3. Selected attributes

In this section, the selected attributes for the choice experiment of this study are further explained. The attributes included both hassle factors and an economic factor to see how homeowners' decision-making is driven. To further decrease the found hassle factors from Table 1, experts of TNO and Klimaatroute were interviewed. The selected attributes were chosen to fit the experimental nature of this research to empirically assess the rational or irrational behaviour of homeowners choosing to adopt a heat pump by maximising their utility. In addition, the terms were rephrased to support the clarity and understanding of the overall survey.

4.3.1. Length disruption

Household disruption is mentioned as a form of hassle in most articles from Table 1 and in both performed interviews. Several articles mention hassle as only one particular aspect, the disruption of a household (DECC, 2013; Snape et al., 2015). This disruption is a visible form of hassle, as it is very recognisable for people to have noise and mess during renovations (Koning et al., 2020). The installation of a heat pump is thus expected to cause unwanted disruptions in someone's personal life. Additional complementary disruptions include cleaning up a loft in advance or afterwards. These disruptions would not have been needed if the installation would not have occurred. However, as this is a less conscious aspect than the disruption of the renovation itself (Klimaatroute, personal communication, April 13, 2022), household disruption and the hassle of cleaning up a specific room before or afterwards were combined into one factor in this research. To give the respondent of the choice-experiment a recognisable name, the term 'length disruption' is given, also to correspond with the unit of time.

4.3.2. Finding reliable information

Tailored information for a specific house, with its own characteristics, makes it challenging to find information for a suitable heating system (TNO, personal communication, April 7, 2022). Households do not base their decision solely on financial aspects but have to take into account many different elements, this search and the information can feel complicated and a hassle to perform (TNO, personal communication, April 7, 2022; de Vries et al., 2020; Nava-Guerrero et al., 2022). This process might be more complicated when someone has limited information on those aspects. So, if a household searches for a specific heat pump and potential extra insulation measures, different websites or contractors can advise different aspects (TNO, personal communication, April 7, 2022). Finding reliable information and understanding the (complicated) information are combined into one hassle factor and called 'information gathering' in the choice experiment of this study.

4.3.3. Finding contractor

The lack of suitable mechanics in the Netherlands poses a barrier to the nationwide adoption of sustainable heating (EenVandaag, 2022; NOS, 2017). This problem of finding a suitable contractor is found to be three-folded for the adoption of heat pumps. First, there is a lack of mechanics in the Netherlands, which makes their availability in the short term difficult. This availability can, for example, create a barrier for people who need a new heating system because their current heating system broke down. Additionally, due to the current global chip shortage, contractors find it more challenging to get a heat pump (Klimaatroute, personal communication, April 13, 2022). Secondly, there is the aspect of finding a contractor that can install a heat pump. Due to the current and past demand for natural gas boilers, some mechanics are currently still specialised only in natural gas boilers (Klimaatroute, personal communication, April 13, 2022; TNO, personal communication, April 7, 2022). A heat pump is a technology which requires a different instalment procedure. Given the still high demand for natural gas boilers up to now, not every mechanic is specialised in this yet or is willing to be trained for it. Thirdly, people might have additional constraints, such as finding a contractor or mechanic whom they perceive as trustworthy. Contractors might not always be supervised when installing a heat pump, which might make trustworthiness for certain homeowners an important additional constraint (Broers et al., 2019). Other constraints and hassles related to this aspect might be the contractor's price, availability and quality (Sanguinetti et al., 2021). The hassle of finding an available and suitable contractor (or mechanic) is thus included in the choice experiment.

4.3.4. Subsidy and loan application

Based on the literature review, applying for a subsidy and/or loan is expected to be a relevant barrier for homeowners wanting to buy a heat pump. It is assumed that every household purchasing a heat pump tries to apply for this subsidy. However, the complexity of Dutch subsidy schemes makes it difficult for households to fill in the right forms and submit the required documents to get approval (Kraan, 2022; Rovers et al., 2021). One indicator was the number of turned-down applications compared to the subsidy budget for 2021, which was not entirely used (Kraan, 2022; RVO, 2022). The additional hassle of receiving the subsidy after the complete installation of the heat pump increases the need for loans to finance the heat pump upfront (Klimaatroute, personal communication, April 13, 2022). Depending on someone’s financial situation, this creates the additional need to request a (sustainability) loan. Various actors offer these sustainability loans, ranging from banks to municipalities (Ebrahimigharehbaghi et al., 2019). Therefore, the combined hassle of finding and applying for subsidies and loans is expected to be a barrier in the implementation process of heat pumps and is included in the choice experiment.

4.3.5. Consultation neighbours

An additional barrier mentioned during expert interviews is the noise disturbance that a heat pump might generate. Although this is also often an argument to frighten households, as an increased noise disturbance will decrease the comfort in their home (Klimaatroute, personal communication, April 13, 2022). However, the noise levels of current heat pumps are greatly reduced (Klimaatroute, personal communication, April 13, 2022). So, it is assumed that households position the outdoor component of the heat pump (i.e. the one making the noise) to their liking so that their personal noise disturbance is negligible. However, this might not be the optimal location for their direct neighbours. Klockner & Nayum (2016) found that the need to coordinate with neighbours can pose as a barrier when performing an energy renovation, especially for terraced houses. The additionally needed renovations of installing a heat pump and the noise of the heat pump can thus provide irritations and/or lead to potential conflicts with neighbours (TNO, personal communication, April 7, 2022; Jansma et al., 2020). Alternatively, consultation with neighbours can also be comforting, as they might have additional tips due to their experiences in their (often) similar houses (Broers et al., 2019; Klimaatroute, personal communication, April 13, 2022). Therefore, the need to consult neighbours when performing the instalment is expected to influence the decision to adopt a heat pump. Due to the exploratory nature of this research, this factor is included as a potential hassle factor in this study.

4.3.6. Financial profit

Aside from the hassle attributes, which are expected to influence a homeowner's utility negatively, the choice experiment should also include positively influencing factors. This positively influencing factor helps a decision-maker feel the benefit of making a choice. The current most important drivers for an energy-efficient renovation are cost savings and increased comfort (Ebrahimigharehbaghi et al., 2019; Klockner & Nayum, 2016). While in the future, this might change because of the obligated installation of a heat pump or sustainable alternative (Geurts, 2022). As previously mentioned in chapter 4.2.3, an economic factor must be included in the choice experiment in order to determine the value of time indicators for hassles. So, the inclusion of the potential cost savings was chosen. By having this potential cost savings as an attribute, the rational economic behaviour of decision-makers can be tested. The term 'cost savings' is redefined as 'profit' over the lifetime of a heat pump, for comprehensibility.

4.3.7. Other hassle factors

The remaining hassle factors of Table 1 are not included in this choice experiment. The hassle factor of the 'adoption being a too complex process' is left out. It is expected that not finding understandable information can make the process feel too complicated and not understandable. Not finding reliable and understandable information can result in a too complicated selection process for a person. As this aspect of 'finding reliable information' is already included and to minimise the number of attributes, the 'process being too complex' is not used in this choice experiment.

The found aspects of 'having not enough time' and 'burden to make an irreversible decision' are assumed to be consequential aspects of other hassle factors. After retrieving some information about the installation process, a person might conclude to have enough time to perform all the actions. Other reasons might be the number of contractors or loans, making it a burden to decide due to the fear of making a wrong choice. Hence, these consequential factors are intertwined with some of the other used hassle factors such as information gathering, subsidy/loan applications or finding a contractor, for example. These two aspects can also be linked to potential cognitive biases as a present bias for effort and choice overload that might play a role (Iyengar & Lepper, 2000; Lades et al., 2021). The last reason for not including 'not having enough time' and 'the burden of making an irreversible decision' in the choice experiment is the difficulty of quantifying these aspects in a unit of time.

Based on the interview with Klimaatroute, the aspect of 'maintenance' is determined not to be an important barrier in the decision for heat pump adoption. This aspect is excluded because a heat pump requires less maintenance than a natural gas boiler, which is currently the norm in the Netherlands (Klimaatroute, personal communication, April 13, 2022). Therefore, this factor would be reduced by implementing a heat pump, and it is considered less of a hassle than maintenance for most current heating systems. The anticipated hassle of 'obtaining permits' is also not included, as obtaining permits will not be an issue when installing solely a heat pump. In the Netherlands, it is not required to have a permit for this case. The hassle of 'obtaining a permit' is thus for most people non-existent. Summarized, this choice experiment does not take the aspect of 'maintenance' or 'permit application' into account.

During the interviews with Klimaatroute two additional barriers came up, 'the extra required inside space' and 'the clashing aesthetics' of a heat pump (Klimaatroute, personal communication, April 13, 2022). The 'extra needed space' of a heat pump compared to a natural gas boiler is considered a technical barrier, not a psychological barrier or a transaction cost. Similarly, does 'clashing aesthetics' of a heat pump not fit the definition of hassle applied in this choice experiment (i.e. non-monetary transaction costs expressed in time that can be perceived as stressful). Aside from this, are aesthetics found to be a driver for energy renovations (Azizi et al., 2019; Stankuniene, 2021; Stieß & Dunkelberg, 2013; Wilson et al., 2015), as well as a barrier in the case of heat pumps (Broers et al., 2019; Snape et al., 2015). Based on those definitions and in order to minimise the number of attributes for the respondents, both barriers are not included in this choice experiment. Nevertheless, further research into the extent to both 'clashing aesthetics' and 'extra required inside space' seem interesting to pursue as potential non-psychological barriers for homeowners.

4.3.8. Attribute levels

For a final overview of the included attributes and attribute levels see Table 4. The choice for each hassle attribute level was based on having both a low, medium and high level while keeping equidistance between levels. Using a wide range of equidistant levels will lead to better parameter estimates (ChoiceMetrics, 2021), while too wide parameters can give problems of unrealism (Rose & Bliemer, 2009). Several realistic levels were determined based on the interviews with the expert from TNO, Klimaatroute and by obtaining advice from my supervisors within TU Delft. Based on a study by Voskuyl (2021), who also empirically determined the influence of the 'length of disruption' on the decision to change heating systems, the attribute levels were compared. However, empirical use of the other hassle factors was not found or not found to be expressed in a unit of time. The comparison of these factors was then made based on the researcher's expectations and own experience.

The attribute levels for profit were based on several personal calculations based on a life expectancy of 20 years for a heat pump (Hage, 2019; Kleefkens, 2019; Vereniging eigen huis, 2022), the yearly reduced energy costs (Milieu Centraal, 2022a, 2022b), the expected price and subsidy of a hybrid and all-electric heat pump (Klimaatroute, personal communication, April 13, 2022) and the costs of potential additional renovations. It is assumed that the increased gas prices of 2022 compared to 2021 will remain at this increased level during the lifetime of coming heat pumps (Klimaatroute, personal communication, April 13, 2022). The potential extra renovation costs will decrease the profit level for homeowners, so the lowest attribute level is capped at 0 euros instead of a negative value. Without this cap the purpose of this attribute, to function as positively influencing factor on utility, would be undermined. With potential extra renovation costs also the wideness of the final attribute level range was considered.

Table 4. Selected attributes and attribute levels

	Attribute	Category	Level 1	Level 2	Level 3
	Length disruption	**Hassle factor**	1 day	4 days	7 days
	Information gathering	**Hassle factor**	1 hour	5,5 hours	10 hours
	Finding a contractor	**Hassle factor**	2 hours	5 hours	8 hours
	Subsidy and loan applications	**Hassle factor**	1 hour	5 hours	9 hours
	Consultation neighbours	**Hassle factor**	0 hours	2 hours	4 hours
	Profit	**Economic factor**	€ 0	€ 3.000	€ 6.000

4.4. Selected covariables

In order to explain potential taste heterogeneity among respondents, several covariables of Table 2 and Table 3 are selected in an effort to determine latent classes using a latent class analysis. By using multiple different covariables, each class can be differentiated based on (multiple) statistically significant covariables. In Table 5 the final selected covariables and available answer options are shown. The questions and answer options were based on the information provided during the interviews, advice from my supervisors and for the answer options specifically, also the Dutch Central Bureau of Statistics (CBS, 2020, 2021a, 2021b, 2021c, 2021d, 2021e, 2021f).

Table 5. Selected covariates and answer options

Covariate	Answer options
Gender	Male, female, other
Age	Open question
Education	Primary school, VMBO/ MAVO/ MBO-1/ HAVO-/ VWO-first half, MBO 2-4/ HAVO- / VWO completed, HBO-/ WO-bachelor, HBO-/ WO-master/ doctor, other
Work situation	Fulltime employed, parttime employed, self-employed, unemployed, student, housewife/-man, retired
Household income	Less than €10.000, €10.000-20.000, €20.000-30.000, €30.000-40.000, €40.000-50.000, €50.000-100.000, €100.000-200.000, more than €200.000, prefer not to say
House type	Flat/ apartment/ gallery apartment / maisonette, corner house, terraced house, semidetached house, detached house, other
Construction year	Older than 1945, 1945-1955, 1955-1965, 1965-1975, 1975-1985, 1985-1995, 1995-2005, 2005-2015, 2015-2022, I do not know
Years of residency	0-5 years, 6-10 years, 11-15 years, 16-20 years, 21 years or more
Surface area	Less than 50m², 50-74m², 75-99m², 100-149m², 150-249m², 250m² or more, I don't know
Expected decision-maker	Yes/probably, no
Likely to move in two years	Yes/probably, no

4.4.1. Socio-demographics

The socio-demographics variables 'age', 'income', 'education', 'gender' and 'work situation' are proposed indicators for the purpose of this study. The variables 'household size', 'household composition' and 'relation status' are left out due to the similar nature of the variables. These left-out variables indicate the number of people present in a household. Not all people in a household decide on the choice of heat pump adoption. For this reason, the covariables are recombined in a different variable that states if someone is the decision-maker for the choice to adopt a heat pump. Children are, for example, not expected to make the decision regarding this matter, as they are not the owner of the house and have less experience in this field. An expected decision-maker is more likely to have experience regarding the dwelling characteristics and might have experience regarding the implementation process. This expertise can be due to earlier renovations or interest. Furthermore, the 'profession type' is considered an indicator of expertise in Sanguinetti et al. (2021). This aspect is discarded in this study, as the expected sample size is expected not big enough for a significant proportion of mechanics or contractors (Klimaatroute, personal communication, April 13, 2022).

4.4.2. Dwelling characteristics

The selected dwelling characteristics 'construction year', 'house size', 'years of residence', 'likely to move' and 'house type' are used as covariates. Therefore, not all dwelling characteristics of Table 3 are included to minimise the time for respondents to fill in the questionnaire. The variable 'heating bill' is, for example, left out due to the time it will take respondents to look up the data. It is expected that most respondents do not know this amount without checking their heating bill. At the same time is this variable expected to be largely correlated to a respondent's 'house size', 'household size', 'work situation’ and ‘level of comfort’. Based on discussions with the mentioned experts, the influence of ‘location’ within the Netherlands, ‘house prices’ and ‘individual gas meters’ are not expected to pose any influence. As a result of the included variable ‘expected decision-maker’, the variable ‘ownership type' becomes obsolete. These variables indicate the same aspect of who makes the decision. While the other aspects such as the ‘current heating system’, ‘age of the heating system’, ‘recent renovation’ and ‘potential renovation considerations’, are based on the scope to not include life events in the study. The aspect of natural moments in time when a heating system is close to its life expectancy or a large renovation allows for the opportunity to make additional large-scale changes are also not included in this study. Nevertheless, the role of reduced hassle due to natural decision-making moments is considered an interesting field of research.

4.5. Design alternatives

A choice experiment consists of multiple choice sets constructed by combining alternatives. In this study, each choice set has two alternatives in order to decrease complexity. To design these alternatives, one can choose a full-factorial or a fractional factorial design (Walker et al., 2018). A full-factorial design consists of a choice experiment containing all possible outcomes of attribute levels. This type of design creates many different choice sets and takes a long time to complete. A fractional factorial design is an alternative to reduce the number of choice sets.

The three main ways of creating fractional factorial designs are random, orthogonal and efficient designs (Walker et al., 2018). A random design chooses randomly attribute levels to make an alternative. This type of design creates correlation among attributes resulting in large standard errors and unreliable parameters. An orthogonal design chooses attribute levels so that the correlation among attributes is zero (Rose & Bliemer, 2009). However, dominant alternatives are possible to occur. These dominant alternatives outperform other alternatives on every attribute and thus provide no information about the trade-off (Walker et al., 2018). The third possibility are efficient designs. It maximises the amount of information about the trade-off and minimises the standard errors of parameters by balancing the utilities of alternatives and hence no dominant alternatives are created. In order to balance the utilities, it is needed to have prior values of the attribute parameters, which can be retrieved in a pre-survey (Walker et al., 2018). Due to the time constraints of this study, an alternative method than a pre-survey was performed. Based on the expected sign, one can use small prior estimates with either positive or negative signs (ChoiceMetrics, 2021). Each hassle attribute was given a negative sign, while profit was given a positive sign. Choosing wrong prior values can result in biased parameters, but with the correct sign efficient designs will still outperform orthogonal and random designs.

Each alternative consists of the selected six attributes, each with three possible levels. The alternatives are, therefore, unlabelled by having generic attributes and attribute levels. Each attribute has the same possible attribute level and does not need any alternative specific parameters (Rose & Bliemer, 2009). The alternatives are thus all possible imaginable scenarios, although some are more likely to occur than others. For this reason, every choice set refers to alternatives as option A or option B. Next to this are the alternatives chosen in a way to preserve attribute level balance. Every attribute level occurs the same number of times, ensuring that all parameter estimates have the same chance of becoming statistically significant (ChoiceMetrics, 2021).

4.5.1. Operationalising the choice and rating experiment

To generate the design, the software program Ngene was used. Ngene is a comprehensive software tool that can generate experimental designs (ChoiceMetrics, 2021). See appendix C for the used Ngene syntax and appendix D for the constructed choice sets. Ngene uses the minimisation of the D-error to determine the most efficient design. The use of a swapping algorithm lets Ngene decrease computational time and still ensures the minimisation of the D-error, preservation of attribute level balance and avoidance of dominance. Ngene constructed 12 choice sets, but two groups of six choice sets were created through blocking. This blocking was applied to decrease the time and effort it would take for respondents to complete the choice experiment (Rose & Bliemer, 2009).

The hassle construct evaluations are created based on a rating experiment using a 5-point Likert scale, where each higher point means more hassle. In every choice set, the respondents are asked to rate their own perception of the amount of hassle both alternatives have. Priming can influence the respondents' decision about their perception of hassle (Chartrand et al., 2008). To reduce the effect of priming, the words 'hassle' and 'effort' are not mentioned in the survey before the hassle construct evaluations. The degree of how much of an influence hassle is, is hence negligibly primed. Rather by asking the question, their own unconscious perception towards the influence of individual hassles is measured, by asking one mark for the whole alternative.

Additionally, one part of the blocked choice experiment is asked to rate the choice sets before making each alternative trade-off. While the other part of the blocked choice experiment is asked to rate the choice sets after making the trade-off between the alternatives. As respondents might alter their previous answers after seeing this rating experiment or the choice experiment, it was not possible to go back to previous answers.

4.5.2. Structure survey

The stated preference choice experiment is performed with the survey program Qualtrics. The Ethics Committee of TU Delft approved the distribution of the survey. The structure of the survey is presented below, a preview of the complete survey can be found via this link.

1. Introduction
   The survey started with an introduction stating the goal of the survey and mentioning that this research is for a graduate research project at the TU Delft. Additionally, the voluntary nature and the anonymity (no personal identifiable data is requested) and confidential data storage were stressed. An overview of the survey was given, combined with an approximation of the time it would take to complete the survey. This time approximation was based on several test runs. Several bias mitigation strategies were used in the introduction: cheap talk, perceived consequentiality and an opt-out reminder, to overcome a hypothetical bias and improve the external validity (Haghani et al., 2021). The cheap talk strategy was operationalised by mentioning the value of honestly filling in the survey. The perceived consequentiality strategy was implemented by stating that municipalities, neighbourhoods and interest groups would receive the survey results. At the same time, the opt-out reminder stated that every question is non-compulsory.

2. Validation check
   A validation question asked the respondents if they were currently in possession of a house in the Netherlands, to check the sample for being the correct audience. If people answer this question with a no, the respondent will automatically be directed to the end of the survey.

3. Choice and rating experiment
   This section started with an explanation of the experiments and the attributes. In the explanation, multiple possible aspects of the attributes were mentioned to increase familiarity

with the attributes. This context provision is mentioned by Haghani et al. (2021) as an additional hypothetical bias mitigation strategy to reduce the complexity of the subject. The deliberate choice was therefore made not to specify the difference between heat pump alternatives. Lastly, the text in all parts of the survey is kept to a minimum to decrease complexity and reduce the time to fill in the survey. Respondents are, after the explanation, randomly coupled to one of two versions of the choice experiment, to distribute the chance evenly. The two versions differ based on one of the two sets of the choice experiment and the two different versions of the rating experiment.

4. Covariates
   In the fourth part of the survey, questions regarding socio-demographics and dwelling characteristics are asked. In addition, due to the distribution methods, five questions were asked to determine possible sample biases.

5. Perception of hassle
   In the survey's final question, the respondents had to rate all the five main hassle factors selected from chapter 4.3 based on a 1 to 6 scale, with 1 as the most hassle and 6 as the least hassle. The sixth option contained an extra open-answer option to see if the literature review missed any additional hassles. This rating question was inserted to see if there are differences between the measured and indicated perception of hassle.

6. Expression of gratitude
   At the end of the survey, the respondents are thanked for their participation and asked to contact the author by email if there are any questions or comments.

4.6. Distribution

The survey was distributed online in order to reach a large group of homeowners. The survey did not differentiate between landlords and owner-occupied homes, but excluded tenants via the validation question.

Various municipalities and interest groups were initially approached for help in distribution to gain a differentiated and representative group of homeowners. The municipality of Woerden and Diemen spread the survey in their sustainability newsletter, while the municipality of Rotterdam shared it on some of its social media channels and an internal platform. Aside from municipal distribution, the political party Groenlinks Zandvoort also shared the survey on its social media channel. In addition to this distribution, convenience sampling and snowball sampling methods were used to boost the number of respondents. Convenience and snowball sampling are forms of non-probabilistic sampling, which have the chance of not correctly representing the population (Edgar & Manz, 2017). The convenience sampling was operationalised through the social media channels of the researcher and personal contacts. Additionally, snowball sampling was performed by asking the respondents for their willingness to reshare the survey in their network. This sharing was done on multiple occasions.

The use of these non-probabilistic sampling methods, including the distribution by the municipalities and political party, allowed for a risk of a sample bias. In chapter 5.2, the representativeness of the respondents is compared to the total population. Nonetheless, a bias was expected for sustainability-minded people as the sampling was done through sustainability newsletters and a political party more associated with sustainable behaviour. Furthermore, a potential bias for hassle-insensitive people was also expected as hassle-sensitive people might be less likely to fill in a survey than hassle-insensitive people. For these reasons, three sustainability questions were asked, based on a representative study by Citisens (2020) and two hassle sensitiveness questions, where no representative comparison means were found. Of the below-mentioned questions, the first three attitudes are sustainability questions and the last two are hassle sensitiveness questions.

1. *I find it important that all Dutch dwellings become natural gas-free.*
2. *I find it important that the Netherlands becomes climate neutral.*
3. *Do you want your house to be disconnected from natural gas?*
4. *I describe myself as active when it comes to performing actions.*
5. *I often see problems ahead.*

5. Data cleaning and comparison

The removal and transformation steps are explained in the first half of the chapter to indicate how the retrieved data was cleaned for analysis and how the factor analysis is performed. In the second part of this chapter, the data representativeness of the sample is compared to the actual population in the Netherlands.

5.1. Data cleaning

The survey was published from the 8th of May 2022 till the 8th of June 2022, collecting 277 respondents over the course of one month. The survey was downloaded from Qualtrics and was first cleaned and treated in SPSS 26 to provide suitable model estimations.

5.1.1. Removal of data

The first cleaning step was the removal of respondents who did not complete the survey or indicated that they did not own a house. This reduction resulted in a significant step of removing 114 respondents. Additionally, eight respondents were removed from the survey as they left out one or multiple questions regarding the choice experiment. 155 useful responses remained after both cleaning steps, a 44% reduction from the total survey. This dropout rate is largely identifiable to people who did not complete the survey, as most participants did not come further than the first question of the choice experiment. A possible reason would be that the survey was too complicated or the respondents found out before answering the validation check that the survey was not meant for them. It was not possible to further determine the respondents as descriptives such as the referral origin or IP-address were not collected as the survey was distributed anonymously.

5.1.2. Checking for non-trading behaviour

Secondly, the data was checked for non-trading behaviour. Non-trading behaviour can occur in unlabelled choice experiments for various reasons such as fatigue, boredom or misunderstanding of the survey. This non-trading behaviour would result in answers that would not indicate someone's true preferences and hinder the parameter estimates' estimation. It is, however, less likely to occur in unlabelled compared to labelled choice experiments, but it can still negatively influence the parameter estimation (Hess et al., 2010). Several respondents were marked with potential non-trading behaviour as all questions considering the rating experiment or the main experiment were answered with the same answer. As no participant had answered all questions for both experiments the same way, non-trading behaviour was difficult to determine. This determination was challenging as the total choice experiment was divided into two blocks of six questions per experiment, making answering all questions the same statistically possible. Subsequently, it was checked if the completion time of all respondents could be realistic due to the fastness. Based on completion time and the combination of similarities of respondents' answers, none were left out. The average time to complete the survey was 1401 seconds, roughly 23 minutes. However, after the deletion of 9 large outliers, the average time was reduced to 663 seconds or 11 minutes.

5.1.3. Transforming data

Lastly, the data was transformed in several aspects to allow for data analysis. Originally, the choice experiment was randomly structured in two blocks containing 89 respondents in block 1 and 74 respondents in block 2, with six main choices and six rating experiments. However, these choices were restructured to single data records containing one main choice and their rating. The total number of data entries increased from 155 to 930. Additionally, the attribute levels of the attribute profit were decreased from 0, 3000 and 6000 to 0, 3 and 6 for better interpretation of the estimated parameter values. At the same time, the covariate age was changed to seven ordinal categories. For the remaining covariate questions where an "I don't know" or "I prefer not to answer" option was selected, the answer has been changed into a missing value. Multiple entries originally already had a missing value for certain covariate questions. These 'incomplete' entries were not discarded as still valuable information can be retrieved from the choices made in the choice and rating experiment and from the other non-missing covariates. The answer distributions for choice and rating experiments are visualised in appendix E.

5.1.4. Factor analysis

The LCA tries to explain taste heterogeneity based on attributes and covariates. Several measurable covariates were already determined, but a factor analysis can help to identify additional attitudes. As the survey contained several questions to account for a possible sustainability or hassle-sensitiveness bias. A factor analysis is performed on those statements to see if those questions are indeed indicators of sustainable or hassle-sensitive attitudes. The sample bias identification questions containing a Likert scale were included in the factor analysis, hence not the question *'Do you want your house to be disconnected from natural gas?*' as this was asked through a 'yes' or 'no' answer. These four questions were recoded from string to numeric values. The highest numbers accounted for agreeing the most on a statement, while the lowest accounted for disagreeing the most. The hassle-sensitiveness question '*I often see problems ahead'* is recoded the other way around, as this question was framed negatively. The factor analysis was also performed with SPSS.

The analysis started by performing Barlett's test of sphericity to statistically test if the correlation matrix differs from the identity matrix. This test gave a p-value of 0.000, which indicated that this statement was highly significant. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was also checked. The KMO value was 0.501, the bare minimum, as values under 0.5 are considered unacceptable (Yong & Pearce, 2013).

Two factors were extracted, each based on two questions, explaining 76% of the total variance. These two factors were expected based on the corresponding two categories of questions that were used as indicators. The factors were extracted based on the eigenvectors. Higher than one means that it explains more variance than a single observed variable, which was our used threshold based on Kaiser's criterion (Kaiser, 1960). The extraction technique used was the Principal Axis Factoring (PAF) and the orthogonal rotation varimax. By using two indicators, it states that there should be a high correlation among those indicators ($r > 0.7$), as three variables explaining one factor is more appropriate (Worthington & Whittaker, 2006; Yong & Pearce, 2013). The correlation between the sustainability indicators was found to be 0.696, indicating a strong correlation just below the value of 0.7. However, due to the large sustainable biased sample, as can be seen in Table 8, it was expected that this factor would be an important potential covariate for model estimation. Therefore, this factor was deemed correlated enough. The hassle-sensitiveness questions had a correlation of 0.332. Potentially is this correlation low due to the researcher's own formulation of the questions, as no similar reference questions were found. Hence, these hassle-sensitiveness variables were not considered correlated enough to be identified as one factor. The sustainability indicators were highly loaded on the sustainability factor as the rotated factor loading was > 0.81. A value above 0.5 is considered good, while a loading of less than 0.32 is preferred on all other factors (Worthington & Whittaker, 2006). This low loading was the case for the sustainability indicators on the hassle-sensitiveness factor and vice versa. The two sustainability questions were thus considered indicators for one sustainability factor and were conjoint to one covariate by summating the values together. The complete SPSS output of the factor analysis can be seen in appendix F.

5.2. Data comparison

Table 6 shows the socio-demographic frequencies and percentages of the sample compared to the percentage of the actual population of the Netherlands. This comparison is performed to show the representativeness of the survey and hence also the output of the analysis.

Table 6. Socio-demographics of the sample population and the actual population

Covariate	Level	Frequency in sample	Percentage in sample	Percentage in population*
Gender	**Male**	92	59.4%	49.7%
	Female	62	40.0%	50.3%
	Other	1	0.6%	
	Total	155	100.0%	100.0%
Age	**0-17 years**	-	-	18.9%
	18-26 years	7	4.5%	11.4%
	27-39 years	18	11.7%	16.4%
	40-54 years	58	37.7%	19.8%
	55-64 years	50	32.5%	13.7%
	65-74 years	20	13.0%	11.3%
	75+ years	1	0.6%	8.5%
	Total	154	100.0%	100.0%
Education	**Primary school**	0	0.0%	9.3%
	VMBO, MAVO, MBO-1, HAVO-, VWO first half	3	1.9%	20.0%
	MBO 2-4, HAVO-, VWO-completed	14	9.0%	36.7%
	HBO-, WO-bachelor	50	32.3%	20.5%
	HBO-, WO-master, Doctor	87	56.1%	11.9%
	Other	1	0.6%	1.6%
	Total	155	100.0%	100.0%
Work situation	**Full-time**	78	50.6%	36.5%
	Part-time	29	18.8%	33.9%
	Unemployed	3	1.9%	3.1%
	Non-working population	21	13.6%	26.5%
	Self-employed	23	14.9%	-
	Total	154	100.0%	100.0%
Household income	**Less than €10.000**	0	0.0%	4.1%
	€10.000-€20.000	2	1.5%	19.2%
	€20.000-€30.000	4	3.0%	30.7%
	€30.000-€40.000	11	8.2%	24.0%
	€40.000-€50.000	11	8.2%	12.2%
	€50.000-€100.000	68	50.7%	8.7%
	€100.000-€200.000	36	26.9%	0.7%
	€200.000 or more	2	1.5%	0.3%
	Total	134	100.0%	100.0%

**Gender and Age (CBS, 2021b), Education (CBS, 2021c), Work Situation (CBS, 2021a), Household income (CBS, 2020)*

Several observations should be pointed out as the sample has many differentiations compared to the real population. These deviations could be due to the sampling methods, while it also must be noted that the real population is not filtered for house-owned citizens. Therefore, it is less surprising that highly educated and high-income households are overrepresented in the survey (City of Amsterdam, n.d.; Kushi, 2021). Similarly, results are also correlated as low-income groups might be younger of age, due to their only recently started career or education. The most notable differences from the true population are the overrepresented group of people between the age of 40 and 64, the underrepresented group of low-educated people and the underrepresented group of low-income households. Lastly, the summation of total frequencies indicates how many respondents filled in a particular question. It can be observed that people are, for example, less willing to share their income in our sample, as this might be a moral taboo for some.

Table 7 shows the difference in dwelling characteristics compared to the true population. Here it should be mentioned that the similarity percentages between most of the construction years of the sample compared to the real population are distorted due to the many options available in this category. Other large deviations, such as the percentage of apartments and small surface area houses, should be considered not unusual. Apartments are more likely to be rented houses, which are not part of the sample, while high-income citizens are able to afford bigger houses.

Table 7. Dwelling characteristics of the sample population and real population

Covariate	Level	Frequency in sample	Percentage in sample	Percentage in population*
House type	**Detached house**	18	11.8%	13.0%
	Semidetached house	27	17.6%	8.8%
	Corner house	20	13.1%	12.7%
	Terraced house	62	40.5%	29.5%
	Flat/apartment/gallery apartment/ maisonette	23	15.0%	36.0%
	Other	3	2.0%	0.0%
	Total	153	100.0%	100.0%
Construction year	**1000-1945**	49	32.2%	18.5%
	1945-1955	6	3.9%	4.5%
	1955-1965	8	5.3%	9.9%
	1965-1975	19	12.5%	16.2%
	1975-1985	14	9.2%	14.5%
	1985-1995	17	11.2%	12.9%
	1995-2005	19	12.5%	10.5%
	2005-2015	14	9.2%	8.4%
	2015-2022	6	3.9%	4.6%
	Total	152	100.0%	100.0%
Surface area	**Less than 50 m^2**	1	0.7%	5.6%
	50-74 m^2	6	4.0%	14.8%
	75-99 m^2	29	19.5%	23.1%
	100-149 m^2	64	43.0%	37.5%
	150-249 m^2	45	30.2%	15.4%
	250 m^2 or more	4	2.7%	3.5%
	Total	149	100.0%	100.0%

**House type (CBS, 2021g), Construction year (CBS, 2021e), Surface area (CBS, 2021f)*

In Table 8, three questions regarding the attitude towards sustainability are compared. Due to the distribution method, a possible sample bias toward sustainable-minded people was expected. For this reason, these three reference questions were included in the survey to check for a potential sustainability bias. The representative study of Citisens (2020) is taken as a reference for the total Dutch population in 2020.

The sample data shows a clear bias toward a preference for all Dutch dwellings becoming natural gas-free and the Netherlands becoming climate neutral. However, it must be observed that the representative study was performed two years earlier than this current survey. In the meantime, the European Commission launched the Green Deal, the awareness of the negative externalities of natural gas increased, and natural gas prices increased due to the war in Ukraine. These societal changes make the comparison less accurate. Regarding whether a respondent's house should be disconnected from natural gas, the respondents were forced to choose yes or no. This mandatory question gave insight into people who are more lenient towards either of those choices. Nevertheless, it did make the comparison more difficult with the representative group, where the 'in doubt' option does not give insight if someone is more lenient towards either alternative.

Table 8. Sustainability preference of the sample population and representative population

Covariate	Level	Frequency in sample	Percentage in sample	Percentage in population*
I find it important that all Dutch dwellings become natural gas-free	**Totally disagree**	8	5%	14%
	Disagree	7	5%	11%
	Slightly disagree	7	5%	13%
	Neither agree nor disagree	13	9%	9%
	Slightly agree	35	23%	20%
	Agree	46	30%	18%
	Totally agree	36	24%	14%
	Total	152	100%	100%
I find it important that the Netherlands becomes climate neutral	**Totally disagree**	3	2%	6%
	Disagree	4	3%	5%
	Slightly disagree	4	3%	10%
	Neither agree nor disagree	3	2%	9%
	Slightly agree	24	16%	21%
	Agree	45	30%	19%
	Totally agree	69	45%	31%
	Total	152	100%	100%
Do you want your house to be disconnected from natural gas?	**Yes**	105	69%	44%
	In doubt	-	-	19%
	No	47	31%	37%
	Total	152	100%	100%

**All based on Citisens (2020)*

The remaining covariates for which no reference data was found are shown in Table 9. The first two questions are about the self-perception of their hassle sensitivity. These answers indicated that the respondents see themselves as undertaking actions rather than inactive, which might correspond to the high level of expected decision-makers. To the question 'if respondents often see problems', a slight preference towards disagreeing is visible. The factor analysis indicated that the hassle sensitivity factor, unlike sustainability-oriented, should not be included as a covariate in the data analysis.

Table 9. Other covariate outcomes of the survey

Covariate	Level	Frequency in sample	Percentage in sample
I describe myself as active when it comes to performing actions	**Totally disagree**	4	2.6%
	Slightly disagree	20	13.2%
	Neither agree nor disagree	24	15.9%
	Slightly agree	73	48.3%
	Totally agree	30	19.9%
	Total	151	100.0%
I often see problems ahead	**Totally disagree**	16	10.6%
	Slightly disagree	46	30.5%
	Neither agree nor disagree	34	22.5%
	Slightly agree	39	25.8%
	Totally agree	16	10.6%
	Total	151	100.0%
Will you be likely to move in two years?	**Yes**	17	11.6%
	No	130	88.4%
	Total	147	100.0%
Are you the expected decision-maker?	**Yes**	126	85.7%
	No	21	14.3%
	Total	147	100.0%
Years of residency	**0-5 years**	52	34.2%
	6-10 years	17	11.2%
	11-15 years	24	15.8%
	16-20 years	22	14.5%
	21+ years	37	24.3%
	Total	152	100.0%

6. Model results

In this chapter, the results of the model estimations are shown, while these will be discussed in chapter 7.1. In section 6.1, the perception of what is hassle during heat pump adoption is determined with the help of the rating experiment. Next are the findings of several models explaining the influence of hassle and financial aspects on a homeowner's utility, described in section 6.2. This utility is created by the trade-offs between attributes and explains empirically if and how much hassles influences homeowners' decision-making. These findings are extended by performing an LCA, to detect heterogeneous clusters in an effort to explain the data even better. Lastly, the best model fit is determined based on the parameters' significance and explanation of the data.

6.1. Perceived hassle factor

Chapter 4.3 concluded that the aspects of 'the length of disruption', 'information gathering', 'finding a contractor', 'subsidy and loan applications' and 'neighbour consultation' are the expected most influential hassle factors. In the rating experiment, each homeowner indicated how much hassle a certain choice set was for him/her. Therefore, a comparison can be made between if homeowners in the Netherlands also perceive the hassle factors described in scientific behaviour literature as hassles. Through the use of multiple linear regression analysis, it is estimated how much an average respondent would perceive the hassle of a random choice alternative. The estimation is based upon the respondent's indicated perception of hassle towards a choice alternative. As each respondent indicated 12 choice alternatives with their perception of hassle, 1860 observations were made in the total survey. The estimation is performed in SPSS 26. In Table 10, the given parameter estimates are shown, where the relative importance indicates how much each parameter relatively influences the perception of hassle.

Table 10. Parameter estimates of regression analysis of the combined hassle factor

Parameters	Estimates	Standard error	P-value	Relative importance
(Constant)	0.711	0.093	0.000	-
Length of disruption	0.152	0.009	0.000	37.3%
Information gathering	0.057	0.006	0.000	21.0%
Finding a contractor	0.074	0.009	0.000	18.2%
Subsidy and loan applications	0.065	0.007	0.000	21.3%
Neighbour consultation	0.069	0.014	0.000	11.3%
Profit	-0.037	0.009	0.000	9.1%

The p-value of a parameter measures the probability that a parameter is actually zero. If a p-value is higher than 0.05, a parameter is found to be statistically insignificant and not an aspect of the perception of hassle by homeowners. However, no estimates were found to be insignificant, not even the amount of profit a homeowner receives. As this parameter shows that a higher profit reduces how much hassle is perceived, this is nevertheless the least strong effect.

The relative importance is calculated by obtaining the maximum contribution of each parameter. The maximum contribution is calculated based on multiplying the attribute level range with the absolute value of the parameter estimates. For the case of the 'length of disruption', this estimation is 6 * 0.152 = 0.912, as the difference between one day and seven days is six, and the parameter estimate is 0.152. The relative importance is then calculated by dividing this number by the sum of all maximum contributions. The model fit is determined with the Rho-square value, which represents how much of the initial uncertainty is explained by the model. A model fit of 1, would mean that the model perfectly explains the data. The Rho-squared for this model is 0.211 or 21.1%. Studies predicting human behaviour generally have a Rho-squared value of less than 50% (Frost, n.d.).

Additionally, this measured perception of hassle can be compared by looking at the declared amount of hassle by the respondents. The respondents were asked in the last part of the survey to list from 1 to 6 how much hassle each task was. This rating indicates the respondent's conscious perception of the amount of hassle. This directly retrieved perception is given in Figure 3, while in Table 11, additional descriptives are shown where the lowest average indicate it is seen as the most hassle relatively.

Table 11. Respondent's conscious perception of hassle

	Length	Information	Contractor	Subsidy	Neighbour	Other
Average	3.060	3.119	2.596	2.795	3.848	5.583
Standard error	1.550	1.465	1.123	1.309	1.446	1.335
Mode	1	4	2	3	5	6

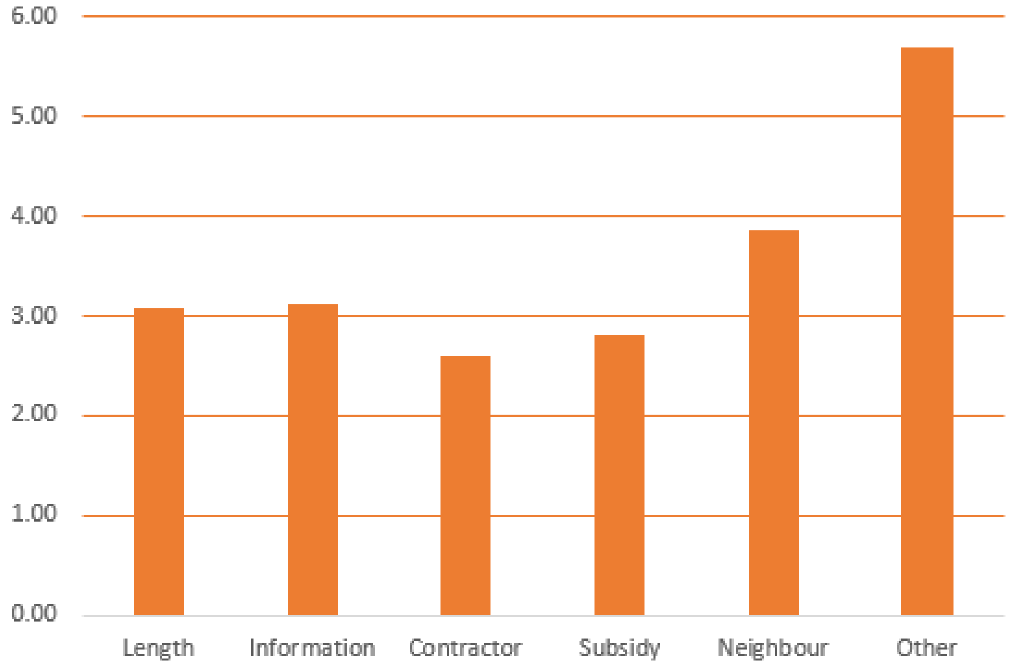


Figure 3. Respondent's conscious perception of the hassle factor on a 1-6 scale

A direct comparison between Figure 3 and Table 10 is not possible due to different units. However, from the declared rating and hence conscious perception, it can be concluded that the most influential factors are: 1) finding a contractor; 2) subsidy and loan applications; 3) length of disruption; 4) information gathering; 5) neighbour consultation; 6) other reasons.

While the measured perception of hassle found the order 1) length of disruption; 2) subsidy and loan applications; 3) information gathering; 4) finding a contractor; 5) neighbour consultation; 6) the amount of profit. Showing that unconsciously the 'length of disruption' is perceived as the most and hence more hassle than 'finding a contractor', while in the declared rating this is the other way around.

The additional option to indicate what other reasons might give homeowners hassle is shown in appendix G, while a summary of the factors is made in Table 12. The interpretation of these factors is given in chapter 7.1.3.

Table 12. Other reasons that people indicated as hassle

Other reasons that are perceived as a hassle	Frequency
Feasibility of installation	4
Determining the profit	3
Space constraints	3
Investment costs	3
Delivery time heat pump	2
Information gathering	2
Relocation	1
Permit application	1
The nuisance of a heat pump	1
Finding a reliable contractor	1
Making a choice	1

6.2. Model estimation

To determine how a choice of a homeowner is established, several predictive models are estimated to see what affects the utility of a homeowner. First, a linear MNL model is estimated, and the model estimation is continuously improved based on the results. These improvements are made to find the best model that fits and hence explains the data. The used apollo code for model 1 is presented in appendix H. Slight iterations of this code were performed due to the other estimated models.

6.2.1. Model 1: MNL

The estimation of the first model includes the six attributes selected in chapter 4.3. The factors are estimated as numeric variables and the systematic utility function is stated in equation (3).

$$V_i = Leng_i * \beta_{Leng} + Info_i * \beta_{Info} + Cont_i * \beta_{Cont} + Subs_i * \beta_{Subs} + Neig_i * \beta_{Neig} + Prof_i * \beta_{Prof} \tag{3}$$

Where:

i = the alternative, i.e. choice A, choice B

V_i = the systematic utility of alternative i

β_{Leng} = the marginal utility of the factor length disruption

β_{Info} = the marginal utility of the factor information gathering

β_{Cont} = the marginal utility of the factor finding a contractor

β_{Subs} = the marginal utility of the factor subsidy and loan application

β_{Neig} = the marginal utility of the factor consultation neighbours

β_{Prof} = the marginal utility of the factor profit

In Table 13, the estimated model parameters are presented, Figure 4 shows their relative importance. Based on the robust p-values, it is concluded that all parameters of this model are found to have a significant effect on the systematic utility function. Meaning that all the expected effects found in literature are also influencing the choice of a homeowner. Looking at the relative importance of the estimates it is observed that the profit estimate is the highest determining factor of the utility.

Table 13. Model 1 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Leng	-0.14377	0.02284	0.000
BETA_Info	-0.05189	0.01254	0.030
BETA_Cont	-0.05589	0.01773	0.010
BETA_Subs	-0.07578	0.01511	0.001
BETA_Neig	-0.07894	0.02607	0.001
BETA_Prof	0.32445	0.02438	0.000

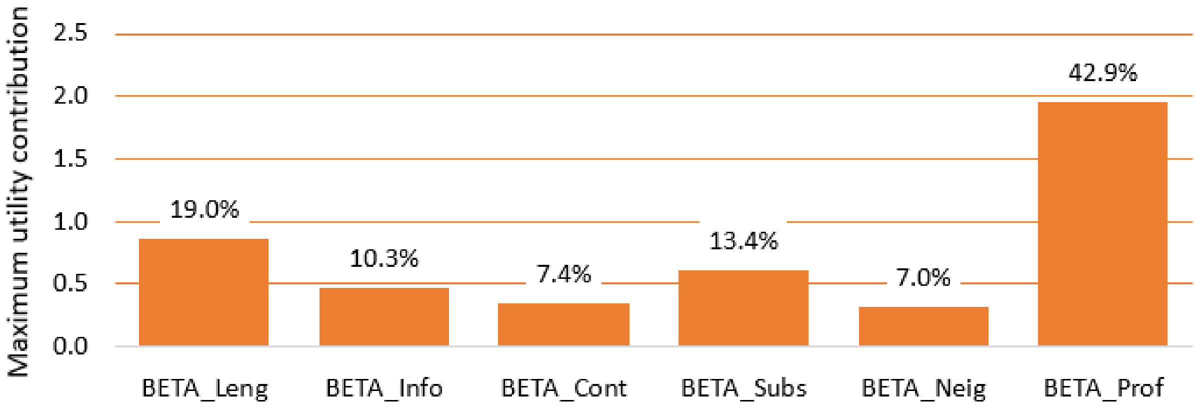


Figure 4. Relative importance model 1 parameter estimates

The model fits is determined through the Log-Likelihood Ratio Statistic (LRS), to see if the model is better at explaining the data than ‘throwing a dice’ (Train, 2009). This LRS is calculated based on equation (4). LL_0 is the log-likelihood (LL) of the null model, and the LL_{Final} is the log-likelihood of the estimated model. Respectively -644.63 and -446.89, resulting in an LRS of 395.48. The accompanying critical Chi-square value of 12.59 for six parameters is lower than the LRS, which means that it can be concluded that the model is better than a random model or ‘throwing a dice’. Additionally, the model fit can be compared with other models based on the BIC value, which also accounts for the number of model parameters. This BIC value is 934.79 for model 1.

$$LRS = -2 * (LL_0 - LL_{Final}) \tag{4}$$

6.2.2. Model 2: MNL with the combined hassle factor

In the second model, the combined hassle factor is added as an attribute in the MNL model of model 1. This attribute is added to see if a joint hassle factor is a better predictor of how much utility a homeowner perceives than the independent hassles. The combined hassle factor should incorporate all the hassles of the individual attributes (Molin & Timmermans, 2009). Meaning that the attributes only directly influence the utility in a non-hassle way. This combined hassle factor is included in the model based on the Likert scores created by the respondents in the rating experiment. The formula of the systematic utility is given in equation (5).

$$V_i = Hassle * \beta_{Hassle} + Leng_i * \beta_{Leng} + Info_i * \beta_{Info} + Cont_i * \beta_{Cont} + Subs_i * \beta_{Subs} + Neig_i * \beta_{Neig} + Prof_i * \beta_{Prof} \tag{5}$$

Where:

β_{Hassle} = the marginal utility of the combined hassle factor

Table 14 represents the parameter estimates of model 2. The individual hassle parameter estimates show a reduction in effect compared to model 1. These values indicate that the combined hassle factor captures the effect of the perception of hassle associated with all parameters. However, some direct effects remain. The p-values of the estimates BETA_Leng, BETA_Cont and BETA_Neig are insignificantly different from 0. Indicating that the hassle perception attribute completely explains their effect on the systematic utility and that it cannot be said with certainty that they are explaining the model at all.

The log-likelihood of this model is -404.04 indicating a better fit than model 1. By performing the LRS test (value of 481.18), it can be concluded that this model is also better than throwing a dice, regardless of the extra estimated parameter (Chi-square value of 14.07). The BIC value of 855.93 also shows a better fit due to the decrease of almost 80 points compared to model 1.

Table 14. Model 2 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Hassle	-0.70344	0.08235	0.000
BETA_Leng	-0.05787	0.02508	0.069*
BETA_Info	-0.02439	0.01333	0.038
BETA_Cont	-0.01018	0.01896	0.341*
BETA_Subs	-0.04064	0.01631	0.004
BETA_Neig	-0.03397	0.01333	0.109*
BETA_Prof	0.34398	0.02623	0.000

**Insignificant based on a 95% confidence level*

6.2.3. Model 3: MNL with combined hassle factor without insignificant parameters

Model 3 is similar to model 2. However, the model is iteratively re-estimated by deleting the parameter with the highest p-value till all parameter estimates are found to be significant. Table 15 states the final model estimates, with the systematic utility function given in equation (6).

$$V_i = Hassle * \beta_{Hassle} + Leng * \beta_{Leng} + Info * \beta_{Info} + Subs * \beta_{Subs} + Prof * \beta_{Prof} \quad (6)$$

After this re-estimation, the parameters 'length of disruption', 'information gathering' and 'subsidy and loan applications' showed a significant direct effect on the systematic utility, regardless of the previous insignificant p-values of the length of disruption in model 2. These attributes still represent aspects that negatively contribute to the systematic utility, aside from the hassle captured in the combined hassle factor. By removing the insignificant parameters BETA_Cont and BETA_Neig, the model's Log-Likelihood remains almost the same, with a value of -404,85, while the BIC value improves to 843.88. The relative importance of all five attributes is given in Figure 5. It can be seen that the combined hassle factor is a more important influence than the amount of 'profit', and that the remaining factors are relatively small influences.

Table 15. Model 3 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Hassle	-0.72768	0.07936	0.000
BETA_Leng	-0.05889	0.02343	0.031
BETA_Info	-0.02341	0.01324	0.033
BETA_Subs	-0.04467	0.01549	0.000
BETA_Prof	0.34776	0.02491	0.000

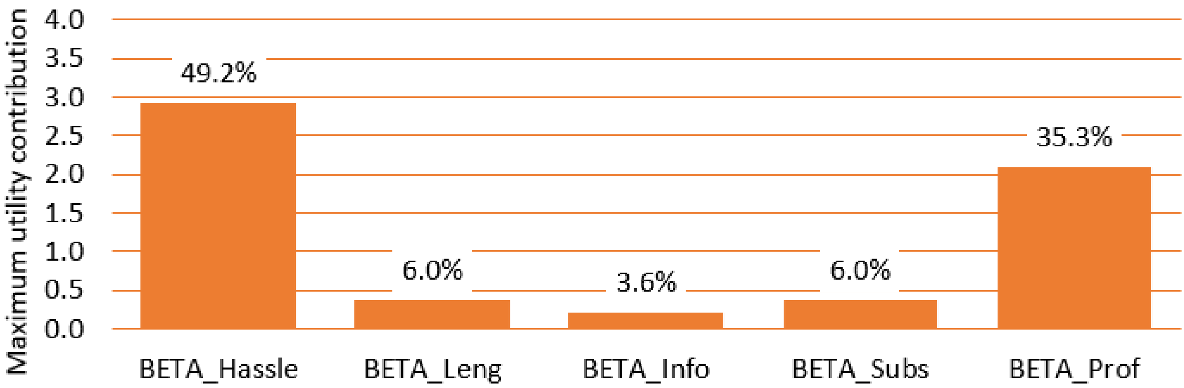


Figure 5. Relative importance model 3 parameter estimates

6.2.4. Model 4: MNL with only the combined hassle factor

Unlike models 2 and 3, in this model all the individual hassle factors were replaced for the combined hassle factor, except for the profit attribute. The relative importance of model 3 indicated that BETA_Leng, BETA_Info and BETA_Subs all had a small importance level, showing only small direct effect. Therefore, it is examined if a better model fit can be obtained without these parameters. The model fit, based on the Log-Likelihood, deteriorates slightly to -411.92, while the BIC further improves to 837.51. The parameter estimates are shown in Table 16, while the systematic utility is stated in equation (7). Additionally, the relative importance is visualised in Figure 6. In this figure, it can be clearly observed that the combined hassle factor is a much bigger determinant for a homeowner's utility than profit.

$$V_i = Hassle * \beta_{Hassle} + Prof * \beta_{Prof} \tag{7}$$

Table 16. Model 4 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Hassle	-0.8338	0.07366	0.000
BETA_Prof	0.3264	0.02269	0.000

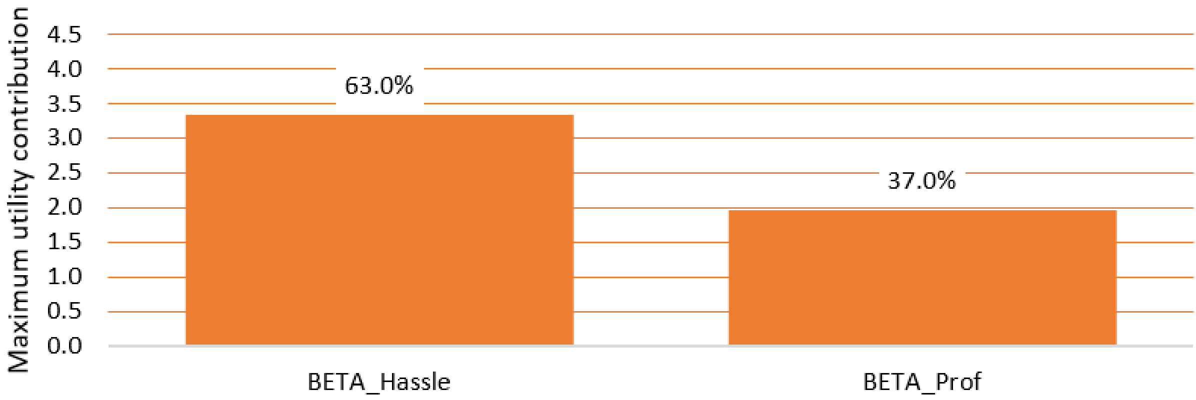


Figure 6. Relative importance model 4 parameter estimates

6.3. Latent Class Analysis

An LCA has been performed in order to improve the model fit further. With this LCA, it is looked if different groups of respondents can be found in the data, where the attributes influence homeowners differently. The regression analysis of the combined hassle factor showed that all estimates of model 1 influence the combined hassle factor. Hassle sensitivity among homeowners towards individual hassle attributes corresponds with the goal of this study. Therefore, this analysis takes model 1 as a basis to gain insights into the existence of possible heterogeneous clusters of homeowners.

6.3.1. Class determination

The optimal number of classes to describe the data is based on the BIC value, as described in chapter 2.6. In the class determination, no covariates are included, as they do not influence the optimal number of classes. Up to four different classes are compared to determine the most appropriate number of classes. Table 17 shows their different model fits. All software settings were estimated based on default settings, except for random sets and iterations, as those were set to 100.

Table 17. Estimation of the number of classes of the LCA

Classes	Parameters	Log-Likelihood	Rho-square	BIC
1	6	-446.89	0.307	924.04
2	13	-398.66	0.382	862.89
3	20	-385.22	0.402	871.31
4	27	-377.32	0.415	890.80

The 2-class model has the lowest BIC value and was therefore selected instead of the other models. However, Table 17 shows that the BIC value of the 1-class model differs from the BIC value of model 1. LatentGold sees every different respondent as one observer, so every respondent is placed in one class instead of placing them in multiple classes as each respondent makes multiple choices. While estimation in Apollo is based on 930 observations, as it sees every choice as one single observation.

6.3.2. 2-class model

The parameter estimation of the 2-class model, with no covariates, is shown in Table 18. The Wald statistic shows if a parameter is statistically different from zero, while the Wald(=) statistically tests if the effect is class independent, in other words, if there is a different effect for both classes or not.

The Wald and Wald(=) show insignificant values for this 2-class model, therefore, two different models are made based on this insight. In the first model, the deletion of insignificant parameters is done first

(BETA_Neig). Afterwards, any insignificant estimate is changed from a dependent class effect to a class independent effect (BETA_Subs). In the second model, this is turned around and first the dependent class effects are set to independent (BETA_Subs and BETA_Neig), and after this change the parameters were checked to be deleted completely. All parameters were iteratively re-estimated, in both models, based on the exclusion of the value with the highest p-value. This distinction is made as BETA_Neig had a significant effect in model 1, indicating that it influences a homeowner's systematic utility. However, this effect was not directly seen in the original 2-class model of Table 18. The comparison for the model fit of both different 2-class models is visualised in Table 19.

The model fit of the two approaches are quite similar, with a Log-Likelihood difference of 2.4, a Rho-square difference of 0.01, both in favour of V1, and a BIC difference of 0.25 in favour of V2. However, due to the small difference in the BIC value, Occam's razor principle is used, the best explanation is the simplest one. Therefore, the first 2-class model with the deletion of the insignificant effects of 'neighbour consultation' and the class independent effect of 'subsidy and loan application' is selected. The estimates of this model are shown in Table 20.

Table 18. LCA model 4 parameter estimates

Parameter	Estimate	Standard error	Wald	P-value Wald	Wald(=)	P-value Wald(=)
BETA_Leng	-0.4136	0.0813	29.05	0.000	12.86	0.000
BETA_Leng2	-0.0717	0.0461	29.05	0.000	12.86	0.000
BETA_Info	-0.1118	0.0286	16.56	0.000	5.23	0.022
BETA_Info2	-0.0237	0.0245	16.56	0.000	5.23	0.022
BETA_Cont	-0.1940	0.0467	17.47	0.000	11.88	0.001
BETA_Cont2	0.0122	0.0388	17.47	0.000	11.88	0.001
BETA_Subs	-0.1164	0.0296	33.81	0.000	0.10	0.750*
BETA_Subs2	-0.1000	0.0338	33.81	0.000	0.10	0.750*
BETA_Neig	-0.0842	0.0452	4.03	0.130*	0.31	0.580*
BETA_Neig2	-0.0391	0.0637	4.03	0.130*	0.31	0.580*
BETA_Prof	0.7830	0.1249	73.8	0.000	69.01	0.000
BETA_Prof2	-0.0853	0.0597	73.8	0.000	69.01	0.000

**Insignificant based on a 95% confidence level*

Table 19. Model fit comparison of the two different 2-class models

Model	Parameters	Log-Likelihood	Rho-square	BIC
V1	10	-401.30	0.377	853.03
V2	11	-398.90	0.381	853.28

Based on the parameters of Table 20, the profit estimate is again shown as the highest determinate, similarly to Table 13. Nevertheless, all parameters of the second cluster show a relatively low influence compared to the first cluster. The sign has even flipped in the case of 'finding a contractor' and 'profit'. Although the significance of all the values, the second cluster parameter all have relatively high standard errors compared to their estimates.

The V1 2-class model was re-estimated based on the ten covariates: 'gender', 'age', 'education', 'work situation', 'household income', 'house type', 'construction year', 'years of residency', 'surface area', 'expected decision-maker', 'likely to move in two years' and the attitude 'sustainable oriented', that was created through the factor analysis. After this estimation, the model was again iteratively re-estimated while excluding the covariate with the highest insignificant p-value. In the final model, no covariates showed to be a predictor (active covariate) for a specific class. Therefore, all covariates were included as inactive describing covariates. The profiles of all inactive covariates and attributes of this model are given in appendix I.

Table 20. 2-class model V1 parameter estimates

Parameter	Estimate	Standard error	Wald	P-value Wald	Wald(=)	P-value Wald(=)
BETA_Leng	-0.3955	0.0786	25.74	0.000	14.80	0.000
BETA_Leng2	-0.0668	0.0472	25.74	0.000	14.80	0.000
BETA_Info	-0.1184	0.0297	15.97	0.000	7.66	0.006
BETA_Info2	-0.0130	0.0251	15.97	0.000	7.66	0.006
BETA_Cont	-0.1656	0.0458	13.77	0.001	10.58	0.001
BETA_Cont2	0.0225	0.0387	13.77	0.001	10.58	0.001
BETA_Subs	-0.1245	0.0178	48.76	0.000	0.00	-
BETA_Prof	0.7579	0.1179	82.62	0.000	78.46	0.000
BETA_Prof2	-0.1000	0.0626	82.62	0.000	78.46	0.000

6.4. Non-linear parameters

In the 2-class models, an observation was made regarding the two different effects of BETA_Cont and BETA_Prof. Both parameters show a positive and a negative effect in Table 18 and Table 20. This effect would mean that part of the respondent prefers to have a long search for contractors while another part tries to minimise this, similarly for profit. A possible reason for this outcome can be that respondents have different attitudes towards different attribute levels. In this case, all the respondents have different parameter preferences for the attribute levels of the attribute, thus for 2, 5 and 8 hours. While the LCA looks at different preference groups within the data, which have the same preference per attribute level. A non-linear effect for attribute levels is checked for the model parameters ‘finding a contractor’ and ‘profit’.

6.4.1. Model 5: MNL with a non-linear contractor parameter

The model estimation is based upon the standard MNL model of model 1, as the effect of the contractor is disregarded in the later models, as it showed to be insignificant. The non-linear effect was added based upon effects coding the variable, and hence the average utility is set as zero. Table 21 shows the parameter estimates and equation (8) its systematic utility function.

As the robust p-values of both the parameters of finding a contractor are insignificant, it was concluded that the parameter ‘finding a contractor’ does not have a non-linear effect.

Table 21. Model 5 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Leng	-0.14377	0.02284	0.000
BETA_Info	-0.05189	0.01254	0.000
BETA_Cont	-0.06707	NaN	0.497*
BETA_Cont2	-0.13414	NaN	0.490*
BETA_Subs	-0.07578	0.01511	0.000
BETA_Neig	-0.07894	0.02607	0.001
BETA_Prof	0.32445	0.02438	0.000

**Insignificant based on a 95% confidence level*

(8)

$$V_i = Leng * \beta_{Leng} + Info * \beta_{Info} + Cont(5) * \beta_{Cont} + Cont(8) * \beta_{Cont2} + Subs * \beta_{Subs} + Neig * \beta_{Neig} + Prof * \beta_{Prof}$$

6.4.2. Model 6: MNL with a non-linear profit parameter

Model 6 estimated the non-linear effect of the parameter profit based on model 4's MNL model, as it had the lowest BIC value of all estimated models. The model's systematic utility function is stated in equation (9), while the parameter estimates are visualised in Table 22.

(9)

$$V_i = Hassle * \beta_{Hassle} + Prof(3) * \beta_{Prof} + Prof(6) * \beta_{Prof2}$$

Table 22. Model 6 parameter estimates

Parameter	Estimate	Standard error	Robust p-value
BETA_Hassle	-0.8338	0.07366	0.000
BETA_Prof	0.3916	NaN	0.000
BETA_Prof2	0.7833	NaN	0.008

The robust p-values of model 6 show a significant effect, so it can be concluded that the profit parameter can be explained as a non-linear parameter. This significant finding means that a step in high profits contributes more to utility than a similar step in low profits. The model fit is given with the Log-Likelihood and the BIC value, which are -411.92 and 844.35, respectively.

6.5. Model selection

In the final model comparison of Table 23, all parameters with significant parameters are compared. This overview compares the model based on the number of parameters, Log-Likelihood, Rho-square and the BIC value. The model fit through the Log-Likelihood and Rho-square indicates the best model estimation of the data. These values are the highest for the V2 2-class model, which outperforms all other models but also has the most parameters. Hence, the BIC value for this model is also larger than other models. As model parsimony is considered an important criterion of a model, the model with the lowest BIC value, model 4, is considered the best fit.

Table 23. Final model comparison

Model	Parameters	Log-Likelihood	Rho-square	BIC
Model 1	6	-446.89	0.307	934.79
Model 3	5	-404.85	0.372	843.88
Model 4	2	-411.92	0.361	837.51
V1 2-class	10	-401.30	0.377	853.03
V2 2-class	11	-398.90	0.381	853.28
Model 6	3	-411.92	0.361	844.35

Figure 7 shows the final operational model based on model 4. Although several effects from Figure 2 can be found in the data, multiple classes, direct and indirect effects and non-linear effects for the profit parameter, is the final selected choice model rather more simplified.

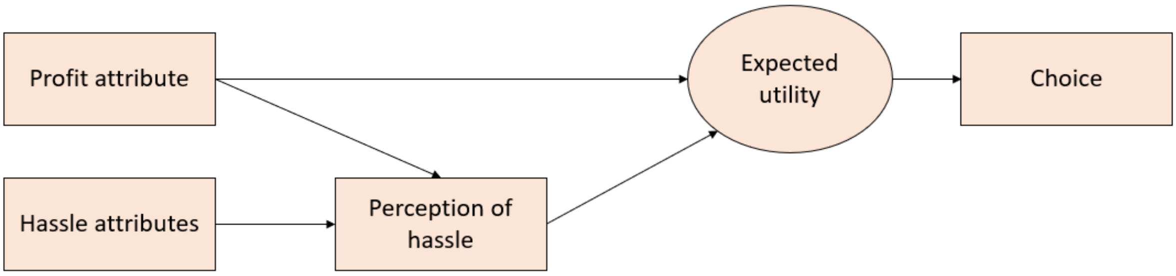


Figure 7. Final operational model based on model 4

In equation (10), the calculation for the value of time is presented. A willingness to pay for the combined hassle can be determined using model 4's parameter estimates. As the combined hassle factor is not represented in a unit of time, unlike the individual hassle factors, the willingness to pay for 1 point on the Likert scale of hassle can be calculated. This value is €2554.53. However, as this value is rather difficult to interpret due to the Likert scale, the objective attribute estimates of model 1 were used to determine the value of time for the individual hassle-containing tasks. Based on model 1, these values are presented in Table 24 and interpreted in chapter Perceived utility7.1.4.

$$Value\ of\ Time = \frac{\beta_i}{\beta_{Prof}} \tag{10}$$

Table 24. Value of time for each individual hassle factor

Parameter	Value of time	Unit
Length of disruption	443.12	€/day
Information gathering	159.93	€/h
Finding a contractor	172.26	€/h
Subsidy and loan applications	233.56	€/h
Neighbour consultation	243.30	€/h

7. Discussion

In this chapter, the found results are interpreted and compared to other relevant studies in order to determine their value and draw final conclusions. This chapter first analyses the findings compared to literature and expectations, from whereon implications and recommendations for society are concluded. After discussing possible limitations of the study, recommendations for useful follow-up steps are provided. This additional research is outlined to increase the understanding of homeowners' decision-making even further, in an effort to speed up the heat transition.

7.1. Analysis

The results of chapter 6 are interpreted and compared to expected findings based on (scientific) literature, interviews and the estimated models. It is analysed how homeowners perceive hassle and on which aspects they base their decision to adopt a heat pump.

7.1.1. Perceived hassle

The regression analysis of the combined hassle factor showed that all five individual hassles are of influence on how much hassle a homeowner sees. Their relative importance is shown in Table 10, indicating that 'information gathering', 'finding a contractor' and 'subsidy and loan applications' are similar in their influence on the perception of hassle. While 'the length of disruption' and 'neighbours consultation' are respectively stronger and weaker. This difference in the influence of the 'length of disruption' might be due to its visible form of hassle (Koning et al., 2020). People experience this disruption as noise and mess during renovations, which might not always be preferred. Renovations that take multiple days are rather disruptive, while other hassle factors are more subtle and can be planned by the homeowner at a preferred time. All the empirically found hassles, except 'neighbour consultation', were also found by de Vries et al. (2020). Therefore, this additional hassle factor extends literature. However, its low importance towards the perception of hassle, compared to the other hassle factor, can be a reason for its missing documentation. The need for an agreement with neighbours for placing a heat pump (Klockner & Nayum, 2016) and the caused (noise) disturbance (Klimaatroute, personal communication, April 13, 2022), are the main expected influences of this factor. However, having a conversation with a neighbour, often a familiar person, can also be comforting due to their additional expertise (Broers et al., 2019; Wilson et al., 2015). These reasons are possible explanations for its low importance.

Additionally, it is found that the amount of 'profit' a homeowner receives also impacts the perception of hassle. An increased amount of profit over the lifetime of a heat pump decreases the perceived amount of hassle in an adoption process. That 'profit' is a driver for homeowners to adopt a heat pump was known. It is even the most important driver, according to Ebrahimigharehbaghi (2022). The relationship between hassle and money is also mentioned in de Vries & Kooger (2020), who found that money and hassle are the most important choice determinants for energy-efficient applications. For this reason, the dependency of 'profit' on hassle is maybe not unusual. Homeowners have to perform specific actions to adopt a heat pump. These actions create hassle, requiring mental bandwidth and energy, for example. The reason for most people to perform these actions is financial profit. So, homeowners might make the mental comparison: 'is this amount of hassle worth the money I will receive during the heat pump's lifetime'? The objective unit labels of money make for an easier comparison, especially as hassles are also expressed in an objective unit, time. Hence, hassle is perceived by indicating what is required and what it yields. This yield has a soothing influence on the perception of hassle, shown by the significance of the profit attribute. It is expected that the vagueness of the term 'hassle' makes homeowners think about something to compare hassle with, to rate it mentally. Other drivers, such as 'comfort' or 'environmental reasons', might also influence this perceived amount of hassle as it gives them a similar comparison, depending on the vagueness or subjectivity of these drivers. The perception of hassle is hence proven to be susceptible to context. The use of context can decrease or increase the perception of hassle. In the behavioural public administration field, context differentiation through the tools of nudging and sludging can significantly affect a choice (Shahab & Lades, 2021; Thaler & Sunstein, 2009). The tools nudging and sludging are therefore also concluded to impact the perception of hassle for a homeowner adopting a heat pump.

7.1.2. Differences in perception

The measured relative importance of hassle in Table 10 and the indicated importance in Figure 3 show different results. The decomposition of importance in determining someone's hassle perception differs between conscious and unconscious. The conscious importance of the 'length of disruption' is similar to 'information gathering', 'finding a contractor' and 'subsidy and loan applications', compared to the unconscious importance, where this first one is by far the most important one. Influences of the attribute levels might have influenced this difference. As with a conscious perception, respondents might use certain expected levels. During the unconscious consideration, the given values might hence be over- or underestimated of the expected mental reference levels. Resulting in differences, possibly even amplified by heuristics. Previous research has shown that there can be a considerable difference between what people think drives their choices and what actually drives them (Nisbett & Wilson, 1977). Respondents can be unaware of the existence of a stimulus that significantly influences a decision or that the stimulus can affect a certain response (Chartrand et al., 2008). This unawareness suggests that people may struggle to understand their cognitive processes and express their true perceptions. Therefore, the conscious process of rating the perception of hassle is maybe directed to a homeowner's image of hassle based on causal judgments or theories. While in contrast, the unconscious rating of hassle perception is also influenced by situational cues.

7.1.3. Hassle as an umbrella term

In Table 12, hassle factors are listed, which were mentioned by the respondents as other important factors aside from the hassle attributes of the choice experiment. Eleven factors were mentioned, with frequencies ranging from 1 to 4 based on a total of 155 responses. For that reason, the statistical significance of these factors is relatively low. However, it shows the variations in perception of what are hassles. Several of these factors are quite similar to the originally used attributes. For example, one respondent mentioned that specifically finding a reliable contractor is a hassle. It is, therefore, discussable if this factor is a stand-alone hassle, as finding a contractor was one of the stated options. Other respondents might have clustered the hassle of finding a reliable contractor with finding a contractor in general.

So, possibly not all respondents of the survey felt that the stated options did cover the exact meaning or criteria they perceived as hassles. Hassle factor or even the individual hassle factors can be, in that sense, umbrella terms for the meant sub-aspects or tasks that actually create most of the hassle of the individual hassle tasks. This hassle is expected to be depended on homeowners' specific preferences or past experiences, as not all homeowners agree on the phrasing of the hassles.

7.1.4. Perceived utility

Aside from how the hassle factor is composed, perceived hassles are also empirically determined to influence the decision of a homeowner to adopt a heat pump. Hassles have rarely been part of modelling studies about the decision-making process of homeowners (Du et al., 2022; Friege & Chappin, 2014; Hesselink & Chappin, 2019), as it was often overlooked or understudied

(Ebrahimigharehbaghi et al., 2020; Hünecke et al., 2019; Lades et al., 2021). That hassles influences the decision-making underlines that they should be incorporated into the conceptualisation of a homeowner's decision-making process. However, the use of one combined hassle factor describes the data better than several individual hassle factors. This conclusion of one combined factor is not uncommon, as de Vries et al. (2020) described hassle factors as micro-stressors that combined act as a barrier to homeowners' decision-making. However, empirical evidence for this argumentation was lacking.

The importance of the hassle factors compared to literature are unique, as this study modelled specifically Dutch homeowners when adopting a heat pump at the beginning of 2022. These boundaries set an important sidenote on the data as, for example, in this period Dutch media mentions the many problems of finding a suitable contractor (AD, 2021; EenVandaag, 2022; NOS, 2017, 2022). Changes in the context of a homeowner, such as social, environmental or institutional setting, can shape the perception of homeowners and, with it, the influence of factors on the utility. The context in which the research is applied sets boundaries for comparison with other scientific literature. The importance of the 'length of disruption' is, for example, in line with Schleich et al. (2022), who emphasised the effect of this barrier. However, two other modelling studies found this factor to be one of the lowest influences on the choice of homeowners (Meles et al., 2022; Voskuyl, 2021). Where all three of these researches investigated different countries and none of them did research specifically on heat pumps. Klockner & Nayum (2016) who also did not look at a new heating system but rather on insulation in Norway, found a similarly limited effect for 'consulting neighbours'. These countries, technology and year-specific findings provide a limited comparison, especially considering the combination of the non-representable sample of this research.

7.1.5. Non-hassle effects

Comparing the relative importance of how unconsciously all hassle factors are perceived (Table 8) and how the hassle factors influence the utility of a homeowner (Figure 6), the same order of importance comes back. Meaning that the 'length of disruption' is the largest determinant of how much hassle someone sees, and aside from profit, it is also the largest influence on a homeowner's utility. The de-hassling effect of 'profit' has relatively the smallest influence on the total amount of perceived hassle, but rather is the largest utility contributor. This finding is not unexpected, as 'profit' also has a non-hassle effect on the utility. The linear non-hassle effect is the financial stimulus, which in total makes this attribute the largest contribution to utility. The found non-linear effect of profit is disregarded as it is not indicative enough for extra parameter estimation.

The direct non-hassle effects can also be observed from the attributes 'the length of disruption', 'information gathering' and 'subsidy and loan applications' in Table 15. In this model, the hassle effects of these attributes are included in a combined hassle factor, while the remaining direct effects indicate that the factors are not purely seen as hassles but also as other barriers influencing a homeowner's decision. These remaining direct effects are unidentified and somewhat small, as can be concluded from Figure 7. However, for a complete picture of the decision-making process should these direct non-hassle effects be identified further.

7.1.6. Value of time

Aside from the fact that the combined hassle factor is a better predictor of the data than the individual ones, is a combined factor also more important in decision-making than financial 'profit'. This finding is unique, as the effect of money compared to the effect of hassle on a homeowner's decision to adopt a heat pump was unknown. The amount of money that people are willing to pay for convenience was undetermined (de Vries & Kooger, 2020) and the result of this study provides for a better understanding of decision-making. The willingness to pay value is on average €2555 per Likert point of Hassle. In comparison, the value of times of each sub-factor of hassle, which is listed in Table 24, is roughly around €200/h. Meaning that with a decrease of one hour in work of these tasks, on average, all the respondents would be willing to pay €200. These values are relatively high, as the Netherlands' minimum wage is only around €10/h and these values are roughly 20 times higher (Rijksoverheid, 2022). With interpreting these values, it should be noted that results are based on a biased sample mainly containing highly educated and income respondents. This bias is expected to overrepresent the average value of time, as respondents with high incomes are expected to value their time on average more. In addition to this bias, the notion should be made that the amount of received 'profit' is used for a value of time. The bias loss aversion is hence expected to have played a role. Meaning that the perceived value of a loss is higher compared to the same value of gain. This bias can be explained by prospect theory, where people weigh the utility of 'receiving money' as less than 'spending money' (Kahneman & Tversky, 1979). This bias is not uncommon for renewable energy projects (Bartczak et al., 2017). The term 'willingness to pay' for these values is despite its frequent use, not correct as people are not spending money but are receiving money (Grutters et al., 2008). The term 'willingness to accept' is thus more appropriate. Loss aversion and a sample bias can hence be reasons for possible overrepresentation of the values of time indicators.

7.1.7. Heterogeneity of homeowners

The finding of two heterogeneous groups within the data shows useful insights for understanding the effect of hassle. A different hassle sensitivity among the population indicates that people perceive the psychological cost of hassle differently. Possible differences can occur due to a limited cognitive bandwidth as it is found that those people have more difficulties in overcoming the effects of sludge, a deliberate form of hassle (Shafir & Mullainathan, 2013; Shahab & Lades, 2021). Such latent attitude values might be valuable for the identification of these groups. Enpuls and Motivaction also clustered people based on their attitudes towards sustainable energy applications (Enpuls, 2018; Thijssen et al., 2020). This type of clustering is expected to provide more explanation of different preferences, as identifying groups within this study was unsuccessful. The use of mainly socio-demographic and dwelling characteristics was not indicative. Predictive covariates were not shown to be significant, and the use of inactive covariates for describing the respondents showed no clear differences between the two classes.

However, these two different groups can be characterised based on their parameter estimates. The first class, a vast majority of 81% of the total sample, are likelier to choose alternatives with low hassle and a high profit. This first group prefers especially a low value for the attribute 'the length of disruption' and clearly, above all, wants the most 'profit'. While 'finding a contractor', 'information gathering' and 'subsidy and loan applications' are somewhat of similar importance as the next determinants for minimising. The hassle factor 'consulting a neighbour' is not found to be different among the classes, and even its effect in general, when using two classes, can be concluded not to be indicative. The second class is much less sensitive to hassle minimisation and profit maximisation. The second class prefers, above all, a low 'subsidy and loan application process', which is also not class unique but is significant and hence has the same value as in class one. The second most important determinant is minimising the amount of profit, which is an unexpected finding. Such findings are, however, also found when looking more closely at the values of the other attributes. The estimates 'length of disruption', 'finding a contractor' and 'information gathering' come sequentially next in order of importance, where the supposed hassle attribute 'finding a contractor' is actually preferred to be maximised instead of minimised. The standard error of all the values, except 'subsidy and loan applications' as that is a class-independent attribute, show extremely high values compared to their parameter estimates. These high standard errors occur due to the relatively small sample group of 19% of the total data (i.e. approximately 29 persons). A small group is hence more susceptible to measurement errors, which in this class heavily influences the reliability of the data. Due to this unreliability of the estimates, the willingness to accept indicators are not estimated for both individual classes.

7.2. Implications and recommendations

This study empirically concluded that the psychological barrier of the hassle factor influences homeowners' decision-making. This insight is useful for local governments, as it should be considered when trying to achieve the Dutch objectives for the heat transition. Hassles can collectively feel like a larger barrier than the monetary driver of expected profit. The Dutch heat transition can hence be hindered as hassles can lead to procrastination and inaction. Therefore, homeowners should not be seen as only economical driven for that sense, but rather also focused on ease. So, to reach the goal of (local) government(s), interventions to tackle hassles are needed to promote and accelerate the heat transition in the Netherlands.

Policymakers can implement these practices by reducing hurdles for homeowners. Specifically, it can be performed by decreasing the administrative burden of 'subsidy and loan applications' by prefilling in forms, decreasing the (complexity of) steps and stimulating the requests of applying for subsidies and loans (de Vries et al., 2020; Shahab & Lades, 2021; Thaler & Sunstein, 2009). Interventions could also be targeted at reducing the hassle of 'information provision' with convenient, concise and consistent information. Proving such information about energy savings, costs and necessities of different heat pump alternatives are ways to experience less hassle for homeowners (Broers et al., 2019; de Vries et al., 2020; Wilson et al., 2015). Possible other options should focus on decreasing the 'length of the disruption' and 'finding available contractors' and decreasing the barrier of 'neighbour consultation'. With these barriers, also business opportunities arise as contractors can focus on providing short 'disruption times' and increasing their publicity to be found faster by a wider public. More broadly speaking, consumer-centred services such as offering a one-stop shop can help decrease hassle (Bertoldi et al., 2021; de Vries et al., 2020; Tigchelaar, van Lidth de Jeude, et al., 2019). These businesses can take out the perceived hassle for homeowners by applying for subsidies and loans, finding a contractor, providing information and/or possibly engaging in discussions with neighbours. Other examples, such as creating a (digital) platform to connect contractors with homeowners offer useful services. Interest in these hassle-free packages exists, as concluded earlier by de Vries & Kooger (2020).

The value of time indicators for the specific hassles, found in Table 24, can be used as a tool by both businesses and governments to identify the appropriateness and profitability of providing such 'hassle-free' alternatives or interventions. It should be noted that these values provide the most usefulness for similar groups as the sample respondents of this study, which contained mainly highly educated and income respondents.

Aside from providing hassle-free alternatives, context differentiation can be used to decrease the perceived hassle, by using psychological barriers as an advantage in stimulating the heat transition. Proposed intervention tools to steer homeowners to choose more (societal) preferred alternatives are nudges and sludges. An example can be making use of social norms in creating comparisons between the negative externalities of natural gas heating and the sustainable benefits of heat pumps. These tricks can also be used to decrease the negative effect of the specific found hassles on adoption. Informational videos or checklists on which aspects someone should focus on can be used as nudges to inform homeowners on the most important aspects of adopting a heat pump. Profit is found to decrease how much hassle is perceived, which verifies that emphasising this gain can provide a lower perceived hassle. This effect decreases the negative influence of hassle on utility and thus provides higher adoption levels. Highlighting certain benefits can hence also be used as a nudge. Additionally, this insight can also be used to create an 'acceptable' level or threshold of hassle by decreasing or increasing the amount of profit for a homeowner through changing subsidy levels or prices for businesses.

To better understand the influence of nudge and sludge, audits are suggested by Sunstein (2020). Annual nudge and sludge audits are periodic reviews to help identify where and when sludge exists and if it needs to be reduced or increased (Shahab & Lades, 2021; Sunstein, 2020). These audits should be focused on (Shahab & Lades, 2021):

1) breaking up processes into required actions;
2) choosing appropriate methods;
3) recruiting relevant participants;
4) asking the right questions;
5) communicating the benefits of sludge audits.

This approach can provide policymakers and businesses with a way to identify the existence of practical (unnecessary) hassles. The effect of nudge and sludge is not always understood, so it requires careful consideration before applying it (Schmidt & Engelen, 2020; Sunstein, 2020). Within the population there are two groups which react differently (strongly and less strong) to the influence of hassle. An intervention to decrease the amount of hassle will hence not influence the whole population, but mainly the hassle sensitiveness group, roughly 81% of the total population. This unclear effect of interventions was also reinforced by the differences between the conscious and unconscious perceptions of hassle. People are to certain degrees unaware of their true preferences, and hence the existence of an unaware stimulus can affect a certain response. Too much emphasis on conscious perceptions might result in unexpected differences in the actual adoption. This difference between conscious and unconscious should be considered an extra dimension when intervening in this field.

7.3. Limitations

This research is subjected to theoretical and methodological limitations. The three main limitations are discussed.

7.3.1. Actual influences

The data collection made use of stated preference data. This type of data made the survey suspectable to a hypothetical bias. The use of fictional choice sets with attribute levels which are not tailored to specific home situations and do not have an opt-out option decreased the validity and representativeness of the true choice preferences of homeowners. Using five different hassle factors and the additionally included profit attribute in the choice/rating experiment primes the factors and can make homeowners more focused on hassle than they would be in real life. The attribute parameter estimates can hence be different in reality, even though several mitigation strategies were performed. This priming is possibly reinforced by situational cues or implied context from the respondents' environment, as it is found that these factors can influence decision-making. Lecouteux (2016) argues that a choice architect should frame the choices in a way that the true preference of a decision-maker can be pursued. However, not all factors regarding homeowner's decision-making can be presented as also the complexity of the choices, the expected completion rates, and the goal of this study should be taken into account. Furthermore, additional interviews with policymakers, homeowners or other interest groups could have improved the realism of the survey. However, based on this study's limited time scope, these extensions were not feasible and provided a pitfall for the chosen methods.

7.3.2. Representativeness considerations

This research's exploratory nature is highly suitable for discovering new findings (Schwab & Held, 2020). Nevertheless, due to the biased sample, the collected data cannot be considered an accurate representation of the actual homeowner population in the Netherlands. Filling in the survey can already be seen as a hassle, which made it less likely to find the influence of hassle in general. People might not fill in or complete the survey, which underrepresents the effects of hassle on the average population. That the survey is perceived as a hassle is visualised by the 44% of respondents who did not finish the survey. Additionally, the feedback and reactions retrieved during its distribution also indicated this presumption. The reactions differed from perceiving it as useful research, to finding extreme aversion, to finding the survey too complicated to fill in or to distribute (according to network gatekeepers).

7.3.3. Potential differences due to model estimation

The performed choice experiment is based on a RUM-based DCM. A RUM model assumes full rational behaviour and independence of the performance of other alternatives or reference levels. It is, however, questionable if such an assumption holds in homeowner decision-making, even if we assume hassles are known by households and taken into account in the expected utility. Chapter 3 concluded that homeowners do not act rationally but behave based on behavioural biases. A different model that takes to some degree this bounded rationality into account is the Random Regret Minimization (RRM) theory, where other alternatives and reference levels are important. Certain context differentiations can break this reference level's independence. RRM is based on the wish to avoid a situation where a non-chosen alternative turns out to be more attractive than the chosen one, which would cause regret (Chorus, 2010; Chorus et al., 2008, 2014). Underlying here is the fact that 'avoiding a loss' is more important than 'pursuing an equal gain', an assumption of loss aversion. Regret minimisation can hence also come in the form of regretting effort or time, for example. This behavioural economic perspective opens up the discussion if regret minimisation is an appropriate consideration for the hassle models. Regret aversion plays a role in cases where 1) respondents believe a choice is important; 2). choices are perceived as difficult; 3) respondents think they need to explain a choice (Zeelenberg & Pieters, 2007). If respondents actually feel these three aspects are unknown, it would be interesting to look at the model fit of estimated regret models. RUM models are by far the most used models and hence provide a proxy of the behaviour, other models, such as the RRM model, could possibly better explain the behaviour of homeowners. Application of the RRM model in this study was nevertheless not possible due to the inclusion of only two alternatives, which makes an RRM model similar to a RUM model (Chorus, 2010).

7.4. Further research

Based on this research, several future research topics are suggested. First, additional research based on studying the model fit using both an RRM model and a RUM model is proposed. The creation of a better fitting model can provide more reliable parameter estimates and explain homeowners' decision-making. Including an extra third alternative within the survey can provide the option to estimate both RRM and RUM models. A possible hybrid model of RUM and RRM can also be used, as these can outperform both RUM and RRM models in some instances (Chorus et al., 2014; Kim et al., 2014). Comparing these models can determine the best behavioural fit of the data.

Next, to better understand homeowners' decision-making, the influences of the found non-hassle effects can be further investigated using a Structural Equation Model (SEM). SEM allows for the study of direct and indirect effects by simultaneous estimation. The indirect effect of attributes through the hassle construct and its direct effect on utility can hence be estimated. An SEM helps account for endogeneity of these attributes and can explain the other non-hassle effects of non-monetary transaction costs. However, when including an SEM and an LCA, a hybrid choice model is also proposed to include in the estimation of the measurement errors of latent attitudes (Molin & Kroesen, 2022). Therefore, the parameter estimates can give new insights.

Furthermore, estimating a larger and more representative sample (possibly through revealed preference data) can provide exact and more reliable parameter estimates. These estimates and the different value of time indicators can be used to identify specific interventions to stimulate the adoption of heat pumps for hard-to-convince groups. These (hard-to-convince) groups are found based on the initial evidence of hassle sensitiveness within the population and are expected to be identifiable based on attitude differences. So, using these reliable group parameter estimates, possible next steps, such as intervention simulation with scenario modelling, can be done. A larger and representable sample can hence provide as a doorway to determining the effectiveness of interventions through simulation.

Extending the research field, the effects of hassles on other sustainable heating appliances or the effect on renters or members of homeowners' associations can provide a useful comparison. The effect of hassle on energy efficiency applications is rarely considered. So comparing hassle in field-specific research can, for example, determine if increasing the hassle of non-preferred alternatives (sludging) is more effective than decreasing hassle (nudging) within the heat transition. However, possibly other hassle factors not included in this study can be of influence. Examples of such hassles can be hassle subparts, hassles mentioned in Table 12 or additional hassles identified through new search terms within a literature review, such as 'effort', 'transaction costs', 'friction' and 'stress'.

Other research extensions can look at hassle during natural decision-making moments. These are moments such as household composition changes, planned renovations or heating system breakdowns. These natural or salient events are found to be influencing the perception of barriers of homeowners (Broers et al., 2019; Wilson et al., 2015). The perceived hassle is hence also expected to be influenced, and possibly those moments provide for better system intervention times.

Lastly, the difference between the conscious and unconscious influences on decision-making is a unique insight within this study. Exploring this difference can show why (possible) over- or underestimation of the effectiveness of interventions can be occurring.

8. Conclusion

This research has analysed the effect of (several) hassle factors on the decision-making of Dutch homeowners. Through the use of a literature review, interviews and a survey/choice experiment an overall conclusion to the research questions is found. The answer to each of the four sub-questions is discussed, which jointly answer the main research question.

1. *Which hassle factors influence homeowners' adoption of heat pumps?*

A literature review regarding the decision-making process of homeowners was performed to gain insights into the influences on homeowner adoption. In the literature review, it was concluded that homeowners do not base their decision solely on rational (economic) influences but are also sensitive to behavioural biases and psychological barriers. Here hassle can be a large trigger for inaction or delays.

Therefore, several hassle factors in scientific literature can be perceived as psychological barriers. Interviews were performed with experts to scope down to the decision-making process of heat pumps. Based on their insights, five main hassle factors were concluded that barrier the adoption process of heat pumps: 1) the length of disruption; 2) information gathering; 3) finding a contractor; 4) subsidy and loan applications; 5) consultation with neighbours. Other found barriers do either not play a (significant) role during the decision-making of heat pumps, can be seen as a sub-aspect of an overarching hassle factor or a consequence of hassle factors.

2. *How are hassle factors perceived by Dutch homeowners when adopting a heat pump?*

That hassle factors can be a barrier to the decision-making of homeowners is concluded in the first sub-question. This second sub-question investigated and proved that Dutch homeowners also perceived these factors as barriers. With the use of an online survey and rating experiment, homeowners were studied regarding their indicated conscious importance and their underlying unconscious preferences towards hassle. The outcomes of these two measurements differ from each other, which shows that hassle is perceived different consciously from unconsciously.

The directly conscious perceptions indicated a similar strength of the four hassle factors: 1) finding a contractor; 2) subsidy and loan applications; 3) the length of disruption; 4) information gathering. With the fifth hassle factor, 'consultation with neighbours', which is perceived as the least important one.

The indirectly unconscious perceptions indicated rather only a similar strength of the factors: 1) subsidy and loan applications; 2) information gathering; 3) finding a contractor. While the 'length of disruption' was significantly more important and 'consultation with neighbours' was again perceived as the least important of those five hassles. However, additionally, the amount of profit is seen as a negative influence. The amount of profit, which was the smallest in relative strength, showed a statistically significant de-hassling effect. This effect indicates that context, such as drivers, could help decrease or increase the perceived amount of hassle.

3. *How are hassle factors traded off by Dutch homeowners?*

Next to the perception of hassle, is the influence of this perceived hassle on Dutch homeowners' decision-making studied. With the help of a stated choice experiment, several choice sets were used to measure the relative importance of the several hassle attributes. These attributes were the five hassle factors of sub-question one that form a barrier in the decision-making process and the additional driver of financial profit. Homeowners trade off these hassle factors not as individual factors, but rather as one combined hassle factor. This combined hassle factor is more important than the amount of financial profit a homeowner will receive. Homeowners are, therefore, also heavily driven by ease in their decision-making process. The determination of several value of time indicators for the individual hassle factors in Table 24, shows the monetary value of the average respondent's willingness to accept for an increase in one hour (or day) of extra hassle.

4. *Which differences among homeowners can be identified based on how they trade off hassle factors?*

Additionally, a latent class analysis is performed to see if heterogeneous clusters within the population are existent, based on how they trade off hassle factors. Two different clusters of people were found. The first cluster, 81% of the sample, shows a rather large aversion to all hassle factors and a large preference for a high amount of profit. The smaller second cluster is much less sensitive to hassle and profit. These two findings indicate that interventions to decrease or increase hassle will influence the adoption behaviour within those groups differently. However, for the parameter 'subsidy and loan applications', this is untrue and it is concluded that a similar effect in both groups is expected. Also, the hassle factor 'consulting a neighbour' is not found to be different among the classes. Its effect, in general, can even be concluded not indicative. Efforts to further predict or describe the two clusters with the measured socio-demographics, dwelling characteristics and the covariate sustainable orientated showed to be inadequate.

To conclude, the answered sub-questions build upon each other in a way to answer the main research question: *"Which hassle factors are a barrier for Dutch homeowners to adopt a heat pump and to what extent do these factors influence homeowners' decision-making?"*. The empirical identification, specification and influence determination of hassle in this study makes a valuable insight for decision-making research to incorporate hassle as a behavioural barrier in the decision-making process of heat pumps. The perceptions of homeowners show that 'the length of disruption', 'information gathering', 'finding a contractor', 'subsidy and loan applications', and 'neighbours consultation' are perceived as hassles and the first three are even traded off differently among the two types of groups that exits in the population. Interventions to decrease the perceived amount of hassle can provide valuable accelerations for the Dutch heat transition. The perception of hassle can, aside from removing a barrier, also be influenced by the degree of profit and context differentiations via nudges and sludges. However, it should be noted that there are differences in conscious and unconscious perceptions of hassle, which makes interventions not completely predictable in their outcome.

The finding of the relative importance of the individual and combined hassle factor(s) as a barrier in a homeowner's decision-making process is empirical evidence for the influence of psychological decision-making.

References

AD. (2021, April 2). *Lange wachttijd voor mensen die huis willen verbouwen*. https://www.ad.nl/wonen/lange-wachttijd-voor-mensen-die-huis-willen-verbouwen~ab7ca75f/

Azizi, S., Nair, G., & Olofsson, T. (2019). Analysing the house-owners' perceptions on benefits and barriers of energy renovation in Swedish single-family houses. *Energy and Buildings*, *198*, 187–196. https://doi.org/10.1016/j.enbuild.2019.05.034

Bartczak, A., Chilton, S., Czajkowski, M., & Meyerhoff, J. (2017). Gain and loss of money in a choice experiment. The impact of financial loss aversion and risk preferences on willingness to pay to avoid renewable energy externalities. *Energy Economics*, *65*, 326–334. https://doi.org/10.1016/j.eneco.2017.04.020

Bertoldi, P., Boza-Kiss, B., Della Valle, N., & Economidou, M. (2021). The role of one-stop shops in energy renovation - a comparative analysis of OSSs cases in Europe. *Energy and Buildings*, *250*, 111273. https://doi.org/10.1016/j.enbuild.2021.111273

Boersema, W. (2021). *Ombudsman: Schadeproblematiek in Groningen is een nationale crisis, die een eigen minister verdient*. Trouw. https://www.trouw.nl/politiek/ombudsman-schadeproblematiek-in-groningen-is-een-nationale-crisis-die-een-eigen-minister-verdient~b0207540/?referrer=https%3A%2F%2Fen.wikipedia.org%2F&utm_source=link&utm_medium=social&utm_campaign=shared_earned

Bos, I., Van der Heijden, R., Molin, E., & Timmermans, H. (2004). The Choice of Park and Ride Facilities: An Analysis Using a Context-Dependent Hierarchical Choice Experiment. *Environment and Planning A: Economy and Space*, *36*(9), 1673–1686. https://doi.org/10.1068/a36138

Broers, W. M. H. M. H., Vasseur, V., Kemp, R., Abujidi, N., & Vroon, Z. A. E. P. A. E. P. (2019). Decided or divided? An empirical analysis of the decision-making process of Dutch homeowners for energy renovation measures. *Energy Research & Social Science*, *58*, 101284. https://linkinghub.elsevier.com/retrieve/pii/S221462961930283X

Calcasa. (2021, May 25). *2021 Q1 WOX kwartaalbericht: Vergroening Nederlandse woningmarkt heeft nog lange weg te gaan*. Calcasa. https://www.calcasa.nl/nieuws/2021-q1-wox-kwartaalbericht-vergroening-nederlandse-woningmarkt-heeft-nog-lange-weg-te-gaan

CBS. (2020). *Inkomen van huishoudens; inkomensklassen, huishoudenskenmerken*. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83932NED/table? ts=1565008102724

CBS. (2021a). *Arbeidsdeelname; kerncijfers*. https://opendata.cbs.nl/#/CBS/nl/dataset/82309NED/table?ts=1651672250000

CBS. (2021b). *Bevolking; geslacht, leeftijd en burgerlijke staat, 1 januari*. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/7461BEV/table?fromstatweb

CBS. (2021c). *Bevolking; onderwijsniveau en –richting 2003-2021*. https://opendata.cbs.nl/#/CBS/nl/dataset/82816NED/table?searchKeywords=opleidingsniveau

CBS. (2021d). *Voorraad woningen; eigendom, type verhuurder, bewoning, regio*. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82900NED/table?fromstatweb

CBS. (2021e). *Voorraad woningen; gemiddeld oppervlak; woningtype, bouwjaarklasse, regio*. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82550NED/table?ts=1651158545114

CBS. (2021f). *Voorraad woningen; woningtype, oppervlakteklasse, regio*.

https://opendata.cbs.nl/statline/#/CBS/nl/dataset/83704NED/table?ts=1654261784095

CBS. (2021g). *Woningvoorraad; woningtype op 1 januari, regio*. https://opendata.cbs.nl/#/CBS/nl/dataset/85035NED/table

Chartrand, T. L., Huber, J., Shiv, B., & Tanner, R. J. (2008). Nonconscious Goals and Consumer Choice. *Journal of Consumer Research*, *35*(2), 189–201. https://doi.org/10.1086/588685

Chen, Q., Romich, E., Cruse, A., Gorzitze, A., Shi, H., & Zhao, L. (2019). SURVEYING THE EDGES: HOMEOWNERS' PERSPECTIVES ON RESIDENTIAL ENERGY EFFICIENCY AND RENEWABLE ENERGY IMPROVEMENTS IN OHIO. *Journal of Green Building*, *14*(1), 111–130. https://doi.org/10.3992/1943-4618.14.1.111

ChoiceMetrics. (2021). *Ngene 1.3 user manual & reference guide*. http://www.choice-metrics.com/NgeneManual130.pdf

Chorus, C. (2010). A new model of random regret minimization. *European Journal of Transport and Infrastructure Research*, *10*(2), 181–196. https://doi.org/10.18757/EJTIR.2010.10.2.2881

Chorus, C., Arentze, T., & Timmermans, H. (2008). A Random Regret-Minimization model of travel choice. *Transportation Research Part B: Methodological*, *42*(1), 1–18. https://doi.org/10.1016/j.trb.2007.05.004

Chorus, C., van Cranenburgh, S., & Dekker, T. (2014). Random regret minimization for consumer choice modeling: Assessment of empirical evidence. *Journal of Business Research*, *67*(11), 2428–2436. https://doi.org/10.1016/j.jbusres.2014.02.010

Citisens. (2020). *Draagvlak voor aardgasvrij wonen*. https://www.citisens.nl/kennis/whitepaper-draagvlak-aardgasvrij-wonen/

City of Amsterdam. (n.d.). *Financing and expenses of home ownership*. Retrieved July 28, 2022, from https://www.amsterdam.nl/en/housing/financing-own-home/

de Vries, G., & Kooger, R. (2020). *Groen en Gemak onder één dak : hoe ontzorg je bewoners bij het nemen van duurzame beslissingen in en om het huis ?* (Issue april).

de Vries, G., Rietkerk, M., & Kooger, R. (2020). The Hassle Factor as a Psychological Barrier to a Green Home. *Journal of Consumer Policy*, *43*(2), 345–352. https://doi.org/10.1007/S10603-019-09410-7/TABLES/1

DECC. (2011). *Understanding Potential Consumer Response to the Green Deal*. http://www.decc.gov.uk/en/content/cms/consultations/green_deal/green_deal.aspx

DECC. (2013). *Removing the hassle factor associated with loft insulation : Results of a behavioural trial*. *September*, 1–5. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48123/2135-behaviour-change-and-energy-

Drysdale, D., Mathiesen, B. V., & Paardekooper, S. (2019). Transitioning to a 100% renewable energy system in Denmark by 2050: assessing the impact from expanding the building stock at the same time. *Energy Efficiency*, *12*(1), 37–55. https://doi.org/10.1007/S12053-018-9649-1/TABLES/8

Du, H., Han, Q., & de Vries, B. (2022). Modelling energy-efficient renovation adoption and diffusion process for households: A review and a way forward. *Sustainable Cities and Society*, *77*, 103560. https://doi.org/10.1016/j.scs.2021.103560

Ebrahimigharehbaghi, S. (2022). *Understanding the decision-making process in homeowner energy* *retrofits: From behavioural and transaction cost perspectives* [TU Delft]. https://doi.org/https://doi.org/10.7480/abe.2022.06

Ebrahimigharehbaghi, S., Qian, Q. K., de Vries, G., & Visscher, H. J. (2021). Identification of the behavioural factors in the decision-making processes of the energy efficiency renovations: Dutch homeowners. *Building Research & Information*, 1–25. https://doi.org/10.1080/09613218.2021.1929808

Ebrahimigharehbaghi, S., Qian, Q. K., de Vries, G., & Visscher, H. J. (2022). Application of cumulative prospect theory in understanding energy retrofit decision: A study of homeowners in the Netherlands. *Energy and Buildings*, *261*, 111958. https://doi.org/10.1016/J.ENBUILD.2022.111958

Ebrahimigharehbaghi, S., Qian, Q. K., Meijer, F. M., & Visscher, H. J. (2019). Unravelling Dutch homeowners' behaviour towards energy efficiency renovations: What drives and hinders their decision-making? *Energy Policy*, *129*, 546–561. https://doi.org/10.1016/J.ENPOL.2019.02.046

Ebrahimigharehbaghi, S., Qian, Q. K., Meijer, F. M., & Visscher, H. J. (2020). Transaction costs as a barrier in the renovation decision-making process: A study of homeowners in the Netherlands. *Energy and Buildings*, *215*, 109849. https://doi.org/10.1016/J.ENBUILD.2020.109849

Edgar, T. W., & Manz, D. O. (2017). Exploratory Study. *Research Methods for Cyber Security*, 95–130. https://doi.org/10.1016/B978-0-12-805349-2.00004-2

EenVandaag. (2022, May 17). *5 vragen aan installateur Patrick Schimmel over de hybride warmtepomp | NPO Radio 1*. NPO Radio 1. https://www.nporadio1.nl/nieuws/binnenland/c4b41b78-9fe5-40a6-8e6c-e6bd748bb440/5-vragen-aan-installateur-patrick-schimmel-over-de-hybride-warmtepomp

Enpuls. (2018). *Duurzaam verwarmen*. https://www.enpuls.nl/duurzaam-verwarmen/

European Commission. (2020). *State of the Union: Commission raises climate ambition and proposes 55% cut in emissions by 2030*. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1599

Friege, J., & Chappin, E. (2014). Modelling decisions on energy-efficient renovations: A review. *Renewable and Sustainable Energy Reviews*, *39*, 196–208. https://doi.org/10.1016/J.RSER.2014.07.091

Frost, J. (n.d.). *How to Interpret Regression Models that have Significant Variables but a Low R-squared - Statistics By Jim*. Retrieved July 4, 2022, from https://statisticsbyjim.com/regression/low-r-squared-regression/

Geurts, L. (2022, May 17). Kabinet wil dat warmtepomp standaard wordt voor verwarmen woningen - NRC. *NRC*. https://www.nrc.nl/nieuws/2022/05/17/kabinet-wil-dat-warmtepomp-standaard-wordt-voor-verwarmen-woningen-a4124620

Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *American Psychologist*, *66*(4), 290–302. https://doi.org/10.1037/a0023566

Gillingham, K., Newell, R. G., & Palmer, K. (2009). Energy Efficiency Economics and Policy. *Annual Review of Resource Economics*, *1*(1), 597–620. https://doi.org/10.1146/annurev.resource.102308.124234

Gillingham, K., & Palmer, K. (2014). Bridging the Energy Efficiency Gap: Policy Insights from Economic Theory and Empirical Evidence. *Review of Environmental Economics and Policy*, *8*(1), 18–38.

https://doi.org/10.1093/reep/ret021

Government of the Netherlands. (2019). *Climate Agreement*. https://www.government.nl/documents/reports/2019/06/28/climate-agreement

Grutters, J. P. C., Kessels, A. G. H., Dirksen, C. D., Van Helvoort-Postulart, D., Anteunis, L. J. C., & Joore, M. A. (2008). *Willingness to Accept versus Willingness to Pay in a Discrete Choice Experiment*. https://doi.org/10.1111/j.1524-4733.2008.00340.x

Hage, J. (2019, December 20). *Installatie warmtepomp Installatie*. Consumenten Bond. https://www.consumentenbond.nl/warmtepomp/installatie-warmtepomp

Haghani, M., Bliemer, M. C. J., Rose, J. M., Oppewal, H., & Lancsar, E. (2021). Hypothetical bias in stated choice experiments: Part II. Conceptualisation of external validity, sources and explanations of bias and effectiveness of mitigation methods. *Journal of Choice Modelling*, *41*, 100322. https://doi.org/10.1016/j.jocm.2021.100322

Heine, S. J., Lehman, D. R., Peng, K., & Greenholtz, J. (2002). What's wrong with cross-cultural comparisons of subjective Likert scales?: The reference-group effect. *Journal of Personality and Social Psychology*, *82*(6), 903–918. https://doi.org/10.1037/0022-3514.82.6.903

Heiner, R. A. (1983). The Origin of Predictable Behavior. *American Economic Review*, *73*(4), 560–595. https://econpapers.repec.org/RePEc:aea:aecrev:v:73:y:1983:i:4:p:560-95

Helveston, J. P., Feit, E. M. D., & Michalek, J. J. (2018). Pooling stated and revealed preference data in the presence of RP endogeneity. *Transportation Research Part B: Methodological*, *109*, 70–89. https://doi.org/10.1016/J.TRB.2018.01.010

Hess, S., Rose, J. M., & Polak, J. (2010). Non-trading, lexicographic and inconsistent behaviour in stated choice data. *Transportation Research Part D: Transport and Environment*, *15*(7), 405–417. https://doi.org/10.1016/J.TRD.2010.04.008

Hesselink, L. X. W., & Chappin, E. J. L. (2019). Adoption of energy efficient technologies by households – Barriers, policies and agent-based modelling studies. *Renewable and Sustainable Energy Reviews*, *99*, 29–41. https://doi.org/10.1016/J.RSER.2018.09.031

Hoffman, A. J., & Henn, R. (2008). Overcoming the Social and Psychological Barriers to Green Building. *Organization & Environment*, *21*(4), 390–419. https://doi.org/10.1177/1086026608326129

Huijts, N., Molin, E., & Steg, L. (2012). Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework. *Renewable and Sustainable Energy Reviews*, *16*(1), 525–531. https://doi.org/10.1016/J.RSER.2011.08.018

Hünecke, K., Braungardt, S., Schumacher, K., Thema, J., Adisorn, T., Lütkehaus, H., & Tholen, L. (2019). What role do transaction costs play in energy efficiency improvements and how can they be reduced? *Eceee Summer Study Proceedings*, *2019-June*, 675–684.

Iyengar, S. S., & Lepper, M. R. (2000). When choice is demotivating: Can one desire too much of a good thing? *Journal of Personality and Social Psychology*, *79*(6), 995–1006. https://doi.org/10.1037/0022-3514.79.6.995

Jansma, S. R., Gosselt, J. F., & de Jong, M. D. T. (2020). Kissing natural gas goodbye? Homeowner versus tenant perceptions of the transition towards sustainable heat in the Netherlands. *Energy Research & Social Science*, *69*, 101694. https://doi.org/10.1016/J.ERSS.2020.101694

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263. https://doi.org/10.2307/1914185

Kaiser, H. F. (1960). The Application of Electronic Computers to Factor Analysis. *Educational and Psychological Measurement*, *20*(1), 141–151. https://doi.org/10.1177/001316446002000116

Kanner, A. D., Coyne, J. C., Schaefer, C., & Lazarus, R. S. (1981). Comparison of two modes of stress measurement: Daily hassles and uplifts versus major life events. *Journal of Behavioral Medicine*, *4*(1), 1–39. https://doi.org/10.1007/BF00844845

Kelly, J. A., Fu, M., & Clinch, J. P. (2016). Residential home heating: The potential for air source heat pump technologies as an alternative to solid and liquid fuels. *Energy Policy*, *98*, 431–442. https://doi.org/10.1016/J.ENPOL.2016.09.016

Kieft, A., Harmsen, R., & Hekkert, M. P. (2021). Heat pumps in the existing Dutch housing stock: An assessment of its Technological Innovation System. *Sustainable Energy Technologies and Assessments*, *44*, 101064. https://doi.org/10.1016/j.seta.2021.101064

Kim, J., Rasouli, S., & Timmermans, H. (2014). Hybrid Choice Models: Principles and Recent Progress Incorporating Social Influence and Nonlinear Utility Functions. *Procedia Environmental Sciences*, *22*, 20–34. https://doi.org/10.1016/j.proenv.2014.11.003

Kleefkens, O. (2019). *Status rapportage warmtepompen*. https://www.rvo.nl/sites/default/files/2019/01/Status rapportage warmtepompen.pdf

Klockner, C. A., & Nayum, A. (2016). Specific barriers and drivers in different stages of decision-making about energy efficiency upgrades in private homes. *Frontiers in Psychology*, *7*(SEP), 1362. https://doi.org/10.3389/FPSYG.2016.01362/BIBTEX

Koning, N. de, Kooger, R., Hermans, L., & Tigchelaar, C. (2020). *Aardgasvrij wonen: drijfveren en barrières van bewoners*.

Kraan, J. (2022, March 11). *Huis verduurzamen ondanks subsidies vaak onhaalbaar voor lagere inkomens*. NU.Nl. https://www.nu.nl/klimaat/6188590/huis-verduurzamen-ondanks-subsidies-vaak-onhaalbaar-voor-lagere-inkomens.html

Kushi, O. (2021, October 14). *Does Greater Educational Achievement Increase the Likelihood of Homeownership?* First American. https://blog.firstam.com/economics/does-greater-educational-achievement-increase-the-likelihood-of-homeownership

Lades, L. K., Peter Clinch, J., & Kelly, J. A. (2021). Maybe tomorrow: How burdens and biases impede energy-efficiency investments. *Energy Research & Social Science*, *78*, 102154. https://doi.org/10.1016/j.erss.2021.102154

Lecouteux, G. (2016). From Homo Economicus to Homo Psychologicus. *OEconomia*, *6–2*, 175–200. https://doi.org/10.4000/oeconomia.2324

Li, P.-H., Keppo, I., & Strachan, N. (2018). Incorporating homeowners' preferences of heating technologies in the UK TIMES model. *Energy*, *148*, 716–727. https://doi.org/10.1016/j.energy.2018.01.150

López Rodríguez, R., Durán Villa, F. R., & Piñeira Mantiñán, M. J. (2021). The Lessons of Public–Private Collaboration for Energy Regeneration in a Spanish City. The Case of Txantrea Neighbourhood (Pamplona). *Sustainability*, *13*(4), 1610. https://doi.org/10.3390/su13041610

Meles, T. H., Ryan, L., & Mukherjee, S. C. (2022). Heterogeneity in preferences for renewable home heating systems among Irish households. *Applied Energy*, *307*, 118219. https://doi.org/10.1016/j.apenergy.2021.118219

Milieu Centraal. (n.d.). *Warmtepomp: tips en stappenplan*. Retrieved June 29, 2022, from https://www.milieucentraal.nl/energie-besparen/duurzaam-verwarmen-en-koelen/warmtepomp-duurzaam-elektrisch-verwarmen/#hoe-werkt-een-warmtepomp-op-buitenlucht

Milieu Centraal. (2022a). *Hybride warmtepomp*. https://www.milieucentraal.nl/energie-besparen/duurzaam-verwarmen-en-koelen/hybride-warmtepomp/

Milieu Centraal. (2022b). *Volledig elektrische warmtepomp*. https://www.milieucentraal.nl/energie-besparen/duurzaam-verwarmen-en-koelen/volledige-warmtepomp/

Molin, E., & Kroesen, M. (2022). Train travel in corona time: Safety perceptions of and support for policy measures. *Transportation Research Part A: Policy and Practice*, *158*, 196–209. https://doi.org/10.1016/j.tra.2022.03.005

Molin, E., & Timmermans, H. (2009). Hierarchical Information Integration Experiments and Integrated Choice Experiments. *Transport Reviews*, *29*(5), 635–655. https://doi.org/10.1080/01441640902829470

Nava-Guerrero, G. del C., Hansen, H. H., Korevaar, G., & Lukszo, Z. (2022). An agent-based exploration of the effect of multi-criteria decisions on complex socio-technical heat transitions. *Applied Energy*, *306*, 118118. https://doi.org/10.1016/J.APENERGY.2021.118118

Nava Guerrero, G. del C., Korevaar, G., Hansen, H. H., & Lukszo, Z. (2019). Agent-Based Modeling of a Thermal Energy Transition in the Built Environment. *Energies 2019, Vol. 12, Page 856*, *12*(5), 856. https://doi.org/10.3390/EN12050856

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, *84*(3), 231–259. https://doi.org/10.1037/0033-295X.84.3.231

NOS. (2017, December 4). *"Tekort aan technici brengt energiedoelstellingen in gevaar" | NOS*. https://nos.nl/artikel/2205931-tekort-aan-technici-brengt-energiedoelstellingen-in-gevaar

NOS. (2022, May 17). *Warmtepompen in 2026: realisatie afhankelijk van kosten en genoeg personeel*. https://nos.nl/artikel/2429171-warmtepompen-in-2026-realisatie-afhankelijk-van-kosten-en-genoeg-personeel

Ossokina, I. V., Kerperien, S., & Arentze, T. A. (2021). Does information encourage or discourage tenants to accept energy retrofitting of homes? *Energy Economics*, *103*, 105534. https://doi.org/10.1016/j.eneco.2021.105534

Pettifor, H., Wilson, C., & Chryssochoidis, G. (2015). The appeal of the green deal: Empirical evidence for the influence of energy efficiency policy on renovating homeowners. *Energy Policy*, *79*, 161–176. https://doi.org/10.1016/j.enpol.2015.01.015

Qiu, Y., Colson, G., & Grebitus, C. (2014). Risk preferences and purchase of energy-efficient technologies in the residential sector. *Ecological Economics*, *107*, 216–229. https://doi.org/10.1016/j.ecolecon.2014.09.002

Rijksoverheid. (2022). *Bedragen minimumloon 2022*. https://www.rijksoverheid.nl/onderwerpen/minimumloon/bedragen-minimumloon/bedragen-minimumloon-2022

Rogers, E. M. (2003). The innovation-decision process. *Diffusion of Innovations*, 168–218. https://www.scopus.com/inward/record.uri?eid=2-s2.0-79954997010&partnerID=40&md5=6956e5be62bda8bdcbdf90c290b047de

Rose, J. M., & Bliemer, M. C. J. (2009). Constructing Efficient Stated Choice Experimental Designs. *Transport Reviews*, *29*(5), 587–617. https://doi.org/10.1080/01441640902827623

Rovers, V., Kooger, R., & Tigchelaar, C. (2021). *Evaluatie Subsidieregeling Energiebesparing Eigen Huis 2016-2020 | TNO Publications*. https://repository.tno.nl/islandora/object/uuid%3A1ff24846-c589-49e2-8a13-af93377d4fe3

RVO. (2017). *Samen aan de slag met aardgasvrij Inspiratie voor gemeenten*. https://www.hieropgewekt.nl/uploads/inline/Start Aardgasvrij_inspiratie voor gemeenten.pdf

RVO. (2021, April 20). *Transitievisie Warmte en Wijkuitvoeringsplan*. https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/duurzame-energie-opwekken/aardgasvrij/transitievisie-warmte-en-wijkuitvoeringsplan

RVO. (2022, February 8). *ISDE: Stand van zaken budget*. RVO. https://www.rvo.nl/subsidies-financiering/isde/budget#stand-van-zaken-2021

Sanguinetti, A., Outcault, S., Alston-Stepnitz, E., Moezzi, M., & Ingle, A. (2021). Residential solar water heating: California adopters and their experiences. *Renewable Energy*, *170*, 1081–1095. https://doi.org/10.1016/j.renene.2021.02.031

Schillemans, T., & de Vries, G. (2016). De Homo Psychologicus op het Schip van Staat. *Bestuurskunde*, *3*. https://pure.tudelft.nl/ws/files/11231784/Schillemans_en_de_Vries_2016.pdf

Schleich, J., Gassmann, X., Faure, C., & Meissner, T. (2016). Making the implicit explicit: A look inside the implicit discount rate. *Energy Policy*, *97*, 321–331. https://doi.org/10.1016/J.ENPOL.2016.07.044

Schleich, J., Guetlein, M.-C., Tu, G., & Faure, C. (2022). Household preferences for private versus public subsidies for new heating systems: insights from a multi-country discrete choice experiment. *Applied Economics*, 1–18. https://doi.org/10.1080/00036846.2022.2030043

Schmidt, A. T., & Engelen, B. (2020). The ethics of nudging: An overview. *Philosophy Compass*, *15*(4), e12658. https://doi.org/10.1111/phc3.12658

Schwab, S., & Held, L. (2020). Different worlds Confirmatory versus exploratory research. *Significance*, *17*(2), 8–9. https://doi.org/10.1111/1740-9713.01369

Shafir, E., & Mullainathan, S. (2013). *Scarcity: Why Having Too Little Means So Much*. New York: Henry Holt and Company.

Shahab, S., & Lades, L. K. (2021). Sludge and transaction costs. *Behavioural Public Policy*, 1–22. https://doi.org/10.1017/bpp.2021.12

Simon, H. A. (1955). A Behavioral Model of Rational Choice. *Source: The Quarterly Journal of Economics*, *69*(1), 99–118. https://about.jstor.org/terms

Snape, J. R., Boait, P. J., & Rylatt, R. M. (2015). Will domestic consumers take up the renewable heat incentive? An analysis of the barriers to heat pump adoption using agent-based modelling. *Energy Policy*, *85*, 32–38. https://doi.org/10.1016/j.enpol.2015.05.008

Stadelmann, M. (2017). Mind the gap? Critically reviewing the energy efficiency gap with empirical evidence. *Energy Research & Social Science*, *27*, 117–128. https://doi.org/10.1016/j.erss.2017.03.006

Stankuniene, G. (2021). Energy saving in households: A systematic literature review. *European Journal of Interdisciplinary Studies*, *13*(1–5), 45–57. https://doi.org/10.24818/ejis.2021.04

Stieß, I., & Dunkelberg, E. (2013). Objectives, barriers and occasions for energy efficient refurbishment by private homeowners. *Journal of Cleaner Production*, *48*, 250–259. https://doi.org/10.1016/j.jclepro.2012.09.041

Streimikiene, D., & Balezentis, T. (2020). Willingness to Pay for Renovation of Multi-Flat Buildings and to Share the Costs of Renovation. *Energies*, *13*(11), 2721. https://doi.org/10.3390/en13112721

Sunstein, C. R. (2020). Sludge Audits. *Behavioural Public Policy*, 1–20. https://doi.org/10.1017/bpp.2019.32

Thaler, R. H., & Mullainathan, S. (n.d.). *Behavioral Economics*. The Library of Economics and Liberty. Retrieved June 20, 2022, from https://www.econlib.org/library/Enc/BehavioralEconomics.html

Thaler, R. H., & Sunstein, C. R. (2009). *NUDGE: Improving Decisions About Health, Wealth, and Happiness*. Yale University press.

Thijssen, R., van Duist, L., Bot, W., van der Werf. G, & Verheggen, P. P. (2020). Vijf tinten groener. In *Motivaction*.

Tigchelaar, C., Kooger, R., Lidth de Jeude, M., Niessink, R., Koning, N. d., & Paradies, G. (2019). *Alle bestaande woningen aardgasvrij in 2050. Wie moet wat, wanneer en hoe doen?*

Tigchelaar, C., van Lidth de Jeude, M., Niessink, R. J. M., Kooger, R., de Koning, N. M., & Paradies, G. L. (2019). How earthquakes shook up Dutch energy policy: an overview on who should do what, when and how to renovate 99% of all Dutch houses in the next 30 years. *Proceedings ECEEE Summer Study on Energy Efficiency: Is Efficient Sufficient?*, 1167. https://repository.tno.nl/islandora/object/uuid%3Ab93ba447-b751-4911-92ae-a7d268b02cd8

Train, K. E. (2009). *Discrete Choice Methods with Simulation* (Second Edi, Vol. 9780521766). Cambridge University Press. https://www.cambridge.org/core/books/discrete-choice-methods-with-simulation/49CABD00F3DDDA088A8FBFAAAD7E9546

van Dijke, W. (2019, May 3). *Helft gezinnen maakte huis zuiniger: bekijk hoe groen jouw buurt is*. RTL Nieuws. https://www.rtlnieuws.nl/nieuws/nederland/artikel/4676076/helft-gezinnen-maakte-huis-zuiniger-bekijk-jouw-buurt-zonnepanelen

Vereniging eigen huis. (2022). *Veelgestelde vragen over de all-electric warmtepomp*. https://www.eigenhuis.nl/energie/maatregelen/duurzaam-verwarmen/warmtepomp/all-electric-warmtepomp#/

Vermunt, J., & Magidson, J. (2002). Latent class cluster anlaysis. In J. Hagenaars & A. McCutcheon (Eds.), *Applied latent class analysis* (pp. 89–106). Cambridge University Press. https://pure.uvt.nl/ws/portalfiles/portal/487979/hagenaars2002b.pdf

Verplanken, B., & Whitmarsh, L. (2021). Habit and climate change. *Current Opinion in Behavioral Sciences*, *42*, 42–46. https://doi.org/10.1016/J.COBEHA.2021.02.020

Voskuyl, J. (2021). *Homeowners' preferences regarding sustainable residential heating systems*. TU Delft.

Walker, J. L., Wang, Y., Thorhauge, M., & Ben-Akiva, M. (2018). D-efficient or deficient? A robustness analysis of stated choice experimental designs. *Theory and Decision*, *84*(2), 215–238. https://doi.org/10.1007/S11238-017-9647-3/FIGURES/6

Webster, J., & Watson, R. T. (2002). Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, *26*(2), xiii–xxiii. http://www.jstor.org/stable/4132319

Wilson, C., Crane, L., & Chryssochoidis, G. (2015). Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. *Energy Research & Social Science*, *7*, 12–22. https://doi.org/10.1016/J.ERSS.2015.03.002

Wilson, C., Pettifor, H., & Chryssochoidis, G. (2018). Quantitative modelling of why and how homeowners decide to renovate energy efficiently. *Applied Energy*, *212*, 1333–1344. https://doi.org/10.1016/J.APENERGY.2017.11.099

Worthington, R. L., & Whittaker, T. A. (2006). Scale Development Research: A Content Analysis and Recommendations for Best Practices. *The Counseling Psychologist*, *34*(6), 806–838. https://doi.org/10.1177/0011000006288127

Yong, A. G., & Pearce, S. (2013). A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis. *Tutorials in Quantitative Methods for Psychology*, *9*(2), 79–94. https://doi.org/10.20982/tqmp.09.2.p079

Zeelenberg, M., & Pieters, R. (2007). A Theory of Regret Regulation 1.0. *Journal of Consumer Psychology*, *17*(1), 3–18. https://doi.org/10.1207/S15327663JCP1701_3

Zey, M. A. (2015). Rational Choice and Organization Theory. *International Encyclopedia of the Social & Behavioral Sciences: Second Edition*, 892–895. https://doi.org/10.1016/B978-0-08-097086-8.73109-6

Appendix A – Summary expert interviews

TNO

- *Making a neighbourhood natural gas-free is a process in which residents go through different steps individually. This process begins with 'Becoming aware of natural gas-free as an issue' (Step 1) and ends with 'Becoming an ambassador' (Step 9). Residents find themselves at different steps of the customer journey. They can get stuck at each step if there is not enough of a reason to move on to the next one. Residents don't act solely on financial aspects. Their behaviour is influenced by the drivers and barriers in each step. The distribution of drivers and barriers across the different steps of the customer journey provides starting points on the type of information and support that residents need (Koning et al., 2020).*
- *There are many different sustainable solutions. People want to know what is the best solution considering their personal situation (their house and their personal drivers) and the plans of the municipality. There is uncertainty about the choices to be made.*
- *Additionally, the lack of contractors makes the installation of heat pumps difficult (NOS, 2022).*
- *Additional barriers in the decision-making process can be:*
    - *Concerns about the disturbance of the installation; a noisy renovation or lots of people passing through (Koning et al., 2020).*
    - *Application process of subsidies. To facilitate the grant application process, a counter could be set up where homeowners can get support, for example through collective applications by intermediary organizations, and where both the subsidy and an energy-saving loan can be taken out (Rovers et al., 2021).*
    - *Perception of the noise a heat pump generates (Koning et al., 2020).*
    - *Cleaning up a house or loft before the actual renovation (de Vries & Kooger, 2020).*
- *Value based design can be helpful; exploring the core psychological values that are important to people, the real drivers or motivators of people. From there, energy products and services can be designed that correctly address these drivers.*
- *New drivers to adopt natural gas-free solutions may be added. E.g. solidarity for people suffering from the war in Ukraine can now be a driver. In earlier research solidarity with the people in Groningen was found as a driver (Koning et al., 2020).*

Klimaatroute

- *Online there is not much reliable information about heat pumps, it is easier to find complaints. Noise complaints are an example, which might result in discussions with a neighbour depending on the relationship. However, current heat pumps do not produce that much noise.*
- *There is a lack of contractors to install a heat pump. People can have to wait over a year to get a heat pump installed. At the same time, contractors do not always want to be re-schooled in installing a heat pump. Additionally, there is a lack of heat pumps due to a global chip shortage.*
- *Subsidy and loan applications are a barrier for households. For example, you can only retrieve the subsidy after having paid the contractor. Partly because of this, low-income households have it more difficult to buy a heat pump.*
- *The costs of an all-electric heat pump are around €10.000 with a possible subsidy of €3.000, while a hybrid heat pump is €4.000 with a subsidy of €1.800.*
- *Buying a heat pump is a conscious step for households, where the influence of social peers can help give confidence to the business case. People have difficulty looking over a period of 10 years or more, especially as you do not see the effect of buying a heat pump on house prices, due to the current housing climate. However, due to governmental influence, gas prices are expected to keep on an elevated level.*
- *The disruption of a household is minimal for the single instalment of a heat pump. The disruption is much higher when additional renovations are being performed.*
- *Cleaning a room in order to do renovations is often not considered a barrier.*
- *There is similar or less maintenance with a heat pump than with a natural gas boiler.*
- *Additional barriers for households can be:*
    - *The extra needed space, especially for all-electric heat pumps with a buffer vessel.*
    - *That heat pumps do not fit in the neighbourhood aesthetics.*
    - *The idea of heat pumps being a new development, which is the contrary.*

Appendix B – Additional information regarding literature review

Table 25. Additional information regarding literature review

Article	Country	Application	Main type of study	Respondents
1	Ireland	Renewable heating system	Discrete Choice Experiment	408
2	-	Energy-efficient renovations	Literature study	-
3	Poland, Sweden, United Kingdom	New heating system	Discrete Choice Experiment	1963
4	United States	Solar water heater	Survey	227
5	-	Sustainability measures	Literature study	-
6	Netherlands	Renovations	Survey	3776
7	United States	Energy efficiency measures and renewable energy systems	Survey	519
8	Sweden	Energy renovation	Survey	443
9	Netherlands	Energy-efficient renovations	Survey	2784
10	-	Energy-efficiency measures	Literature study	-
11	Norway	Energy-efficient renovations	Survey	3787
12	United Kingdom	Heat pumps	Agent-based model	-
13	United Kingdom	Energy-efficient renovations	Repeated survey	1028 and 502
14	-	Energy-efficient renovations	Literature study	-
15	United States	Energy-efficiency measures	Survey	432
16	Germany	Energy-efficient refurbishment	Survey	1008

Where: 1). Meles et al. (2022); 2). Du et al. (2022); 3). Schleich et al. (2022); 4). Sanguinetti et al. (2021); 5). de Vries et al. (2020); 6). Ebrahimigharehbaghi et al. (2020); 7). Chen et al. (2019); 8). Azizi et al. (2019); 9). Ebrahimigharehbaghi et al. (2019); 10). Hesselink & Chappin (2019); 11). Klockner & Nayum (2016); 12). Snape et al. (2015); 13). Pettifor et al. (2015); 14). Wilson et al. (2015); 15). Qiu et al. (2014); 16). Stieß & Dunkelberg (2013).

Appendix C – Ngene syntax

```
design
;alts = alt1*, alt2*
;rows=12
;eff = (mnl,d)
;block= 2
;model:
U(alt1) =       b1[-0.01]*disruption[0,1,2] +
                b2[-0.01]*information[0,1,2] +
                b3[-0.01]*contractor[0,1,2] +
                b4[-0.01]*subsidy[0,1,2] +
                b5[-0.01]*neighbours[0,1,2] +
                b6[0.01]*profit[0,1,2]/
U(alt2) =       b1*disruption +
                b2*information +
                b3*contractor +
                b4*subsidy+
                b5*neighbours +
                b6*profit
$
```

Table 26. Accompanied explanation of coding used within Ngene syntax

Factor	0	1	2
Length of disruption	1 day	4 days	7 days
Information gathering	1 hour	5,5 hours	10 hours
Finding a contractor	2 hours	5 hours	8 hours
Subsidy and loan applications	1 hour	5 hours	9 hours
Neighbours consultation	0 hours	2 hours	4 hours
Profit	€ 0	€ 3000	€ 6000

Appendix D – Experimental design

Table 27. Experimental design

Choice situation	LengA	InfoA	ContA	SubsA	NeigA	ProfA	LengB	InfoB	ContB	SubsB	NeigB	ProfB	Block
1	2*	0	2	1	2	2	0	2	0	1	0	0	1
2	1	2	2	1	0	2	1	0	0	1	2	0	1
3	2	0	0	0	0	1	0	2	2	2	2	1	1
4	2	1	0	1	2	1	0	1	2	1	0	1	2
5	0	0	1	2	1	0	2	2	1	0	1	2	1
6	2	2	1	2	0	0	0	0	1	0	2	2	2
7	1	1	2	0	2	0	1	1	0	2	0	2	2
8	1	2	0	2	2	1	1	0	2	0	0	1	1
9	0	1	1	0	1	0	2	1	1	2	1	2	1
10	0	0	1	2	1	2	2	2	1	0	1	0	2
11	1	1	2	1	0	1	1	1	0	1	2	1	2
12	0	2	0	0	1	2	2	0	2	2	1	0	2

**The explanation of the Ngene coding is mentioned in appendix C.*

Appendix E – answer distributions to rating and choice experiment

Table 28. Answer distribution to first 12 choices of the rating experiment

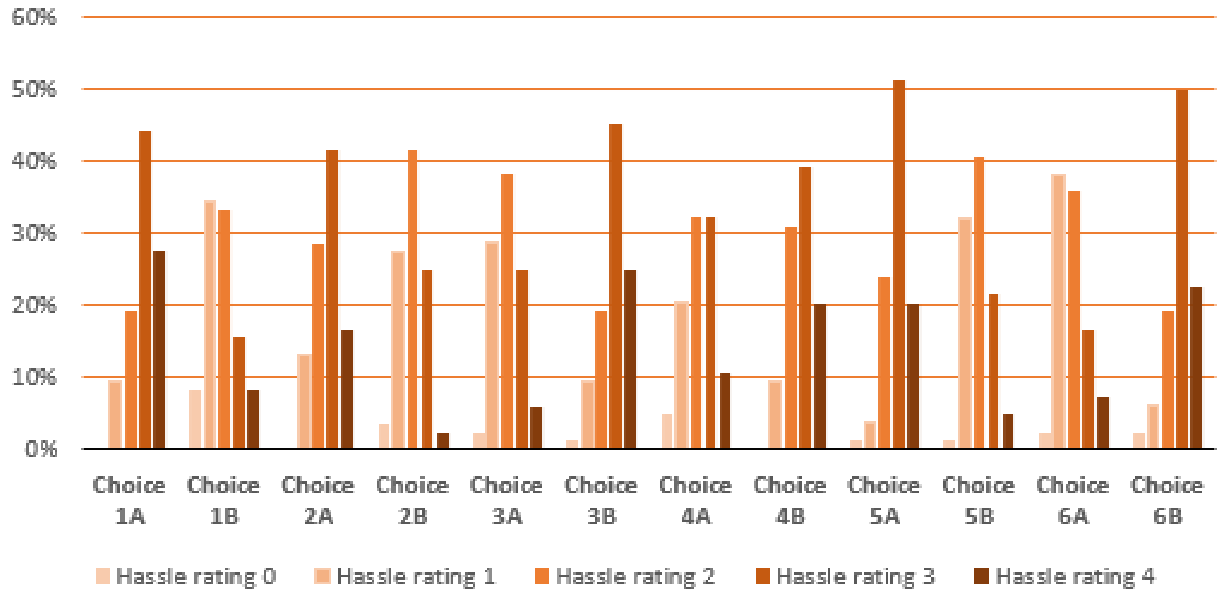


Table 29. Answer distribution to second 12 choices of the rating experiment

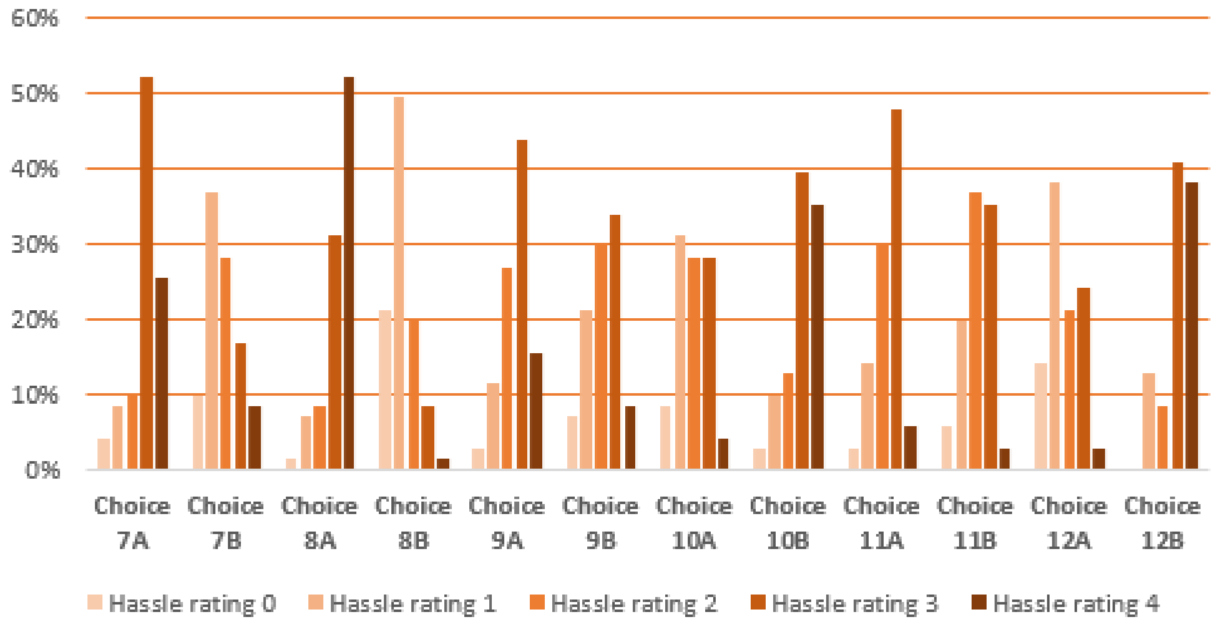
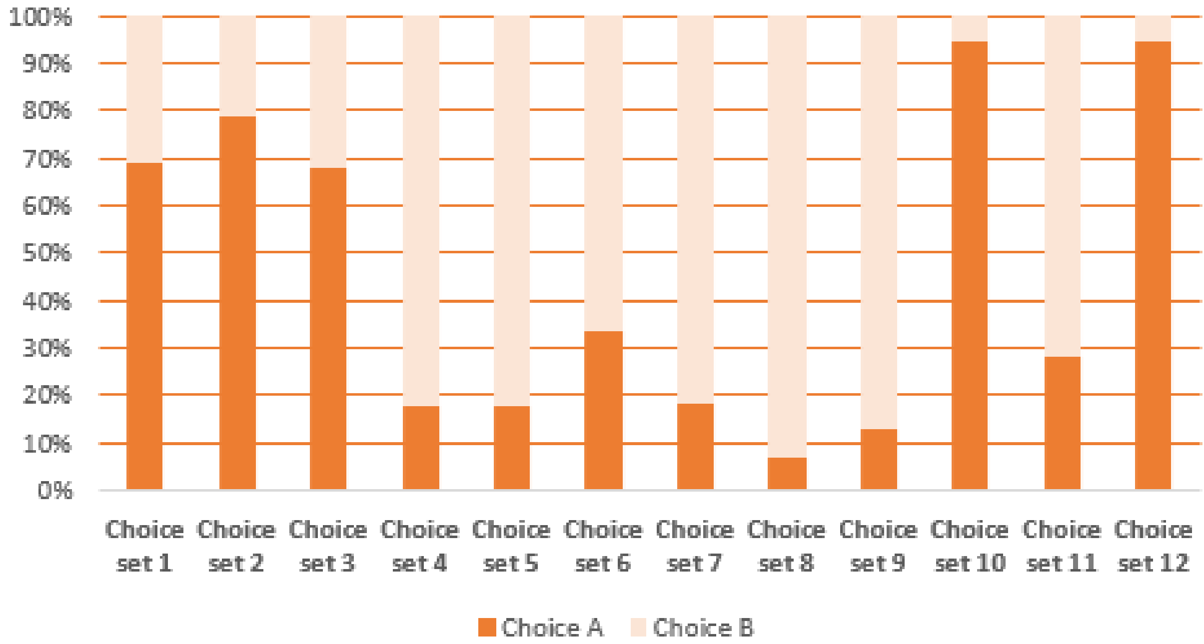


Table 30. Answer distribution of the choice experiment



Appendix F – SPSS output factor analysis

Table 31. Descriptive statistics of the factor analysis

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Factor10	5.2384	1.64753	906
Factor11	5.9669	1.35964	906
Factor13	3.6954	1.01694	906
Factor14	3.0795	1.17162	906

Table 32. Correlation matrix of the factor analysis

Correlation Matrix[a]

		Factor10	Factor11	Factor13	Factor14
Correlation	Factor10	1.000	.696	.047	-.075
	Factor11	.696	1.000	.132	-.019
	Factor13	.047	.132	1.000	.332
	Factor14	-.075	-.019	.332	1.000
Sig. (1-tailed)	Factor10		.000	.077	.012
	Factor11	.000		.000	.282
	Factor13	.077	.000		.000
	Factor14	.012	.282	.000	

a. Determinant = .445

Table 33. KMO and Bartlett's test of the factor analysis

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.501
Bartlett's Test of Sphericity	Approx. Chi-Square	731.461
	df	6
	Sig.	.000

Table 34. Communalities of the factor analysis

Communalities

	Initial	Extraction
Factor10	.489	.677
Factor11	.494	.730
Factor13	.130	.375
Factor14	.118	.317

Extraction Method: Principal Axis Factoring.

Table 35. Total explained variance of the factor analysis

Total Variance Explained

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.719	42.965	42.965	1.417	35.414	35.414	1.413	35.334	35.334
2	1.332	33.303	76.267	.683	17.077	52.491	.686	17.157	52.491
3	.651	16.269	92.536						
4	.299	7.464	100.000						

Extraction Method: Principal Axis Factoring.

Table 36. Factor matrix of the factor analysis

Factor Matrix[a]

	Factor	
	1	2
Factor11	.854	
Factor10	.817	
Factor13		.597
Factor14		.562

Extraction Method: Principal Axis Factoring.

a. 2 factors extracted. 22 iterations required.

Table 37. Rotated factor matrix of the factor analysis

Rotated Factor Matrix[a]

	Factor	
	1	2
Factor11	.851	
Factor10	.822	
Factor13		.605
Factor14		.559

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 38. Factor transformation matrix of the factor analysis

Factor Transformation Matrix

Factor	1	2
1	.998	.066
2	-.066	.998

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.

Appendix G – Open responses of hassle factors in the survey

- *Levering van de pomp is een probleem, overal een jaar wachttijd op levering.*
- *Verhuizing binnen vijf jaar, angst voor aanvullende werkzaamheden binnenshuis.*
- *Laten bepalen welke warmtepomp voor ons oude en moeilijk te isoleren huis geschikt is.*
- *Business case rond krijgen (elektra verbruik gaat nl fors omhoog en dat t.o.v. een beperkte vermindering van ons gasverbruik.*
- *Levertijden en vooral levensduur ofwel hoe duurzaam is de nieuwe apparatuur!*
- *De kosten die gepaard gaan met het voldoende isoleren van een jaren 30 woning.*
- *Winstgevendheid.*
- *Of het technisch en praktisch haalbaar is.*
- *Ruimtegebrek voor de installatie.*
- *Geen idee wat de mogelijkheden zijn.*
- *Vergunningen aanvragen bij gemeentes die niet meewerken.*
- *Overlast van de warmtepomp.*
- *De kosten die ik moet betalen en de ruimte in huis die ik moet opofferen.*
- *De prijs.*
- *Of er wel ruimte in/rond de woning is voor een warmtepomp.*
- *Oplossing creëren die zon-thermisch werkt en buffert, met de warmtepomp als component.*
- *Uitrekenen of het winstgevend is.*
- *Technisch en esthetisch inpassen in oude woning (<1900) met beperkte ruimte.*
- *Overall blik op energievoorziening woning krijgen.*
- *Een aannemer vinden is één, een BETROUWBARE aannemer vinden, die levert wat je verwacht, is afwachten.*
- *Keuze maken.*

Appendix H – Apollo code MNL model

```
### Load Apollo library
library(apollo)

### Initialise code
apollo_initialise()

### Set core controls
apollo_control = list(
  modelName  ="MNL_Basic",
  modelDescr ="MNL model 1",
  indivID    ="ID"
)

#### LOAD DATA
database = read.delim("MNLdata.dat",header=TRUE)

### Vector of parameters, including any that are kept fixed in estimation
apollo_beta=c(BETA_Leng = 0,
              BETA_Info = 0,
              BETA_Cont = 0,
              BETA_Subs = 0,
              BETA_Neig = 0,
              BETA_Prof = 0)


### Vector with names (in quotes) of parameters to be kept fixed at their starting value in apollo_beta,
### use apollo_beta_fixed = c() if none
apollo_fixed = c()


#### GROUP AND VALIDATE INPUTS
apollo_inputs = apollo_validateInputs()


#### DEFINE MODEL AND LIKELIHOOD FUNCTION

apollo_probabilities=function(apollo_beta, apollo_inputs, functionality="estimate"){

  ### Attach inputs and detach after function exit
  apollo_attach(apollo_beta, apollo_inputs)
  on.exit(apollo_detach(apollo_beta, apollo_inputs))

  ### Create list of probabilities P
  P = list()

  ### List of utilities: these must use the same names as in mnl_settings, order is irrelevant
  V = list()
  V[['A']]  = LengA * BETA_Leng + InfoA * BETA_Info + ContA * BETA_Cont + SubsA * BETA_Subs + NeigA * BETA_Neig + ProfA * BETA_Prof
  V[['B']]  = LengB * BETA_Leng + InfoB * BETA_Info + ContB * BETA_Cont + SubsB * BETA_Subs + NeigB * BETA_Neig + ProfB * BETA_Prof


  ### Define settings for MNL model component
  mnl_settings = list(
    alternatives  = c(A=1, B=2),
    avail         = list(A=1, B=1),
  ### Compute probabilities using MNL model
  P[['model']] = apollo_mnl(mnl_settings, functionality)

  ### Take product across observation for same individual
  P = apollo_panelProd(P, apollo_inputs, functionality)

  ### Prepare and return outputs of function
  P = apollo_prepareProb(P, apollo_inputs, functionality)
  return(P)
}

#### MODEL ESTIMATION
model = apollo_estimate(apollo_beta, apollo_fixed, apollo_probabilities, apollo_inputs)

#### MODEL OUTPUTS
apollo_modelOutput(model,modelOutput_settings=list(printPVal=TRUE))

apollo_saveOutput(model)
```

Appendix I – Profiles V1 2-class model

Table 39. Profiles of the V1 2-class model

	Class1	Class2
Class Size	81%	19%
Attributes	**Class1**	**Class2**
Length of disruption		
1 day	72%	40%
4 days	22%	33%
7 days	7%	27%
Mean	2.05	3.60
Information gathering		
1 hour	68%	37%
5.5 hours	8%	30%
10 hours	24%	33%
Mean	0.20	0.46
Finding a contractor		
2 hours	51%	31%
5 hours	31%	33%
8 hours	19%	36%
Mean	4.05	5.14
Subsidy and loan application		
1 hour	51%	51%
5 hours	31%	31%
9 hours	19%	19%
Mean	3.72	3.72
Profit		
0 euro	1%	44%
3 euro	9%	32%
6 euro	90%	24%
Mean	5.67	2.41
Inactive covariates	**Class1**	**Class2**
Gender		
Male	61%	50%
Female	38%	50%
Other	1%	0%
Age group		
18-25	3%	4%
26-35	9%	9%
36-45	17%	7%
46-55	28%	31%
56-65	33%	31%
65+	9%	17%
Empty	1%	0%
Education		
VMBO, MAVO, MBO-1, HAVO-, VWO-first half	2%	4%
MBO 2-4, HAVO, VWO completed	9%	10%
HBO-, WO-bachelor	31%	37%
HBO-, WO-master, Doctor	58%	49%
Other	1%	0%

Income		
€ 10.000 - € 20.000	2%	0%
€ 20.000 - € 30.000	2%	4%
€ 30.000 - € 40.000	7%	8%
€ 40.000 - € 50.000	6%	10%
€ 50.000 - € 100.000	45%	37%
€ 100.000 - € 200.000	23%	24%
More than € 200.000	2%	0%
Empty	13%	16%
House type		
Flat/ apartment/ gallery apartment / maisonette	13%	21%
Corner house	14%	9%
Terraced house	40%	40%
Semidetached house	17%	20%
Detached house	13%	4%
Other	2%	2%
Empty	1%	3%
Construction year		
Older than 1945	29%	44%
1945-1955	5%	0%
1955-1965	5%	4%
1965-1975	13%	11%
1975-1985	10%	6%
1985-1995	9%	18%
1995-2005	12%	11%
2005-2015	11%	1%
2015-2022	5%	0%
Empty	1%	5%
Years of residency		
0-5 years	36%	24%
6-10 years	12%	9%
11-15 years	17%	11%
16-20 years	15%	12%
21 year or more	20%	39%
Empty	1%	5%
Sustainability		
2 (Not sustainable orientated)	1%	2%
3	0%	7%
4	2%	0%
5	3%	0%
6	2%	2%
7	1%	0%
8	4%	5%
9	5%	5%
10	13%	8%
11	11%	9%
12	18%	13%
13	17%	18%
14 (Really sustainable orientated)	21%	25%
Empty	1%	5%

Employment		
Fulltime employed	53%	40%
Parttime employed	17%	25%
Self-employed	16%	12%
Unemployed	2%	2%
Housewife/-man	2%	0%
Retired	11%	18%
Empty	0%	3%
Surface area		
Less than 50 m^2	1%	0%
50-74 m^2	4%	5%
75-99 m^2	18%	22%
100-149 m^2	41%	41%
150-250 m^2	31%	21%
250 m^2 or more	3%	0%
Empty	2%	11%