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DETERMINANTS OF HOME HEATING SYSTEM CHOICE – A STATED PREFERENCE EXPERIMENT

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ABSTRACT OF THE MASTER'S THESIS

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Abstract

The heating of residential areas contributes to over 80% of total energy consumption in Finland. This indicates huge possibilities to save energy. The objective of the thesis is to identify the factors that affect a homeowner's decision making while choosing a heating system. Among various factors that influence the homeowners' choice, this thesis investigates three types of determinants: the features of the heating system, the features of the building and the socio-demographic characteristics of the homeowner.

The thesis uses the stated preference technique called choice experiment. In the choice experiment, respondents were presented with choice scenarios where the main heating system choices, namely ground heat, exhaust air heat pump, solid wood boiler, wood pellet boiler, electric storage heating and district heating, were described using five attributes which took various levels. In the choice analysis, the preference heterogeneity for the heating systems and attributes was modelled.

The results indicate that among the attributes of the heating system, homeowners view costs as the most important ones, especially the operating costs. The results also show that their heating system choice is influenced by socio-demographic characteristics as well as building and heating system attributes. Preference heterogeneity in main heating system choices can be explained by individual characteristics such as age, education and forest ownership as well as building attributes such as energy saving capabilities of houses. Similarly, preference heterogeneity in comfort of use and environmental friendliness attributes were explained by the size of the house as well as forest ownership by the homeowner.

Keywords
Home heating, stated preference, choice experiment, economic valuation

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1 INTRODUCTION

Adhering to 2030 climate and energy framework by the European Union (EU), countries set out to reduce greenhouse gases (GHGs) by at least 40% below 1990 levels by 2030. In addition, they agreed to increase the share of renewables in the energy mix to at least 32% as well as increasing the energy efficiency by 32.5%. (European Commission, 2019.) Achieving the EU target requires a combined effort from all sides of the energy market. The Finnish National Climate Change Act (609/2015) has set the target to reduce the GHG emissions by 39% below 1990 levels by 2030 (Ministry of the Environment, 2018). Given the higher GHG emission reduction targets, it is important to identify the major contributor to the emissions.

Heating of residential buildings is responsible for the biggest share of consumption of energy by households in Finland as residential heating and heating of domestic water contribute to 83% of energy consumption by households (Official Statistics of Finland (OSF), 2018). In the EU 79% of residential energy consumption can be attributed to heating and cooling of houses (European Commission, 2019). Due to its high share in final energy consumption, residential heating requires a high level of efficiency. In addition to the EU 20-20-20 target, Finland’s individual target is to increase the share of renewables in the energy mix to 38% by 2030 (Ministry of the Environment, 2018).

According to (Official Statistics of Finland (OSF), 2017) there are 1.15 million detached and semi-detached houses in Finland. Detached and semi-detached houses are an area of interest because they represent 76% of the total buildings and thus a huge potential to save energy. Only 6% of the detached and semi-detached houses use long-distance or district heating. A majority, 43% of the house stock uses electricity, 22% oil, and 23% wood (and peat) as the primary fuel for heating. A recent Finnish study by Sahari (2019) shows that the rise in electricity distribution prices as well as taxes has induced attraction towards renewable energy.

Finland being a country with cold climate requires all houses to be fitted with a heating system during the time of construction. Heat is produced by a generator that converts energy to heat. The most commonly used heat generating technologies in Finnish households are solid wood heating, wood pellets, ground heating, direct electric and electric water heating, oil and district heat. (Rouvinen & Matero, 2013; Ruokamo, 2016; Sahari, 2019). Heat generated is distributed around the house in the form of hot water or air using radiator networks, electric heaters, underfloor heating pipes or air ducts and cables. The heating system also includes a storage unit that stores heat usually in the form of hot water. Storage capabilities of heating systems enhance efficiency and save costs. Equipment are also installed to regulate and adjust the heating to a desired level. (Motiva, 2017.)

This thesis intends to identify the factors consumers take into consideration when choosing a heating system. It is important to identify what motivates (or compels) them to make a certain choice in favour of a certain type of heating system. Do the attributes of the heating system like investment cost, operating cost, amount of emission, ease of use, or certain features of the system influence the consumer's decision? Do the consumer's own socio-demographic characteristics affect his or her choice? To answer these questions the thesis uses the stated preference method known as choice experiment (CE) to identify individual preferences among alternatives with multiple attributes. CE's allow the estimation of use and non-use values of public goods (Johnston, et al., 2017). The CE method allows the examination of hypothetical heating scenarios as well as the possibility of trade-off between attributes of heating systems (Ruokamo, 2016).

This thesis is constructed as follows. The research methodology contains discussions about the value elicitation from public goods which includes revealed and stated preference techniques. The thesis focuses on stated preference techniques especially, the choice experiments. This is followed by the discussion of existing literature in relation to home heating systems. The next section contains the research methodology which includes chapters on survey design and the theoretical as well as econometric framework for the thesis. Finally, the outcome of the thesis is presented along with the discussion of the results before presenting the conclusion.

2 RESEARCH METHODOLOGY

Investigating the factors that affect the heating system choice made by households requires assessing the energy resources consumed in the process of producing the heat energy. Due to the fact that production of energy involves the utilisation (exploitation) of natural resources, it is necessary to analyse the determinants of heating system choice from the perspective of how value is extracted from public goods.

2.1 Theory about value elicitation from public goods.

The concept of total economic value (TEV) recognises two kinds of values individuals derive from public goods – use values and non-use values (Plottu & Plottu, 2007). The economic concept of value discussed here, according to (Freeman, Herriges, & Kling, 2014), is based on neoclassical economics of welfare. The fundamental assumptions of welfare economics are that economic activity is supposed to increase the well-being of individuals in a society and that each individual knows how well-off s/he is in a given circumstance. The welfare of each individual is dependent not only on her/his consumption of private and public goods and services, but also on the service flow of quantities and qualities of nonmarket goods and services from resource-environmental systems such as health, visual pleasantness and prospects of outdoor recreation.

Welfare economics considers that the measures of economic value of changes in resource-environmental systems are basically derived from their effects on human welfare. The ability of things (goods and services) to fulfil human necessities and wants, or to improve their well-being or utility underlines the economic theory of value. How the change is environmental goods is evaluated primarily depends on the source of data. The data can arise from observation of people's actions in real-world situations or from their responses to hypothetical questions such as, "how much are you willing to pay for……?" or "which option would you choose if……?" The methods that use data arising from the former method is known as revealed preference methods and those from the latter are known as stated preference methods. Figure 2 shows the structure of economic valuation. (Freeman et al., 2014.)

Use values which can be further distinguished into consumptive and non-consumptive arise from actually using the resource (see Figure 1). Consumptive use values come at the cost of exploitation of the resource. The examples include timber harvesting, fishing and hunting. Valuation in this case is straightforward and reaches the end consumer in the form of observable market prices. Non-consumptive uses include for example, using forest and rivers for recreational purposes as well as the satisfaction individuals receive from watching birds or reading articles about rivers. Activities concerning such values are not detrimental to the environment. Use values are estimated using either revealed or stated preference techniques. (Perman, Ma, Common, Maddison, & McGilvray, 2011.)

The second kind of value is non-use value. These are the benefits individuals derive without any interaction with the resource physically or the intention to use it. For example; individuals living in Europe may derive satisfaction from the knowledge that a rare species of rhino gave birth to two new calves in an African sanctuary for no other reason than they would find it unacceptable if the rhino went extinct. Non-use values can be further divided into existence values (the satisfaction that is derived from the continued existence of a species), altruistic values (satisfaction that arises from other people using the resource even though the individual might not value it as much) and bequest/option values (that arise from the willingness to pay for possible future use). Non-use values are estimated using stated preference techniques. (Perman et al., 2011.)

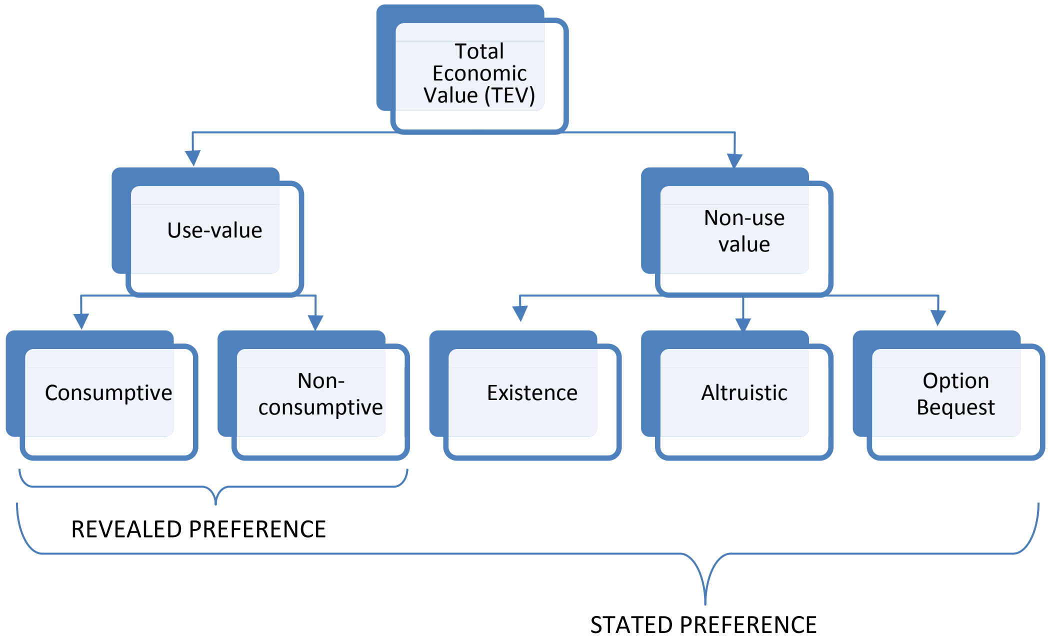

Figure 1. Concept of Total Economic Valuation (adapted from Perman et al., 2011; Plottu & Plottu, 2007).

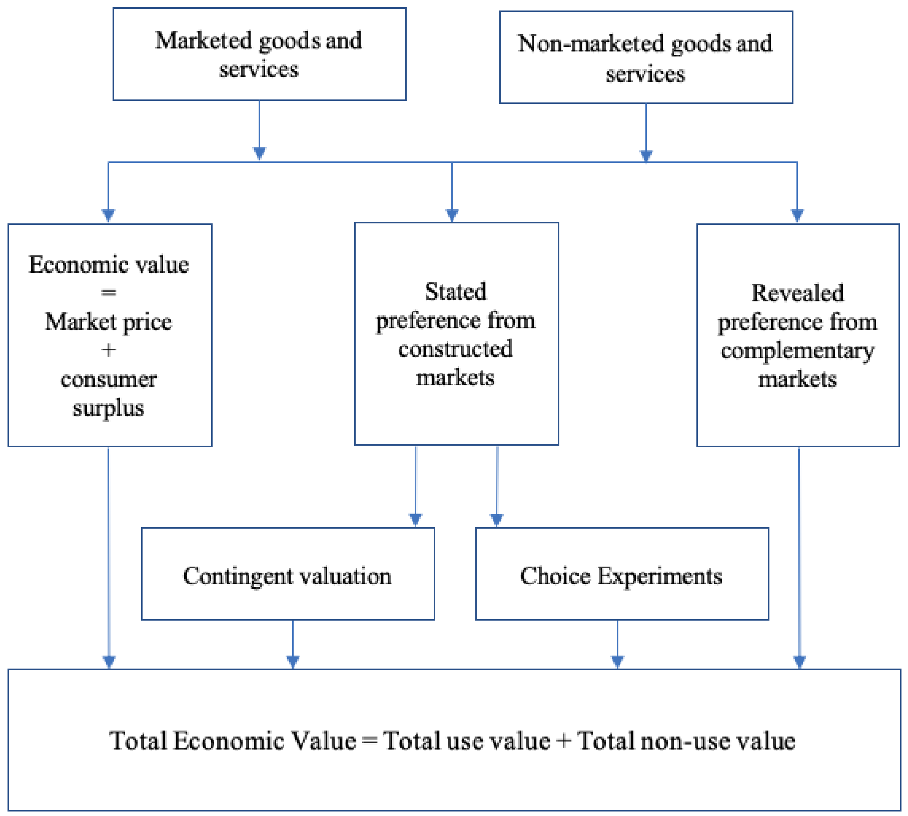

Figure 2. The structure of economic valuation (adapted from Bateman et al., 2002).

2.2 Revealed Preference

Revealed preference (RP) methods are used to estimate the use values. RP methods are based on the actual utility maximizing behaviour bounded by constraints (Freeman et al., 2014). In the RP method, the value people derive is inferred from their behaviour in related markets (Hensher, Rose, & Greene, 2005). Instead of explicitly asking individuals for the value they place on a resource, it is deduced from the data they leave behind through prices and other economic signals (Freeman et al., 2014). For instance: a study might gather information from a family about whether it had visited a nearby tourism spot in the recent past. If the family took the trip, the information "reveals" that the value (utility) of the trip was greater than the costs the family incurred to visit the spot. The revealed information only shows whether the value of the good offered to the individual was larger or less than the offering price which includes the cost of admission and travel. Due to the limited information available from such data, assumptions about preferences have to be made while estimating the model. The values derived from RP methods suffer from limitations due to the reasons such as this and the ones which will be discussed below. (Freeman et al., 2014.)

There are cases where the non-marketed (public) good does not have stated offering price, but its quantity and/or quality does affect the choices made by people about other market goods. In order to elicit value from a public good, models incorporating the relationship between the non-marketed and market goods are applied. (Freeman et al., 2014). Many popular RP methods are built around the relationship and intend to recognise how a public good impacts actual markets for another good (Bateman et al., 2002).

The models in RP methods measure value using data in observed behaviour. The theoretical framework behind modelling this observed behaviour requires relating the behaviour to some monetary value and change in welfare. An important aspect of the theoretical framework is the optimizing behaviour of a rational individual who is subject to prices and constraints that include the level of quality (q) of a public good. If a relationship between observable choice variables and q can be specified and estimated, the relation can be used to calculate the marginal rate of substitution between q and the examined choice variable in monetary terms thus revealing the marginal value of change in the quality of q. It involves three steps to measure the welfare where the change in q affects the individuals. The first step involves deriving the willingness to pay (WTP) as a function of the public good variable, either from the indirect utility function or the expenditure function. The expression for WTP gives the change in income that is compensated by holding the utility as constant for the change in the public good parameter. The second step involves developing a model for the utility maximising behaviour of the individual which relates her/his choices to the relevant prices and constraints including the level of quality, q. The first-order conditions thus derived involve equating marginal value to price or equating marginal rate of substitution or marginal rate of transformation to a price ratio. The final step involves checking whether a relationship between the expected marginal value for the change in the quality of the public good and any observable variable exists in the first-order conditions. If there exists any relationship, then the observed variable can be considered as a measure of the marginal change in welfare. (Freeman et al., 2014.)

Travel cost (TC) is one of the revealed preference methods. The assumption under the TC method is that individuals react to the increase or decrease of the travel cost the same way they would do to a change in admission fees (Perman et al., 2011). The price to access a site (for example: a national park or a lake) can be represented by the time and travel expenses people incur to visit the site. (Ecosystem Valuation, 2018).

Hedonic pricing (HP) is another common technique for RP valuation. It is mostly applied to the property market within which trading of environmental goods happens. HP technique is widely used in the context of air pollution and even if clean air is not a good that is traded, it is an attribute that seemingly influences the property market. Let us suppose we collect data on housing rents, quality of air and other attributes affecting rents. We can estimate the relationship between the rent and air quality through multiple regression analysis by holding the other attributes constant. This estimated relationship is known as the hedonic price equation. (Perman et al., 2011.)

Revealed preference data contains information on real life choices and can thus provide the insight on actual market behaviour (Hensher et al., 2005) making it more scientific and objective. RP methods are limited by their inability to provide sufficient variation in observations and the difficulty in relating actual (observed) behaviour to qualitative attributes such as environmental friendliness and comfort of use (Louviere, Hensher, & Swait, 2000).

2.3 Stated Preference

Another approach of eliciting value from public goods exists whose source of data for analysis is from the individuals' responses to questions regarding hypothetical situations. Since values are inferred from the stated responses to such questions, this approach is known as stated preference (SP) method. (Freeman et al., 2014). This approach measures economic value by using survey questionnaire to estimate (Johnston et al., 2017). SP methods can be used to estimate both use and non-use values (see Figure 1) The primary distinction between RP and SP methods is that SP methods extract the data from individuals' responses to hypothetical questions that are designed to reveal information about their preferences or values (Freeman et al., 2014) rather than from the observation of real-world actions.

The non-use values can only be elicited using stated preference as they "cannot be inferred from observed behaviour" (Perman et al., 2011). One of the most basic features of SP methods is the cost (monetary value) for the chosen alternative. These costs are (or should be) mentioned clearly along with details such as who should pay, what is the frequency of payment, how is it paid and if the payments are optional or obligatory. (Johnston et al., 2017.) SP techniques measure the value related to the change in welfare due to the change in real world variables, which implies the requirement to measure value by comparing with a clearly defined status quo baseline. It is important to note that a status quo baseline is not required in labelled CE. This allows the survey respondents to clearly see the baseline condition as well as the suggested change compared to it. (Johnston et al., 2017). Contingent valuation (CV) and choice experiment (CE) are two of the most common stated preference methods of estimating economic value.

2.3.1 Contingent valuation

One of the early stated preference methods included directly asking people questions about the values they would place on environmental services by effectively creating a hypothetical market. As the responses are contingent on the specific conditions or assumptions set in the hypothetical market, this type of SP method is referred to as contingent valuation (CV) (Freeman et al., 2014). The CV technique estimates the values for a change or set of changes from a holistic perspective. (Johnston et al., 2017). It is an evaluation technique that is based on surveys where a representative sample population is asked questions regarding the impact on welfare due to the change in quality or quantity of public good (Freeman et al., 2014). The survey instrument typically contains the following elements:

1) Introduction of the organisation or individuals behind the survey and the topic.
2) Questions regarding previous knowledge about the good and their attitude towards it.
3) Presentation of the CV scenario as well as the objective of the project, how it will be implemented and paid for, what will the status quo look like if the project were not to be realized.
4) Questions about their willingness to pay (WTP) and willingness to accept (WTA) compensation for a change or set of changes as a whole.
5) Debriefing questions to ensure the respondents comprehend the scenario presented.
6) Questions regarding the socio-demographic characteristics of the respondent.

Various elicitation methods are used regarding the questions in item 4. Using *open-ended questions* is a popular method. The data obtained using open-ended questions are easy to understand. The respondents are normally asked to state their WTP for an improvement in environment or to avoid a loss. One of the methods used to elicit this number is known as a bidding game in which individuals are asked whether they were willing to pay a certain amount. If the individual replies with a ‘yes’, the question is asked again with a higher price. This process it iterated until the individual says ‘no’. the highest price with a ‘yes’ reply is then considered to be the maximum WTP. If the initial response of the individual is ‘no’, the iteration continues in the opposite direction until the individual replies with a ‘yes’. This method of elicitation however suffers from what is called “starting point bias” when the starting point used in the bidding game influences the individual’s claimed maximum WTP. A slightly modified version of the open-ended approach is to present the respondent with a card with various monetary values and ask them to pick the amount that would be their WTP. This method is sometimes called the *payment ladder*. (Freeman et al., 2014.)

One of the most common elicitation methods in CV is the single-shot binary discrete choice question also known as or *single-bounded dichotomous choice*. The survey questions are usually formulated in a referendum format. Initially, the respondent is presented with the proposed change in public good (for example: environmental change) and the cost they would have to bear if they would vote in favour of the referendum (in other words, if the referendum goes through). The cost which is also called the “bid amount” varies across respondents. The respondent indicates a WTP that is greater than or equal to the specified cost by voting in favour of the referendum. If the respondent answers no, then it is understood that the true WTP is less than the bid amount. The respondents are randomly allotted to different sub-samples, with each sub-sample with a different bid amount. Following that, it is possible to test the hypothesis that the ‘yes’ responses proportionately decrease with the rise in the price of the good. The data thus collected can be analysed using a discrete choice model to estimate indirect utility functions or bid functions. (Freeman et al., 2014.)

Single-bounded dichotomous choice tasks are easy to understand and are incentive compatible. The procedure minimises non-response and avoids outliers. On the other hand, empirical studies have shown that values elicited from dichotomous choice are significantly greater than those resulting from similar open-ended questions. The information available for each respondent is very less and thus requires a larger sample and strong statistical assumptions. It may also suffer from starting point bias. (Bateman et al., 2002.)

An attempt to extract more information from each respondent and to evade the limitations of pure open-ended questions has led to a popular variation called the double-bounded discrete choice format or the *double-bounded dichotomous choice*. The standard single bounded dichotomous choice format is tweaked by adding a follow-up question to the referendum, which asks the respondent to narrow the range of WTP (Bateman et al., 2002). Suppose a respondent answers 'yes' to the first question that asked if they would vote in favour of a referendum if the cost was *T*. The follow-up question would then ask if they would still vote in favour of the referendum if the cost was higher, consider $T_H > T$. If the respondent answers 'no' to the initial question, the follow-up question then asked if they would vote in favour if the costs were reduced to $T_L > T$. The responses from a double bounded discrete choice yield the individual's WTP in tighter bounds as such.

$$(no, no) => WTP_i \in (-\infty, T_L)$$
$$(no, yes) => WTP_i \in [T_L, T)$$
$$(yes, no) => WTP_i \in [T, T_H)$$
$$(yes, yes) => WTP_i \in [T_H, \infty)$$

More precise results are achieved due to the tighter bounds. (Freeman et al., 2014.)

Table 1. Types of WTP data collected in CV (adapted from Bateman, et al., 2002).

Data Type	Elicitation Method	Description
Continuous	Open-ended Bidding game	Each respondent identifies the amount corresponding to their maximum WTP
Binary	Single-bounded discrete choice	Each respondent reveals whether their maximum WTP is above or below a certain amount
Interval	Double-bounded discrete choice Multiple-bounded discrete choice Payment ladder (and similar methods)	Each respondent reveals two amounts that bound their maximum WTP, one greater than and one less than their maximum WTP

Even though double-bounded dichotomous choice is statistically more efficient than the single-bounded because more information is elicited about the WTP of each respondent, it still suffers from all the problems of the single-bounded procedure as well as the loss of incentive compatibility and increased possibilities of anchoring and yea-saying biases (Bateman et al., 2002).

The analysis of the data collected through CV survey should begin with the summarisation of the data. The summary of the data is dependent on the type of elicitation used in the survey. The data yielded from different elicitation methods are categorised in the Table 1. Non-valid responses should be identified early in the analysis process. These responses often reflect the objections of respondents to certain aspects of the CV scenario and should be identified in pre-testing and the scenario should modified to minimise the possibility of nonresponse. (Bateman et al., 2002.)

Along with the above-mentioned limitations the contingent valuation stated preference techniques suffers from various other biases and problems. Information bias may occur due to the poor explanation of the investigated goods and services. Hypothetical bias may occur because the stated response may differ from actual values. Strategic bias can occur when the respondent may not give his/her actual WTP with the intention of influencing the availability of the environmental good to his/her economic favourability (Perman et al., 2011). A popular study using CV method was carried out by Claudy, Michelsen and O'Driscoll, (2011) to extract WTP of Irish households for different heating systems. Other examples include Stevanović and Pucar (2012), Kim, Lim, and Yoo (2019) and Olsthoorn, Schleich, Gassmann, and Faure, (2017). The analysis techniques and mathematical models used in CV experiments are not discussed in this thesis. The thesis instead focuses on the choice experiments.

2.3.2 Choice Experiment

A choice experiment (CE) estimates value as a function of multiple attributes, each of which may take different levels. As one of the stated preference methods, CEs can be used to assess both use and non-use values. Respondents are provided a set of hypothetical alternatives and are asked to choose the alternative they prefer the most, to rank them in the order of preference, or to rate them on a scale (Bateman et al., 2002.) Each alternative is explained by some attributes. Typically, one attribute carries a monetary value. Both the discrete choice methods and the stated choice methods (or CEs) allow the tradeoff among attributes and are able to estimate the marginal rates of substitution among pairs of attributes and if one of the attributes is price, the marginal WTP for the attribute. Additionally, using the CEs the analyst can control the experiment by designing attributes presented to the respondents in the choice set. (Freeman et al. 2014.) Ultimately, the CEs are designed to identify the trade-offs respondents make between cost and the levels taken by different attributes Perman et al. (2011).

In environment economics, CEs are gaining popularity due to many reasons. CEs allow researchers to combine multiple attributes and to examine hypothetical scenarios thus giving them more control of the experimental design. CEs extract more information than CVs do from survey respondents. The monetary values in CEs are implicit rather than explicit thus reducing the respondents' hesitation to participate. (Perman et al., 2011).

The choice experiment approach like many of the choice modelling techniques is based around the notion that any good can be described by using attributes and the levels they take. For instance: a freshwater lake can be described by using attributes such as size, diversity of species and recreational opportunities. The change in the levels of the attributes creates a different 'good' and choice modelling approach focuses on the value of these changes in attributes. The difference between choice modelling method and the CV is that choice modelling elicits rankings or ratings rather than values. This method does not suffer from some of the problems regarding protest votes because it is easier for the respondents to rank or rate alternatives without needing to think directly in monetary terms. For public goods, the money indicator, which is included to elicit economic value, may be a price, entry fee or a tax. (Bateman et al., 2002.)

Widely used in valuing environmental goods, CEs have also become popular in marketing, health and transport economics. (Perman et al., 2011). Adamowicz, Louviere, and Williams (1994), Boxall, Wiktor, Swait, Williams and Louviere (1996) and Verelst, Willem, Kessels, and Beutels (2018) utilize CEs to analyse individuals' discrete choices for various applications. In order to carry out a successful CE, the experimental design is a key process. The next section describes the process by which choice scenarios are created before being presented to the survey respondents.

2.3.3 Experimental design of choice experiments

Experimental design is the foundation of any value estimation technique. A scientifically designed choice experiment observes how manipulating the levels of one or more variables affects another (response) variable. (Hensher et al., 2005). The survey experiment should clearly define the attributes, state the possible levels each attribute can take (Johnston et al., 2017) and construct choice sets consisting various alternatives (Perman et al., 2011). The experimental design can be carried out using a software such as Ngene 1.1.1, which specialises in experimental designs for choice experiments. (ChoiceMetrics, 2018).

CEs are conducted to investigate the independent influence of different factors on an observed outcome. As discussed earlier, choice tasks consist of alternatives described by attributes that take various levels. How attribute levels are defined can affect the independent influence of the determinant in question as well as the statistical power of the experiment. A CE design experiment can be viewed as a matrix of values that represent the various attribute levels where the rows and columns represent the choice scenarios, alternatives and attributes. (ChoiceMetrics, 2018.)

Rose & Bliemer (2008) suggest setting up the matrix with rows representing different choice scenarios and columns representing attributes. Additionally, columns are grouped to form alternatives within the choice. Another concept suggests representing alternatives using rows and attributes using columns (Carlsson & Martinsson, 2003). This concept groups multiple rows to form choice scenarios. No matter which technique is used, the objective of experimental design is to allocate the attribute levels to the choice tasks.

The Ngene user manual suggests some steps for creating choice experiments. Firstly, the model and the parameters to be estimated should be specified. This involves specifying utility functions, deciding if an attribute is generic over different alternatives or alternative-specific and deciding if any interaction effects are to be included. After the model specification is decided, the next step is to create the experimental design. Before choosing the best design, it is important to finalise few other design aspects such as: whether the design should be labelled or unlabelled, how many attribute levels to use, what the range of attribute levels should be, what type of design to use and how many choice scenarios there will be. If the model specification contains alternatives with alternative-specific parameters (also known as alternative-specific constants or ASCs), the alternatives should be labelled (for example: ground heat, exhaust air heat pump, solid wood boiler, wood pellet boiler, electric storage heating, district heating in our experiment as can be seen from Figure 3. The alternatives can be unlabelled if they have generic parameters (for example: heating system 1, heating system 2, heating system 3 and so on). (ChoiceMetrics, 2018.)

Among the several design types that can be implemented, full factorial design generates too many choice scenarios making it impractical even though this design type is capable of estimating all possible effects and interactions. A popular alternative is the fractional factorial design type known as orthogonal design. This design type attempts to reduce the correlation between attribute levels on the choice scenarios. Orthogonal designs are limited by the inability to avoid choice scenarios where one alternative is clearly favoured over others. Instead of simply considering the correlation between attributes, another fractional factorial design type known as efficient designs attempt to choose designs that have better statistical efficiency when it comes to predicted standard errors of parameter estimates. Efficient designs depend on the correctness of prior parameter estimates. Bayesian efficient designs reduce the reliance on the accuracy of the priors by considering them as random parameters instead of fixed. (ChoiceMetrics, 2018.)

The final step is to construct the actual questionnaire. This involves transforming the matrix of numbers into meaningful choice scenarios. Survey questions are created and implemented using a software or the internet and finally distributed to respondents. (ChoiceMetrics, 2018.)

2.3.4 Analysis of CE data

One of the important tasks in choice modelling, especially CE is the organisation of data. Every entry in the record must possess the detailed information about the levels of attributes for each alternative presented to a respondent including a dependable variable that denotes which variable was selected. This is typically done by allowing the attribute or variable to take binary values with 1 indicating the option, attribute, attribute level was chosen and 0 indicating non-selection. The description of the choice experiment for this study is presented in section 4.2. In order to analyse CE data and obtain the results, an econometric model that describes the discrete choice behaviour, an econometric model is required. The model is provided by the random utility theory that is based on the assumption that a utility maximizing individual will choose from a set of alternatives, an alternative that gives her/him the highest expected utility. Additionally, CE assumes that the utility derived by an individual by choosing any one alternative depends on the attribute levels of that alternative subject to the cost of providing the alternative. Thus, different individuals get different utilities from the same alternative. The utility does not just depend on the chosen alternative and its attributes, but also on the individual's characteristics. (Bateman et al., 2002.)

The econometric model used in this study and the mathematical derivations are discussed in Chapter 5 in detail but briefly summarized in this section. To formulate an econometric model, it is necessary to specify an indirect utility function that shows the relationship between attribute levels, costs and individual characteristics that make up the utility s/he derives. Subsequently the parameters for the function is determined based on the individuals' choice. This derived utility is only an approximation of the individual's actual utility. A random element is added to the analyst's indirect utility function which is an error component that captures the difference between the true and the modelled utility of the consumer. This kind of utility model is generally known as the random utility model (RUM). The model now contains an error component now encompassing the probabilistic element. This enables the analyst to express the probability that a respondent prefers an option over all available options as the probability that the utility achieved from the chosen alternative is the highest. (Bateman et al., 2002.)

3 PREVIOUS STUDIES ON HEATING SYSTEM CHOICES

The economic literature contains numerous researches which investigate the factors that influence a home owner's decision while choosing a heating system. Michelsen and Madlener (2013) divide the existing relevant literature based on i) behavioural approach towards adoption of technology and ii) empirical studies on adoption decisions. The first category focuses on researches on behavioural aspects of heating system adoption decisions which are based on cognitive and normative behavioural models. Cognitive models exhibit the influence of individual's attitude towards a behaviour and subjective norms such as, peer influence on behavioural intention (Michelsen & Madlener, 2013). The theory of reasoned action (TRA) by Ajzen and Fishbein (2009) and the theory of planned behaviour (TPB) by Ajzen (1991) two popular cognitive models. These models assume that behaviours and beliefs have a linear relationship and that behaviour is driven by rationality. Normative models on the other hand emphasize the importance of values and moral norms (Michelsen & Madlener, Motivational factors influencing the homeowners' decisions between residential heating systems: An empirical analysis for Germany, 2013). Norm activation theory (NAT) by Schwartz (1977) and value-belief-norm (VBN) theory by Stern (1999) are some of the popular normative decision models for environment-friendly behaviour. Another model by Rogers (2003) known as diffusion of innovation (DoI) model, views the adoption and diffusion of technology as a social progress.

Numerous empirical studies have been carried out to investigate how individuals' behaviour affect their heating system choice. In a study conducted by Sopha, Klöckner, Skjevrak and Hertwich (2010) in Norway, the effect of households' perception on electric heating, heat pumps and wood pellet heating systems was investigated. Their results showed that the perceived importance of heating system attribute influenced their choice. In another Norwegian study conducted by Bjørnstad (2012), the success of a subsidy programme that invested on new heating technologies such as heat pumps and pellet stoves, was measured based on the degree of overall satisfaction. This study was motivated by the DoI and TPB models discussed in the previous paragraph. He found out that the difference in economic returns on investment in different technologies did not affect the investment satisfaction. Other economic and non-economic factors such as electricity price, service availability, comfort and technical quality were taken into consideration while valuing investment satisfaction. A German study by Decker, Baumhof, Röder and Menrad (2018) investigated the factors that determine the extent of energy-related refurbishments of single and two-family houses. They found that personally relevant goals (like appearance of the house, attitude towards dependence on fossil fuels, comfort) as well as the ability (characterized by age, skill, societal and financial resources) influence the households' decisions. Michelsen and Madlener (2012) studied German homeowners' preferences on innovative heating system adoption decisions and found that individual attitudes such as energy saving and independence from fossil fuels are among the factors that affect their preferences. Their results also showed that for owners of newly built houses, the heating system choice was motivated by environmental benefits, ease of use, costs and recommendation by others. The results indicate the existence of heterogenous preference patterns. In another study by Michelsen and Madlener (2013) motivational factors influencing heating system choice were investigated. The results showed that adopters are motivated by convenience, comfort, peer influence, costs as well as the general attitude towards a specific heating system. Michelsen and Madlener (2016) showed that homeowners are driven by technology-specific knowledge, environmental protection and lower dependency on fossil but perceived difficulty of use and lack of awareness about the features of the heating system act as barriers. Environmental factors had differing influences on heating system choices. According to Decker, Zapilko and Menrad (2010) in Germany, environmental factors were considered important while in Sweden (Mahapatra and Gustavsson (2008, 2009, 2010)), they were not.

The second category focuses on the empirical studies based on real and hypothetical adoption decisions. This category of literature can be further divided into two sub-categories: the ones that do not use stated preference techniques and the ones that do. The first sub-category consists of studies that are based on household specific data collected from large household surveys as well as real adoption decisions. Empirical researches in this category concentrate on sociodemographic characteristics of the individual or household as well as characteristics of the home or geographical location but do not focus on behavioural factors that motivate their adoption decision

(Michelsen & Madlener, Motivational factors influencing the homeowners' decisions between residential heating systems: An empirical analysis for Germany, 2013). Dubin and McFadden (1984) formulated a model based on their research on the choice of energy appliances by households and the energy consumption in US. Vaage (2000) analysed the choice of heating technology and the resulting energy consumption in Norway and found out that energy prices are important to consumers while choosing a heating system. Braun (2010) investigated the factors affecting the house heating technology applied by German households and identified building, socio-economic and regional characteristics as potential determinants. Michelsen and Madlener (2012) analysed the spatial aspects of households. Their results implied that the choices made by households reflected their location. Sahari (2019) studied consumers' sensitivity to energy costs while making a long-term investment on heating technologies. The result indicate that households show high sensitivity to energy costs especially during initial investment stage and that low-income households respond less to costs of expensive (and durable) heating systems.

The second sub-category of literature focuses on stated preference methods. This category includes data on both real and hypothetical adoption decisions using choice experiments or surveys. This section includes researches that implement CV and CE methods to study attribute-related preferences of heating systems. To recall, CV methods elicit individuals' willingness-to-pay (WTP) and willingness to accept (WTA) compensation for proposed changes. Claudy et al. (2011) implemented the CV method to obtain the WTP for microgeneration technologies such as micro wind turbines, wood pellet boilers, solar panels and solar water heaters. The results suggested significant variation in WTP values between these technologies and that the individuals' beliefs about the technologies also influence their WTP. In another study, Scarpa and Willis (2010) implemented a CE to examine the British households' WTP for home heating systems that use renewable energy technologies. They investigated technologies such as solar photovoltaic, micro-wind, solar, thermal, heat pumps, and biomass boilers and pellet stoves. The study showed that even though households value renewable energy, majority of households are discouraged due to the higher investment costs related to the renewable energy technology. Willis, Scarpa, Gilroy and Hamza (2011) used the same data and investigated the effects of ageing population on the uptake of renewable energy technologies. The results showed that age does not impact the primary heating system choice, but households owned by older generation are less likely to adopt the renewable energy technologies. Achtnicht (2011) carried out a CE on retrofits during refurbishment of existing houses and found out that environmental benefits significantly influence heating system choices. The results, however, indicate that the benefits had no effect on insulation choices. Rommel & Sagebiel (2017) conducted a CE to investigate German consumers' preferences for micro-cogeneration products. These products included heating technologies that could be installed to allow consumers to generate their own energy which they could use to heat water and space. The results indicate the existence of a positive WTP for micro-generation technologies which can increase based on the attributes of the system, particularly when the technology is cost saving and produces less emissions. The WTP was also affected by the socio-demographic characteristics of respondents. The results also indicated the presence of preference heterogeneity.

Using CE, Rouvinen & Matero (2013) investigated how Finnish private homeowners' heating system choice is affected by different attributes of residential heating systems following renovations while allowing heterogeneity in preferences. The results indicate that the investment and annual operating costs have significant effect on the choice of the heating system. The results also show that various system-specific attributes as well as socio-demographic characteristics have varying effects on their choice. In another study from Finland, Ruokamo (2016) conducted CE to investigate the household preferences for hybrid home heating systems. The results indicate general acceptability among respondents towards hybrid home heating systems. The results also imply that socio-demographic characteristics affect consumers' perception thus leading to varying views towards alternative heating systems. This thesis uses the same data as Ruokamo (2016).

4 SURVEY DESIGN

4.1 Data Collection

The survey was developed through multiple rounds of information gathering. The process began with the initial identification of factors that would affect an individual's heating system purchase decision. This was done based on the previous literature available as discussed in Chapter 3. Various rounds of discussions were held with experts like engineers, researchers and building authorities to arrive at the most relevant and current attributes associated with the heating technologies. The survey was carried out by Ruokamo (2016) for her research.

The first (pilot) round was conducted in two parts. In the first pilot survey 12 individuals who had recently been issued a building site were interviewed in September of 2013. These interviews helped to narrow down the most relevant attributes. The second pilot survey was conducted by mailing pilot questionnaires to 400 Finnish households drawn from the Population Information System of Finland. Among them were randomly selected 200 households that had built a detached house after 2012 and randomly selected 200 households that were issued a building license after 2012. The sample of the second pilot survey allowed the examination of preferences of a very narrowed down group of people that were making the heating technology purchase decisions. The second pilot survey yielded a 19.5% response rate. The response rate was 23.5% among the 200 households that had already built a detached house compared to 15.5% among those that were building or planning to build. Due to its higher response rate, the first group was chosen for the final survey.

For the final survey that was conducted in August 2014, two thousand homeowners were randomly drawn from the Population Information System of Finland from a group of people whose detached houses were finished building between January 2012 and May 2014. The final survey had a response rate of 21.6% as 432 respondents completed the questionnaire. Ngene 1.1.1 was used to create the choice tasks. 36 choice tasks were created and blocked into six versions of questionnaire. Bayesian efficient D-optimal design was used in the conditional logit framework.

Efficient designs not only try to reduce the correlation in the data but also intend to estimate parameters with the smallest possible standard errors. As discussed earlier, Bayesian efficient designs use random prior parameter estimates rather than fixed. For the final survey, these prior parameter estimates originated from the estimates from the second pilot survey.

4.2 Choice experiment description

In a choice experiment, a decision maker chooses one alternative out of all available alternatives. Each alternative is described by multiple attributes. The goal of our experiment is not to ask respondents how they would rank various alternatives but to ask them which alternative they would choose based on the levels various attributes assume. Realistic heating system choice scenario cannot be built using generic framework as all the chosen main heating systems have label-specific attribute levels as shown in Table 2. Therefore, labelled CE was chosen instead of generic (unlabelled) CE. In labelled experiments, each alternative is carefully labelled instead of being given generic names such as *Alternative1*, *Alternative2*, and so on. The possibility to use alternative specific constants (ASCs) is one of the advantages of using labelled CE. Labels are more realistic, provide more information to the respondents and act like attributes themselves. (Hensher et al., 2005.)

4.2.1 Alternatives

The choice alternatives provided to the respondents in the CE were ground heat pump, exhaust air heat pump, solid wood boiler, wood pellet boiler, electric storage heating and district heating. These are discussed briefly below.

- **Ground heat pumps**: Ground heat pumps or geothermal heat pumps use the earth as the heat source. They heat the living space by transferring the heat from the ground using pipes filled with fluid that are buried underground. These systems use electricity and are easy to operate.
- **Exhaust air heat pumps**: Exhaust air heat pumps extract heat from the exhaust air in the ventilation ducts of buildings. The heat is then transferred

to the supply air and/or water-circulating heat distribution system. Like ground heat pumps, they also require electricity and are easy to operate.

- **Solid wood boilers**: These systems use solid firewood or wood chips to generate heat. The heat generated is then stored in the form of hot water which is then distributed into the heat network of the house. They require manual work to feed the firewood into the stoves. They do not require electricity but need storage space.
- **Wood pellet boilers**: These boilers work similar to the solid wood boilers but use compressed wood pellets as fuel instead of firewood. The wood pellet boilers are usually more automated compared to their solid wood counterparts and require some maintenance but in regular intervals.
- **Electric storage heating**: The heat is generated by boiling water stored in tanks using electric resistors. The water is then distributed into the heating network of the building. Electric storage heating system can be turned off during peak hours to increase efficiency and has high comfort of use.
- **District heat**: The heat in district heating is generated in a plant, typically a combined heat and power plant. It is then distributed to consumers as hot water using a network of water pipes. The end users do not concern themselves with generating heat or maintaining the system.

The heat distribution system transfers the heat to the required area in the house in the form of hot water. (Motiva, 2018.) The distribution system also includes the network of radiators with water circulating inside them or underfloor heating pipes. Finally, the house needs some equipment to adjust and control the indoor temperature to a desired level. Some examples of adjustment and control equipment are thermostats, adjuster (that adjusts the temperature of heat entering the network by comparing it with the outside temperature) and remote and automatic control systems are some examples of adjustment and control equipment. (Motiva, 2017.)

4.2.2 Attributes

Each alternative in the experiment is described using attributes. Each of the six heating systems choices had the following attributes: supplementary heating systems, investment costs, operating costs, comfort of use and environmental friendliness.

Supplementary heating system describes what kind of secondary heating system the household has, if any, in addition to the main heating system. This attribute had four alternative levels: no supplementary heating (SUPP1), solar water heater/solar panel (SUPP2), water circulating fireplace (SUPP3) and outside air heat pump (SUPP4). It is important to notice that the supplementary heating system attribute takes various levels for each main heating system alternative except for the district heating. This is because households with district heating systems do not require additional heating systems. The investment costs (INVE) and (annual) operating costs (OPER) attributes take continuous values to represent the monetary costs incurred. Table 2 presents the attributes associated with each heating system.

The comfort of use attribute as the name suggests, describes the level of difficulty associated with using (or operating) a heating system. Three levels were used to describe the level of comfort of use: satisfactory (COMF1), good (COMF2), and excellent (COMF3). Due to the high maintenance requirement of solid wood and wood pellet boilers compared to other main heating system alternatives, the comfort of use attribute was limited to satisfactory and good levels only. The comfort of use level for the other four heating systems ranged from good to excellent. The environmental friendliness attribute describes the extent to which a certain heating system's impact is to the environment. Similar to the comfort of use attribute, the environmental friendliness attribute was described using three levels: satisfactory (ENV1), good (ENV2) and excellent (ENV3). Based on the energy efficiency and emission levels as well as the relative energy requirements (Ruokamo, 2016), the environmental friendliness levels ranged from good to excellent levels for ground heat pump, district heating, solid wood boiler and wood pellet boiler and satisfactory to good for the other two heating system alternatives.

Table 2: Attributes and levels.

Attribute	Heating System	Levels
Supplementary heating system	District heat	No supplementary heating system
	Others	Level 1: no supplementary heating system
		Level 2: solar panel and solar water heater
		Level 3: water-circulating fireplace
		Level 4: outside air heat pump
Investment Costs (€)	Ground Heat Pump	13000€, 16000€, 19000€, 22000€
	Exhaust Air Heat Pump	7000€, 9000€, 11000€, 13000€
	Solid Wood Boiler	4500€, 7000€, 9500€, 12000€
	Wood Pellet Boiler	8000€, 11000€, 14000€, 17000€
	Electric Storage Heating	6000€, 8500€, 11000€, 13500€
	District heating	6000€, 7500€, 9000€, 10500€
Operating Costs (€ per year)	Ground Heat Pump	500€, 650€, 800€, 950€
	Exhaust Air Heat Pump	800€, 1000€, 1200€, 1400€
	Solid Wood Boiler	600€, 850€, 1100€, 1350€
	Wood Pellet Boiler	750€, 950€, 1150€, 1350€
	Electric Storage Heating	1050€, 1350€, 1650€, 1950€
	District heating	800€, 1000€, 1200€, 1400€
Comfort of Use	Ground Heat Pump	good, excellent
	Exhaust Air Heat Pump	good, excellent
	Solid Wood Boiler	satisfactory, good
	Wood Pellet Boiler	satisfactory, good
	Electric Storage Heating	good, excellent
	District heating	good, excellent
Environmental Friendliness	Ground Heat Pump	good, excellent
	Exhaust Air Heat Pump	satisfactory, good
	Solid Wood Boiler	good, excellent
	Wood Pellet Boiler	good, excellent
	Electric Storage Heating	satisfactory, good
	District heating	good, excellent

4.2.3 Choice scenarios

Using the alternatives and the various levels their attributes take, six choice sets were designed. A choice set is the tool through which the information regarding alternatives, attributes and attribute levels under a hypothetical scenario are collected (Hensher;Rose;& Greene, 2005). This CE presented respondents with six hypothetical scenarios. Due to the fact that hypothetical scenarios were used, it was important to include clear explanation about the scenarios. The choice sets were presented along with the description that asked the respondents to imagine that they were choosing a heating system for a new 150 m^2 detached house that had a water-utilizing heat distribution system. They were also reminded that the annual heating energy consumption level of the house was approximately 16000 kWh and that detached houses assumedly have a fireplace for supplementary heating. They were finally asked to compare the alternatives and select the alternative they think is best given the different attribute levels. They were also asked to treat each choice situation as a new and isolated situation. An example of a choice task is presented in Figure 3.

As a reminder: the heating system is chosen for a new150 m2 detached house. The house has a fireplace						
Choice Task 2	Ground Heat Pump	Exhaust Air Heat Pump	Solid Wood Boiler	Wood Pellet Boiler	Electric Storage Heating	District heating
Supplementary heating system	Water-circulating fireplace	No supplementary heating systems	Outside air heat pump	No supplementary heating systems	Solar panel and solar water heater	No supplementary heating systems
Investment cost (€)	13000	11000	12000	14000	6000	9000
Operating cost (€/year)	950	1400	600	950	1050	1400
Comfort of use	Good 😐	Good 😐	Good 😐	Good 😐	Excellent ☺	Excellent ☺
Environmental friendliness	Excellent ☺	Satisfactory ☹	Good 😐	Good 😐	Satisfactory ☹	Excellent ☺
I CHOOSE	☐	☐	☐	☐	☐	☐
Choose the best alternative by checking one of the above boxes						

Figure 3. An example of a choice task.

Apart from the choice scenarios presented to the respondents, they were asked to answer additional questions. The respondents' attitudes and awareness about heating systems were asked using multiple choice questions as well as Likert scales. Another set of questions asked information regarding the new detached house they were actually living in. In order to capture the respondents' perceptions of various heating systems, a brief description of each heating system was given followed by the question, "Did you consider this heating mode for your new detached house?" They could answer the question using the Likert scale with points labelled as: certainly not, probably not, probably, certainly and do not know. The last section of the questionnaire collected the respondents' socio-demographic information such as age, gender, type of locality, education level, occupation, field of work, number of people in household and income level. They were also asked if they owned a forest.

5 THEORETICAL FRAMEWORK AND ECONOMETRIC MODEL

To model a decision maker's choice behaviour, we use the Discrete Choice model. These models are derived under the assumption of the utility-maximizing behaviour by consumers (Train, 2009). According to Louviere et al. (2000) three key factors should be taken into account when modelling an individual's choice behaviour: i) choice set generation (choice and sets of alternatives available to decision makers), ii) observed attributes of decision makers and a rule to combine them, iii) a model of individual choice and behaviour, and the distribution of behaviour patterns in the population. The decision made by a homeowner to choose one alternative over another can be modelled using the random utility modelling. The random utility model (RUM) specifies "the relationship between the selection of an alternative and the sources of utility that influence that selection." (Louviere et al., 2000.)

A representative homeowner n $(n = 1,2, \dots, N)$ attempts to maximize his/her utility by choosing one alternative j $(j = 1,2, \dots, J)$ out of the available alternatives. The utility function represents the process through which attributes of alternatives as well as the individuals' socioeconomic background aggregate to affect choice probability. It is a very important part of modelling individual choice and thus the predictive capability of the model. (Louviere et al., 2000.)

Let U_{nj} be the utility of the j^{th} alternative for the n^{th} individual. It is assumed that individuals will choose an alternative that yields them the highest utility. It is based on the key assumption that individual n will choose i if and only if:

$$\mathrm{U_{ni}} > \mathrm{U_{nj}}\ \forall\, \mathrm{j} \neq \mathrm{i}. \tag{1}$$

Now, looking at it from a researcher's point of view, s/he does not observe the utility yielded by the homeowner. Instead, the researcher observes some attributes of the alternative chosen by the homeowner, say $x_{nj}\ \forall\, j$, and some attributes of the homeowner, say s_n, and is able to stipulate a function that shows how these observed attributes are related to the homeowner's utility. This function, called the representative utility, is denoted as $V_{nj} = V(x_{nj}, s_n)\ \forall\, j$. Due to the fact that there are unobserved aspects of the utility, V_{nj} is not equal to U_{nj}. The homeowner's utility can thus be decomposed as the sum of observed and unobserved parts represented in the form:

$$U_{nj} = V_{nj} + \epsilon_{nj}. \quad (2)$$

where, ϵ_{nj} is a random component that includes the factors that influence the homeowner's utility but are not captured in V_{nj}. (Train, 2009.)

Using the utility-maximizing assumption presented in equation (1) and the utility function in equation (2), the individual will choose *i* iff,

$$V_{ni} + \epsilon_{ni} > V_{nj} + \epsilon_{nj}. \quad (3)$$

Rearranging the deterministic and random components of equation (3) together,

$$V_{ni} - V_{nj} > \epsilon_{nj} - \epsilon_{ni}. \quad (4)$$

The random components on the right-hand side of equation (4) is unobservable thus it is difficult to exactly determine if $V_{ni} - V_{nj} > \epsilon_{nj} - \epsilon_{ni}$. Therefore, the probability that $\epsilon_{nj} - \epsilon_{ni}$ will be less than $V_{ni} - V_{nj}$is calculated as:

$$P_{ni} = P(\epsilon_{nj} - \epsilon_{ni} < V_{ni} - V_{nj}) \; \forall \, j \neq i. \quad (5)$$

Equation (5) gives the probability that the individual decision maker *n* will choose alternative *i*. (Train, 2009.)

Furthermore, the logit model is obtained by assuming that the random parts of equation (2) i.e., ϵ's are independent from irrelevant alternatives (IIA) and independently and identically distributed (IID) extreme values. Out of the many available statistical distributions, the Gumbel distribution (or extreme value distribution type 1) is the one that is widely used in discrete choice modelling.

(Train, 2009). Thus, the cumulative density function for each unobserved component of utility is given by equation (6) as:

$$F(\epsilon_{ni}) = \exp(-\exp(-\epsilon_{ni})) = e^{-e^{-\epsilon_{ni}}}. \quad (6)$$

According to McFadden (1974), the probability that the individual *n* will choose alternative *i* can be expressed in closed-form multinomial logit model as

$$P_{ni} = \frac{\exp(V_{ni})}{\sum_{j=1}^{J} \exp(V_{nj})}. \quad (7)$$

The representative utilities V_{nj} are assumed to be linear, additive functions in attributes that determine the utility of i^{th} alternative. It can be expressed as:

$$V_{nj} = \sum_{k=1}^{K} \beta_{kj} X_{nkj}. \quad (8)$$

The βs in equation (8) are utility parameters that are independent of *n* and can be allowed to vary across the sample or be expressed as functions factors that affect the socioeconomic or demographic characteristics of consumers. This allows flexibility to the researcher. (Louviere et al., 2000.)

In some cases, for an alternative j, one of the *X*s can be set to be equal to 1 for all *n*, for example: if we set $X_{n1j} = 1$, the utility parameter β_{1j} is understood to be an alternative-specific constant (ASC) for alternative j (Louviere et al., 2000). The ASC for an alternative is the average effect of all unobserved factors (ones that are not included in the model), on the utility. The mean of the unobserved part of utility, ϵ_{nj} is designed to be zero when ASCs are included. For example: if $U_{nj} = \beta X_{nj} + \epsilon_{nj}{}^{*}$ with $E(\epsilon_{nj})^{*} = k_j \neq 0$, then $U_{nj} = \beta X_{nj} + k_j + \epsilon_{nj}$ with $E(\epsilon_{nj}) = 0$. In other words, if ϵ_{nj} has a non-zero mean when ASCs are not included, then adding them makes the remaining error have zero mean. (Train, 2009).

One of the desirable properties that the logit probabilities in Equation (7) have is that P_{ni} lies between 0 and 1. Holding $V_{ni}\ \forall\, j \neq i$ constant, when there is improvement in observed attributes of alternatives (i.e., when V_{ni} increases), P_{ni} approaches one and when V_{ni} decreases, P_{ni} approaches zero. Another desirable property is that the sum of the choice probabilities for all the alternatives equals to one (i.e., $\sum_{i=1}^{J} P_{ni} = 1$). The denominator in Equation (7) is merely the sum of the numerator over all the available alternatives. (Train, 2009.)

The logit model, however, has three important limitations: First, it only captures tastes that vary with respect to observed variables but not with unobserved or purely random variables. Second, it displays restrictive substitution patterns across alternatives due to the IIA property. Third, it cannot handle instances where unobserved factors are correlated over time for each decision maker. These limitations are eliminated by the mixed logit which is a greatly flexible model with the capability to approximate any random utility model. Mixed logit models allow for random taste variation, unrestricted substitution patterns as well as correlation in unobserved factors over time. (Train, 2009.)

Mixed logit models can be defined in terms of their choice probabilities as models whose choice probabilities are the integrals of standard logit probabilities over a density of parameters. In other words, mixed logit model probabilities can always be expressed in the form

$$P_{ni} = \int L_{ni}(\beta) f(\beta) d\beta, \tag{9}$$

where $f(\beta)$ is a density function and $L_{ni}(\beta)$ is the logit probability estimated at parameters β and is equivalent to equation (7), i.e.,

$$L_{ni}(\beta) = \frac{e^{V_{ni}(\beta)}}{\sum_{j=1}^{J} e^{V_{nj}(\beta)}}\,. \tag{10}$$

$V_{ni}(\beta)$ is the observed part of utility that depends on the parameters β. (Train, 2009.)

The mixed logit probability that is derived from utility-maximizing behaviour is based on random coefficients. The utility of an individual decision maker *n,* from choosing *j* out of available *J* alternatives is specified as

$$U_{nj} = \beta_n' x_{nj} + \epsilon_{nj} \, , \tag{11}$$

where x_{nj} are observed variables related to the chosen alternative and the decision making individual, β_n is a vector of coefficients of these variables for individual *n* that represents the individual's tastes and ϵ_{nj} is an iid extreme random term. The coefficients vary over individuals in the population with density $f(\beta)$. The only difference this specification has from the standard logit is that β varies over individuals rather than being fixed. This allows for the random taste variation. The individual decision maker knows the value for his/her own β_n and ϵ_{nj} for all *j* and chooses alternative i if and only if $U_{ni} > U_{nj} \forall\, j \neq i$. The researcher can only observe the value of x_{nj} but not of β_n or ϵ_{nj}. If the researcher could observe β_n, the standard logit choice probability conditional on β_n is

$$L_{ni}(\beta_n) = \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \, . \tag{12}$$

Due to the fact that β_n in equation (12) is unknown to the researcher, the probability cannot be conditioned on β. The unconditional choice probability, therefore, is the integral of $L_{ni}(\beta_n)$ over all possible variables contained in β_n, i.e.,

$$P_{ni} = \int \left(\frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \right) f(\beta) d\beta. \tag{13}$$

Equation (13) is the mixed logit probability. (Train, 2009.)

Allowing unrestricted substitution patterns is another desirable property of mixed logit. Substitution patterns pertain to the change in probability of an alternative being chosen given the change in the attribute of that alternative. For example: let us look at the choice scenario presented in Figure 3, If the investment cost for one of the heating alternatives, say ground heat pump, drastically decreases from 22000€ to 13000€, the chances of it being selected over other alternatives increases. Since the probabilities sum up to 1, the probability of other alternatives being chosen obviously decreases. This possibility to choose one alternative over another due to the change in attributes is known as substitution pattern. The standard logit model restricts the substitution to a specific pattern limiting its capabilities. It exhibits independence from irrelevant alternatives (IIA) property which is obviated by the use of mixed logit model. (Train, 2009.)

To better understand the IIA property, let's take the ratio of logit probabilities for any two alternatives i and k, $\frac{P_{ni}}{P_{nk}} = \frac{e^{V_{ni}}/\sum_j e^{V_{nj}}}{e^{V_{nk}}/\sum_j e^{V_{nj}}} = \frac{e^{V_{ni}}}{e^{V_{nk}}} = e^{V_{ni}-V_{nk}}$. It is clearly visible that the ratio depends only on the two alternatives *i* and *k*. In other words, the relative probability of *i* being selected over *k* remains the same and is affected neither by the presence of other alternatives nor by the attribute levels of the other alternatives. Due to the fact that the ratio is independent from alternatives except *i* and *k*, it is said to be IIA. Mixed logit however does not exhibit the IIA property and the restrictive substitution pattern of a standard logit model. The ratio of probabilities in mixed logit P_{ni}/P_{nj} depends not only on alternatives i or *j* but on all the data including the attributes of other available alternatives. Unlike the standard logit formula, the denominators in the mixed logit formula are within the integrals and therefore do not cancel as can be seen in Equation (13). (Train, 2009.)

6 RESULTS AND DISCUSSION

This section presents the results of the survey carried out to collect the data as well as the econometric estimations using the data. The section begins with the descriptive statistics of the survey respondents followed by the respondents' perception towards the attributes of the heating systems. Lastly, the results of the choice experiment are presented. Nlogit5 was used to estimate the models. The analyses were conducted under three categories of factors that influence the heating system choice: heating system attributes, building attributes and individual's characteristics.

6.1 Descriptive statistics of respondents

Out of the 2000 individuals randomly selected from the Population Information System of Finland, 432 responded to the survey. Table 3 presents the descriptive statistics of the respondents as well as a comparison with available corresponding statistics of the random sample of 2000 individuals. A sample is said to be representative of the population if it accurately reflects the characteristics of the population. The average age of homeowners was 42.6 years which is very close to that of the random sample. Similarly, the average household size as well as the gender distribution are also very close to those of the random sample. Therefore, based on the variables that were available from the Population Information System of Finland, it can be said that the collected sample was representative of the original random sample of individuals living in new detached houses. Information about the individuals' income, education, forest ownership or building characteristics was not available in the original sample. Nevertheless, it should be possible to generalize the results to some level for all individuals installing or planning to install a heating system.

Table 3. Respondents' descriptive statistics.

Homeowner characteristics					
Socio-demographics	Random Sample		Gender	Random Sample	
(Average) Age	42.6 years	40.5 years	Female	26.5%	25.69%
(Average) Household size	3.26	3.5	Male	73.5%	73.84%
Gross Monthly Income			Education		
Less than 2000€		3.01 %	Basic education		7.64 %
2000€ - 3999€		14.35 %	Secondary /vocational		36.81 %
4000€ - 5999€		33.33 %	Polytechnic degree		33.10 %
6000€ - 7999€		29.17 %	University degree		21.53 %
8000€ - 9999€		9.95 %			
10000€ - 11999€		4.17 %	Forest Owner		
12000€ - 13999€		0.93 %	No		70.83 %
More than 14000€		3.01 %	Yes		28.70 %
Building Characteristics					
Type of Building (Energy Classification)			Size of the building		
Normal (minimum standards)		43.52 %	< 100 m^2		5.56 %
Low-energy (-30% of min. standards)		43.06 %	100 - 149 m^2		39.35 %
Passive-energy (-50% of min. standards)		5.32 %	150 - 199 m^2		39.35 %
Zero-energy (consumption = production)		0.23 %	200 - 249 m^2		8.80 %
			> 250 m^2		6.48%
Locality					
Rural Area		30.09 %			
Village (< 500 inhabitants)		5.09 %			
Town		23.15 %			
Small City (< 50000 inhabitants)		14.35 %			
Large City (>50000 inhabitants)		25.00 %			

Number of respondents (N) = 432, *Random sample size (N) = 2000* The missing percentages account for the share of responses that were not available or where the respondent chose the "Do not know" option

Around 17% of households that fell under the low monthly income category, where the income was less than 4000€ monthly. More than half of the respondents (54.63%) were highly educated with a polytechnic or university degree and only 28.7% owned a forest. Among all the buildings in the study, less than half of them (48.61%) had some kind of energy saving capabilities. Based on size, the houses that are considered as big houses accounted for 15.28% of the houses. About a third (35.18%) of the buildings were located in rural area or villages with a population of less than 500 inhabitants.

6.2 Perceptions towards heating system attributes

To investigate homeowners' preference of heating systems, it is important to understand how they view the importance of different heating system attributes.

Even though the presence of a supplementary heating system is also considered as one of the attributes of the heating systems, only the attributes that are directly define a heating system were considered for the analysis of homeowners' perception. Respondents were asked to evaluate the importance of environmental friendliness, comfort of use, operating costs and investment costs in choosing a heating system. Each question was accompanied by a short definition of the attributes to ensure the respondents understood what the attribute means. A five-point Likert scale was used by also including the "Do not know" option. The results shown on Figure 4 reveal that homeowners place high importance on costs. Even though investment costs was rated as important by a majority (86%) of respondents, more people (98.6%) rated operating costs as being important before making a heating system choice.

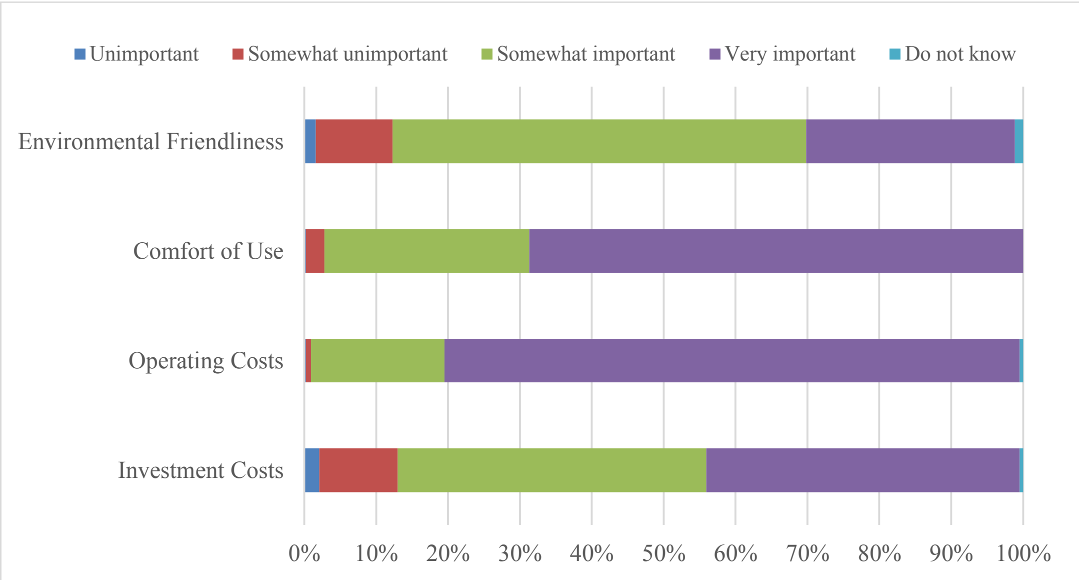

Figure 4. Importance of Heating System Attributes.

Environmental friendliness is another attribute of home heating systems that homeowners place importance on with only 12.3% viewing it as unimportant. This indicates the homeowners' tendency to choose a heating system that produces the least emission. Comfort of use was also popularly (97.2% respondents) rated as important indicating homeowners' inclination towards heating systems that are easy to operate.

Based on the initial analysis of perception of homeowners, the coefficients for costs in the choice experiment results are expected to be negative indicating the decrease in probability of a heating system being chosen when there is an increase in costs. Additionally, the effects of operating costs are expected to be greater than that of investment costs because the results suggest that more homeowners give importance to operating costs than investment costs. Sopha et al. (2010) also found the influence of perceived importance of heating system attributes in the choice made by households.

6.3 Choice Experiment Results

The list of explanatory variables included in the model are presented in Table 5. The dataset consisted of 2484 observations for 414 individuals. The questionnaire asked individuals if they had chosen the same heating system in each task and if so, what the reason behind it was. If the respondent answered the follow-up question by stating that the chosen alternative was truly the best one, all attributes for these individuals were excluded from the analysis. There were 80 such individuals and their utility functions were composed of ASCs only. The models were estimated using Nlogit5 and the results are presented in Table 6. The McFadden's pseudo R^2 for the conditional logit model is 0.09 whereas for the mixed logit model is 0.39. The initial CL model is statistically significant (Chi-squared = 696.47601 with 9 degrees of freedom) with p-value equal to zero. Similarly, the mixed logit model is also statistically significant (Chi-squared = 3439.90447 with 35 degrees of freedom) with p-value equal to zero. The mixed logit model was based on 1000 Halton intelligent draws. The ASCs along with LCOMF, HCOMF, LENV ,HENV, WATER, SOLAR and HP were treated as random parameters while INVE and OPER were treated as non-random (see Table 5 for the description of these variables).

Table 4. Main heating system choices.

Chosen Alternatives	Individuals (%)
Ground Heat Pump	42.4
Exhaust Air Heat Pump	10.7
Solid Wood Boiler	11.7
Wood Pellet Boiler	3.9
Electric Storage Heating	5.6
District heating	23.6

From the results of Table 4, it is clear that the most popular choice among respondents was the Ground heat pump (42%), followed by District heating (23.6%) and Solid wood heating (11.9), while Electric storage heating (5.6%) and Wood pellet boilers (3.9%) were the least popular choices. Comparing the magnitude of mean coefficients of ASCs in the mixed logit model reveals the choice of main heating systems in decreasing order of preference as ground heat, exhaust air heat pump, solid wood boiler and wood pellet boiler followed by electric storage heating.

The ability to determine the possible sources of any heterogeneity that exist is one of the appealing features of mixed logit. It is done through the interaction between ASCs and other attributes or variables suspected to be the sources of preference heterogeneity. The standard deviations of all the ASCs, supplementary heating system variables, comfort of use and environmental friendliness variables were statistically significant and greater than their corresponding means. This suggests the presence of preference heterogeneity which is discussed further in the results.

Table 5. Explanatory Variables.

Variable	Type	Description
AGE	Continuous	Age of the homeowner
LINC	Categorical	Low income household (Gross monthly income<4000€)
RURAL	Categorical	Living in rural area or villages with <500 inhabitants
BIGH	Categorical	Big house (size of the building >199m^2)
HTYPERG	Categorical	Energy saving house (energy classification has higher than normal standards)
FOWNER	Categorical	Forest owner
HEDU	Categorical	Higher education (homeowner has received a polytechnic or university degree)
INVE	Continuous	Investment cost
OPER	Continuous	Operating cost
HCOMF	Categorical	Excellent in comfort of use (increase from good to excellent)
LCOMF	Categorical	Satisfactory in comfort of use (decrease from good to satisfactory)
HENV	Categorical	Excellent environmental friendliness (increase from good to excellent)
LENV	Categorical	Satisfactory environmental friendliness (decrease from good to satisfactory)
SOLAR	Categorical	Presence of solar panel or solar water heater as supplementary heating system
WATER	Categorical	Presence of water-circulating fireplace as supplementary heating system
HP	Categorical	Presence of outside air heat pump as supplementary heating system

The results in Table 6 indicate that the ground heat pump with the largest ASC coefficient was the most favoured alternative followed by district heating, exhaust air heat pumps, solid wood fired boilers, wood pellet fired boilers and electric storage heating. This finding supports the results of Mahapatra and Gustavsson (2008, 2010), Rouvinen and Matero (2013) and Ruokamo (2016). One of the reasons behind the popularity of ground heat pump can be explained by the locality of the buildings. As the results showed, buildings in sparsely populated areas (rural and villages with <500 inhabitants) are highly likely to choose ground heat pumps. The buildings in sparsely populated areas account for about a third of the total buildings in the study. Rouvinen and Matero (2013) credit the popularity of ground heat pumps to high market share leading to increased credibility and learning from others' experience.

Table 6. Results of Conditional Logit and Mixed Logit Models.

VARIABLES	Conditional Logit		Mixed Logit	
	Coefficient	Std. Err.	Coefficient	Std. Err.
Ground heat				
ASCGHP	1.19849***	.08273	.77230***	.29285
Std. Dev. ASCGHP			2.59724***	.18603
ASCGHP:RURAL			.76415**	.32820
ASCGHP:BIGH			.67373**	.29643
Exhaust air heat pump				
ASCEHP	-.58030***	.09958	-1.01994***	.29095
Std. Dev. ASCEHP			2.10562***	.24840
ASCEHP:HEDU			-.60199*	.32196
Solid Wood Boiler				
ASCWO	-.96092***	.09727	-2.69583***	.39507
Std. Dev. ASCWO			2.60205***	.25957
ASCWO:RURAL			2.09095***	.40776
ASCWO:FOWNER			.84080**	.40508
ASCWO:HEDU			-1.66880***	.40650
Wood Pellet Boiler				
ASCPEL	-1.47812***	.12564	-2.84484***	.33394
Std. Dev. ASCPEL			1.46088***	.35194
ASCPEL:RURAL			1.22473***	.37263
Electric Storage Heating				
ASCELE	-.97385***	.11384	-3.48027***	.81943
Std. Dev. ASCELE			2.70544***	.32531
ASCELE:AGE			.02835*	.01715
Investment & Operating Costs				
INVE	-.22325***	.00989	-.32555***	.02052
OPER	-2.79130***	.14226	-4.84191***	.26993
Presence of Supplementary Heating				
SOLAR	.50745***	.07959	.87634***	.15425
Std. Dev. SOLAR			1.42006***	.17285
WATER	.24766***	.08349	.13531	.21096
Std. Dev. WATER			1.21495***	.20390
WATER:HEDU			.43783*	.25653
HP	.24437***	.08167	.26481	.18824
Std. Dev. HP			1.08306***	.20611
HP:HTYPERG			.51496**	.23762
Comfort of Use				
LCOMF	-.68349***	.11909	-1.77660***	.41990
Std. Dev. LCOMF			2.58974***	.39733
LCOMF:BIGH			-1.28129***	.48319
HCOMF	.22503***	.05711	.32401***	.09930
Std. Dev. HCOMF			.74024***	.16832
Environmental Friendliness				
LENV	-.43650***	.11750	-1.50678***	.28198
Std. Dev. LENV			2.00329***	.36052
HENV	.35855***	.05660	.65865***	.12241
Std. Dev. HENV			.90125***	.13947
HENV:FOWNER			-.42755**	.21124
No. of observations	2484		2484	
Log likelihood	-3351.264		-2765.747	
Log likelihood (0)	-3699.5018		-3699.5018	
McFadden Pseudo R^2	.09		.39	

*, **, *** indicate significance at 10%, 5% & 1% levels

6.3.1 Influence of heating system attributes

The attributes of the heating system on the heating choice are explained by the presence (or absence) of supplementary heating systems such as solar panel/solar water heater (SOLAR), water-circulating fireplace (WATER) and/or outside air heat pump (HP), investment costs (INVE), operating costs (OPER), comfort of use and environmental friendliness. Comfort of use and environmental friendliness variables were organized into label groups that had same attribute levels in each groups and the joint parameters specific to the corresponding label group were estimated. Coefficients HCOMF and HENV measure the increase in the level of comfort and environmental friendliness for the associated heating group. Similarly, LCOMF and LENV measure the decrease in levels.

The coefficients for costs i.e., INVE (-.32555***) and OPER (-4.84191***) denote expected signs. This signifies that an increase in the costs of installing and operating a heating system would decrease in probability of the particular heating system being chosen. The effect is higher in operating costs which denotes the tendency of the homeowner to choose a heating system that had lower recurring, operating costs. This aligns to the results shown in Figure 4, where respondents placed a very high importance of the operating costs. These results are consistent with the studies by Michelsen and Madlener (2012, 2013, 2016) who showed that the heating system choice was motivated by environmental benefits, ease of use and costs. Investment and operating costs are important determinants of heating system choice and people are sensitive to them, especially the operating costs due to their recurring nature. The negative signs indicated by the cost related coefficients are intuitive and consistent with the economic behaviour of a utility maximizing consumer. As the cost for a good or service increases, a consumer's tendency to choose the product decreases.

The standard deviations of SOLAR, WATER, HP, LCOMF, HCOMF, LENV and HENV were statistically significant and were greater than their corresponding means indicating the presence of heterogeneity. The presence of supplementary heating system increases the probability of a particular heating system as exhibited by the positive coefficients. The presence of a solar panel or solar water heater increased the probability the highest with the largest coefficient among the three supplementary heating systems followed by outside air heat pumps and water-circulating fireplace. When interacted with other explanatory variables for preference heterogeneity, the interaction WATER:HEDU (.43783*) was found to be statistically significant and positive denoting the preference heterogeneity in heating systems with water-circulating fireplace as supplementary heating system can be explained by a higher level of education. This means that highly educated individuals are more likely to select a heating system with water-circulating fireplace as supplementary system.

Similarly, heterogeneity in the presence of outside air heat pump as the supplementary heating system can be explained by the energy saving capabilities of the houses as denoted by the statistically significant positive relationship between HP and HTYPERG indicating that individuals with energy efficient houses are more likely to choose outside air heat pumps than those who live in houses with minimum energy saving standards. According to Dinçer and Kanoglu (2010), outside air heat pumps are more suitable for warmer climates and perform inefficiently when the outside temperature decreases requiring regular defrosting. The preference heterogeneity in HP explained by HTYPERG can be an indication of the energy saving houses having the capability to offset any inefficiencies from the heat pump by the energy saved by the house itself.

Relating to the concept of Total Economic Valuation (TEV) as discussed in Section 2.1, environmental friendliness variables capture the use values of environment with respect to a heating system. The comfort of use and environmental friendliness coefficients behave expectedly as can be seen in Table 6. HCOMF (.32401***) and HENV (.65865***) have positive signs denoting the increase in the probability of a heating system with higher comfort of use and environmental friendliness being chosen. Correspondingly, LCOMF (-1.77660***) and LENV (-1.50678***) have negative signs and thus denote the decrease in probability. When tested for preference heterogeneity, the interaction LCOMF:BIGH (-1.28129***) exhibited a negative and statistically significant relation denoting homeowners living in big houses are less likely to choose heating systems with lower comfort levels. The variable HCOMF however did not exhibit any observed preference heterogeneity. The environmental friendliness variable HENV showed statistically significant and negative relationship when interacted with FOWNER (-.42755**) indicating the low probability of forest owning homeowner choosing a heating system with high environmental friendliness. The variable LENV on the other hand did not exhibit observed preference heterogeneity.

The results showing negative coefficients for lower environmental friendliness and lower comfort of use levels and the positive coefficients for their higher counterparts is in line with Rouvinen and Matero (2013) and Ruokamo (2016). Achtnicht (2011) also showed that environmental benefits significantly influenced heating system choices. People living in big houses showing disinclination towards heating systems with lower comfort levels could be related to the economic status of the homeowners. Bigger houses can be an indication of better economic status denoting lower sensitivity towards costs and higher sensitivity towards comfort. Thus, people living in bigger houses would rather choose heating systems with higher comfort levels. Forest owning individuals have easy access to wood and may be accustomed to the overuse of wood due to the fact that wood can be used not only for main heating systems but also the supplementary heating systems leading to lower environmental friendliness. This can explain the negative interaction between HENV and FOWNER.

6.3.2 Influence of building attributes

This thesis also intended to investigate the influence of building attributes on the heating system choice made by homeowners. The explanatory variables to capture the attributes of the house are size (BIGH) and energy saving classification (HTYPERG) of the house as well as its locality (RURAL). Table 6 presents the interaction between ASCs and these variables. If the interaction term is statistically significant, then the model implies that the change in the marginal utilities for the choice (denoted by the interacting ASCs) may be, explained by the difference in the levels of the interacting covariate.

The statistically significant and positive correlation between BIGH and ASCGHP (.67373**) indicates that individuals with bigger houses are more likely to choose ground heat pumps than those with smaller houses. The locality of the building was able to explain the preference heterogeneity in the choice of the main heating system.

The interaction of RURAL with ASCGHP (.76415**), ASCWO (2.09095***) and ASCPEL (1.22473***) exhibited statistical significance as well as positive correlation suggesting that people living in rural and village areas are highly likely to choose ground heat pumps, solid wood fired and wood pellet fired heating systems.

This result is consistent with the findings of Ruokamo (2016) which suggest that people that do not live in cities are more likely to choose ground heat pumps, solid wood boilers and wood pellet boilers. Michelsen & Madlener (2012) show that people living in newly build houses in rural areas are likely to choose wood pellet boiler. The popularity of these heating systems in the rural areas can be explained by the freedom from heating system space requirements. People living in rural areas and villages have easy access to wood and those households usually already use wood for supplementary heating systems, making solid wood and wood pellet boilers more popular among them as compared to those living in cities.

The energy saving classification on the other hand did not explain preference heterogeneity in any main heating systems. It however affected the presence of outside air heat pump as supplementary heating system as explained in Section 6.3.1.

6.3.3 Influence of individual characteristics

The influence of the individual decision maker's characteristics was also analyzed by investigating the interaction between the ASCs and variables explaining the attributes. The attributes of interest were age (AGE), monthly household income (LINC), education level (HEDU) and forest ownership (FOWNER).

The interaction between AGE with ASCELE (.02835*) was statistically significant and positive indicating the individuals from higher age groups are more likely to choose electric storage heating systems than those from lower age groups. Ruokamo (2016) presented similar results. The inclination of older individuals towards the electric storage heating system can be explained by the higher level of comfort associated with it. Willis et. al. (2011) show that older individuals would rather enjoy the comfort of familiarity than adopt innovative technology.

Monthly income level did not explain preference heterogeneity in either of the heating systems or the comfort of use and environmental friendliness levels. This is in contrast to Michelsen and Madlener (2012) which shows significant relationship between income and various heating system choices. In contrast to our results, Ruokamo (2016) shows that people with higher income level were highly likely to choose ground heat pumps. However, education level and forest ownership exhibited statistically significant relationships with certain ASCs. The negative interaction of HEDU with ASCEHP and ASCWO indicates that highly educated individuals are less likely to choose exhaust air heat pump and solid wood boilers than those with less education. This result aligns with the findings of Ruokamo (2016) and Rouvinen and Matero (2013). Braun (2010) also identified individual characteristics as determinants of heating system technology along with building and regional characteristics. The negative relationship between higher education levels and solid wood boilers is also consistent with Braun (2010) who argued that higher education can be a proxy to environmental awareness and showed that households with lower education tend to choose solid fuel-fired heating systems. Forest ownership (FOWNER) showed no statistical significance when interacted with any of the ASCs. It however explained the preference heterogeneity in environmental friendliness as discussed in Section 6.3.1.

6.4 Discussion of total economic value

In terms of economic valuation, it is understood that a respondent chooses the bundle of marketed or non-marketed good (the alternative that is collection of its attributes that have varying levels) that gives her/him the highest utility. In our study, the marketed good is the heating system and the non-marketed good is the environment. Given their individual characteristics, the respondents signal the preference that best suits them. The results in Table 4 show that for the majority of respondents (42.4%) in our sample, their welfare is enhanced (or utility is maximized) when they choose ground heat pumps followed by district heating and solid wood heating. Electric storage heating and wood pellet boilers were the ones that maximized the utility for the least number of respondents. The utility derived by using a certain heating system gives the respondents the consumptive use-value of the heating system. Meanwhile, the environmental friendliness variable captures the consumptive use-value of the environment. Respondents trade-off attributes levels, for example: environmental friendliness (that captures that the change in the quality of environment), for another attribute or feature, say, investment costs. This shows how individuals try to maximize their utility by forgoing one value for another. The negative interaction between HENV and FOWNER (-.42755**) shows that the individuals who own forests will maximise their utility, but they have forgone the environmental friendliness attribute for some other attribute.

The behaviour where the respondents chose a heating system with high environmental friendliness can also be interpreted as option value or bequest value of the environment and natural resources exploited to generate energy or heat. This is with the understanding that if an expensive heating system is chosen for its higher level of environmental friendliness, the respondent is paying for the option value as well as the bequest value of the environment.

7 CONCLUSION

The objective of the thesis was to investigate the determinants of home heating systems using a choice experiment. One of the goals was to investigate homeowners' perceptions towards heating system attributes. Furthermore, how these attributes along with various other factors affected the choice of heating systems made by them was investigated. The factors affecting the choice of a heating system was divided into three categories: heating system attributes, building attributes and individual's characteristics. In addition to the study done by Ruokamo (2016) using the same data, the thesis also intended to test for observed preference heterogeneity for comfort of use and environmental friendliness attributes as well for the main and supplementary heating system alternatives. The thesis discussed how socio-demographic characteristics of homeowners and the building characteristics explained taste variation.

The thesis can suggest some policy implications and marketing suggestions regarding various aspects of choosing a heating system. The results showed how homeowners that the homeowners viewed operating costs as more important when it comes to making a heating system choice. Heating system manufacturers should focus more on reducing the recurring costs as most homeowners valued operating costs more than investment costs. Given the ambitious climate and energy targets set by the national government as well as European Union, Finnish policymakers should subsidise renewable energy solutions such as solar-based heating systems as our results suggest that such systems are favoured as supplementary systems working alongside the main heating system. Solar-based systems usually also produce electricity for other household uses. Capturing this sector has a huge potential of efficiency increase and rise in share or renewables.

The results indicate the importance of socio-demographic characteristics as well as building and heating system attributes while choosing a heating system. Attributes such as age and education levels of individuals have significant effects as shown by the results and can be used to target products and policies to consumers. The results indicate that older individuals are inclined to opt for electric storage heaters. Heating systems other than electric storage heating can target older individuals by improving their comfort of use. The locality in which the building is located plays an important role in the choice made by homeowners. Ground heat pumps, solid wood fired boilers and wood pellet boilers could be targeted in rural areas and villages. Households that live in houses with energy saving capabilities favour outside air heat pumps as supplementary heating systems. These determinants of heating systems should be considered during policy making or marketing a product.

The comfort of use and environmental friendliness of a heating system is also an important factor that should be considered by policy makers and marketers. Results indicate that homeowners highly value these features of a heating system. Heating systems that required extra work or are too technical to use decrease the chances of that system being chosen. Marketers of heating systems can improve the chances of their products being selected by homeowners by making them easy to operate. Similarly, the heating systems that were perceived as harmful to the environment also had low probabilities of being chosen. This suggests the need to develop policies and market trends favouring technologies that are least impactful to the environment. Not owning a forest increased the chances of choosing a heating system with higher environmental friendliness indicating the potential to improve the behaviour of forest owning individuals.

As the energy market is shifting towards smart technologies like smart grids and smart meters, the insights from this study can be used for better implementation of those technologies especially, the energy saving capabilities of houses. This should contribute towards increasing the efficiency of energy use in Finland. The findings of this thesis can be used in policy making and marketing in not only Finland but other countries as well particularly, countries with similar climates. The longstanding trend of using heating systems driven by the cold climate makes studies based on Finnish data as excellent reference for countries looking to implement similar policies. The study makes important contributions to existing literature by giving an insight into the preference heterogeneity observed in comfort of use and environmental friendliness variables.

The study investigates how certain attributes of heating systems influences the choice made by homeowners but does not include various other attributes of heating systems. Variables reflecting household size, heating system specific training, gender did not show significant effects and were not included in the model. Even though the cost variables could be considered a proxy for energy consumption, the actual consumption of energy could be included for further research. Variables reflecting TEV has been analysed by testing preference heterogeneity thus giving an opportunity to study homeowners' behaviour towards non-marketed goods while making decisions regarding marketed goods. This thesis does not compute the WTP for the presented alternatives but for future research, other environmental friendliness variables such as CO_2 and fine particle emissions by the heating systems could be taken into account to measure the environmental impact more and calculate the total economic value correctly. It would be interesting to compare these results with the results of a similar revealed preference study. That would allow the assessment of the hypothetical choice made by homeowners with the actual choices made by them.

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