Aalto University
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Heating mode choices of Finnish households and the Energy Paradox

Economics

Master's thesis

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2012

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AALTO UNIVERSITY SCHOOL OF ECONOMICS **ABSTRACT**
Economics, Master's Thesis 25.1.2012

Keywords: Residential space heating; Finland; Energy efficiency; Multinomial logistic model

Consumers do not in all circumstances tend to behave as the neoclassical economic theory would predict. In fact, consumers have often the tendency to overweight the initial investment cost of a technology versus the operating costs that accrue in the future. In this thesis, the hypothesis is tested by investigating Finnish households' heating mode choices in their newly built detached houses. If the hypothesis holds true, the lower level income households choose the heating mode that entails lowest initial investment costs despite the predicted future energy price development. Similarly, households with high income levels would have greater probability to choose more expensive heating modes. Direct electric heating is the most economical solution by its purchase price for a detached household in Finland and ground heat pump one of the most expensive. However, when discounting the predicted future energy costs back to the investment period, the NPV of ground heat pump for a type consumer is lower the NPV of the direct electric heating. The net savings of ground heat pump over its lifetime owes to the energy efficiency of the technology. If the diffusion of an energy efficient technology is very low despite being competitive, researchers talk about energy paradox.

The empirical approach of this thesis belongs to the discrete choice model family. Multinomial logistic and logistic regression models are applied to predict the probabilities of households to choose certain heating mode. The model is estimated by utilizing data from Finnish research company Rakennustutkimus Ltd. The data contains heating mode choices as well as socio-economic information of 1,260 Finnish households that were building a detached house in 2008. The results of the empirical examination do not give unreserved support for the hypothesis between income level and heating mode choice. Strong correlation between the income level and certain heating modes can be however found indicating that lower income level households would prefer direct electric heating and higher income level households ground heat pump. It is not possible to draw clear political implications based on the findings of the study. The importance of the empirical part of the study is to provide indication for further, wider and more profound study that should be conducted by applying more accurate data.

AALTO- YLIOPISTON KAUPPAKORKEAKOULU **TIIVISTELMÄ**
Taloustiede, pro gradu – tutkielma 25.1.2012

Avainsanat: Omakotitalojen lämmitysjärjestelmät, Suomi, Energiatehokkuus, Multinomial logistic -malli

Kuluttajien käyttäytyminen ei ole kaikissa tapauksissa noudata neoklassisen talousteorian periaatteita. Useissa tapauksissa kuluttajat painottavat investointikustannusta liikaa suhteessa tulevaisuudessa lankeaviin laitteen käyttökustannuksiin. Tässä Pro gradu -tutkielmassa kyseistä hypoteesia testataan tutkimalla suomalaisten kotitalouksien lämmitysvalintoja heidän vastarakennettuihin tai rakenteilla oleviin pientaloihinsa. Mikäli hypoteesi pitää paikkaansa, alemman tulotason kotitaloudet valitsisivat lämmitysmuodon, jonka investointikustannus on alhaisin riippumatta odotetusta energian hintakehityksestä. Näin ollen puolestaan ne korkean tulotason kotitaloudet todennäköisemmin valitsisivat kalliimman investointikustannusten lämmitysteknologian. Suomessa suora sähkölämmitys on investointikustannuksiltaan kaikkein alhaisin pientalojen lämmitysmuodoista ja maalämpöpumppu kaikkein kallein. Kun tulevaisuuden odotetut energiakustannukset diskontataan ostohetkeen, tyyppitalon maalämpöpumpun nettonykyarvo on suoraa sähkölämmitystä alhaisempi. Lämpöpumppu on siis taloudellisempi vaihtoehto yli sen elinkaaren ajan, sillä se on teknologialtaan energiatehokkaampi. Mikäli tällaisen energiatehokkaan teknologian diffuusio on erittäin hidasta kilpailukykyisestä hinnasta huolimatta, puhutaan akateemisessa kirjallisuudessa usein energiaparadoksista.

Tämän Pro gradu – tutkielman empiirinen menetelmä kuulu epäjatkuvan valinnan mallien kategoriaan. Empiirisessä osiossa käytetään multinomial logistista ja logistista regressiomalleja, joiden avulla selvitetään kotitalouden todennäköisyyttä valita tietty lämmitysmuoto. Mallin estimoinnissa käytetään hyväksi Suomalaisen tutkimusyhtiön Rakennustutkimus Oy:n keräämää aineistoa. Aineisto sisältää 1.260:n pientaloa rakentavien kotitalouksien lämmitysvalinnat sekä sosioekonomisia tietoja vuodelta 2008. Empiirisen tutkimuksen tulokset eivät tarjoa suoraviivaista tukea hypoteesille tulojen vaikutuksesta lämmitysvalintoihin. Näiden kahden muuttujan välillä voidaan kuitenkin havaita aineiston tarkastelun perusteella vahvaa korrelaatiota, joka viittaisi siihen, että matalan tulotason kotitaloudet suosivat suoraa sähkölämmitystä kun taas korkean tulotason kotitaloudet valitsevat todennäköisemmin maalämpöpumpun. Tulosten perusteella on vaikeaa muodostaa selkeitä poliittisista päätöksentekoa tukevia suosituksia. Työ selkeästi kuitenkin tuo esille syvällisemmän, laajemman ja perusteellisemman tutkimuksen tarpeellisuuden aiheesta täsmällisempää aineistoa hyödyntäen.

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1. Introduction

This thesis aims at investigating consumer behaviour in the Finnish heating market. The effect of various socio-economic factors on heating mode choices of households is studied through multinomial logistic and logistic regression analysis. The main focus is on the effect of income level on the decision between different heating modes, especially direct electric heating, available for detached houses in Finland. The results are then reflected to "the energy paradox" phenomenon, first of all to find out whether there is evidence of slow diffusion of energy (and cost) efficient heating technologies and second of all, to find the relationship between income level and heating technology diffusion.

The first chapter of the thesis introduces the overall aim and subject of the study. The background and the motivation of the study is presented in the chapter 1.1, the objective of the study is identified in the chapter 1.2 and the main findings of the study are summarized in chapter 1.3 before going to the structure of the study in the chapter 1.4.

1.1 Background and motivation for the study

Understanding and affecting household energy demand and consumption is essential from the point of view of social equilibrium. It is also important to understand the demand patterns when aiming at reducing greenhouse gas emissions in a local or global scale. In Finland, a remarkable share, approximately half of household energy consumption consists of indoor space heating. On a national level of energy consumption, it corresponds to some 9% of the total energy use, which is allocated for domestic space heating. Space heating in many cases involves fossil fuel combustion; some 10 % of the total greenhouse gases in Finland originate from heating the detached houses alone. Hence, taking into account the concern about air quality and climate change in the political agenda, the energy and heat generation can be considered as one of the cornerstones in environmental policy issues. The more energy efficient the technology is the less is the negative impact on the environment.

Household's energy consumption is dependent on many dwelling related factors such as household size and square meter size of the building, ventilation, and insulation. In addition, living habits, setting of thermostat and hot water consumption have an enormous impact on the net energy consumed in a household. But most importantly, energy efficiency-related solutions, especially heating technology choices are the core factors to be considered when calculating net energy consumption patterns and possibilities.

According to researches (e.g., Alcott and Wozny 2009; Hausman 1979) households do not calculate the total cost of an energy product but rather tend to underweight the costs accrued in the future. At the time of the purchase, households often do not give enough weight for future energy prices when choosing between heating modes. A household could select a heating technology that entails low investment costs but is not the most energy efficient solution. It might thus lead to a higher level of net energy consumption than would be optimal and result higher net costs. If an annual cost for a type consumer heating a detached house by direct electric heating is close to 2,000 €, misoptimization on an aggregate level leads to substantial welfare losses.

Too low diffusion of energy saving technologies can be a significant factor hindering, or at least making the process to cut down the amount of greenhouse gases slower. The situation, where the diffusion of energy saving technologies is too slow, is in academic literature often called the energy paradox. There are several studies that show, how on macro and micro level such energy conserving technologies are not yet widely adopted though being already cost-effective (e.g., Allcott and Wozny 2009; Jacobsson and Johnson 2000; DeCanio 1993; Masini and Menichetti 2012). Hence, it is possible that households are not choosing the most economic and environmentally friendliest heating system, despite the total costs would be competitive compared to conventional heating technologies.

Much of the literature concerning the energy paradox is concentrated on analysing market conditions and possible market failures. Beside the market failure explanation for the paradox, many authors are interested in the cost-minimization behaviour of the households. The household energy technology choices are important for assessing the cost of potential non-optimizing behaviour and identifying the role of different policies to correct the possible failure.

An investigation of heat energy consumption habits and characteristics on a micro level can offer valuable information when designing policies and regulations aiming at reducing consumer energy consumption in order to cut the carbon emissions. Choosing a less harmful heating system such as ground heat pump instead of direct electric heating can help reducing emissions substantially. However, one should bear in mind that the new greener technologies with higher energy efficiency and lower heat energy costs can as a matter of fact lead to higher net energy consumption offsetting the gains from efficiency. Thus, the possible rebound effects, larger square meter sizes and luxurious living habits should be taken into account when designing such policies.

Many synonyms are used to describe the heating technology alternatives available for detached houses. These alternatives are further referred as heating systems, technologies or modes throughout the rest of the thesis. In the same logic, detached houses are sometimes referred as one-family houses and holiday houses as summer houses or (summer) cottages.

1.2 Objective of the study and the research questions

In this thesis, the main target is exploring the energy paradox by examining the behaviour of the Finnish households when they choose a heating mode for their newly built detached house. The study examines how characteristics of individuals or households, here namely income, affect the space heating choices of households. The assumption behind the study is the hypothesis that technology choices are dependent on socioeconomic factors. The results are then compared to expected average costs of different heating technologies over their lifecycle to find weather there exists evidence of so called energy paradox in domestic heating sector or not. That is, whether or not people fully consider the effect of energy prices when deciding the heating technology.

Thus, the purpose of this thesis is firstly, to examine how income and other household related characteristics affect the Finnish one-family house builder’s heating type decision. Secondly, to compare the total costs of different heating types over their lifetime and the technology choices made by the households to discover if people are behaving as rationally as economic theory suggest.

This study is intuitively following the assumption that the increase in energy prices over the past decade should increase the relative market shares of energy conserving technologies versus the conventional heating modes. Especially the share of direct electric heating is the main interest in the empirical exercise. The initial investment cost of direct electric heating is substantially lower than those of the other heating systems’ available for detached houses in Finland. Nevertheless, the direct electric heating is expensive to operate in particular if the price of the electricity will continue to increase in the future. It often is the case that consumers underweight the price of the add-on, the future energy prices. Therefore, the households with lover income levels tend to use the heating mode that entails the lowest investment cost, that is, the direct electric heating.

The hypothesis of the thesis is tested by analyzing micro level data on households who were building or had recently built a detached house in Finland in 2008. Similar study on Finnish household data has not been conducted previously. Therefore, the results of the study offer interesting and new information on Finnish households' energy consumption behaviour.

1.3 The main findings of the study

The data applied in the thesis is collected from Finnish one-family and summerhouse builders during 2008 by Finnish building research company Rakennustutkimus RTS Ltd. In total 2,635 households responded to the survey. Altogether 1,260 households responded to the questions concerning heating mode choices.

The empirical part concentrates on investigating how the income level explains the probability of six different heating modes available for Finnish households building a detached house. The heating modes analysed in the regression models are electric heating, district heating, ground heat pump, other heat pumps, wood heating and furnace. The empirical consists of two different models; logistic and multinomial logistic models. The results of logistic regression model yield interesting results that are in line with the hypotheses; lower income-level households tend to have higher probability on selecting direct electric heating.

On the basis of this study, there seems to exist evidence for energy paradox in the Finnish household energy consumption. The higher income households seem to choose the heating mode that entails the highest initial investment cost, but the lowest Net Present Value (NPV), a ground heat pump. Whereas the lower income households favour the direct electric heating with low initial investment cost, but high NPV. It means therefore, that households actually seem to weigh the purchase cost over the net operating cost in their decision of heating technology.

A closer investigation of direct electric heating is particularly interesting in the light of the research question that is exploring the relationship between income level and the probability of a household to choose direct electric heating. The results of the marginal effects of the logistic regression are presented in table 1. The model entails 827 observations in total. In addition to income, age, residential area and building costs, housing square metre and occupation were selected as the variables in the model. The more control variables are added in to the model, the smaller are the changes in probabilities related to income levels. In the model 6, the probability to choose direct electric heating decreases by some 11-12 %, when a household moves into any of the income classes except the lowest one.

	Marginal effect dy/dx (delta method standard error in parentheses)					
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
income1	0.347 (0.092)***	0.249 (0.097)***	0.225 (0.099) **	0.196 (0.01)**	0.116 (0.107)	0.002 (0.126)
income2	0.117 (0.047)**	0.066 (0.049)	0.056 (0.049)	0.015 (0.051)	-0.043 (0.053)	-0.121 (0.053)**
income3	0.031 (0.045)	0.006 (0.045)	0.005 (0.045)	-0.03 (0.046)	-0.073 (0.047)	-0.122 (0.046)***
income4	-0.031 (0.049)	-0.462 (0.043)	-0.049 (0.048)	-0.072 (0.0477)	-0.096 (0.048)**	-0.117 (0.0467)**
age_30		-0.118 (0.047)**	-0.115 (0.047) **	-0.124 (0.046)***	-0.111 (0.051)**	-0.095 (0.05)*
age_30_40		-0.208 (0.043) ***	-0.197 (0.043***	-0.207 (0.042)***	-0.198 (0.047)***	-0.151 (0.047)***
age_40_50		-0.102 (0.05) **	-0.095 (0.049)*	-0.107 (0.049)**	-0.101 (0.052)*	-0.085 (0.052)
age_50_60		-0.072 (0.053)	-0.078 (0.520)	-0.069 (0.052)	-0.069 (0.03)**	-0.094 (0.0526)*
city			-0.084 (0.029)***	-0.067 (0.03)**	-0.063 (0.053)	-0.051 (0.029)*
cost_sqm				0.000 (0.000)***	0.000 (0.000)***	0.000 (0.000)***
farmer					0.224 (0.081)***	0.213 (0.079)***
worker					0.164 (0.051)***	0.139 (0.051)***
clerical_w~r					0.134 (0.051)***	0.122 (0.052)*
entrepreneur					0.161 (0.055)***	0.166 (0.055)***
manager					0.233 (0.077)***	0.208 (0.077)
housing_sqm						-0.002 (0.000)***

Table 1. Logistic regression results

The initial investment cost of direct electric heating is the lowest from all of the heating modes, but the total cost measured over the lifetime of the system is the highest. When all the electricity payments over the electric heating system's lifetime are discounted back to the investment period, the NPV of the direct electric heating is the greatest. When a comparative cost calculation of direct electric heating, district heating and ground heat pump is done for a type consumer between 2008 and 2023, electric heating is the most expensive heating mode with NPV of roughly 30.000 €. For district heating the corresponding NPV is 28.000 € and for ground heat pump 27.000 €.

A multinomial logistic regression was applied to analyze and make comparisons of the impact of income and other socioeconomic factors (age, residential area, building costs, number of inhabitants) on these heating mode choices of households. Total number of observations accounted for 793 in the model. The most significant finding is that if a household is changing from the upper or medium income class to the lowest class, the probability to choose ground heat pump drops by some 23 %. From the other socio-economic factors, the residential area seems to have the most significant impact on the selection of the heating technology. If a household is located in an urban area, the probability to choose district heating is increased by 21 %, whereas choosing ground heat pump is reduced by 10 %.

Even though the regression models themselves, do not offer straightforward answers concerning the effect of income and other socio-economic factors on the heating mode decision-making process of the households, the descriptive analysis of the data yields stronger relations. When comparing the income levels of the households and the chosen heating modes, clear pattern seems to exist especially with direct electric heating and ground heat pump (diagram 1).

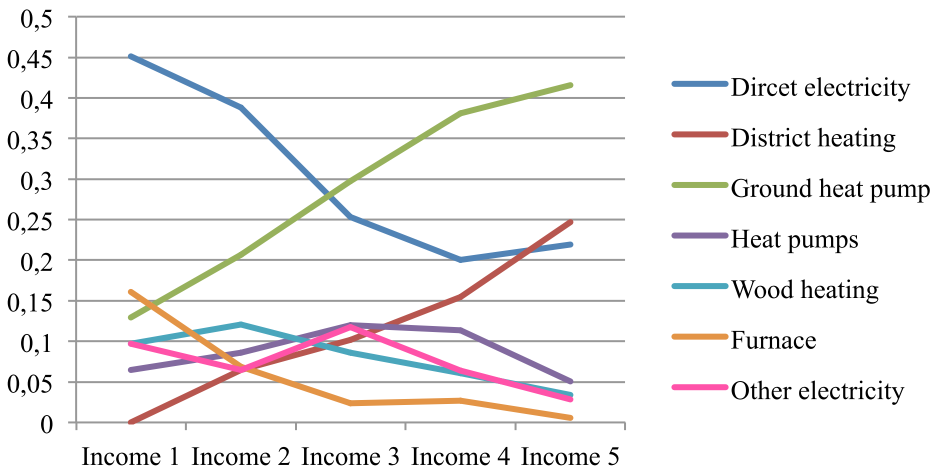


Diagram 1. Shares of different heating modes in five income classes

The income levels are categorized so that the level 1 corresponds to the lowest gross annual income level of a household (less than 20.000 €) and the income level 5 the highest (more than 80.000 €). It is clear that direct electric heating is more popular in relative terms in lower income level households (some 45% in the lowest income group) and its share drops in the higher income households. Ground heat pump on the other is not very popular among the lower income level households whereas its share increases in the higher income groups reaching over 40 % in the highest income group.

1.4 Structure of the study

The analysis consists of introducing the heat energy market energy paradox discussions and the empirical investigation of the paradox. The thesis is organized around these two themes. First of all, the Finnish heating market is described shortly in chapter 2 as an introduction for the analysis. The main focus of the chapter is on the household heat energy consumption and different heating technologies available for detached houses in Finland.

Second of all, in chapter 3, the energy paradox discussion is presented in a form of literature review. The concept of energy paradox is defined and the key barriers for the paradox are discussed briefly, mainly focusing on the most relevant explanations in the light of this study. Finally, some arguments on how to overcome the energy paradox are touched upon before going to discussion and critique on energy efficiency.

The chapter 4 is the theoretical framework for the empirical analysis. The regression models applied in the empirical section are based on the random utility theory. The logistic models are natural continuation of the random utility theory which are derived and explained in detail in chapter 5.

Basing on the theory, chapter 6 focuses on analysing the empirical results. The RTS Ltd's data is described by introducing the backgrounds, key variables and characteristics of the data. After introducing the data, the regression specifications are explained and the results reported.

Chapter 7 finally further discusses the results of the empirical exercise, results of previous studies and the connections of the results to the energy paradox discussion leading to concluding marks of the study and further research suggestions.

2. Characteristics of the Finnish heating market: heating sources and systems of detached houses

Chapter 2 aims at explaining Finnish detached house heating patterns and heating choices available for one-family house builders. Most of the technological specific information presented is gathered from Motiva Ltd's online brochures[1] for detached house builders. Motiva Ltd is a Finnish company that offers expertise services in the field of efficient and sustainable use of energy and materials.

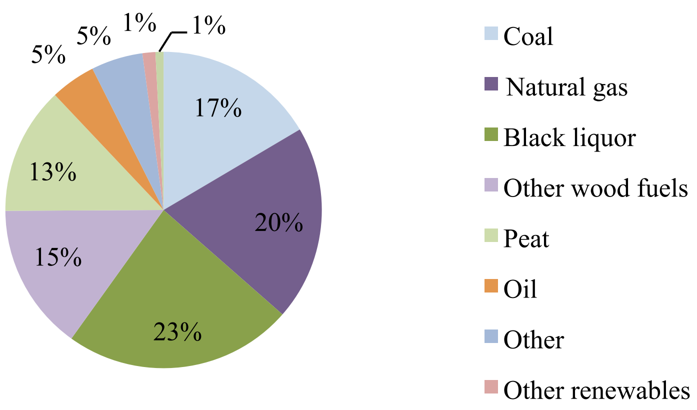
Chapter 2.1 briefly describes the heat energy production and consumption in Finland. Chapter 2.2 presents the consumption patterns and amounts of heat energy in Finnish one-family houses. Finally, chapter 2.3 defines different heating systems currently available for detached house builders in Finland.

2.1 Heat energy production and consumption in Finland

The supply of heat is essential globally, but especially in those countries located in moderate to low temperature areas. Finland, located in Northern Europe, has clear seasonal changes and the climate has distinguished elements from both maritime and continental climate. According to the Finnish Meteorological Institute, the average temperature of a year is cold and lies between +5 ºC in the south to -3 ºC in the north. Winter, when the average temperature of a day lies below 0 ºC, is the longest of the thermal seasons. Thus, the need for continuous space heating during several months is evident.

Many energy sources are utilized in heat production in Finland, some of them more common than the others. Heat can be produced for instance by fossil fuel combustion, such as oil, gas or peat, or by burning bio fuels, for example wood. Fossil fuel combustion is remarkable in heat production in Finland. Shares of different fuels used in electricity and heat production in 2008 are presented in picture 1. Fossil fuels, coal, natural gas and oil together accounted for 42 % of the total production. However, the share of renewable sources was also significant. Black liquor, other wood fuels and other renewables accounted together for some 39 %. Peat, which is categorized as a slowly renewable energy source, had in addition a share of 15 % of total heat production.

[1] All Motiva Ltd's brochures can be found in http://www.motiva.fi/julkaisut/lammitysjarjestelmat.



Picture 1. Use of fuels in electricity and heat production in 2008 (Source: Statistics Finland)

Beside the production of heat energy, the demand side of total heat energy is essential in the analysis of the energy market structure. The final energy consumption of five sectors in Finland between 1985 and 2008 are depicted in diagram 2. These sectors are industry, transport, space heating and others. The amount of space heat stayed on average close to 200 000 TJ[2] between 1985 and 1999. Between 2000 - 2008 the amount of energy used in space heating has gotten close to 250 000 TJ.

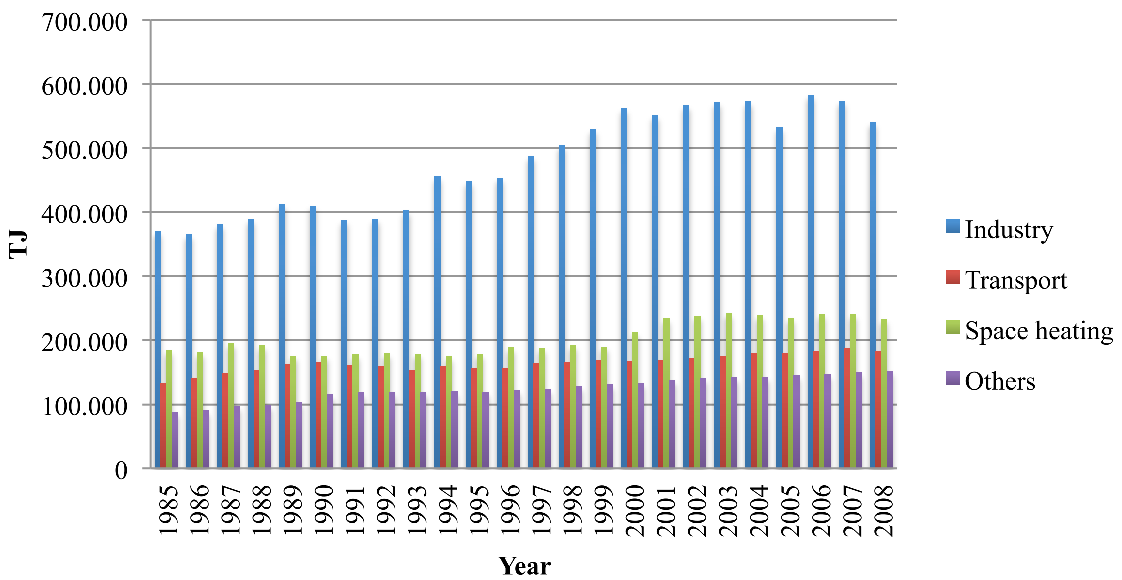
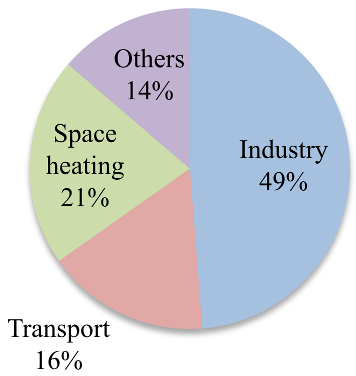


Diagram 2. Final energy consumption by sector in Finland between 1985 and 2008 (source: Statistics Finland 2011).

Despite the fact, that the space heating sector has increased in absolute terms, the relative share of space heating consumption of total energy consumption has nevertheless decreased between 1985 and 2008. It means that the energy consumption of other sectors, mainly

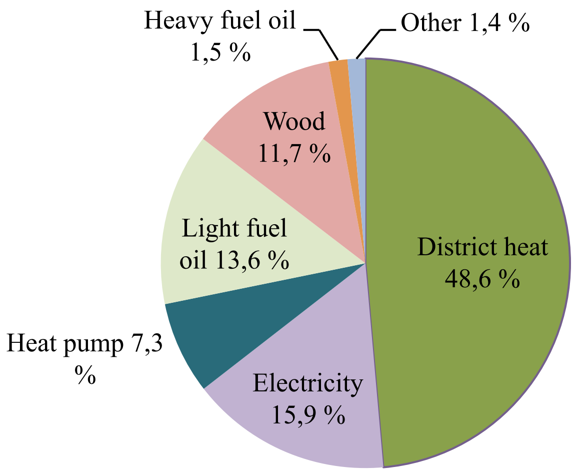
[2] Terajoules = 10^{15} joules

industry, has increased more than the space heating consumption. The final energy consumption in 2008 in Finland is also depicted as percentage shares of the five sectors: industry, space heating, transport and others in picture 2. Space heating accounted for 21 % of the final energy consumption, of which roughly 10 % was used for space heating in the domestic sector (Ministry of employment and economics).



Picture 2. Final energy consumption by sector in Finland in 2008 (source: Statistics Finland 2011).

Electricity is included in the most common sources of heat energy modes and is still widely used in heating of detached houses, though its share of the market has been declining over the past few years. In Finland, electricity is often produced by fossil fuel combustion or nuclear power. In 2007, its share of total Finnish heating market accounted for nearly 16 % (picture 3). However, the Finnish heating market is dominated by district heating, which market share accounted in total for 48.6% of the total heating in 2007. Light fuel oil was the third largest heating source with a market share of 13.6 %. Wood, as a traditional heating mode, is still remarkable source of heat energy. In 2007, its market share reached nearly 12 %. Wood is not generally widely used in commercial, public or apartment buildings, indicating that its' market share of detached house heating is substantially higher.



Picture 3. Market shares of heating residential, commercial and public buildings in 2007 (source: Statistics Finland 2009)

Despite the popularity of the traditional heating sources and technologies, producing heat from renewable sources such as utilizing geothermal heat is becoming increasingly common. The Ground heat pump for instance is gaining ground in newly built detached houses, especially in sparsely populated areas. Heat pumps in total accounted for 7.3 % of the space heating in 2007. The figure is most likely substantially higher for detached houses.

2.2 Consumption of household heat energy

Detached houses use heat energy mainly for heating room space, supply air and service water. A heating system of a regular one-family house consumes of energy on average some 100 – 120 kWh/m^2. A Finnish household living in a detached house consumes of heat energy on average 10 000 – 15 000 kWh annually only to heat room space and service water (Motiva 2009).The energy consumption of so-called low energy houses uses half of that energy and passive houses consume only 20 - 30 kWh/m^2 annually. Shares of space heating of total household energy consumption differ in studies, but the share in northern Europe lies usually between 60 and 75 % (Braun 2010, p. 5493; Santin et al. 2009, p. 1223, Schwartz et al. 1995).

Usually the size of the house significantly sets the heating possibilities that are suitable for a building. The bigger the house, the greater is the amount of energy consumed. In addition to the amount of heated square and cubic metres, weather, building regulations, building type, insulation, occupant behaviour, energy type, design of a dwelling, heating systems and habits, and maintenance have a substantial effect on the heat energy demand (Santin et al. 2009, p.

1224). Household characteristics are important and have an effect on energy use for households' space heat consumption. Younger households tend to use less energy for space heating than older households. Studies have also found positive linear correlations between household size and energy consumption (Leth-Petersen and Togeby 2001, Santin et al.2009).

Besides the house specific characteristics, the significance of the living habits makes a drastic difference in the net energy consumption of housing (Davis and Durbach 2010; Weber and Perrels 2000). According to by Jeeninga et al. (2001 cited in deGroot et al, 2008) in the Netherlands, it was discovered that an energy intensive lifestyle in a low energy house could lead to higher net energy consumption than an energy conserving lifestyle in a normal or less energy efficient house. Especially the consumption of hot water can differ considerably between households and individuals. According to Motiva Ltd, heating of the service water accounts for 10 to 25 % of a one-family house's total heating energy consumption. Warm water is used in one-family houses on average 30 – 50 litres per person per day and the temperature of the water must stay between 55 ºC and 65 ºC for health and safety reasons. The demand for warm service water stays more or less even a year round excluding the holiday seasons.

Even though energy efficiency in buildings and infrastructure on average is rising, the net heat energy consumption is not coming down at the same rate due to the growth of the average size of the houses and living space per person as well as rising living standards. According to studies, energy savings in energy efficient buildings is often less than calculated or expected due to living habits (Santin et al. 2009, Jeeninga et al. 2001 cited in deGroot et al 2008; Dubin et al. 1986; Hirst and Goeltz 1985). Diverse factors have caused an increase in energy consumption in global terms. Despite of declining energy intensity in heating, structural factors increase the heat consumption by more than 1 % every year. The rising energy consumption is often explained by growing living standards and increasing living space measured in square metre size per person. The sizes of the houses are staying constant or even increasing at the same time as the average size of a family decreases.

2.3 Heating technologies in Finnish detached houses

The heating system of a detached house consists of heat production, heat storage, heat exchange and delivery, and control equipment. The heat can be directly delivered to the heated space or it can be stored when transferred from the power factory. Heat generator equipment transfers the energy from an external source. Boilers, district heat exchangers, electric heaters and heat pumps are all heat generator equipment.

Heat is transferred with a mediator, usually water or air. It is delivered to the heated space utilizing various different equipment including heaters, blowers and fans and underfloor heating pipes. Most common domestic heating systems in Finland are electric heaters, heat pumps, radiators or under floor and ceiling heaters. Many heating systems require a separate technical space, such as district, oil or pellet heating. Some of the heating systems store part of heat energy before it is utilized in the heating of the room space. For instance, wood or wood pellet heating and solar heating the heat is stored in an accumulator.

The heat exchanger and delivery system transfers the heat from the heat development source to the room space. The equipment that is part of the heat delivery system include various transfer pipes and channels and the heating device of the supply air. Also electric heaters and heating cables work as heat delivery device. Low-temperature heat delivery device, such as underfloor heating or ventilation heating, are getting more popular in the newer detached houses. These systems make the heat transmission more stabile and guarantee a pleasant living environment. Moreover, low temperature heating delivery equipment creates better preconditions for utilization of geothermal heat or solar radiation.

There are numerous factors that affect the decision of heating system, such as the size of the house and family, need for the heating energy, living standards and habits, and changes in all of them. Even the building site itself sets certain limits for the heating system choice. For example, the size of a lot or the quality of the soil affect whether it is possible to install a ground heat pump or not. District heating is an option only if the distribution network is located in the area. In practice it means that district heating is only available in the urban areas, where its popularity is correspondingly high. Solar heating instead is sensible for the net amount of the solar radiation on the lot.

The most common heating systems available for detached houses in Finland that are relevant for this study are explained in more into detail in this chapter. These heating systems are electric heating, oil and gas heating, district heating, wood and pellet heating and different heat pumps. Diagram 3 illustrates the market share development of these heating systems in Finland between 2000 and 2008.

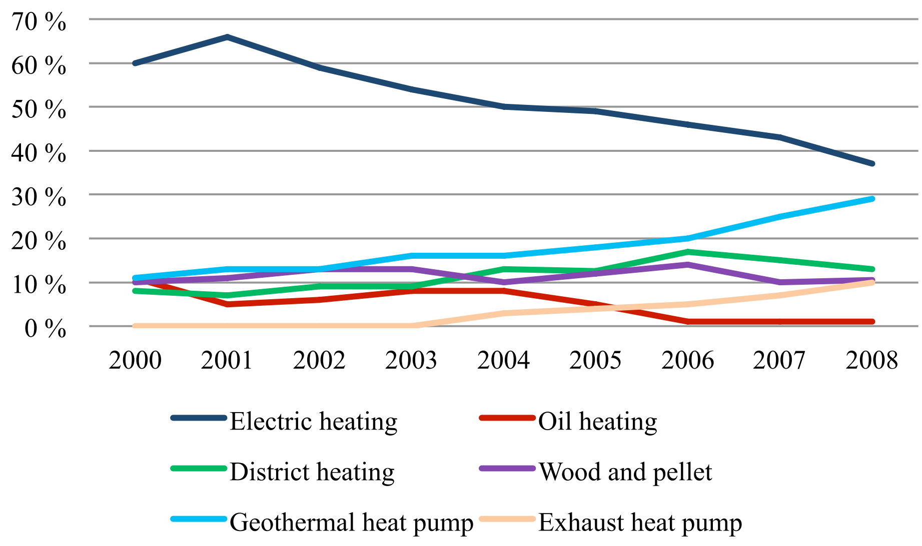


Diagram 3. Market shares of different heating modes in Finland between 2000 and 2008 (source: Motiva Ltd 2009).

Electric heating has been the most popular heating mode in detached houses during the past decade. However, its share of the total heating market has declined steadily since 2001. By 2008, electric heat's market share has gone down to under 40 % from nearly 70 % in 2001. Ground heat pump, on the other hand, has increased its relative share from 10 % in the early 2000's to nearly 30 % by 2008. The popularity of oil heating has predictably sunk in to only couple of percentages as the price of crude oil has gone up. The share of exhaust heat pump has been rising gradually reaching 10 % by 2008, where as the popularity of wood and pellet heating has stayed rather close to 10 % the entire eight-year timeframe.

2.3.1 Electric heating

Despite being moderate by its initial investment cost, the net cost of electric heating is usually higher than any other heating system for a standard detached house. Thus, electric heating is able to compete with the other heating systems in price only if the house consumes minimal amount of heating energy, such as energy-efficient or passive houses. In a smaller sized low or passive energy one-family house, electric heating may in fact be the most economical solution. Usually it is reasonable to utilize auxiliary heating system aside electric heating during the coldest periods such as air heat pump or wood heating.

Electric heating can be divided into direct and water circulated electric heating systems. Direct, room specific heating systems are underfloor heating systems, radiators, ceiling heating and warm-air heating. The direct electric heating is economical to install and therefore nowadays popular combined with different ancillary heating modes, such as air heat pumps. Water circulated electric heating systems cover electric resistant heaters and boilers.

During the last decades, the electric heating has been very popular in Finnish detached houses, but as many other heating systems have entered the market, the share of electric heating has gone down steadily. At the same time, the net consumption of electric heating has risen from under 2000 GWh in the 70's to nearly 10 000 GWh by the 2006 (diagram 4). The popularity of the electric heating mode can most likely be explained by the low initial investment costs and user friendliness. The benefit of direct electric heating is that the temperature can be set often manually in each room and the heating can be switched on and off according to the changes in demand during the seasons.

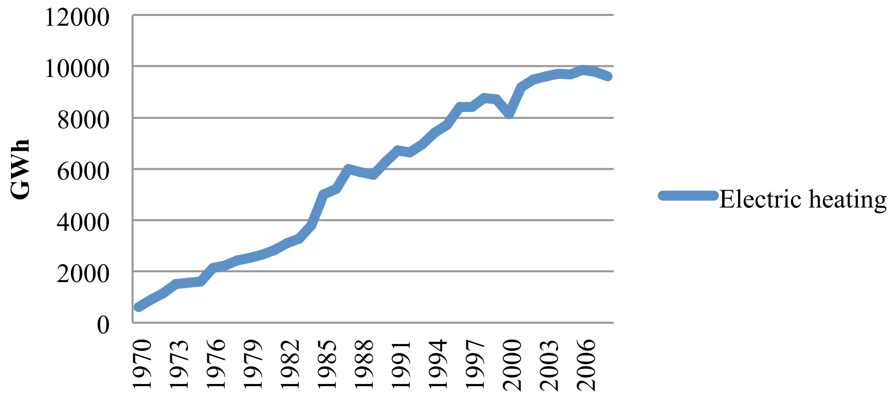


Diagram 4. Consumption of electric heat for space heating in Finland between 1970 and 2008. (Source: Statistics Finalnd 2011).

One of the biggest draw backs of electric heating beside the high operating costs are the adverse environmental impacts of electricity production. Diagram 5 is a rough comparison between different heating sources available for one-family houses according to their CO_2 intensity. On an average in a house that consumes 10.000 kwh of heat energy in a year, electric heating produces most (3.5 t) CO2 –emissions and wood the least (0 t).

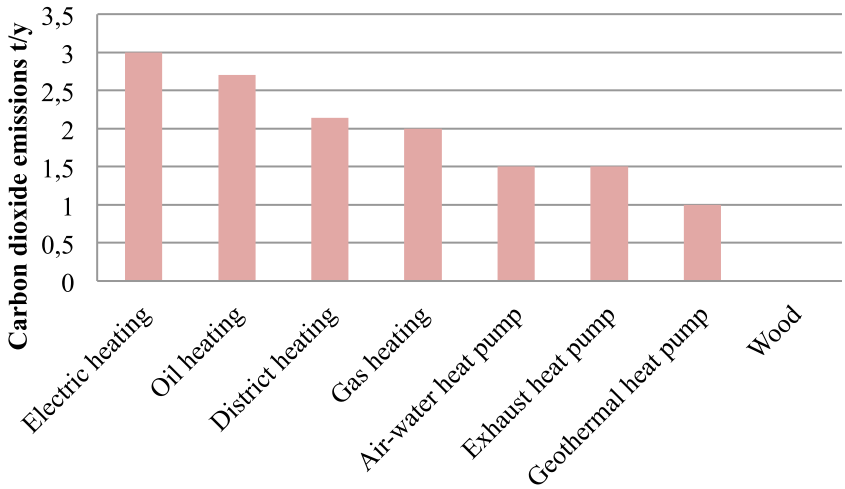


Diagram 5. Average annual CO_2 –emissions of different heat sources of a one-family house that consumes 10.000 kWh heat energy in a year (source: Motiva Ltd 2009).

The environmental impacts of electric heating are directly proportional to the production of electricity. Much of the electricity is generated by fossil fuel combustion. Its share accounted for some 29 % of the total electricity production in Finland in 2010. Some 28 % of the total electricity produced in Finland originates from renewable sources[3]. Waterpower and bio energy are the most common renewable energy sources in electricity production. The most common source in electricity production is nuclear power, in 2010 it accounted for 25 % of the total production. (Finnish Energy Industries 2010).

2.3.2 District heating: combined heat and power (CHP)

In Finland, the district heating is by far the most common form of heat energy sources in space heating (diagram 6). The consumption of district heating is increasing in all buildings, but especially in residential areas. It is used mostly in densely built areas. Somewhat 2.6 million Finns live in houses heated by district heat, almost 50 % of the total heating market accounts for district heating and nearly 95% of the Finnish apartment buildings are connected to the district heating network. Nowadays district heating is getting more popular in detached houses as well. In 2008, nearly 14 % of the one-family houses were part of the district heating network. Even though district heating is easy and reliable, its drawbacks are its limited availability nationwide and usually dependency on a single supplier.

[3] In 2010 14.6 % of the electricity produced was produced by utilizing hydro-electric power, 11.9 % biomass, 0.8 % waste and 0.3 % wind power (Finnish Energy Industries 2011).

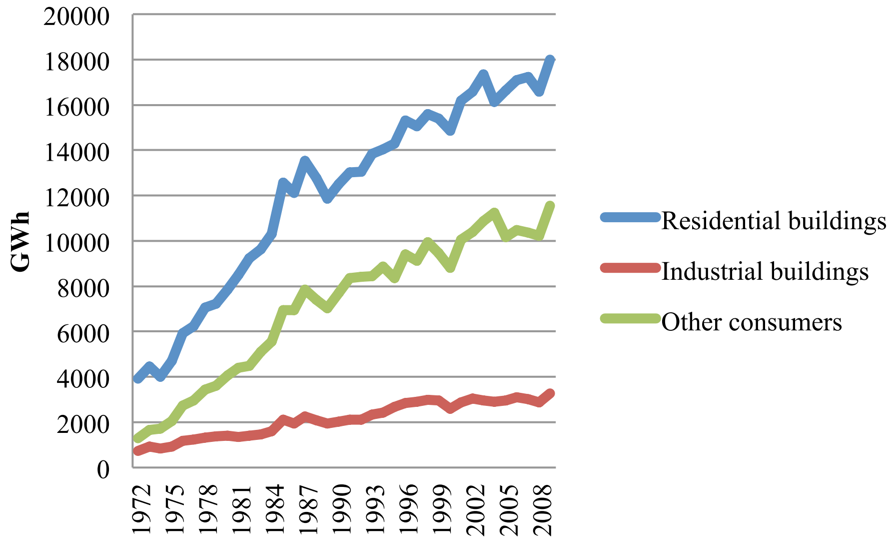


Diagram 6. Consumption of district heat in Finland between 1972 and 2008. (Source: Statistics Finland 2011)

District heating is often considered to be relatively easy and fast, and in some cases even energy efficient and economic heating choice. The heat is transferred to the end user through circulating water in the district heat network. The district heat system requires very little maintenance from the end user and it is easy to join the network. In a detached house the heat is directed into rooms via water radiators and underfloor heating systems, leaving no need for separate warm water accumulator. The heat energy is transferred into the house with heat exchangers, which are placed in a room with floor drain. In a detached house, some 75 % of the annual heating energy is used for space heating and the rest for heating the warm water. In a low-energy building, the share of water is clearly higher.

Most effective way to generate district heat is in a combined heat and power production (CHP). CHP facilities generate electricity at the point of end use instead of a high-voltage transmission system. Most importantly, CHP gathers leftover, or otherwise wasted heat from the generation process and converts it into energy to be further utilized in heating, cooling or other energy needs. CHP systems can turn more than 80 % of the fuel's theoretical energy content into useful energy, compared to 33% for traditional centralized power plants (Gronheit 1999, p. 108; Amiri and Moshfegh 2010). What is more, a CHP-system provides often substantial financial savings on energy costs especially in cases where high demand for the recovered heat exists.

The environmental effects depend on the production patterns such as whether the heat energy is produced together with electricity production in a combined heat and power (CHP) facility.

The fuel type used in the combustion also affects the environmental friendliness of district heat. District heat is in Finland usually produced together with electricity. The efficiency of the fuel can rise up to 90 % when the heat generated as a by-product of electricity production is captured and utilized. Nevertheless, In Finland the district heating and CHP usually rely on conventional energy production that involves a great amount of fossil fuel combustion. The most common fuels are coal, oil, natural gas, peat or wood. Natural gas accounted in 2008 for 37.2% of the total district heat production, coal 23.7 % and peat for 18.3 %. The share of wood and other bio fuels were 13.2 % in 2008. The average emission measurement for district heat is 214 g/kWh, which means that 10,000 kWh of heat energy consuming house produces 2.14 tons of carbon dioxide in a year, meaning that all heat pumps and gas heating are environmentally friendlier than district heating (diagram 5).

2.3.3 Wood and pellet heating

Wood heating is the environmentally friendliest heating mode when measured in greenhouse gas emissions. Accessibility of wood is usually good as it is a local renewable heating source. Wood combustion is not equivalently counted to increase the effects of climate change. As trees grow, they absorb carbon dioxide the same amount that is released when the wood is burned (diagram 4).

The best efficiency rate from burning wood (up to 85 %) is received by using trapping fireplaces that slowly release the trapped heat evenly and long lasting into the room space. The wood burns purely in an inverse fire stove, where it vaporises. The hot gas can then be led to a secondary combustion space where it burns purely at a very high temperature.

It is also possible to burn wood chips, pellets, chopped firewood and firewood in a stove or furnace. The heat is then led to the room space with circulating water in heaters. The heat from the burned wood is first led to an accumulator filled with water and the water further to the heat network. The accumulator decreases the need for wood. Wood chips are usually fed to the stove by using a stoker.

Pellet fireplace and pellet central heating are common heating sources in both new and old houses. An automatic pellet fireplace is an adequate auxiliary heating system in electric and oil heated houses. Pellet can be easily used also in summerhouses where continuous heating is not needed. An average Finnish one-family house's[4] annual wood pellet demand for heating and warm water is some 5 tons (8 cubic meters) of pellet.

Nowadays it is common that wood in its many forms is used as an ancillary heating source in the detached houses. A proper sized fire place can cover even a third of a building's heating energy supply. Wood is an easy way to reduce the need for other costly heating sources, such as electricity, during the coldest months. Wood is also a convenient way to secure the heat supply during possible power cuts; almost any other heating system is run by electricity.

2.3.4 Heat pumps

In 2000s the popularity of heat pumps has drastically increased especially in the detached houses. The development of different heat pumps in total numbers are depicted in diagram 7. Especially the number of air heat pumps has gone up rapidly reaching 140,000 by 2006.

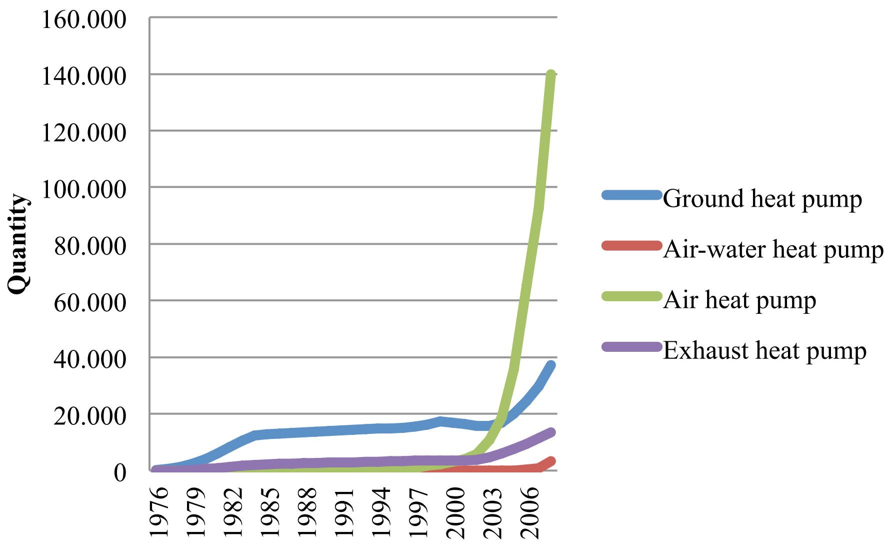


Diagram 7. Heat pumps of detached houses in Finland between 1976 and 2008 (source: Statistics Finland 2011).

In this study the ground heat pump (or geothermal heat pump) is separated in the econometric analysis from the other heat pumps. This is due to the different nature of the pump and the special infrastructure it requires. Other heat pumps usually function as auxiliary heat source and are used aside for instance electric heating. Different heat pumps specified in this study are aside geothermal heat pump air heat pump, exhaust heat pump and air-water heat pump.

Ground heat pump

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[4] With an average square meter size of 130-150 m^2

Ground heat pump absorbs solar heat stored in the soil, rock or water. The geothermal heat has been utilized since 1970's and it its popularity has been steadily growing by the 2000's. In 2008 nearly 30 % of the one-family house builder chose geothermal heat pump as their heating mode. The acquisition cost is high compared to many other heating systems, especially electricity heating, but geothermal heat pump is relatively cost effective solution for heating measured over its whole lifecycle, which lies usually between 15 and 20 years. The cost-effectiveness is higher the bigger the heated space is. If the square metre size of the house is at least 150 m^2 the geothermal heat pump is often with the current technology the most economic solution in the long run.

As the energy costs get higher, the geothermal heating becomes more and more cost-effective in smaller houses as well. Currently, the cost of geothermal energy is approximately 30 % of the electricity price. In fact, there is a clear correlation between the popularity of the geothermal heat pump and the increasing prices of oil and electricity. At the same time, the technology of heat pumps has developed making them today effective and reliable heating systems. Ground heat pump is easy to use; there is very little need for maintenance, and it is environmental friendly: the energy produced is mainly renewable energy, depending on how the electricity need to operate the pump is produced. What is more, the drill dwell is a good source for cooling. Besides the fact that the ground heat pump is gaining popularity in new detached houses, it can be installed in to old houses too, especially if the heating is water based heat delivery system.

To capture and utilize the heat in the ground, electricity is needed. The heat is usually taken from a deep drill well or from a long horizontal pipe system installed on the soil. If the house is located next to a water system, it can also function as a source of heat. The heat pump transfers heat from colder to warmer. The geothermal heat pump works with the same mechanism as a refrigerator, but there the heat from the soil is transferred to the heating system and service water of the house.

Coefficient of performance (COP) is a heat measure that describes the efficiency of the heat pump by expressing how much heat is produced per electricity unit used. The better the multiplier the smaller the difference between heat source (e.g. soil) and the heat delivery system (e.g. radiators or pipes). Typically the average of the multiplier on an annual level for geothermal heat pump is close to three.

Geothermal heat pump is classified as renewable energy. Heat pumps however require some amount of electricity to function. Thus, the environmental effect is also dependable on the electricity production. If the COP of a geothermal heat pump is 3, it can be roughly estimated that the emissions of the geothermal heat is some 30 % of the emissions of the electricity used to heat the building. For instance if a house consumes 10,000kWh for heating, it creates 0.7 to 1.3 tons of CO_2 depending the multiplier used (diagram 4).

Air heat pump

The investment of air heat pump is relatively low, and it can reduce the net heating energy costs of a detached house almost by half. On average, it can usually cover some 30 to 40 % of the total annual heat energy demand. A pump transfers heat from cooler to warmer. The air heat pump uses the open air or the outgoing air form ventilation by transferring it directly into heating energy to be utilized in the room space heating or into water for heat exchanger system.

Air heat pump is however inadequate as a main heating source in Finland since it cannot cover the heat demand during the coldest months. Thus, it is most effective to use air heat pump as a auxiliary heat source next to electric heating. The pump can also be installed into houses that use oil, pellet, wood or water based electric heating.

The amount of heat produced is depending on the outdoor temperature. The lower the temperature the less energy a pump can produce. The energy is mainly saved during spring and autumn. During the summer time, the heat pump can also be used as an efficient ventilation system. The mechanism of the pump works inversely compared to heating mode during the cold months.

In geographical sense, heat pump is most beneficial in Southern Finland inland. The colder the air the worse is the capacity of the pump. Once the temperature goes under -20 °C, the air pump cannot perform.

When measured on annual levels, the COP of an air heat pump changes as a function of outdoor temperature. Usually in Finland the multiplier gets a value of two or slightly more. The net heat energy saved depends on the scale of the pump and its placement in the house.

Air-water heat pump

Air-water heat pump is the newest of the heat pump techniques. With air-water heat pump it is possible to save heat energy up to 40-60 % compared to direct electricity heating. The initial costs are lower than those of the geothermal heat pump. The air-water heat pump can be used to lower total heating costs as long as the outdoor temperature stays above – 20 °C. However, there are already pumps in the market that can function even in -26 ° C. The air-water heat pump guarantees savings during milder temperatures, but during the coldest periods in the winter times, the main heating source is usually electricity. Since the pump generates the least amount heat energy when the need is at its highest, a backup system is needed.

The air-water pump absorbs heat energy from the air outside and transfers it into the water heating system. The pump is applicable for heating the service water too. The advantage of the air-water heat pump compared to the geothermal heat pump is its lower initial investment cost. The air-water pump is also easier to install than geothermal heat pump and can usually be installed to lots that are not suitable for geothermal heat pumps. The air-water heat pump can also be installed afterwards into houses to replace existing heating system or complete it.

The air-water heat pump can produce free energy some 8 000 – 12 000 kilowatt hours in a year when the total consumption is 20 000 kWh. The COP of the heat pump is around 2.0 meaning that it produces 2 kWh of heat for every kWh of electricity it uses. The better the insulation in a house the less is the need for maximum power. Insulation has most significant effect during the peak frost.

The air-water heat pump is not included in the empirical analysis of this study, since the heating mode was not receivable in the 2008 data.

Exhaust air heat pump

By applying the exhaust air heat pump it is possible to spare some 40 % of the heating energy compared to direct electric heating. The exhaust air heat pump mechanically removes air from the house from which it absorbs the heat and transfers it into water based heating system, service water or supply air. It is often possible to use the pump as well as an air conditioning. Usually the pump has an additional electric resistor which is used to replace the extra power demand. The source of the heat energy is the indoor air and the heat production capacity is constant[5] a year round despite the season or changes in the weather. The pump cools the removable air that from 20 °C to some 0 °C. The system requires a fixed amount of continuous ventilation[6]. The exhaust air heat pump replaces the usual ventilation equipment of a detached house and also removes air from the bathrooms and wardrobe.

The COP of the pump lies usually between 1.5 and 2.2. During the coldest period of a year, the heating capacity of the pump is usually not sufficient. Thus, an auxiliary heat source is needed. Electric resistors o of the equipment or wood heating are often a solution. Wood heating is a good source to reduce need for external heat (e.g. direct electricity). The initial investment cost of the pump is remarkably lower than that of a geothermal or air-water heat pump. Exhaust heat pump is suitable for smaller one-family houses. It is relatively easy to maintain.

Exhaust heat pump and air-water heat pump have lower COP than geothermal heat pump. If the annual COP of an exhaust heat pump is 2, 10,000 kWh heating energy annually consuming house creates 1 to 2 tons of carbon emissions a year. With an annual COP of 2.5 the carbon emissions of a similar house are some 0.8 to 1.6 tons a year. Approximately half of the energy air heat pumps produce is renewable energy. Nowadays it is common that the upper ozone layer damaging CFC's of the systems have been replaced by HFC's (fluorine hydrocarbons). HFC's are non-toxic, not burnable and bio degradable. They do not cause ozone depletion but act as greenhouse gases such as CO2.

2.3.5 Heating modes in the empirical exercise

In the empirical section of the thesis, electric heating (and direct electric heating in the logistic regression model), district heating, ground heat pump, other heat pumps, wood heating and furnace are considered. Direct electric heating is not separated from electric heating because it would create more categories to the multinomial logistic model making it too heavy compared to the number of observations and reduce the explanatory power of the model. Ground heat pump is separated from the family of the other heat pumps because its mechanism is substantially different as it can work as the principal heating mode on its own. The other heat pumps are more or less ancillary heating modes so they are bundled as one heat source. Wood heating consists wood, pellet and wood chip as their technical logic is somewhat similar and the number of the observations of each of these technologies are quite low in the data.

[5] some 2 to 3 kWh
[6] ½ times the air volume of a house in an hour

The heating mode choice is the subject of the investigation of the energy paradox in the study. It means that different heating mode choices of the households are investigated and compared related to the socio-economic factors of the households. The aim is to find out if there exists too low diffusion of energy efficient technologies compared to conventional technologies, such as ground heat pump compared to electric heating. The next chapter discusses and analyses the concept of the energy paradox and summarizes the pervious literature and studies related to the phenomena.

3. Literature review on energy paradox

The energy paradox has been on the agenda of energy efficiency discussion in economics and energy politics for over three decades. There is no single definition for the phenomena of the energy paradox, it is dependent on the perspective and purpose of the exercise. In simplicity the idea behind the energy paradox is irrational behaviour of a decision maker (firm, household, individual). The irrational behaviour becomes apparent in too low diffusion of energy saving technologies despite their cost effectiveness compared to conventional technologies.

Much of the theoretical literature concerning the energy paradox is focused on the technological diffusion of energy efficient technologies in production on firm-level (e.g., Jaffe & Stavins 1994; Verhoef & Nijkamp 2003; Mulder et al. 2003; Weber 1997; Kounetas & Tsekouras 2008; Anderson and Newell 2004). However, empirical studies have shown that both households and firms are reluctant or face barriers to invest in energy-saving technologies (e.g., Alcott and Wozny 2010; DeCanio 1998; Harris et al. 2000; Rohdin et al. 2007; Dianshu et al. 2010). The behaviour of households is a matter of relevance in this study and thus more attention will be paid on the consumer and individual behaviour when explaining the energy paradox.

Chapter 3 altogether covers a compact review over the decades' long discussion of the energy paradox aiming at summarizing and analysing the various aspects and conclusions related to the topic. As a motivation climate change and need for clean and energy efficient technologies are discussed shortly in chapter 3.1. The technology diffusion theme is presented in chapter 3.2 followed by the problems related to energy-efficiency improvements in chapter 3.3 The aim of chapter 3.4 for its part is to classify the various explanations of the energy paradox. Finally, chapter 3.5 presents some of the suggested measures and policy responses for the paradox and critique towards energy efficiency claims is gone through in chapter 3.6.

3.1 Climate change, energy conserving technologies and energy efficiency

Many authors during the past decades have studied the puzzling energy paradox. There are many definitions available ultimately explaining the same phenomena. For example, DeCanio 1998 defines the energy efficiency paradox as the situation where "there is abundant evidence that highly profitable energy-saving opportunities exist, yet the technologies embodying these opportunities have not spread universally throughout the economy”. Jaffe and Stavins 1994 on the other hand define the phenomenon “in which (new) energy conserving technologies despite being cost-effective are not fully or at all adopted by the users, firms or decision makers” as the paradox. This study examines the slow diffusion of energy efficient heating technologies among Finnish detached house builders. Thus, the definition of Jaffe and Stavins (1994) for the paradox is used as the background for the study and the hypotheses.

Climate change and global warming have been on the political agenda for at least a couple of decades, in the scientific field a bit longer. It is quite unanimously accepted among academic professionals that global climate change that is strongly connected to the wide combustion of fossil fuels will demand an urgent adoption of energy saving technologies (Mulder et al. 2002; Jaffe & Stavins 1994; Allcott & Wozny 2009; Nässén et al. 2008; Fleiter et al. 2011; Tanaka 2008). A lot of the prevention of global warming and restraining the climate change is concentrated around cutting down the CO_2 –emissions. Emissions from burning fossil fuels and cement production are responsible for an estimated 75% of the increase in atmospheric CO2 concentrations since pre-industrial times (Denman et al. 2007, p.512).

The energy production involves a great deal of fossil fuel combustion. In fact, energy-related greenhouse gas (GHG) emissions account for around 70 % of the total emissions (IPCC 2007 p. 253). As stated previously in chapter 2, 42 % of Finnish heat and electricity production originated from fossil fuel combustion in 2008. What is more, in the northern part of the EU, some 41 % of the energy consumption originates from buildings, of which 30 % is used in residential buildings (Santin et al. 2009 p.1223). Hence, there is a clear call for the development and introduction of new technologies that do not involve GHG emitting. Technologies that utilize renewable energy sources or energy efficient technologies are recognized widely as part of the solution to the problem. In practice, it means development of completely new technologies and more widespread adoption of already existing technologies. It is relevant, at least for the study at hand, that some of the technologies can already be argued to be cost-effective with current prices, but still un-adopted.

Despite some critique, energy efficiency is one of the key policies to cut down increasing CO_2 in the atmosphere. In order to achieve better environmental conditions, most OECD countries have adopted schemes or regimes to reduce harmful emissions of which adoption of energy efficiency technologies is one of the major components. (Kounetas & Tsekouras 2008). The traditional environmental economics literature is focused on environmental regulation through Pigouvian taxation. The model assumes firms' technologies fixed leaving the room for emissions reduction through command-and-control, which is not favoured by the economists in general, or suggesting cap-and-trade-systems such as taxation. (Tietenberg and Lewis 2009).

It has been recognized, however, that the adoption of environmentally friendly technologies may offer important alternative means of reducing emissions (Verhoef & Nijkamp 2003). In that case it is meaningful to loosen the restriction of production or consumption that is a key assumption in the basic model. In the case of energy use, where CO_2 –emission is the direct consequence, the emission reduction is not necessarily a pure cost without any benefits for the firm or consumer itself. For instance, more energy efficient technology in production process (more efficient use of input) goes together with the reduction of emissions. This might seem as a perfect motivation for energy efficiency improvements and CO_2 –emissions reduction. (Verhofen & Nijkamp 2003). It might be the case that energy efficiency truly succeeds in reducing pollution, but there are some complications to be taken into account that might give rise to counter-intuitive or counter-productive impacts of environmental policies. These problems are discussed with more depth later in chapter 3.6.

3.2 Diffusion of energy conserving technologies and Energy paradox

Energy conservation is often defined as a reduction of the total amount of energy consumed. Energy consumption can thus be reduced without an increase in energy efficiency. Energy efficiency on the other hand, only refers to the production of energy, meaning energy input saved per unit of energy services. Hence, energy efficiency itself does not automatically lead to reduced energy consumption. These two distinctions are important when considering the so called rebound effect, a term that is widely used when criticising the solely energy efficiency goals as policy guide lines. The rebound effect is discussed more into depth in chapter 3.6.

The energy efficiency could be defined in this context as mean energy services per unit of energy input. Energy efficiency in this study is contemplated on the disaggregated, product level, rather than on the sectoral level. As in many economic problems, the energy efficiency boils down to measuring the costs and benefits. For the individual energy user (household) it means higher purchasing cost of energy-efficient technology against the expected benefits of future cost of savings of the energy-efficient equipment.

In this context, it is important to distinguish energy efficiency from the concept of economic efficiency. Maximizing economic efficiency leads us often to the planner's problem that is, maximizing the net benefits of the society. The general maximization problem does not automatically include energy efficiency maximization. Therefore, it is meaningful and arguable to examine the phenomenon on a microeconomic level, such as households in this study.

Due to the existence of significant externalities associated with burning fossil fuels, the paradox is important beside in the academic literature, also in public policies around the world. Despite the global need to tackle the problem related to fossil fuel combustion, the diffusion of energy conserving technologies is not likely to be rapid even though it has been shown that widespread adoption of existing energy-saving technologies could enable a markeable reduction in energy use (Mulder et al. 2003). Firms are unwilling or slow to adopt the energy efficient technologies, though rate of return calculations from energy saving investments "is quite higher than the discount rate for projects of comparable risk" (Kounetas and Tsekouras 2008 p. 2518).

Many previous studies have identified factors that influence adoption of technologies (see Jaffe and Stavins 1994; Mulder et al. 2003; Weber 1997; Kounetas and Tsekouras 2008; Ansar and Sparks 2009; Faiers et al. 2007) which include for instance technology's profitability, firm structure and technical knowledge. Ultimately, the technical progress, the energy intensity output, is depending not only on the amount of innovations of the energy saving technologies, but also the extent to which users of energy services adopt innovations. Thus the process of adoption might in many cases be the reason behind the poor diffusion of energy conserving technologies instead of the development of the technology. In many cases, firms and households rather invest in old and proven technologies than take an irreversible risk by investing in new technologies. (Decanio and Laitner 1997).

The energy efficient technology adoption decision involves two important phases. Firstly, one must decide whether or not to adopt the energy conserving technology in the first place and secondly, when to adopt the technology if this is the case. Successful adoption of green energy is often dependent upon the high level of availability of the product or technology, aggressive marketing and competitiveness with other energy products. It is highly important to recognize the source of the gradual diffusion so one can identify correct policies and measures to respond to the issue. (Jaffe and Stavins 1994, Faiers et al. 2007).

The diffusion, that is, the adoption of technologies by agents in general, may sometimes take a long period. Scientific literature trying to capture and explain the phenomenon is vast and divided into different disciplinary schools. Usually the diffusion follows an S-shaped curve. The diffusion rate first rises and then falls over the time. The rapid adoption period lies between slow take up and slow approach to satiation. One of the most popular models explaining the S-curve is an epidemic model of information diffusion, and the leading alternative model is a probit model (Geroski 2000 p. 604). The epidemic model is based on the idea, that some actors find about the new technology later than the others. The probit model on the other hand assumes that adoption time among agents differ, because the goals, needs and abilities of the actors differ as well. The heterogeneous adopters and epidemic models both are important when considering the diffusion process of energy technology. What model is more applicable depends on the reasons behind the paradox, that is, the barriers to the efficient use of energy. When the costs related to the technology are high, for instance, it is likely that epidemic model is more suitable to explain the slow diffusion. The various explanations for the paradox raised in the vast academic literature on the energy efficiency and technology diffusion are analyzed in the next chapter.

3.3 Explanations for the paradox, barriers to the efficient use of energy

Researchers have created several hypotheses to explain the energy paradox. There are several types of obstacles to the efficient use of energy categorized in different ways in the literature (e.g., Jaffe and Stavins 1994; Weber 1997; Mulder et al. 2003; Kounetas and Tsekouras 2008; Fleiter et al. 2011; Sorrell et al. 2004). There is however no exclusionary way to classify the barriers to energy efficient technology utilization. Barriers cannot be classified since they are invisible (Weber 1997 p.834). This chapter nevertheless puts an effort on to summarizing the findings and theories brought up in the previous studies by presenting a rough classification between market failure explanations and other explanations in table 2.

The most important market failures that explain the paradox are related to lack of information, principal-agent problem and artificially low energy prices. Non-market failures cover such barriers as costs of adoption, imperfect substitutability between old and new technology, high implicit discount rates, consumers' misevaluation of the energy prices, option value of waiting and institutional barriers. (Ansar and Sparks 2009; Mulder et al 2003; Jaffe and Stavins 1994; Kounteas and Tsekouras 2008; Jaffe and Stavins 1994; Weber 1997; Ek and Söderholm 2010; Faiers et al. 2007; Murtishaw and Sathaye 2006; Fleiter et al. 2011; Sorell et al. 2004).

Market failure explanations	**Non-market failure explanations**
Information assymetries, lack of information concerning the technologies	Imperfect substitability in technologies and learning-by-using efefct
Principal-agent probelms	High discount rates of future energy prices
Too low energy prices	Consumer behaviour: underweighting the costs
Unobserved costs of adoption	Institutional barriers and informal regulation
Market structure and concentration	Private costs of adoption
Stochastic rate of technological progress	Demand uncertainty
	Heterogeneity among potential adopters
	Labels and standards
	Investment incentives
	Taxes and permits
	Environmental regulation
	Firm-specific factors
	Bounded rationality
	Loss aversion
	Option value of waiting

Table 2. Market and non-market failure explanations for the enrgy paradox .

Aside from market failures, most economic analysis takes cost-minimizing or utility maximizing behaviour of households as a starting point when analysing energy efficiency. (Gillingham et al. 2009). There exists an abundant literature that focuses on the decision-making process of microeconomic players; individuals and households.

In the literature, the energy efficiency gap is often analysed by comparing the market discount rate and high implicit discount rates that are evident in consumer behaviour. Thorne-Holst et al. (2008) have identified six main barriers that influence households' energy saving efforts. These are cultural, economic, information, political and individual-psychological barriers of which they identified economic, information and cultural barriers as most important ones. Thorne-Holst et al. (2008) further discovered that consumers demand a short payback period for their investment, as they are discounting the future with a heavy rate. Households might also need better information on when to make their investments beside the information how to save energy.

The most relevant explanations to the energy paradox on the light of this study however belong to the non-market failure category, moreover to this "behavioural failure" category. In chapter 3.3. the consumer behaviour and undervaluation of the future energy prices are covered more in depth.

3.4 Underweighting of future energy prices

Energy market and market prices affect consumer decisions on firstly, how much energy to consume and secondly, whether to invest in more energy-efficient technology or not. An increase in energy price, according to theory, will stimulate energy conservation and thus investment in such technologies. The more persistent the price increase is, the more significantly it affects household's energy efficiency adoption. (Gillingham et al. 2009). Price elasticises of energy demand depict the responsiveness of consumers to changes in price. Long-run price elasticises tend to be higher than short run, as the energy efficiency is improving. Many studies have focused instead of elasticises on technology adoption and factors that have influence on it.

Behavioural barriers focus on individuals with their values and attitudes towards energy conservation (Weber 1997, p.834). Undervaluation of energy prices or costs could be one explanation to the observed energy paradox. Some studies have already proven that consumers tend to underweight the costs of a so-called "add-on" that fall in the future, such as energy prices (Ellison 2004; Alcott and Wozny 2009; Hausman 1979). Consumers do not invest in energy conserving technologies since they do not believe it pays off at the existing energy prices. Consumers may lack attention towards their energy consumption or they are missing a link between their attitudes, values and action. Lifestyle and social norms and roles might also affect their behaviour. Whatever the reason, it is highly important to understand costumers' demand for energy conserving technologies in heating when analysing the "welfare and profit implications of new products and regulatory changes in the industry". (Allcott and Wozny 2009, p. 6). From economic perspective energy efficiency decisions in the end boil down to the trade off between higher initial capital costs and uncertain future energy costs. (Gillingham et al. 2009). Firms are affected by the customers distorted way to take future costs into account. It means that firms, providers and builders will change their behaviour in the equilibrium followed by customer demand. If the consumers do underweight the costs that are accrue in the future by the use of the product or heating technology, it will most likely to be a proper explanation of the energy paradox. It means in practice that consumers are slow adopting those energy efficient technologies that actually are presently cost efficient.

Previous studies have shown evidence that consumers tend to undervalue price of products that fall in the future. For instance, Alcott and Wozny (2009) studied American automobile buyers over the time and found out that consumers do not take the future gasoline prices into account in their buying decision. Alcott and Wozny (2009) observed that there was a bias towards less fuel economy choices. The conclusion of the study was that consumers took only approximately 60 % of the future gasoline prices into account when purchasing automobiles. Similarly, when choosing the heating technology or equipment, the energy price, say electricity price, can be seen as an "add –on" to the product itself. It is thus likely, that the consumers do not choose the heating technology that would lead in to the private optimum. The misoptimization could possibly lead to a great level of welfare losses measured on the aggregate level.

Hassett and Metclaf 1993 suggested the uncertainty of the future energy prices as the explanation for the paradox. They created a theoretical framework to model underinvestment in energy saving capital. It is important to notice that for evaluating the benefits of the investment the ability to forecast uncertain future energy prices are crucial. The decision of whether or not to invest in energy saving capital requires weighting the initial capital cost against the expected future savings.

In their model Hasset and Metcalf (1993) define a hurdle rate (Γ) for the investment which is the minimum savings required before investment becomes profitable. The important intuition behind the model is that the investor recognizes that once the investment has been made, it is undoable. If the investment takes place today, the household or consumer is stuck with it whether it is profitable or not. If the household waits for one more period, it is possible to decrease the chances to lose money. The energy prices are assumed to follow a random walk theory. The theory contains an assumption that once prices go to the region above break-even energy price[7], they are likely to stay at that region longer. That is, the probability that energy prices will drop below the brake even price P^* decreases as the price goes above P^*. The more the energy price rises above P^*, the likelier it is that prices will stay high making the benefit of the investment exceed the costs. Following the same logic, if prices fall below P^* the less likely it gets that they will rise above the break-even price, resulting greater investment costs than the benefits. An investor, for instance a household, holds an option not to invest. If the prices are above P^* a household may want to wait for a period to see whether the prices will go further up and thus decrease the likelihood of energy costs falling below P^*. The option is lost once the investment is done since it cannot be undone. The problem at hand is an optimization problem. Hassett and Metclaf 1993 offer a solution by deriving an optimal time to invest:

$$\delta P_t > \Gamma(\gamma - \alpha)C \qquad (1)$$

where δ is the fraction of energy cost saved each period with energy saving technology, P_t is the energy price, γ the discount rate and α the trend rate for exponentially rising energy costs C and Γ a hurdle rate that receives a value over one. With high levels of uncertainty the rate can reach levels of even seven times higher compared to the case when there exists no uncertainty (Hassett and Metclaf 1993, 712).

To apply the diffusion patterns above into practice, it is useful to recognize the heterogeneity of the structure, equipment etc. of the houses. For some households it is easy to save energy with efficient insulation, for example. In some houses, on the other hand, insulation does not have such a remarkable effect due to the weather conditions, existing insulation capacity or other factors. With the rising energy costs, investment in energy saving technology becomes more attractive to households with low fractions of energy costs saved in each period with the existing energy technology. That is, those individuals who would have larger energy savings are most likely to change technologies. A private optimal decision entails choosing the level of energy efficiency to minimize the present value of costs, while economic efficiency at a

[7] Break even energy price is the energy price rate P^* that satisfies the condition where energy savings B equal the cost of energy investment C. Energy savings B is defined as $\frac{\delta P_t}{\gamma - \alpha}$ where δ is the fraction of energy cost saved each period with energy saving technology, P_t is the energy price, γ the discount rate and α the trend rate for exponentially rising energy costs.

societal level would entail minimizing the social costs. The energy efficiency is different for this reason from many other product attributes. (Gillingham et al. 2009, p. 4).

3.5 Measures to overcome the paradox

According to Jaffe and Stavin's 1994 analysis, among other things, the market imperfections can hinder technology diffusion and hence explain the observed energy paradox. They suggest that some of the problems do not require government intervention, such as high discount rates, the private costs of information acquisition, heterogeneity of potential adopters, and the "wait-and-see" conditions (possibility that the technology is cheaper in the future). However, it is also stated that some of the market failure imperfections should justify government policies. These imperfections are numerous including incomplete information, principal-agent issues and federal and state subsidies to name but a few. They all require unique policies and methods to tackle the problem at hand.

For example, when talking about imperfect information it is suggested that government could conceivably establish standards for energy audits and disclosure requirements for new buildings. Or internalizing externalities such as environmental damage in pollution taxes or tradable permits. Need for higher energy prices to send signals to consumers that there is a need for efficiency improvements in energy efficiency and renewable technologies. The energy prices are raised by energy taxes. (Herring 1999, p. 212). Some studies however indicate that the price elasticises of energy products often receive low values (e.g., Boonekamp 2005; Yoo et al. 2007) leading to a conclusion that price changes do not have major effect on the energy consumption. It might on the other hand be a signal, that there is a lack of opportunity for households to save energy consumption and thus better response to the price changes. In that, further development of energy efficient technologies would be a solution.

Alcott and Wozny (2010) found out in their study on American automobile industry, that cap-and-trade program to internalize the marginal damages of carbon dioxide would affect through an increase in gasoline price. What is more, if consumers nevertheless undervalue future gasoline prices, other sectors would have to abate more carbon to meet the required reductions. Thus, the marginal cost of abatement would be above the optimum and not equal across all sectors. This is followed the deduction, that all consumers would have to arrive to their private optima given the higher relative prices of pollution-intensive goods. This could be applied on house heating markets easily. If builders or buyers do not value the future energy price accurately, other sectors would have to replace the CO_2 slack caused in the heating markets. Thus, the findings that would support the existence of energy paradox would support the view that suggests placing a tax.

Energy taxes and regulation however will most likely increase the costs to society. Cost-effective improvements in energy efficiency, such as energy standards, could on the other hand lead to a shift to less carbon-intensive fuels such as renewables. Energy standards are often seen as one of the most efficient ways to ensure the diffusion of energy efficient capital (e.g. Alcott and Wozny 2010; Dianshu et al. 2010; Tao and Yu 2011). On the other hand, according to Hausman (1979), households that have higher income levels have an implied discount rate closer to the interest rate that prevail credit markets. Poorer households had higher discount rates due to lack of savings or uncertainty of future income streams. Thus, the efficiency standards on heating products would have a much greater impact on households with lower level income, since they would find the increased purchase price of the equipment more burdensome than high-level households with lower discount rate (Hausman 1979, p. 53).

If energy efficiency is the solution to the energy problem, it is possible to cut down the harmful effects of energy consumption by placing proper policies to enhance the energy efficiency. If government places the right policies such as subsides and rebates, it can help households to find the capital needed to invest in energy efficient technologies and make them more lucrative options (Dianshu et al. 2010 p. 1207). A solution could be an integrated policy where one would combine carbon taxes, energy efficiency standards and renewables. According to Herring (1999), the money collected in form of taxes could be used to subsidize renewables and thus replace the fossil fuel related technologies, and energy efficiency would mitigate the higher cost of fuels. It would in practice mean high efficiency, high consumption and low carbon future. It is not likely that net consumption of energy, whatever the form, will drop in the future as the economic growth goes hand in hand with the increased consumption of it.

3.6 Energy efficiency dilemma: Jevon’s Paradox and economic rebound effect

The standard neoclassical economic theory argues that diminishing natural resources lead to higher energy prices which will stimulate investment into development of energy efficient technologies. The energy efficiency is further expected to lead into reduced energy consumption. Nevertheless, some economists and environmentalists have presented structural critique towards energy efficiency improvements by stating that it does not guarantee the reduction of net energy consumption (e.g., Polimeni and Polimeni 2006; Sorell 2009; Hertwich 2005). Economic rebound effect is related to the concern that changed behaviour offsets part of the (environmental) gain achieved. Rebound effect is often referred as the systematic response to a measure that is taken to reduce environmental impacts and that ultimately offsets the effect of the measure leading to lower than anticipated or even negative result (Hertwich 2005). The rebound or take-back refers often to an increase in the supply of energy services leading to corresponding decrease in price.

Various articles (Sorell 2009; Polimeni and Polimeni 2006; Khazzoom 1980; Haas et al. 1998; Greening et al. 2000) have examined the well-known paradox presented by William Stanley Jevons in 1865 and many authors ever since, that energy-efficiency improvements at micro level will eventual lead in to increased energy consumption at macro level. A typical example of such a rebound effect would be a driver who after replacing her old car with a new fuel-efficient model, ends up driving further and more than before due to the reduced gasoline costs. The energy-efficiency improvements reduce the marginal cost of energy services which could offset some or all predicted reduction in energy consumption. Following the intuition, a more efficient heating technology could thus result even greater use of energy due to the reduced price offsetting the benefits that were estimated while keeping the energy consumption constant. Beside the direct rebound effect an indirect rebound effect should be considered. The indirect rebound effect means that even though the use of energy does not rise after the implementation of energy-efficient technologies, a household, for example, can afford to purchase more goods, embodying energy in their production.

The forms of indirect rebound effects are many. Embodied energy effects means that equipment that improves energy efficiency, thermal insulation for instance, requires energy in its production so that it offsets the benefits of saved energy in its usage. Re-spending effects capture the idea that consumers use the money saved to consume other goods and services that have required energy in their production. The case when producer ends up producing more output i.e. increases the consumption of capital due to the cost savings brought by energy efficiency is called the output effect. The improved energy-efficiency that in fact yields a lower energy demand, can also stimulate the aggregate output and energy use through lower energy prices which increased energy consumption. The composition effects on the other hand relate to the situation when both energy-efficiency improvements and the associated reductions in energy prices will reduce the cost of energy-intensive goods and services relative to goods produced by using the old technology, encouraging consumer demand to switch the consumption to the former. (Sorell 2009; p. 1457). The overall economy-wide rebound effect is a sum of the two effects; direct and indirect. It is a share of expected energy savings of a certain action or policy. If the overall effect exceeds 100%, it will lead to Jevons' paradox.

Verhoef and Nijkamp (2003) developed a model by which they studied the adoption of energy-efficiency enhancing technologies, requiring irreversible investments, in small, heterogeneous, price-taking Cournot-oligopolists. As a result they discovered Pareto optimality could require both output reduction of some firms and adoption of new technologies by the others associated with output reduction or expansion case-specifically. The study demonstrated that promotion of energy-efficient technologies by subsidies (or other policy measures) might actually lead to an increased energy use, but the use of energy taxes can reduce the attractiveness of energy-saving technologies. The more elastic the demand for the output is, the more important the subsidy and tax –policy's negative effects become.

Problem with Jevon's paradox is, that the theoretical analysis is often hard to back up with empirical evidence of rebound effects (Sorell 2009, p. 1463). If such a phenomenon would exist in the heat energy markets, it would mean that the efforts and policies that are in place or planned to reduce the use of heat energy by introducing energy efficient solutions could have clear implications. When it comes to achieving sustainability and reducing carbon emissions and thus adjusting the costs to climate change, the counter-effect would be an utmost relevant factor to be taken into account. The Jevon's paradox implies that all economically justified energy-efficiency improvements will increase energy consumption above where it would be without those improvements (Sorell 2009, p. 1466). The claim is strong and most will definitely need some evidence as a support. This evidence does at least not yet exist. It does not nevertheless mean that the contemplation of the paradox would not have any importance.

A technological improvement should in theory reduce energy prices and correspondingly increase the supply. The decrease in price should be evident as direct or pure price effect, which would affect directly the demand. However, on the consumer side the direct price effect may be decomposed in a substitution effect and income effect. Indefinite substitution is nevertheless unlikely. In reality, most probably consumers meet a saturation point limiting the substitution and tradeoffs with other commodities. Direct effects can thus not be decomposed into substitution and income effects. What is more, short run estimates as these cannot be applied for long-run capital cost change estimation (Greening et al. 2000).

When it comes to single-family households, substantial amount of total household fuel or energy consumed is allocated to space heating. Greening et al. 2000 suggest thus that the rebound effect in this use may be significant.[8] Several authors have found evidence for the rebound effect in household space heating (Dubin et al. 1986; Klein 1985; Klein 1987; Hsueh and Grener 1993; Schwartz and Taylor 1995; Haas and Biermayr 2000), but with different magnitudes depending on the definition of activities and methods used in the studies. However, despite the variation in the empirical evidence for the rebound effect's magnitude, it is possible to estimate rebound from space conditioning. According to Greening et al. for a 100 % increase in fuel efficiency, the levels of take-back from either price effects or substitution and income effects together lie between 10 and 30 % of the total savings in household energy consumption (Greening et al 2000, 394). The studies that indicate that rebound effect exists, state that the technology improvements are not likely to be the answer for the energy problem. It would require more structural changes in behavioural patterns in consumption that would consequently force changes in the production patterns (Polimeni and Polimeni 2006, p. 352).

The Jevons' paradox itself is not explaining the existence of the energy paradox, but is still an important and interesting matter to be at least theoretically considered, since it is closely linked to the energy saving efforts and whether or not it pays off for the government to invest in energy conserving technologies. The Jevons' paradox would step into the picture after the energy paradox is solved. Therefore it is important to take into account when designing the policies to improve energy efficiency. To find out whether or not the energy paradox

[8] Some 53 % of household fuel (electricity and natural gas) is used for heating in single-family houses (Schwartz and Taylor 1995).
Even up to 75 % of the total energy consumption of a household is allocated for space heating (Braun 2010, 5493; Santin et al. 2009, 1223).

considerations are important in the heating mode choices of Finnish households, an empirical investigation is useful. Before presenting the estimator for the probability of choosing certain heating modes in the chapter 5 and the results in chapter 6, it is useful to analyse the foundation of the multinomial logistic and logistic modelling. These both regression models are part of the discrete choice family, which all are based on the random utility theory often used as the approach for consumer choice in economics. In the next chapter, the consumer choice theory is presented briefly as a background and justification for the empirical investigation.

4. Theoretical framework on consumer choice theory

In economics, rationality is considered as the starting point of the theory. The term rationality refers to the rational behaviour of economic agents. The rational behaviour is furthermore described in the standard economic theory through utility maximization. That is, an economic agent, say a household, maximizes its utility given the options, income, information, etc. The assumption behind the utility maximization is that an agent is able to perceive measure and ultimately, categorize the utilities that she/he receives for instance from acquiring a certain product.

The random utility theory offers the background for the empirical strategy used in this study, which are the multinomial logistic regression model and logistic regression model. In this chapter, the theory is presented and discussed further in the light of energy goods consumption.

4.1 Random utility theory behind the consumer decision

Social sciences including economics attempt to explain and forecast the behaviour of agents. According to the standard microeconomic models, consumers utilise commodities on which consumption they make choices based on their individual needs. In practice, economics aims at predicting the individual, firm or household decision-making process. Random utility models are widely used to predict these choices of an economic agent. The models are based on the assumption that individual's preferences among the available alternatives can be described by using a utility function. Utility is the net benefit (material and immaterial) that a person receives when she chooses a certain alternative. According to the theory an agent chooses the alternative that will give her the highest level of utility, that is, she is maximizing her utility given specific constraints she meets. (Hausman and Wise 1978; Hanemann 1984; Haas et al. 1998; Goto et al. 2011). The utility that an agent receives in each alternative is determined by the attributes of the alternatives and characteristics of the agent. The utilities can be ranked in order according to the preferences of an agent among alternatives. An agent always chooses the alternative the gives her the highest utility. The households are assumed to maximize their utility when choosing a heating mode. The utility-maximizing behaviour is often used as the theoretical base for discrete choice modelling. Unordered choice models, such as logistic and multinomial logistic models that are used in this study, can thus be motivated by using a random utility theory.

According to the definition, an agent obtains a certain level of utility form each of the alternatives. It is not possible to predict accurately which alternative an individual will choose due to the unobserved characteristics of an individual (Hanemann 1984; Hausman and Wise 1978). Random utility theory therefore instead suggests that probabilities for choosing each alternative should be used. Random utility models in fact are often classified according to the probability distribution of the random component of the utility function.

In the model a household $n = 1, \dots, N,$ chooses form a finite set of heating mode alternatives, $j = 1, \dots, J.$ The utility of an household from an alternative j is thus:

$$U_{nj} = \beta_j' x_n + \varepsilon_{nj,} \tag{2}$$

where x_n describe the independent variables, such as income, age, occupation etc, β_j unknown coefficients, and $\varepsilon_{nj,}$ is the error term. The error term consists of the “left over” factor that influence the utility, but are not included in $\beta_j' x_n$. The household always chooses the alternative j that yields them the highest utility. The joint density of the random component vector is $\varepsilon_n' = (\varepsilon_{n1}, \dots, \varepsilon_{nJ})$. (Dubin and McFadden 1984; Vaage 2000; Nesbakken 2001; Braun 2010, Train 2003, Nesbakken 1999, Allcott and Wozny 2009).

The indirect utility function for a heating system depends on income, prices and space heating cost and other exogenous variables. The probability that any alternative i is chosen is the probability that the utility of the alternative exceeds the utility of any other alternatives:

$$P_{ni} = \Pr\ (U_{ni} > U_{nj} \text{ for all alternatives } j \text{ other than } i) \tag{3}$$

$$= \Pr\ [(\beta_i' x_n + \varepsilon_{ni,}) > \left(\beta_j' x_n + \varepsilon_{nj}\right), \text{ for all available alternatives } j \text{ other than } i] \tag{4}$$

Choosing a heating mode can be seen as an input in the household’s production of space heating service that includes the energy consumption as well. Then the utility of a household can be assumed to be dependent on this space heating service (Nesbakken 2001, 169, Nesbakken 1999). But the household utility depends also on consumption of other goods, observable and unobservable characteristics of the household and the dwelling, and unobservable characteristics of the heating equipment. In this study, the indirect utility of a household n for purchasing a heating equipment j in a year/time period t is:

$$U_{njt} = a + \beta I_n - \gamma p_{jt} - \delta G_{jt} + \varepsilon_{njt}, \quad (5)$$

where the I_n is household n's income, p_{jt} is the purchase price and G_{jt} is the discounted present value of future energy costs over the heating equipment's lifespan. G_{jt} is dependent upon the discount rate, expected future energy prices and expected usage of the equipment.

4.2 Consumer choice in energy products, space heating

The most common consumer choice situation is to select most preferred among a set of discrete alternatives. According to the standard economic model, the increased energy price should increase the relative prices and market shares of energy efficient technology versus conventional technology. Nevertheless, energy consumption is different from other consumption goods. Energy is not demanded by households per se, but in a mode of services like heating. In the short run a household is typically quite reluctant to retrofit fixed capital inputs (heating equipment) due to the systems' long durability and relatively high cost of the systems. (Braun 2010, p. 5949). It is thus possible, that the fuel and energy prices may have only a slight effect when choosing a heating system for a one-family house.

Leth-Petersen and Togeby (2001) have divided the space heating consumption decision into two levels. First level of the decision is associated with the choice of technology and the other level with the decision to consume energy for heating given the technology available. The first level refers to the technology of the heating system and the other to the temperature level in the dwelling. The decision to consume energy for space heating is thus an equation of choice of technology and utilisation level (Leth-Petersen and Togeby 2001, p. 389).

Consequently, the consumer demand on energy products may have an effect on how firms behave. It is often the case that firms sell the actual product with low mark-ups, but the "add-on" here, the energy price with high mark-up. Even though energy is not offered by the firms who deliver the equipment, the theory can be applicable since the energy efficiency embodied in the heating equipment determines energy (e.g. electricity or oil) demand and improving energy efficiency increases the costs. (Allcott and Wozny 2009, p. 7).

In the light of the neoclassical theory the decision whether or not to increase efforts to save energy, say in heating, is determined by the net utility of a consumer or household. A consumer or individual will take an energy saving action if the net benefit is positive, i.e. $U_{nj} > 0$. (Ek & Söderholm 2010). The costs that individuals or households face by taking energy saving measures include both transaction costs (time, inconvenience, information gathering, searching for suppliers etc.) and monetary costs (purchase and installation of the technology). The benefits an individual or household faces are the expected reductions in energy costs but also contain non-monetary values such as satisfaction from environmentally friendly act.

In the short run, the demand for heating can be altered relatively quickly; since the setting of thermostat determines the amount of heat consumed. In the long run, nevertheless, heating demand will be dependent on changes in the stock of the houses. The demand cannot adjust completely in the short run before the capital stock adjustment (building new equipment or depreciation of the old equipment).

5. The econometric model

For the empirical investigation and modelling of household heating mode choice, discrete choice models are applied. Discrete choice models are different from a linear regression model in special requirements for the choice set. Chapter 5.1 briefly explains the discrete choice model specific features and chapters 5.2 and 5.3 derive the logistic and multinomial logistic models that were used in the empirical exercise.

5.1 Discrete Choice models, Boolean response variable models

The discrete choice models describe decision makers', an economic agents' choice among alternatives. The models are driven from utility theory explained in the previous chapter. The choice set can be defined as the set of all alternatives that are available for the agent. There are requirements for the choice set that have to be met in order to apply the discrete model framework. First of all, the alternatives must be mutually exclusive from the decision maker's perspective. That is, if an agent chooses a certain alternative from the choice set, the agent cannot choose any other of the alternatives. Only the alternatives within the choice set can be chosen. Second of all, the choice set has to be exhaustive; all possible alternatives are included. These criteria are not restrictive. Third of all, the number of alternatives must be finite, that is countable, unlike in linear regression analysis. (Train 2003, p. 11-15).

As a matter of fact, investigating heating mode choice using the discrete choice model approach violates two of the conditions; the alternatives are not exclusive in real life since a household might have picked two or more different heating modes if they wished. Nor is the choice set exhaustive, a household does not need to acquire any heating mode if they do not want to do so. To overcome the problem, it is possible for instance to examine only those heating modes that have been categorized as primary heating modes in the study, say electric heating, ground heat pump, district heating and wood heating. When it comes to exhaustiveness, the research question can be formulated in a way, that the choice of an household is conditional on having heating.

Discrete dependent variables arise from discrete-choice models in which individuals choose from a finite number of outcomes and form count processes a restricted range, which runs from 0 to highest level.

Discrete choice models have many different forms such as Binary Logistic, Binary Probit, Multinomial Logistic, Conditional Logistic, Multinomial Probit, Nested Logistic, Generalized Extreme Value Models, Mixed Logistic and Exploded Logistic. A binomial model is a model where there are only two alternatives and multinomial models contain three or more alternatives. Multinomial models can be further divided into models that do and do not take the correlation of the unobserved factors into account.

In models of Boolean response variables, or binary-choice models, the response variable is coded as 1 or 0, 1 representing true and 0 false. The data used in this study contains mainly this kind of variables. The model should produce a predicted probability that a person response is “yes” or “no”. It is usually the case in dummy regression variable models that the dependent variable is in quantitative form and the explanatory variables either quantitative or qualitative. In this study the dependent variable, households’ heating choice, is coded in 1 or 0 response as well as the main independent variables including income levels. In other words, the households have either chosen a certain heating system for instance electric heating or not. All the different one-family house heating systems are coded according to the yes or no principle. (Baum 2006, p. 247 – 257).

The formulation of a discrete choice model is based on the random utility theory. An economic agent faces a choice situation (here choosing the heating mode), where the agent n’s probability to choose an alternative i can be presented from (3) and (4) as:

$$= \Pr(\varepsilon_{nj} - \varepsilon_{ni} < \beta_i' x_n - \beta_j' x_n \; \forall_j \neq i). \tag{6}$$

The probability is a cumulative distribution. It is the probability that the random error term $\varepsilon_{nj} - \varepsilon_{ni}$ stays below the observed term $\beta_i' x_n - \beta_j' x_n$. By following Train 2003, using density function $f(\varepsilon_n)$, the cumulative probability can be written as:

$$P_{ni} = \Pr(\varepsilon_{nj} - \varepsilon_{ni} < \beta_i' x_n - \beta_j' x_n \; \forall_j \neq i) \tag{7}$$

$$= \int_{\varepsilon} I(\varepsilon_{nj} - \varepsilon_{ni} < \beta_i' x_n - \beta_j' x_n \; \forall_j \neq i) f(\varepsilon_n) d\varepsilon_n, \tag{8}$$

where $I(\cdot)$ is the indicator function that equals 1 when the expression holds true and 0 in other cases. (Train 2003, p. 15). The formulation is a multidimensional integral over the density of the unobserved portion of utility $f(\varepsilon_n)$. The different discrete choice models are all derived from this density depending on the assumption about the distribution of the unobserved portion. The forms of discrete choice models that are applied in this exercise are logistic and multinomial logistic models. The specification and identification of these models are presented in the next chapters.

5.2 Logistic and Multinomial logistic regression models

Multinomial logistic model is often used when the categories of the dependent variable are unordered. It compiles different groups through a combination of binary logistic regressions. The groups are then compared to the reference group. Chapter 5.2.1 derives and specifies the logistic regression model based on the utility maximization problem. Chapter 5.2.2 defines the Multinomial logistic regression model for heating choice by deriving the logistic functions for each heating modes and corresponding utility functions.

5.2.1 Logistic model specification

According to the logistic model the economic agent maximizes the indirect utility as presented in the previous chapter:

$$U_{nj}=\beta_j' x_n + \varepsilon_{nj,} \tag{9}$$

where U_{nj} is the indirect utility of the agent n choosing an alternative $j = 1, \dots, J$. The observed choice of an agent n is

$$\begin{cases} 1 \; if \; U_{n1}^* \geq \; U_{ni}^* \; for \; all \; i \\ 2 \; if \; U_{n2}^* \geq \; U_{ni}^* \; for \; all \; i \\ \qquad\qquad \vdots \\ J \; if \; U_{nJ}^* \geq \; U_{ni}^* \; for \; all \; i \end{cases} \tag{10}$$

There are J error terms ε_{ij} for any agent n. The logistic model is derived from the assumption that each ε_{nj} is an independently and identically distributed extreme value (Train 2003, p. 42). If one assumes that ε_j is independent and identical type I extreme value distributed as suggested above, the choice probability can be expressed by the logistic model. The error terms then follow independently and identically a distribution and the densities of each unobserved components can thus be expressed as:

$$f(\varepsilon_{nj}) = e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj,}}}, \tag{11}$$

and cumulative distribution as:

$$F(\varepsilon_{nj}) = e^{-e^{-\varepsilon_{nj}}}. \tag{12}$$

The variance of the distribution is $\pi^2/6$ that implicitly leads to normalized utility. The difference of two extreme value variables is distributed logistic, if ε_{nj} and ε_{ni} are extreme value, then $\varepsilon^*_{nji} = \varepsilon_{nj} - \varepsilon_{ni}$ follows logistic distribution of

$$F(\varepsilon^*_{nji}) = \frac{e^{\varepsilon^*_{nji}}}{1 + e^{\varepsilon^*_{nji}}}. \tag{13}$$

The distribution allows a bit more irregular behaviour than normal distribution due to the slightly heavier tails. However, the important element is not the shape of the distribution of itself but rather the assumption of independent errors. In practice it means that the unobserved portion of utility for one alternative is independent from the unobserved portion of utility for another alternative. Logistic model is applicable when the utility is specified well enough in the empirical strategy. (Train 2003, Zelterman 1999, Hahn 2011).

The exogenous explanatory variables x_n describe only the agent and are identical across alternatives. Parameter β_j on the other hand differs across the alternatives.

If the indirect utility contains a non-random part $\beta_j' x_n$ and a random part ε_j, the choice probability P_{nj} following McFadden (1974) can be expressed as presented previously in the chapter 5.1.

The cumulative distribution over all $j \neq i$ is the aggregation of the individual cumulative distributions if ε_{nj} is given:

$$P_{nj}|\varepsilon_{nj} = \prod_{j \neq i} e^{-e^{-(\varepsilon_{nj} + \beta_j' x_n - \beta_i' x_n)}}. \tag{14}$$

As the error term in reality is not given the choice probability is expressed as the integral of $P_{nj}|\varepsilon_{nj}$ over all values of error term weighted by its density:

$$P_{nj}|\varepsilon_{nj} = \int \left(\prod_{j \neq i} e^{-e^{-(\varepsilon_{nj} + \beta_j' x_n - \beta_i' x_n)}} \right) e^{-\varepsilon_{nj}} e^{-e^{-\varepsilon_{nj}}} d\varepsilon_{nj}. \tag{15}$$

From the integral it is possible to derive the logistic choice probability model, which can be presented in the following form:

$$P_{nj} = \frac{e^{\beta_j' x_n}}{\sum_j e^{\beta_i' x_n}}. \tag{16}$$

Thus, the multinomial logistic model the probability of household i choosing heating mode j (Braun 2010; Manski and McFadden 1981;Vaage 2000) is:

$$P_{nj} = P(i = j|x_n) = \frac{e^{\beta_j' x_n}}{\sum_{n=1}^{J} e^{\beta_i' x_n}} = \frac{\exp(\beta_j' x_n)}{1 + \sum_{i=1}^{J} \exp(\beta_i' x_n)} \tag{17}$$

$$\text{for } j = 1,2, \dots, J,$$

where x_n are the explanatory variables, β_j the unknown coefficients. (Vaage 2000, Braun 2010).

The logistic models are good in representing choice behaviour and model systematic taste variation but not the random taste variation. The systematic taste variation describes the observed characteristics of the decision maker, where as random taste variation relates to differences in tastes that cannot be linked to observed characteristics. The model predicts proportional substitution across alternatives, given the specification to the utility. The outcome of logistic model, the probability, P_{nj}, stays always between zero and one.

5.2.2 Defining the Multinomial logistic model for heating choice

The key assumption behind the multinomial logistic or multinomial logistic model is the Property of Independence from the Irrelevant Alternatives (IIA) (Arrow 1963). It means that the ratio of the probabilities for choosing any two of the alternatives is independent of the presence of any other alternative (Braun 2010, p. 5495). In the model, the probabilities of different outcomes of the dependent variable can be analyzed by utilizing odds ratio. (Norton et al. 2004). The odds are the ratio of a probability P to one minus the probability:

$$odds = \frac{P}{1 - P} \tag{18}$$

If there are two alternatives i and k, the ratio of the logistic probabilities is:

$$\frac{P_{ni}}{P_{nk}} = \frac{e^{\beta_i x_n} / \sum_j e^{\beta_j x_n}}{e^{\beta_k x_n} / \sum_j e^{\beta_j x_n}} = \frac{e^{V_{ni}}}{e^{Vnk}} = e^{V_{ni} - V_{nk}}. \tag{19}$$

The ratio is independent on any other alternatives than i and k. The relative odds of choosing i over k are the same whatever other alternatives would be available or what the attributes of the other alternatives are, the odds or alternatively, relative risk ratio is said to be independent from irrelevant alternatives (Train 2003, p. 46). In principle, the ratio tells how the probability of choosing an alternative j relative to 0 changes if we increase x by one unit.

The ratio (P_{ni}/P_{nk}) depends log-linearly on x_n:

$$\log\left(\frac{P_{ni}}{P_{nk}}\right) = x_n'(\beta_i - \beta_k). \tag{20}$$

As the probability P_{ni} is always located in between zero and one, it approaches one as $\beta_i' x_n$ rises and $\beta_k' x_n$ stays constant. Alternatively, P_{ni} gets closer to zero as $\beta_i' x_n$ decreases: $(e^{\beta_i' x_n} \to 0)$ as $(\beta_i' x_n \to -\infty)$. An alternative never obtains zero probability. If the alternative would be zero for certainty, it could be excluded from the choice set from the start. Similarly, probability $P_{ni} = 1$ will be obtained only if there is a single alternative in the choice set (Train 2003, p. 42). It is important to bear in mind, that the sum of probabilities of all alternatives equal to one: $\sum_{i=1}^{J} P_{nj} = 1$. The probability follows an S-shaped logistic curve. It means in practice that the utilities that have probabilities close to 0,5 are more sensitive to small changes in x than those closer to probabilities in the extremes; zero or one. This feature of sigmoid shaped curve is important when interpreting the results and constructing policy implications. Roughly saying changes in areas where the result is either very good or very bad, is less effective than changing moderate result.

The logistic model aims at “to model the odds of plan choice as a function of the covariates and to express the results in terms of odd ratios for choice of different plans” (Hosmer and Lemeshow 2000). The IIA hypothesis is related to the rational choice theory broadly used in the classical economic theory. According to the theory, economic agents (individuals, households etc.) choose alternatives and take actions by weighing the attributes of each available alternative, and finally choose the alternative that maximizes their utility. IIA is a structural feature of logistic, which means that “the relative odds for any two alternatives are independent of the attributes, or even availability, of any other alternative” (McFadden 1977, p. 6). This property of the model is useful in econometric estimation and forecasting for its simplicity. The IIA condition is needed to assure that the error terms are independently distributed over all alternatives. If the IIA-assumption cannot be guaranteed, it is best to apply for example nested logistic or multinomial probit models. The power of multinomial logistic however, compared to these two models, is that the log likelihood function

$$logL = \sum_i \sum_j d_{ij} \, log \, p_{ij} \tag{21}$$

is concave and easy to maximize (McFadden 1974).

Daniel McFadden was the first to call modifications of the logistic regression model as discrete choice model. Thus, the model is called often in econometric and business literature as discrete choice model whereas in health and life sciences the model is referred as multinomial, polychotomous or polytomous logistic regression. In this study, the term multinomial logistic model is applied.

In most cases when multinomial logistic is applied, the discrete dependent variables have no order. One of the most common examples is a traveller choosing a mode of travel. In this study, households choose a heating system. Multinomial logistic model uses only variables that describe characteristics of the agent and not of the alternatives. The characteristics of the agent can be for instance income level, age, gender, nationality etc.

In this thesis, a multinomial logistic model is applied since the households face a set of unordered alternatives of heating technologies. The heating choice is thus the uncategorized dependent discrete variable. As the explanatory variables in the study are the characteristics of the households (i.e. income, occupation etc.) a multinomial logistic model is applicable.

As already stated, multinomial logistic is used for situations where an agent (household, individual, firm) chooses from an unordered set of alternatives:

$$y_n \in \{1,2, \ldots J\}. \tag{22}$$

For the data at hand, the one-family house builders were asked to fill a questionnaire about various different house characteristics (Appendix A). One of the sections covered heating systems. Responses were limited to a discrete choice (yes or no) for ten different heating mode choices. The heating systems taken into consideration were electric heating, oil heating, district heating, pellet heating, wood chip heating, fire wood, wood furnace, geothermal heat pump, exhaust air heat pump, outdoor heat pump and solar accumulator.

The raw data was altered in a meaningful way to create categories that each contained enough observations. Solar energy and oil heating were left out due to a low number of responses in these categories. Wood pellet, wood chip and firewood were combined as one heating mode. In principle, there is no limitation to the amount of levels of the outcome variable in the model. As a result, the dependent variable gets six different categories; electric heating, district heating, geothermal heating, heat pumps, wood heating and wood furnace. The measurement scale is an important matter to be considered; here the case is such that the outcome is nominal scale.

The notation of the logistic functions follow Hosmer and Lemeshow (2000). The categories of the outcome variable Y are coded as 0,1,2,3,4 and 5. If the model contains six outcome categories, five logistic functions are needed. To develop the model, it is useful to assume that there are p covariates and a constant term, vector x of independent variables, of length $p+1$ where $x_0 = 1$. The five logistic functions are:

$$g_1(x) = ln\left[\frac{P(Y=1|x)}{P(Y=0|x)}\right] \tag{23}$$

$$= \beta_{10} + \beta_{11}x_1 + \beta_{12}x_2 + \cdots + \beta_{1p}x_p \tag{24}$$

$$= x'\beta_1 \tag{25}$$

$$g_1(x) = ln\left[\frac{P(Y=2|x)}{P(Y=0|x)}\right] \tag{26}$$

$$= \beta_{20} + \beta_{21}x_1 + \beta_{22}x_2 + \cdots + \beta_{2p}x_p \tag{27}$$

$$= x'\beta_2 \tag{28}$$

$$\vdots$$

$$g_1(x) = ln\left[\frac{P(Y=5|x)}{P(Y=0|x)}\right] \tag{29}$$

$$= \beta_{50} + \beta_{51}x_1 + \beta_{52}x_2 + \cdots + \beta_{5p}x_p \tag{30}$$

$$= x'\beta_5. \tag{31}$$

The conditional probabilities of each outcome category given the covariate vector are thus:

$$P(Y=0|x) = \frac{1}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)} + e^{g_4(x)} + e^{g_5(x)}}, \tag{32}$$

$$P(Y=1|x) = \frac{e^{g_1(x)}}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)} + e^{g_4(x)} + e^{g_5(x)}}, \tag{33}$$

$$\vdots$$

$$P(Y = 5|x) = \frac{e^{g_5(x)}}{1 + e^{g_1(x)} + e^{g_2(x)} + e^{g_3(x)} + e^{g_4(x)} + e^{g_5(x)}}. \quad (34)$$

The utilities of each heating modes are functions of observed characteristics, such as income (I), age (A), household size (S) and occupation (O) and the unobserved characteristics such as taste, values, quality etc (ε). Each of the heating modes can be presented in the form of general utility functions:

$U_1 = \beta_0 + \beta_{11}I + \beta_{12}A + \beta_{13}S + \beta_{14}O + \varepsilon_1$ for electric heating (35)

$U_2 = \beta_0 + \beta_{21}I + \beta_{22}A + \beta_{23}S + \beta_{24}O + \varepsilon_2$ for district heating (36)

$U_3 = \beta_0 + \beta_{31}I + \beta_{32}A + \beta_{34}S + \beta_{35}O + \varepsilon_3$ for ground heat pump (37)

$U_4 = \beta_0 + \beta_{41}I + \beta_{42}A + \beta_{43}S + \beta_{44}O + \varepsilon_4$ for heat pumps (38)

$U_5 = \beta_0 + \beta_{51}I + \beta_{52}A + \beta_{53}S + \beta_{54}O + \varepsilon_5$ for wood heating and (39)

$U_6 = \beta_0 + \beta_{61}I + \beta_{62}A + \beta_{63}S + \beta_{64}O + \varepsilon_6$ for furnace. (40)

The probability that a household chooses, say electric heating is thus:

$$P_e = \frac{e^{\beta_0+\beta_{11}I+\beta_{12}A+\beta_{13}S+\beta_{14}O}}{1+e^{\beta_0+\beta_{11}I+\beta_{12}A+\beta_{13}S+\beta_{14}O}+e^{\beta_0+\beta_{21}I+\beta_{22}A+\beta_{23}S+\beta_{24}O}+\dots+e^{\beta_0+\beta_{61}I+\beta_{62}A+\beta_{63}S+\beta_{64}O+\varepsilon_6}}. \quad (41)$$

The regression function, the tables and the results are presented in chapter 6.4.

6. The data and the Empirical strategy

The aim of this chapter is to answer the research questions targeted to the study in the light of the theory presented in previous chapters. The data that is used to test these hypotheses are described in chapter 6.1 by analyzing the main variables. The relationship between the variables, the characteristics of the data is investigated in chapter 6.2. A rough comparison between the total costs of the different heating modes applied in the empirical investigation is done in chapter 6.3 before presenting the multinomial logistic and logistic regression results in chapter 6.4.

6.1 Description of the data

The data used in this study was acquired from a Finnish private company Rakennustutkimus RTS Ltd. The company collects data from households that are building a one-family house or summerhouse in Finland on yearly basis. Several questions are addressed to these private house builders related to both the dwelling and household characteristics.

The data used in this study has been collected during 2008 with a questionnaire (Appendix A) targeted to households who had recently build or were building a one-family house or summer house in Finland. The year 2008 was chosen for the study to minimize the effects of the global economic crisis 2009 onwards in the building and heating market.

The data contains altogether 2,635 observations, of which 1,260 include heating choice. The questionnaire contains 111 questions related to material, equipment and house characteristic choices as well as house hold details such as income level, age category, occupation and location to name but a few. In total 1,189 households announced whether the house they were building would be used as a primary residence, or so called “second house” or as a summerhouse. In total 1,177 (99 %) households were building the house as the primary residence of their families.

For this study, the most essential sections were selected from the questionnaire that had relevance on the heating and energy use of the building or described the preferences and attitudes towards energy conservation and other house characteristics of the house builders. Only half of the answerers received a questionnaire that contained heating mode choice questions. The part of the questionnaire that contains the questions applied in this study is found in the appendix A.

6.1.1 Key variables

The main variables of the study are the dependent variable, the heating mode choices and income level of the household as the independent variable. These most important variables and other explanatory variables are summarized in the table 3. The names and explanations to the variables are listed with the number of total observations for each variable, mean, minimum and maximum values and standard deviations. The most important variables are explained more specifically in this chapter.

Variable	Definition	Number of observations	Mean	Min	Max	Std. Dev.
Heating mode	Heating mode choice of a household					
Electricity (Direct electric heating)		410 (291)	0.3256	0	1	0.46881
District heating		154	0.1223	0	1	0.3278
Ground heat pump		359	0.2851	0	1	0.4517
Heat pumps		115	0.9134	0	1	0.2882
Wood heating		91	0.7723	0	1	0.3278
Furnace		44	0.3495	0	1	0.1837
Income	Household gross income class					
Less than 20.000		35	0.246	0	1	0.1639
20.001- 40.000		281	0.2216	0	1	0.4155
40.001- 60.000		438	0.3424	0	1	0.4757
60.001 - 80.000		307	0.2421	0	1	0.4285
Over 80.000		198	0.1562	0	1	0.3631
Age	The average age of the primary residents					
Under 30		242	0.1789	0	1	0.3835
30-40		475	0.3513	0	1	0.4776
40-50		216	0.1598	0	1	0.3665
50-60		171	0.1265	0	1	0.3325
Over 60		122	0.0902	0	1	0.2866
		1226				
Occupation	The occupation category of the primary residents					

Farmer		49	0.3638	0	1	0.1873
Worker		396	0.2939	0	1	0.4558
Clerical worker		394	0.2925	0	1	0.4551
Entrepreneur		213	0.1582	0	1	0.3649
Manager		83	0.1562	0	1	0.3631
Pensioner		83		0	1	
Living area	The building area					
Urban		629	0.5522	0	1	0.4975
Rural		510	0.4477	0	1	0.4975
Number of inhatitants		1334	3.1237	1	9	1.3962
Cost/Sqm		1141	1457.956	138.89	5000	476.1786
Sqm		1300	151.51	45	500	44.8328

Table 3. Summary statistics

6.1.2 Heating mode

Heating mode is the dependent variable in the study. In the survey a total number of 1.260 households responded to the questionnaire section of heating mode choices. There were eleven different heating mode choice possibilities to be chosen from the questionnaire. These different heating choices are described with total observation numbers in table 4. The number of observations in the table accounts in total for 1.522. This is due to the fact that there were no restrictions on the amounts of heating mode choices a household could select.

Heating	Amount	Percent	Cum.
Electric heating	489	32.13	32.13
Oil heating	6	0.39	32.52
District heating	157	10.32	42.84
Pellet	23	1.51	44.35
Woodchip	23	1.51	45.86
Fire wood	66	4.34	50.20
Furnace	166	10.91	61.10
Geothermal heat pump	360	23.65	84.76
Exhaust air heat pump	206	13.53	98.29
Outdoor heat pump	11	0.72	99.01
Solar Accumulator	15	0.99	100
Total	1522		

Table 4. Heating modes

The ancillary heating sources are described in table 5. 1.152 ancillary heating choice answers were given in total. The most common additional heating sources are furnace (644 houses) and exhaust heat pump (219 households).

Ancillary heating	Amount	Percent	Cum.
Electric heating	120	5.32	5.32
Oil heating	4	0.16	5.48
District heating	4	0.24	5.71
Pellet	5	0.08	5.79
Woodchip	2	0.16	5.95
Fire wood	19	0.87	6.83
Furnace	644	37.78	44.6
Geothermal heat pump	13	0.79	45.4
Exhaust air heat pump	85	5.79	51.19
Outdoor heat pump	219	7.78	58.97
Solar Accumulator	37	1.11	60.08
Total	1152	100	100

Table 5. Ancillary heating modes

As there was no limitation to the amount of heating modes to be chosen in the questionnaire, a household might have picked as many primary and ancillary heating modes as they wished to. The problem of one household being presented in various different categories had to be eliminated; this was taken into account when creating the variables for the multinomial logistic regression model. Completing heating sources were not taken into consideration in the empirical exercise.

Different heat distribution modes are presented in table 6. Only the categorization between direct electric heating and others (water based heating modes) were taken into account.

Heat distribution	Amount	Percent	Cum.
Electric heater	101	20.57	20.57
Ceiling heating	11	2.24	22.81
Floor heating in wet rooms	5	1.02	23.83
Floor heating in all rooms	269	54.79	78.62
Water based floor heating	23	4.68	83.30
Water resistors	66	13.44	96.74
Other heat delivery	16	3.26	100.00
Total	491		

Table 6. Heat distribution

Due to the low number of responses in oil and solar heating, those heating modes were left out of the empirical investigation. What is more, the data was modified by creating less categories to fit better the multinomial logistic strategy. Six different heating categories were created: electric heating, district heating, ground heat pump, heat pumps, wood heating and furnace. When creating the categorical variable for heating mode, the problem of overlapping answers had to be eliminated. If a household for instance had announced to have both electric heating and a heat pump, the household was selected to present only electric heating. All those heating modes that require electric heating or other heating modes and are not functioning independently were classified as ancillary heating modes and thus left outside the empirical part. The problem arises of course, that the distinction between principal heating mode and ancillary heating mode is not always clear. With the current technology, as it was stated in chapter 2, it is possible to cover up to 50 % of household's heating demand by using heat pumps in Finland.

After making sure that each household had only one heating mode, the total amount of observations accounts for 1.173. In total 410 households had chosen the electric heating, of which 291 households had chosen direct electric heating. Ground heat pump was left outside of the other heat pumps (exhaust and outdoor heat pump) due to its unique mechanism and high number of observations. Ground heat pump can better function as a primary heating source whereas other heat pumps always require some other heating system to cover up the need for heating in the coldest period of the winter. Pellet, wood chip, and firewood were compiled as a wood heating whereas furnace was left as an individual category also due to the technical considerations and its popularity. The electric heating variable dominated all the other heating mode choices since. District heating and geothermal heat pump dominated wood, woodchip, pellet, furnace, exhaust and outdoor heat pump choices.

6.1.3 Income

Information on household income level was collected for the data by asking the households to estimate the gross income of the primary residents and placing them on the scale of five different categories presented in the summary statistics previously. In total 1.259 households gave their annual gross earnings information. The largest income group is 40.001- 60.000 €/year with 438 household. The mean income of a person in Finland in 2008 was some 25.000 € (Statistics Finland 2009). If this is counted for two persons, we get 50.000 € which corresponds the income class 3 (40.001- 60.000 €) in the study, which is the largest group of the income categories measured by observations.

For the multinomial logistic model, three income categories were created and applied in the regression. These are low, medium and high. The low income group consist of households whose annual gross income is under 40.000 €, the medium 40.001-60.000 € and high above 60.000 €. The numbers of observations in each income groups were respectively 312 for the low income group, 745 for the middle income group and 198 for the high income group.

6.1.4 Age

The households were asked to place themselves in an age group based on the average age of the primary residents. 1.226 of the households that had revealed their heating mode choices also announced the age group. The largest age group was between 30 and 40 years with total of 472 households. The smallest of the age groups was over 60 with 122 households. The number of households under 30 was 242 and households in the group of 40-50 were in total 216. For the multinomial logistic regression, three age groups were created. Households of under 40 had 717 observations, the group of 40-60 in total 387 observations and over 60 contains 122 observations.

6.1.5 Occupation

In addition, the households were asked to inform their occupation. In total 1.218 households that had announced their heating mode choices also revealed their occupation. The possibility was to choose out of the six different occupation groups: farmer, worker, clerical worker, entrepreneur, manager and pensioner. Worker and clerical worker are the most common groups accounting together for almost 59 % of the total. In the multinomial logistic model the occupations are not included the prevent the extension of the model and remaining reasonable amount of observations in the regression. On the logistic model approach on the other hand, the occupations are one of the independent variables.

6.1.6 Residential area

In total 1.077 households of the 1.260 that reported their heating modes, responded to the question concerning the purpose of the house. 1.025 (95 %) houses in total of the 1.077 were built as a primary residence. 35 were summer houses, 15 “secondary” houses and 10 other houses. Of all those households that announced their heating choices altogether 1.139

revealed the location of the residential area of the house. 629 of the houses are located in the urban area and 510 in the rural area.

6.2 Characteristics of the data

All the different heating modes in the model are categorized by the income categories in table 7. The amount of observations is lower in each category than what is presented in table 7. The amount of responses decreases because not all those households, who had announced their heating mode choice had announced their income level. The first row presents the amount of households that had chosen the electric heating in each income classes. The figures in parentheses present the amount of households with direct electric heating.

Heating mode	Income 1	Income 2	Income 3	Income 4	Income 5
Electricity	17 (14)	105 (90)	142 (97)	70 (53)	44 (39)
District heating	0	15	39	41	44
Ground heat pump	4	48	114	101	74
Heat pumps	2	20	46	30	9
Wood heating	3	28	33	16	6
Furnace	5	16	9	7	1

Table 7. Heating modes in earnings categories

To investigate whether there exists any relation between income and heating mode choice, it is useful to observe relative shares of heating modes in each income class. Diagram 8 depicts these relations. The vertical axis measures the percentage share of distinct heating mode. It is obvious that there is a correlation between the income level and certain heating modes. Electric heating is much more common in lower income classes and its share drops significantly in the higher income classes 4 and 5. On the contrary, the share of geothermal heat pump and district heating increase in income. The empirical evidence would thus support the hypothesis that lower income households tend to choose the heating mode that yields lower initial investment cost whereas the likelihood of those heating modes that entail higher initial investment cost increases the higher the income category.

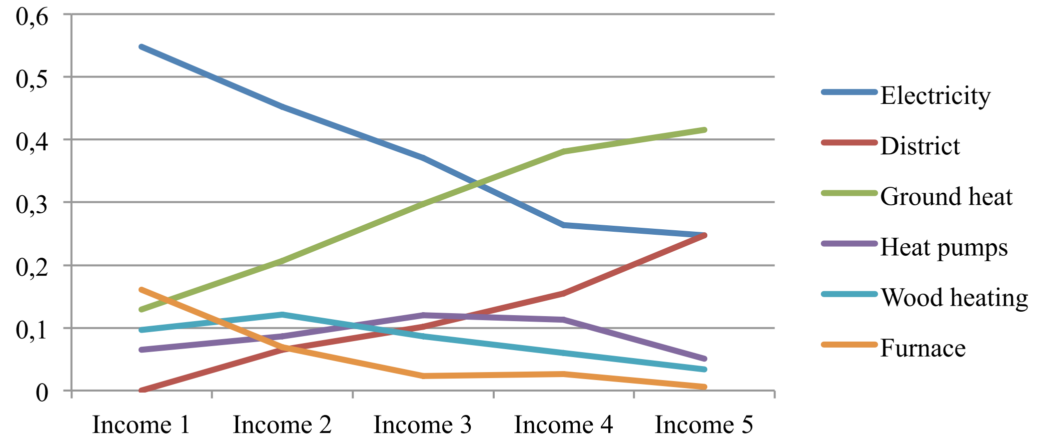

Diagram 8. Shares of heating modes in each income class

When comparing diagram 8 and diagram 9 where the direct electric heating has been separated from the other electric heating modes it becomes clear, that the share of direct electricity is clearly decreasing in all income classes despite the highest one. When the direct electricity has not been separated from other electric heating modes, the total electric heating is more popular in income classes 1 and 3 and declining in the others.

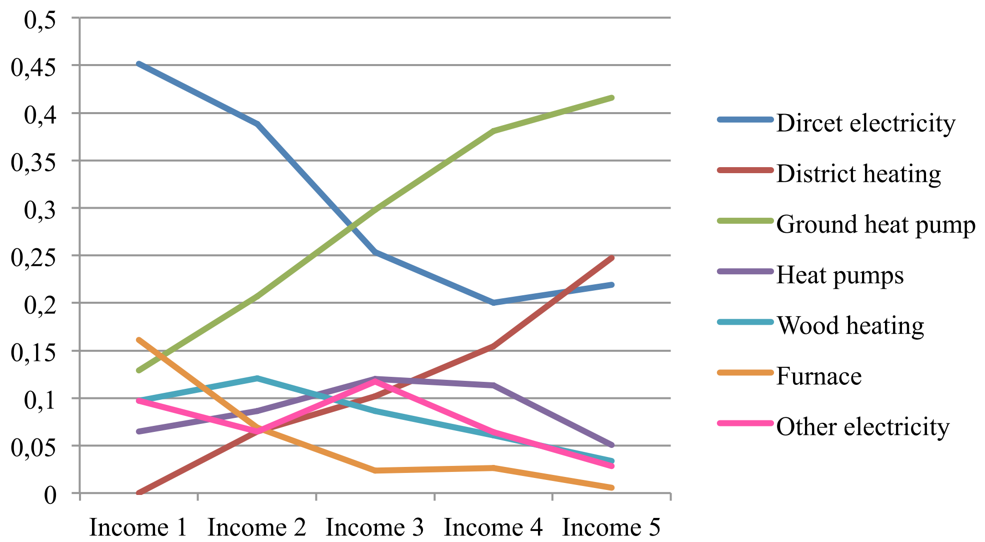

Diagram 9. Shares of heating modes in each income class, direct and other electric heating separated

When observing the share of direct electric the impact of income is very clear. The share of direct electricity is the largest, some 45% in the lowest income class, but gradually drops close to 20 % in the income groups 4 and 5. The share of direct electricity compared to total electric heating (covering also the water circulated heat delivery systems), is dropping down steeper in higher income classes. This finding supports well the hypothesis, that lower income households prefer electric heating due to its low implementation costs compared to higher income households. In both diagram 8 and 9, the share of district heating is rising from 0 % in the lowest income group to around 25 % in the highest income group. The district heating is available only in the densely populated areas, where the average income level is higher compared to the rural areas. Shares of wood heating and heat pumps do not have clear implications in different income classes, but furnace is slightly more popular among the lower income classes than the higher ones. Its share is around 15 % in the lowest income group and drops close to 0 in the higher income groups. It does not necessarily mean that higher income households would not employ furnaces, but they are likely classified as ancillary heating modes.

Table 8 presents heating mode choices in each age category, direct electricity is included in electricity, but its share is also reported in separate row.

Heating mode	**Under 30**	**30-40**	**40-50**	**50-60**	**Over 60**
Electricity	73	105	71	56	59
Direct electricity	56	71	51	44	52
District heating	26	67	28	16	5
Ground heat pump	56	161	59	31	20
Heat pumps	30	33	19	13	7
Wood heating	21	37	14	13	0
Furnace	5	9	10	9	8

Table 8. Heating modes in each age group

Households were asked to place themselves in a certain age group; under 30, 30 to 40, 40 to 50, 50 to 60 or over 60 based on the age of the primary residents. When observing the relative heating mode choices in each age group, it is evident, that electric heating is more common among middle aged and older households than that of the young households (diagram 10). The share of electric heating is the lowest in age group 30-40, where the share of geothermal heat pump is the highest. The popularity of electric heating and especially direct electric heating is rising substantially among the households where the average age of inhabitants reaches 60 or more. The shares of other heating modes do not have significant changes.

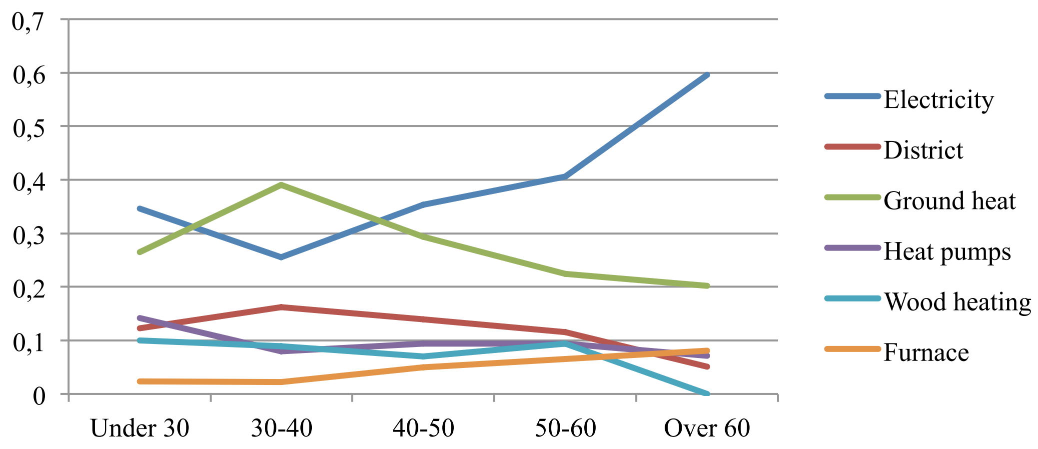

Diagram 10. Heating modes in each age group

Of all those households, who had announced their heating mode choices, altogether 982 had also announced their building location. 546 households' lots located in the city or urban area and 436 on the country side or rural area. The shares of the six different heating modes are compared between urban and rural areas in diagram 11. Electric heating[9] is clearly more popular at the country side, as is also the case with the ground heat pump. However, in the urban area electric heating is as common as the ground heat pump whereas in the rural area the electric heating is clearly the most common heating mode with nearly 40 % share. Not surprisingly, district heating is relatively common in urban area, accounting for more than 20 % of the heating modes. At the countryside, the share of district heating is low, less than 5 % as expected. The reason for the strong difference is clearly the lack of district heating infrastructure in the rural areas. Furnace and wood heating are slightly more popular in the rural areas, both under 10 %, whereas heat pumps are slightly more common in the urban areas.

[9] The share of direct electric heating of the total electric heating is 84 % in the country side and 72 % in the urban area.

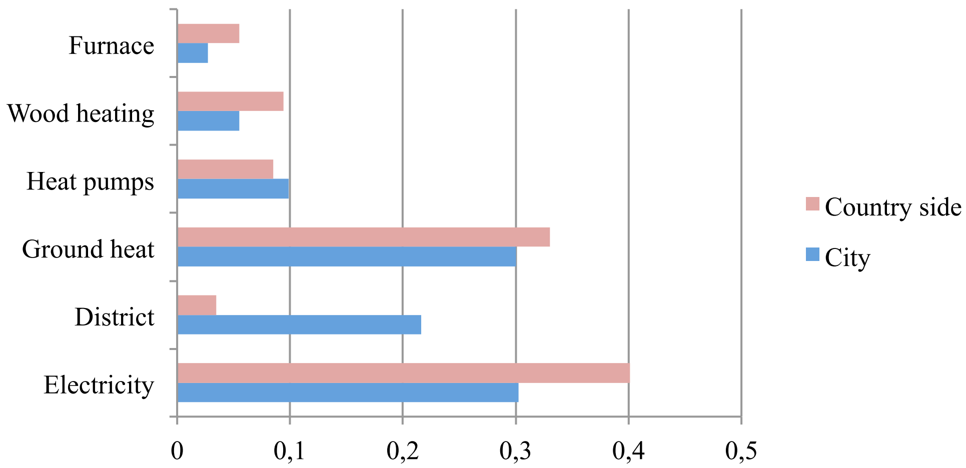

Diagram 11. Shares of heating modes in urban and rural areas

In diagram 12, the net building costs of the houses are compared in each heating mode choice. The net costs have been divided into six different cost categories, of which €100.000-200.000 and €200.000-300.000 are the largest. Electric heating is clearly more common in the lower building cost categories; electricity is the most popular heating mode choice in the first two categories. Over 200 households, the vast majority of the biggest cost group of €100.000-200.000 selected electric heating. The share of electric heating clearly decreases in the higher cost groups. In the second largest cost group, € 200.000 - 300.000, the ground heat pump is the most popular heating mode choice with almost 150 households as electric heating reaches 100 households limit. In the last three groups, the share of electricity is clearly lower than that of district heating and ground heat pump.

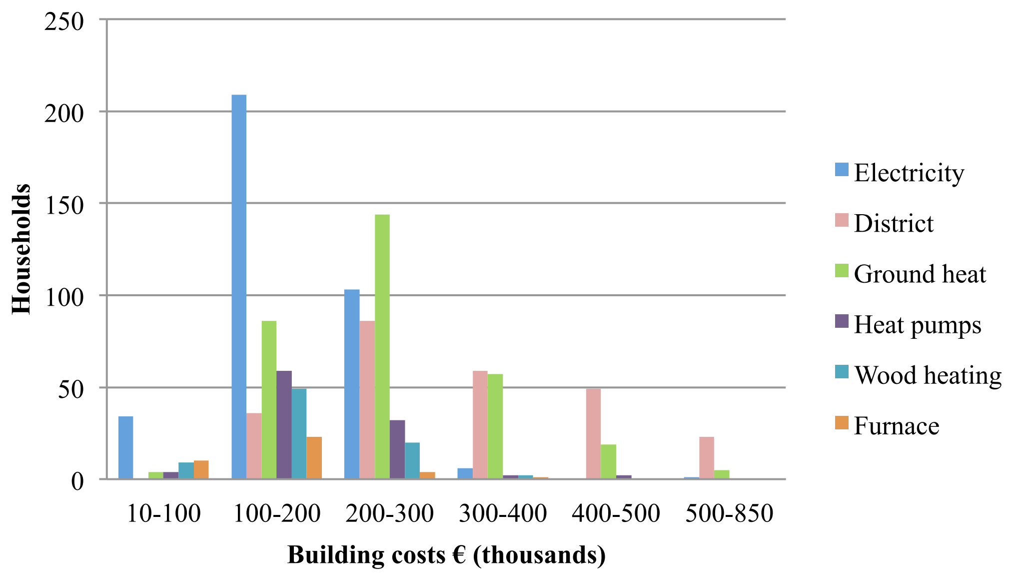

Diagram 12. Total building costs and heating mode choices

Electric heating is negatively correlated not only with total building costs, but also with the net square metre size of the house (diagram 13). The average size of an electrically heated house is close to just 60 m^2. The sizes of houses that are heated by district heating or wood are on average the largest, both around 120 m^2.

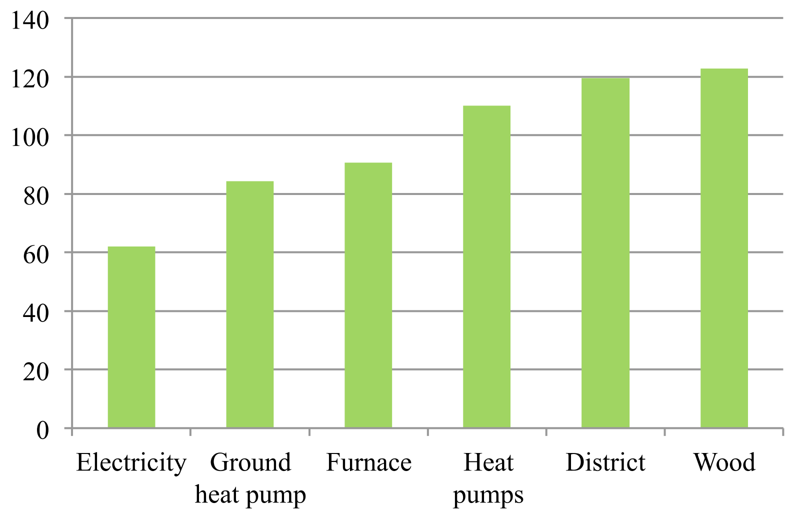

Diagram 13. Average square metre size of houses in each heating mode group

The households that have chosen district heating had the most expensive building costs per square meter. Diagram 14 depicts the average building costs per square meter in each heating mode category. The households that chose the electric heating had the lowest €/m^2, a bit over a 1.000 €/m^2. The building costs of those households that chose district heating were on average close to 1.400 €/m^2.

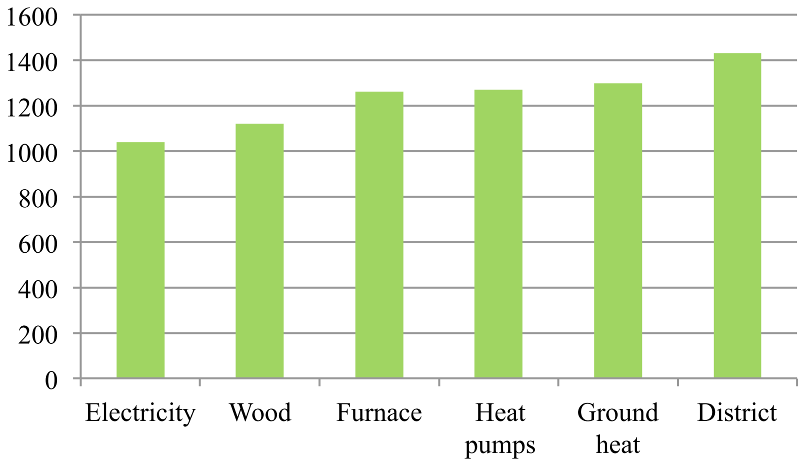

Diagram 14. Average cost per square meter in each heating mode type

Most of the households included in the study have bought their lots from the private sector. In diagram 15, the percentage shares of different lot acquisitions are defined in each heating mode category. The share of rented lots is the highest in the district heating group as expected with some 25 % share. In other heating mode groups renting the lot is distinguishably lower.

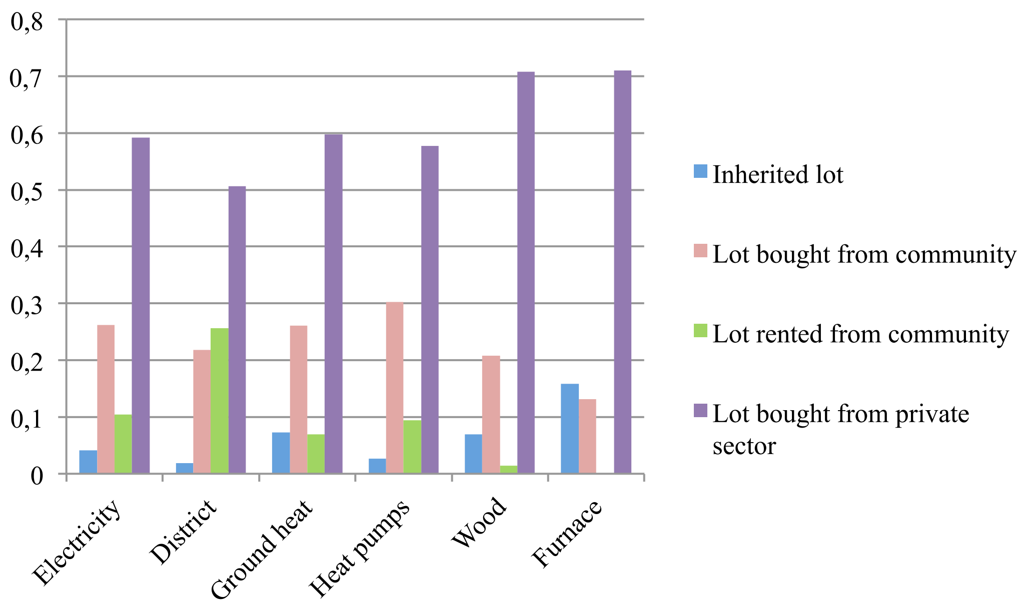

Diagram 15. Lot statuses in each heating mode group

6.3 Total costs of heating modes and energy prices

Usually the economic initial investment price is correlated with higher usage costs during the whole life cycle of a heating system. For instance, electric heating is relatively economical to install, but if the price development of electricity is expected to follow its upwards sloping trend, the net cost of electric heating will be high. In the same manner, the costs of heating systems that embody higher installing costs will be economical in a long run due to lower or non-existing energy price. In many cases, it makes sense to invest into the possibility of switching or swapping heating systems. The energy price changes will thus have less effect on the heating costs.

Calculating the total costs of heating system is not simple. The costs consist principally of investments during the building phase, the annual energy costs and fixed basic fees and maintenance and possible reparation costs. The period of cost calculations is usually 15 or 30 years. Since it is not possible to predict future energy prices correctly, the calculations can deviate from the real prices as the period is long. Even though the energy prices cannot be predicted accurately, there are some justifiable methods to estimate the price development. The general view is that the energy prices will continue to increase in the future. In this sense it is recommendable to invest in energy efficiency of the heat capturing ventilation of the house. The initial investment costs are compared in table 9. Room specific direct electric heating has the lowest initial costs and geothermal heat pump the highest. Pellet, air-water and exhaust heat pumps and district heating are in the middle cost category.

Geothermal heat pump	15,000–20,000 €
Wood pellet	10,000–20,000 €
Air-water heat pump	10,000–15,000 €
District heating	10,000–15,000 €
Exhaust heat pump	7,500–12,500 €
Electric heating with circulating water	7,500–12,500 €
Room specific direct electric heating	5,000–10,000 €

Table 9. Initial investment costs of different heating capital (source: Motiva Ltd 2009).

The most common practice to calculate the investment is to use net present value (NPV) method. The operating costs accrued in future are discounted to the monetary value of the initial investment period. NPV is popular due to its simplicity despite the wide recognition of its drawbacks. First of all, NPV calculation the weight of future costs is smaller compared to the present value. The rate of interest used in long term investments is usually between 4 and 6 per cents (Lind 1982; Portney 1990; Quirk and Terasawa 1991).

The investment price of the heating system gets smaller weight, as the using period of the system gets closer to 30 years. The initial investment price is consisting of planning costs, heat development, transfer and storage systems, control equipment, possible joining fees for instance to district heat network and installing.

To compare the accruing costs of different heating systems, it is simplest to use NPV calculation of approximate costs of heating systems over a long time period. In the following example, three different heating systems that are used in this study for modelling the household heating mode choice, direct electric heating, district heating and ground heat pump are compared. To be able to evaluate the future energy costs, it is useful to investigate the past price development. First the, electricity and district heating prices for detached houses for the next 15 years from 2008 are computed. Then the total annual costs of each heating type are calculated by using a representative household. In the calculations a typical household is used. The definition of typical household is based on the averages of Statistics Finland, Motiva Ltd and Finnish Energy Industries. The size of the house is 150 m^2 (450m^3). The average heating energy consumption of this type of household is annually some 16,500 kWh for direct electric heating, 20 MWh of district heating and 7,200 kWh of electricity with ground heat pump. (Statistics Finland 2011, Motiva Ltd 2009).

The annual energy costs are then discounted to the investment period, which is 2008. The total net investment is then consisting of the discounted estimated future energy prices and the average investment cost of a heating technology. Then the different heating modes can be compared to one another based on the cost estimations.

The estimation of the future energy prices is useful to start by exploring the past price development to understand the long-term trend on the price development. In table 10, the average annual prices of direct electricity, transmission of electricity and district heating in Finland are presented. The average annual increase of direct electricity is some 5.3 %, transmission of electricity some 3 % and district heating 4.6 %. When looking at the past price changes, it is important to distinguish the effect of inflation in the annual price increase.

	Direct Electricity cnt/kWh	Transmission of electricity cnt/kWh	District heating €/MWh	Inflation % (average annual change of consumer price index)
1997	3.41	3.23	36.45	1.2
1998	3.30	3.39	37.35	1.4
1999	2.91	3.54	37.85	1.2
2000	2.80	3.24	38.40	3.4
2001	2.90	3.55	40.79	2.6
2002	3.23	3.56	42.38	1.6
2003	4.05	3.62	43.65	0.9
2004	4.11	3.62	44.59	0.2
2005	4.01	3.60	46.63	0.9
2006	4.52	3.60	49.63	1.6
2007	4.83	3.63	51.76	2.5
2008	5.73	3.99	55.41	4.1
2009	6.14	4.11	61.66	0
2010	6.30	4.67	62.85	1.2
2011				3.5[10]

Table 10. Prices of direct electricity, transmission of electricity and district heating for detached houses and inflation between 1997 and 2010 in Finland (source: Statistics Finland 2011).

The average inflation between 1997 and 2011 has been approximately 1.6 % annually. The predicted future prices of direct electricity, transmission of electricity and district heating are presented in table 11. The prices have been derived by first calculating the average price change between 1997 and 2010 minus the average overall annual inflation rate (1.6 %). After the removing the effect of inflation, the annual growth percentage for direct electricity price is estimated to be 3.6 %, for transmission of electricity 1,4 % and for district heating 3 %. The prices of direct electric heating and district heating include price of energy and the basic charge but not taxes or prices of transmission.

	Direct Electricity cnt/kWh	Transmission of electricity cnt/kWh	District heating €/MWh
2008	5.73	3.99	55.41
2009	6.14	4.11	61.66
2010	6.30	4.67	62.85
2011	6.53	4.74	64.74
2012	6.76	4.80	66.68
2013	7.01	4.87	68.68

[10] Average between January and October 2011

2014	7.26	4.94	70.75
2015	7.53	5.01	72.87
2016	7.80	5.08	75.06
2017	8.08	5.15	77.31
2018	8.38	5.22	79.64
2019	8.68	5.29	82.03
2020	9.00	5.36	84.49
2021	9.33	5.44	87.03
2022	9.66	5.51	89.64
2023	10.02	5.59	92.33

Table 11. Future predicted prices for direct electricity, transmission of electricity and district heating for detached houses in Finland between 2011 and 2023.

The future prices are estimated only for the next 15 years, since first of all, that is a minimum reasonable time period one can assume a heating technology functions without need for repair or costly maintenance. Second of all, estimating price changes and inflation rate even to the near future is vague and based on rough assumptions. The longer the estimated period the less is the explanatory power of the calculation example. Furthermore, the discounting method guarantees that future price flows gains a smaller weight than the ones closer to the investment period. Thus, the costs accruing very long in the future do not have that significant effect on the investment price.

Table 12 includes the total investment calculation of direct electric heating for an average Finnish household between 2008 and 2023 assuming that an households consumes 16,500 kWh of heat energy annually. The discount rate used in the calculation is 5 % which is normal discount rate applied for long-term investments in economic calculations. The net total cost of a direct electric heating is in the example some 29,696 €.

	Annual direct electricity fees (€)	**Annual transmission of electricity fees**	**Total annual payments**	**Discount factor. r= 5 %**	**Discounted payments t=2008**	**Initial investment (€)**	**Total investment (€)**
2008	945.45	658.35	1603.80	1.00	1603.80	**7500**	
2009	1013.10	678.15	1691.25	1.10	1534.01		
2010	1039.50	770.55	1810.05	1.16	1563.59		
2011	1077.45	782.10	1859.55	1.22	1529.86		
2012	1115.40	792.00	1907.40	1.28	1494.50		
2013	1156.65	803.55	1960.20	1.34	1462.73		
2014	1197.90	815.10	2013.00	1.41	1430.60		
2015	1242.45	826.65	2069.10	1.48	1400.45		

2016	1287.00	838.20	2125.20	1.55	1369.92		
2017	1333.20	849.75	2182.95	1.63	1340.14		
2018	1382.70	861.30	2244.00	1.71	1312.02		
2019	1432.20	872.85	2305.05	1.80	1283.54		
2020	1485.00	884.40	2369.40	1.89	1256.54		
2021	1539.45	897.60	2437.05	1.98	1230.88		
2022	1593.90	909.15	2503.05	2.08	1204.01		
2023	1653.30	922.35	2575.65	2.18	1179.93		
					22196.53		**29696.53**

Table 12. The total costs of a direct electric heating system in a type consumer detached household

The similar calculation procedure was also done for district heating (table 13). It is assumed in the calculations, that a household consumes annually 20 MWh of heat energy. The total net cost of the investment is somewhat lower, 28,185 € in total.

	District heating €/MWh	**Total annual district heating payments**	**Discount factor. r= 5 %**	**Discounted payments t=2008**	**Initial investment (€)**	**Total investment (€)**
2008	55.41	1108.2	1.00	1108.20	**12500**	
2009	61.66	1233.2	1.10	1118.55		
2010	62.85	1257	1.16	1085.84		
2011	64.74	1294.8	1.22	1065.24		
2012	66.68	1333.6	1.28	1044.91		
2013	68.68	1373.6	1.34	1025.00		
2014	70.75	1415	1.41	1005.61		
2015	72.87	1457.4	1.48	986.43		
2016	75.06	1501.2	1.55	967.69		
2017	77.31	1546.2	1.63	949.23		
2018	79.64	1592.8	1.71	931.28		
2019	82.03	1640.6	1.80	913.55		
2020	84.49	1689.8	1.89	896.14		
2021	87.03	1740.6	1.98	879.12		
2022	89.64	1792.8	2.08	862.37		
2023	92.33	1846.6	2.18	845.95		
TOTAL				**15685.10**		**28185.10**

Table 13. The total costs of a district heating system in a type consumer detached household

Finally, the investment calculation procedure is accounted for ground heat pump as well and the results summarized in the table 14. It is assumed in the calculations that a households consumes 7,200 kWh of electricity annually to run the heat pump. The total costs of the investment is 27,185 €.

	Annual direct electricity (EUR) fees	Annual transmission of electricity fees	Total annual payments (€)	Discount factor. r= 5 %	Discounted payments t=2008	Initial investment (€)	Total investment (€)
2008	412.56	287.28	699.84	1.00	699.84	**17500**	
2009	442.08	295.92	738.00	1.10	669.39		
2010	453.60	336.24	789.84	1.16	682.29		
2011	470.16	341.28	811.44	1.22	667.57		
2012	486.72	345.60	832.32	1.28	652.14		
2013	504.72	350.64	855.36	1.34	638.28		
2014	522.72	355.68	878.40	1.41	624.26		
2015	542.16	360.72	902.88	1.48	611.10		
2016	561.60	365.76	927.36	1.55	597.78		
2017	581.76	370.80	952.56	1.63	584.79		
2018	603.36	375.84	979.20	1.71	572.52		
2019	624.96	380.88	1005.84	1.80	560.09		
2020	648.00	385.92	1033.92	1.89	548.31		
2021	671.76	391.68	1063.44	1.98	537.11		
2022	695.52	396.72	1092.24	2.08	525.39		
2023	721.44	402.48	1123.92	2.18	514.88		
TOTAL					**9685.76**		**27185.76**

Table 14. The total costs of a ground heat pump heating system in a type consumer detached household

From the different heating technologies, direct electricity is the most expensive, ground heat pump the most economic taking both the initial investment cost, and the rising energy prices into account. The aim of the cost calculations of these three different heating modes was to show that the net investment costs highly depend on the fluctuating energy prices. What is more, if the energy prices do go up in the future, as it was assumed in the example, the affordability of the electric heating and district heating against technologies that utilize partly renewable resources such as ground heat pump, is poor. Despite its low initial investment cost, direct electric heating could turn out to be the highest of all heating mode types by its costs as is the case in the calculations.

However, it is important to bear in mind, that the investment calculations done here are based on strong simplifications. Firstly, the representative household is only the average of a Finnish detached house in 2008. The size of the houses varies significantly as is the case with the insulation, materials, energy passivity and so on. All these household-specific details change substantially the net heat energy needed for a space heating services, as do the effect of the lifestyle factors. Secondly, forecasting the future price development based on the past prices is not very reliable. Thirdly, NPV calculations as an investment criterion have often been criticised due to its sensitivity to discount rates and rejection of an option value that at least in the case of energy technology, can often be valuable. It is a fact that a high discount rate lower the competitiveness of capital-intensive technologies (i.e. ground heat pump) and favour low investment cost technologies (i.e. direct electric heating). For instance ground heat pump is characterised by a high initial investment cost, but low operating, maintenance and fuel costs. Fourthly, the investment period was in this example assumed to be relatively short, only 15 years whereas a heating technology is usually in place up to 30 years. The period is kept relatively short for the uncertainty related to the energy price development and for the reason that with a relatively high discount rate the payments that take place in 20 years or longer have very little effect on the NPV.

The simplifications done and used in these calculations are nevertheless applicable in detecting and presenting the problem behind the phenomenon. The assumption of a representative household, using past energy prices as a guideline for computing future prices and the simplicity of NPV method allows us to compare the heating mode investment costs on a very general level. The investment period was on purpose shorter than usually expected due to the increasing uncertainty of the increasing investment period in prices and possible maintenance costs.

6.4 Model for heating equipment demand and earnings, Multinomial logistic and logistic regression results

In the empirical part, multinomial logistic and logistic regression models were applied.

6.4.1 Multinomial logistic regression

Utilities for a household from each heating mode alternative are presented below. The equations (42-47) show how the probability functions of each heating alternatives consist of the gross household income, average age of the inhabitants, residential area, building costs per square metre, number of inhabitants and the error term. The results of the multinomial logistic regression are presented in appendix B. Electric heating was used as the reference category for the other alternatives.

$$Electric\ heating = \beta_{10} + \beta_{11}Income + \beta_{12}Age + \beta_{13}City + \beta_{14}Cost\ per\ Sqm + \beta_{15}Numebr\ of\ Inhabitants + \varepsilon_1 \quad (42)$$

$$District\ heating = \beta_{20} + \beta_{21}Income + \beta_{22}Age + \beta_{23}City + \beta_{24}Cost\ per\ Sqm + \beta_{25}Numebr\ of\ Inhabitants + \varepsilon_2 \quad (43)$$

$$Ground\ heat\ pump = \beta_{30} + \beta_{31}Income + \beta_{32}Age + \beta_{33}City + \beta_{34}Cost\ per\ Sqm + \beta_{35}Number\ of\ Inhabitants + \varepsilon_3 \quad (44)$$

$$Heat\ pumps = \beta_{40} + \beta_{41}Income + \beta_{42}Age + \beta_{43}City + \beta_{44}Cost\ per\ Sqm + \beta_{45}Number\ of\ Inhabitants + \varepsilon_4 \quad (45)$$

$$Wood = \beta_{50} + \beta_{51}Income + \beta_{52}Age + \beta_{53}City + \beta_{54}Cost\ per\ Sqm + \beta_{55}Number\ of\ Inhabitants + \varepsilon_5 \quad (46)$$

$$Furnace = \beta_{60} + \beta_{61}Income + \beta_{62}Age + \beta_{63}City + \beta_{64}Cost\ per\ Sqm + \beta_{65}Number\ of\ Inhabitants + \varepsilon_6 \quad (47)$$

Magnitude and the sign of a coefficient cannot be interpreted directly as the marginal effect of a variable x_n on the dependent variable (i.e. the probability P_{nj} of a heating mode j), but to interpret the results for multinomial logistic, the effects must be observed separately. Instead of focusing on the analysis of the odds ratios, an interpretation of marginal effects is done. It means in practice that the results are not interpreted through the risks but rather the predicted probabilities. The effects are calculated by applying the average marginal effects (AME) instead of the marginal effects at the means (MEM). The reason is that MEM could refer to nonexistent or nonsensical observations, which is a problem that often rises when dummy variables are involved in the regression analysis (Long 1997). The marginal effect of x_n is:

$$\frac{\partial P_{nj}}{\partial x_n} = P_{nj}\left[\beta_j - \sum_{i=0}^{J} P_{ni}\beta_i\right] \quad (48)$$

The marginal effect does not solely depend on the coefficient estimate β_j, but on the other coefficient estimates and variables as well. The reporting of the marginal effects are done by observing the effects of the variables in each of the heating categories. The marginal effect (dy/dx) in table 15 is the predicted probability for a decrease or increase of the variable when it changes from 0 to 1. The effect thus points out the direction and magnitude of increase or decrease in the probability of a household to choose a certain heating mode as a household moves to a certain group from another (e.g. change in probability to choose electric heating when a household moves from high income to low income group). The computed marginal effects from the averages of the data for the multinomial logistic regression are presented in table 16.

Electricity	Marginal effect (dy/dx)	Delta method Std. Err.	z	P>z	[95% Conf. Interval]	
income_low*	0.120334	0.061785	1.95	0.051	-0.0007624	0.2414303
income_med~m	0.0129229	0.0554454	0.23	0.816	-0.0957481	0.121594
age_40	0.0426518	0.0455265	0.94	0.349	-0.0465786	0.1318822
age_40_60	-0.0475976	0.0436468	-1.09	0.275	-0.1331439	0.0379486
city***	-0.0892671	0.032648	-2.73	0.006	-0.153256	-0.0252781
cost_sqm	-0.0000239	0.0000398	-0.6	0.549	-0.0001018	0.0000541
number_inh~s	-0.0024918	0.0145423	-0.17	0.864	-0.0309942	0.0260106

District heating	Marginal effect (dy/dx)	Delta method Std. Err.	z	P>z	[95% Conf. Interval]	
income_low	-0.0614996	0.0393836	-1.56	0.118	-0.1386901	0.0156909
income_med~m**	-0.0583958	0.0282826	-2.06	0.039	-0.1138287	-0.0029628
age_40	-0.0461346	0.0357575	-1.29	0.197	-0.1162181	0.0239489
age_40_60	0.0237594	0.0297986	0.8	0.425	-0.0346448	0.0821635
city***	0.2092956	0.0345941	6.05	0	0.1414924	0.2770987
cost_sqm	0.000037	0.0000227	1.63	0.103	-7.46e-06	0.0000816
number_inh~s	0.0064025	0.0062055	1.03	0.302	-0.00576	0.018565

Ground heat pump	Marginal effect (dy/dx)	Delta method Std. Err.	z	P>z	[95% Conf. Interval]	
income_low***	-0.2376508	0.0556179	-4.27	0	-0.3466598	-0.1286418
income_med~m**	-0.1122972	0.0449149	-2.5	0.012	-0.2003287	-0.0242657
age_40	-0.0025141	0.0484995	-0.05	0.959	-0.0975713	0.0925431
age_40_60**	0.0890676	0.0421323	2.11	0.035	0.0064897	0.1716454
city***	-0.1038862	0.03293	-3.15	0.002	-0.1684279	-0.0393446
cost_sqm***	0.0001202	0.0000372	3.23	0.001	0.0000472	0.0001931
number_inh~s	0.0161388	0.0110444	1.46	0.144	-0.0055078	0.0377853

Heat pumps	Marginal effect (dy/dx)	Delta method Std. Err.	z	P>z	[95% Conf. Interval]	
income_low	0.0767508	0.0487135	1.58	0.115	-0.0187259	0.1722275
income_med~m**	0.0976673	0.045021	2.17	0.03	0.0094278	0.1859067
age_40	-0.0108383	0.0295557	-0.37	0.714	-0.0687664	0.0470899
age_40_60	-0.0094626	0.0281072	-0.34	0.736	-0.0645517	0.0456266
city	0.0075269	0.0204803	0.37	0.713	-0.0326137	0.0476676
cost_sqm	-0.0000352	0.0000246	-1.43	0.152	-0.0000834	0.0000129
number_inh~s	-0.0079791	0.0077999	-1.02	0.306	-0.0232667	0.0073085

Wood heating	Marginal effect (dy/dx)	Delta method Std. Err.	z	P>z	[95% Conf. Interval]	
income_low	0.0457767	0.0413362	1.11	0.268	-0.0352408	0.1267943
income_med~m	0.0430499	0.0409758	1.05	0.293	-0.0372611	0.123361
age_40	0.0260111	0.025562	1.02	0.309	-0.0240895	0.0761118
age_40_60	-0.0103364	0.0264628	-0.39	0.696	-0.0622025	0.0415298
city	-0.0215352	0.0174644	-1.23	0.218	-0.0557648	0.0126943
cost_sqm***	-0.0000853	0.0000256	-3.33	0.001	-0.0001355	-0.0000352
number_inh~s	0.0025396	0.0053122	0.48	0.633	-0.0078722	0.0129514
Furnace	**Marginal effect (dy/dx)**	**Delta method Std. Err.**	**z**	**P>z**	**[95% Conf. Interval]**	
income_low	0.0562877	0.0363873	1.55	0.122	-0.0150301	0.1276054
income_med~m	0.0170522	0.0370398	0.46	0.645	-0.0555445	0.0896489
age_40	-0.0091758	0.014522	-0.63	0.527	-0.0376384	0.0192868
age_40_60	-0.0454294	0.0213025	-2.13	0.033	-0.0871815	-0.0036774
city	-0.002134	0.0123092	-0.17	0.862	-0.0262596	0.0219915
cost_sqm	-0.0000128	0.0000161	-0.79	0.428	-0.0000445	0.0000188
number_inh~s**	-0.0146096	0.0071786	-2.04	0.042	-0.0286794	-0.000539

Table 15. Marginal effects for multinomial logistic regression

*** significant at 0.01 level

** significant at 0.05 level

* significant at 0.1 level

Income

For the electric heating, the medium class income group did not yield a significant result. The probability that a household chooses electric heating when the income group changes form medium and higher to the lowest increases by 12 %, but the result is not very reliable since it is significant only at 90 % confidence interval. For the district heating, the results varies a bit. When a household moves to a low or medium income class, the probability to select district heating decreases by some 6 %. The result is significant only for medium income class. For the ground heat pump, the effect of income is the clearest and significant at 99 % confidence level. When a household changes the income class to the lowest from the upper two classes, the probability to choose ground heat pump decreases by 23.7 %. As the income class is changed to the medium class, the probability drops by 11.2 %. In the heat pumps category, the income plays less significant role. The probabilities that a household chooses a heat pump (other than ground heat pump) increases both in the low and the medium income classes by 7.6 % in the low and 9.7 in the medium income class. Only the latter one is statistically significant with 95 % significance level. For both wood heating and furnace the income class yields minor and non-significant results in low and medium income classes. The probability seems to increase a bit in both of the heating modes when a household changes to either of these income categories from the others.

Age

The impact of the age variable in the regression is not very important. The results are either not statistically significant or the effect is very small. For none of the electric district and wood heating and furnace the age categories yield significant results. For choosing a ground heat pump a change in to the highest age category, 40-60, seems to have a significant result increasing the probability to choose ground heat pump by almost 9 %.

Residential area

The impact of the residential area is the clearest and the most significant for electric heating, district heating and ground heat pump. All of these three categories the confidence level of the city variable is 99 %. When a household moves from rural area to urban area, the probability to choose electric heating drops almost by 9 %. For the district heating, on the contrary, the probability increases by 20 %, which is logical taking the restriction to the availability of the district heat in the rural area into account. Ground heat pump’s probability to be selected on the other hand drops by 10 % for the urban households. When it comes to the rest of the three heating mode categories, heat pumps, wood heating and furnace, the variable city does not yield any significant results and the effects seem to be modest, staying clearly under 3 %.

Building costs per square metre

The effect of the building costs of the houses per square meter do not seem to have clear effect on any of the selected heating modes above. The results are not significant any other heating modes than ground heat pump and wood heating. Even for those heating categories the probabilities to choose those heating modes change only slightly when the building costs/square meter increases by one euro. For ground heat pump the change in probability increases by 0,01 % and foe wood heating it drops by 0,008 %.

Number of inhabitants

The total number of the persons in a household does not seem to have large effect on the probability to choose any of the heating modes. All of the results for the variable are not significant aside from furnace. The probability to choose furnace as a heating mode drops by some 1.4 % when the number of inhabitants increases by one.

6.4.2 Logistic regression

Logistic regression is run separately for direct electric heating versus other options. This is done to separate the effect of the income in direct electric heating which is different from the technical point of view and somewhat less costly on its initial investment cost. The utility function of a household can be presented as the sum of the constant and the dependent and independent variables as previously, and consists now of gross household income, average age of the inhabitants, residential area, total building costs per square metre, occupation, total housing square metres and the error term:

$$U_1 = \beta_{10} + \beta_{11} Income + \beta_{12} Age + \beta_{13} City + \beta_{14} Cost\ per\ Sqm + \beta_{15} Occupation + \beta_{16} Housing\ Sqm + \varepsilon_1 \quad (49)$$

For logistic specification, the marginal effects are calculated following the same procedure as previously for multinomial logistic regression applying the average marginal effects instead of the marginal effects at the mean. Six direct electric specific models were tested and the results are summarized in table 16. The first model includes only income level variables. The results are in line with the hypotheses and show, that low-income level households have greater probability to select direct electric heating. According to the results, the effect of a household moving to the first income category significantly increases the probability to choose direct electric heating, by more than 30 %. If a household moves to the second income category, the probability to choose direct electric heating is still rising by over 11 %. In the third income group the increase in probability is quite small, some 2.5 % and in the highest income group the probability turns even negative. It would thus seem that there is a strong evidence that low-income households tend to favour direct electric heating whereas in the higher income categories the probability to choose direct electric heating is very small or even negative. However, only the first two income groups yield significant results.

In the second model, the average age of the residents is added as control variable into the model. The model 2 generates significant results in general. The directions of changes in income groups are similar though the magnitudes of the changes in the probabilities are a bit milder. In the second model, the probability of a household to choose direct electric heating is increased by 24.9 % and 6.6 % as a household moves to the first and second income groups. The corresponding probability for income group 3 is only 0.6 % and in the income group 4, the probability has turned negative with a magnitude of 4.6 %. Interestingly, all age groups seem to decrease the probability to choose direct electric heating. As a household moves to age group 30, 30 to 40, 40 to 50 or 50 to 60, the probabilities drop by 11.8 %, 20.8 %, 10.2 % and 7.2 %. The households that have average age under 40 correlate with a greater reduction in the probability compared to the older age groups over 40. It means that the older the average age of the residents of a household, the more likely is the selection of direct electric heating.

As the residential location, that is, the control variable "city" is added in to the model 3, the magnitudes of the probabilities and the significances of the results are somewhat changed. Again, first and second income group yield higher probabilities to choose direct electric heating: 22.5% and 5.6% (though being substantially lower than in the first model), but the third income group increase the probability only slightly (by 0.5 %) and in the highest income category the effect is yet again negative (-4.9%). The results of the tow higher income groups are not significant. The age variable, on the other hand provides again similar results as the previous model. Though the result of the variable "city" are significant, its impact on the probability to choose direct electric heating is not. If a households moves from rural to urban area, the probability to choose direct electric heating decreases by some 8 %. The direct electric heating seems to be a bit more favoured in the country side than in the city. This, however, is in line with the income effect results, as the lower income households tend to choose direct electric heating more often than the higher income households and the average income level is lower in the country side than in the cities.

Building costs per square meter are included in the model 4. Yet being significant, its impact on the probability of direct electric heating is zero. It means that building costs does not seem to relate with the heating mode decisions. On the other hand, income level is correlated with the heating mode decision, which measures more or less the same impact as the building costs of the detached houses.

By adding the occupations of the residents in to the model, the results change interestingly. First of all, only the first income groups probability to choose direct electric heating remains positive, but is dropped to 11.6 %. All other income levels have a negative impact on the probability to choose direct electric heating. Nevertheless, only the highest income level yields significant result; if a household changes to the highest income group, its probability to select direct electric heating drops by almost 10 %. The effects of age groups remain all negative, but the effects of the youngest and older groups are somewhat closer to each other's. Unlike the age, the occupation seems to have a positive impact on the probability to choose direct electric heating. Farmer and managers yield the highest probabilities, 22.4 % and 23.3 %. The result contradicts with the results of the impact of the income. It would seem that occupations with the corresponding highest and the lowest income levels would choose the direct electric heating.

In the last model, the effects of income are clearer in the logistic regression model than in the multinomial logistic regression. All other income categories but the lowest income category yield significant results. According to the marginal effects, moving the first category (the gross annual income level of a household less than 20.000 €) the effect does not change the probability to choose direct electric heating much. The other income categories on the other hand, provide more interesting results. If a household moves to the second income group from the other five groups, the probability to choose direct electricity surprisingly drops by some 12 %. The same amount and direction is the change for probability in the income group 3 and for income group 4 the probability decreases by approximately 11 %. Moving into any of the income groups seem to increase the probability to choose the direct electric heating.

All the age groups have negative effect on the probability to choose direct electric heating. Age groups under 30 and 40 to 59 are significant at level of 90 % and in both of them the probability decreases by some 9 % when households move into these groups from the other groups. When a household moves to the group 40 to 50, the probability to select direct electric heating decreases by 8.4 %, but the result is not significant. For the age group 30 to 40 the reduction in the probability to choose direct electric heating is the largest, around 15 % and the result is significant even at a 99 % confidence level. If a household moves from a rural area to a urban area, the probability to choose direct electric heating seems to be increasing by 5 % (significant only at a 90 % confidence level). Building costs per square metre or the total housing square meter do not play an important role in the decision of direct electric heating according to the marginal effect results. If either the costs per square metre or the total size of the house increases by one unit, euro or square metre, the probability to choose direct electric heating drops by less than 1 %.

Occupation of the residents on the contrary has greater effect on the direct electric heating mode choice. Interestingly, whereas the effect of income seemed to be negative on households decision to choose direct electric heating, the impact of occupation is positive. If a households primary residents are farmers, the probability to choose direct electric heating increases by more than 21 %. If a household moves to the category of working class the probability increases by 13.8 % and for clerical worker 12.2 %. The probability to choose electric heating is high even when the household moves to entrepreneurs or managers category the corresponding increases in probabilities being 16.6 and 20.8 %, though these occupation classes would presumably correlate with the income classes.

	Marginal effect dy/dx (delta method standard error in parentheses)					
Variable	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
income1	0.347 (0.092)***	0.249 (0.097)***	0.225 (0.099) **	0.196 (0.01)**	0.116 (0.107)	0.002 (0.126)
income2	0.117 (0.047)**	0.066 (0.049)	0.056 (0.049)	0.015 (0.051)	-0.043 (0.053)	-0.121 (0.053)**
income3	0.031 (0.045)	0.006 (0.045)	0.005 (0.045)	-0.03 (0.046)	-0.073 (0.047)	-0.122 (0.046)***
income4	-0.036 (0.049)	-0.462 (0.043)	-0.049 (0.048)	-0.072 (0.0477)	-0.096 (0.048)**	-0.117 (0.0467)**
age_30		-0.118 (0.047)**	-0.115 (0.047) **	-0.124 (0.046)***	-0.111 (0.051)**	-0.095 (0.05)*
age_30_40		-0.208 (0.043) ***	-0.197 (0.043***	-0.207 (0.042)***	-0.198 (0.047)***	-0.151 (0.047)***
age_40_50		-0.102 (0.05) **	-0.095 (0.049)*	-0.107 (0.049)**	-0.101 (0.052)*	-0.085 (0.052)
age_50_60		-0.072 (0.053)	-0.078 (0.520)	-0.069 (0.052)	-0.069 (0.03)**	-0.094 (0.0526)*
city			-0.084 (0.029)***	-0.067 (0.03)**	-0.063 (0.053)	-0.051 (0.029)*
cost_sqm				0.000 (0.000)***	0.000 (0.000)***	0.000 (0.000)***
farmer					0.224 (0.081)***	0.213 (0.079)***
worker					0.164 (0.051)***	0.139 (0.051)***
clerical_w~r					0.134 (0.051)***	0.122 (0.052)*
entrepreneur					0.161 (0.055)***	0.166 (0.055)***
manager					0.233 (0.077)***	0.208 (0.077)
housing_sqm						-0.002 (0.000)***

Table 16. Marginal effects of logistic specification for Direct electric heating

*** significant at 0.01 level

** significant at 0.05 level

* significant at 0.1 level

6.5 Limitations of the data and the empirical strategy

The most problematic feature in the data is how it was collected. There was no control on how the questionnaires were filled in. What is more, there were two different questionnaires, half of the households received another and the other half the other questionnaire leading ultimately to a lower amount of observations to be compared and used for the empirical observations. Since not all households answered to the same or all questions in their survey form, the number of observations in the regression model decreases the more variables are added into the model. The explanatory power of the model thus suffers and different observations are included or excluded depending on the variables that are picked.

Moreover, there was no control over the amount of options the households could choose in each category. For instance, a household could have announced their income level in two different categories or picked two heating modes. This is problematic for the estimation if same household is represented in many categories. Therefore, when creating categorical variable for the multinomial logistic regression model, it had to be made sure that one household is represented only in of the available categories.

When trying to estimate heating mode decisions, it is not straight forward to decide which of the households' heating modes truly is the principal heating mode. Coming up with a simple rule, such as in this study, to modify the answers so that they satisfy the condition that each household can choose only one alternative, may affect the results to favour for instance electric heating. Here the choice was in a way, that if a household had announced electric heating as their principal heating mode, other alternatives they might have picked were ignored. District heating and geothermal heat pump also dominated wood, pellet, woodchip, exhaust or outdoor heat pump choices. All the cases when a heat pump or furnace were selected as the primary heating sources for the house with electric heating, it was decided that electric heating is the primary heating source of a household. This was because these other heating sources cannot cover the total heating energy need of a household in Finland, and need other sources during the coldest periods (usually electric heating). Nevertheless manipulating the data afterwards might have led to an outcome that diverges from the real life situation since only one heating mode could be accepted per household.

In the estimations, ancillary heating modes were not taken into consideration. However, in some cases the line between an ancillary and principal heating choice remains vague. A household using a heat pump in all cases needs electricity to run the device and as mentioned earlier, in Finland a heat pump cannot cover the total heating demand during the coldest periods. If a household had say, a direct electric heating and an air heat pump side to side, it is not clear which of the heating modes the household will perceive as the primary and which as the ancillary heating mode. What is more, for instance a heat pump chosen to be completing heating source may in fact cover the most of the heating requirement of the household on an annual level. These cases could not be taken into account since the questionnaire did not specify the cases but rather left the decision of heating mode definitions to the households themselves.

The number of observations was dropped drastically from the original response number. In the multinomial logistic model the number of observations was 793 and correspondingly 827 in the logistic model. That is due to the overlapping problem of the multiple categorical choices and the problem that not all households had answered to the same questions. The number of variables that could be applied in the model was thus limited, since every new variable that was brought to the model dropped the number of observations.

7. Discussion and conclusion

In this chapter the results of the multinomial logistic and logistic models are concluded. First, results from previous studies are summarized in chapter 7.1 The key results of this thesis are then presented briefly in chapter 7.2 by linking the discussion of the energy paradox and the empirical results together. The chapter 7.3 continues the discussion by suggesting topics for further research.

7.1 Results from previous studies on income levels' effect on households' heating demand and heating mode choice

Several studies have found a correlation between income and household energy use. Many of these studies have focused on modelling especially household energy consumption or heating energy consumption and tried to find patterns that could be explained by income levels. The studies have often come to the conclusion that higher income levels result in higher net energy consumption. For instance, Virnger (2005) studied the influence of household characteristics including income on patterns of expenditures and energy use of 2,800 households. It was found out that a 1 % increase in income results a 0.63 % increase in energy use. According to various other empirical studies, households with higher income levels consume more space heating compared to lower income households (e.g., Capper and Scott 1982; Schuler et al. 2000; Klein 1987; Nesbakken 2001; Colton 2002). However, some empirical studies show different results. Soytas et al. (2007) discovered in their study of the relation between carbon dioxide emissions, energy consumption and income, that reducing income levels does not necessarily mean reduction in emissions. Soytas and Sari (2006) investigated the impact of income on energy consumption in G-7[11] countries. They found evidence in all seven countries that there exists causality between energy use and income level.

Schuler et al. (2000) studied energy consumption for space heating. They used in their research West-German household data from 1988. According to their results, observed socio-economic household characteristics do not seem to explain the non-technical terms of the space heat consumption. Net income and household size however more importantly, are

[11] Seven industrialized countries including the United States, the United Kingdom, France, Germany, Japan, Italy and Canada.

suitable for explaining dwelling size, which then indirectly affects space heating demand. Weber and Perrels (2000) also found in their study on lifestyle effects on energy demand and related emissions that space heating in general was influenced only to a small degree by socio-economic household characteristics. On the other hand, Meier and Rehdanz (2010) studied how different socio-economic determinants (including income) affect space heating behaviour by residential British households and found significant results.

Much of the previous literature on the topic presented here, is related to the effects of income and the energy consumption. This thesis however aims at finding a relation between income (and other socio economic factors) and heating system choices. Studies focusing on explaining the space heating consumption of consumers by identifying different socio-economic factors affecting heating mode choices have been increasingly on the scientific agenda. Not many empirical investigations nevertheless have been made previously on the subject paying attention especially on the consumer choice on the energy product and the income connection without considering the energy consumption. Vaage (2000) studied household's energy demand on Norwegian cross-sectional micro data by utilizing discrete/continuous approach. He found out that prices are significant when estimating appliance choice and conditional energy demand. Importantly, one of the conclusions was that high-income households favour electric heating.

Liao and Chang (2002) for example focused in their study on exploring the space-heating and water-heating demand of the elderly people in the US. The main result was that the aged require more natural gas and fuel oil, but less electricity for space heating. Mansur et al. (2008) on the other hand aimed at explaining how climate change may impact fuel choice in residential and commercial markets by applying a multinomial logistic approach. The main result was, that in warmer areas electric heating was favoured both by consumers and firms. The low capital cost of electric heating is probably attractive for consumers that demand low amount of heat energy despite the high marginal cost. Surprisingly, the net energy costs were discovered to be slightly higher in warmer areas than in the cooler areas.

Braun (2010) studied household's socio-economic, regional and building characteristics effect on space heating choices in Germany. In the study the determinants of heating technology applied by German households were studied by using multinomial logistic modeling. The aim was to discover which household's socio-economic, regional or building characteristics influence the likelihood of choosing a certain heating type. The study also compared whether or not the characteristics differ between house owners and renters. The results showed an importance of socio-economic and regional characteristics in space heating types. However, there was found that certain income groups would only have a minor effect on the space heating type (Braun 2010, p. 5501). Dwelling features instead were found to be important in determining the heating type. There were no significant differences between renters and house owners but instead geographical location showed interesting differences between East and West Germany. Education was also one of the most important factors to explain household heating mode choices (Braun 2010).

7.2 Conclusions of the empirical strategy

In the empirical exercise, the main interest was in estimating the relationship between income and heating mode choices. In the multinomial logistic model and logistic models, the effect of other socio-economic factors were taken into consideration.

On the basis of the results, there is some evidence for irrational behaviour of the households. It is thus quite likely that households do not consider the total operating costs at the time of investment decision, but are rather biased towards the initial investment costs. It means that the investment decision is mainly done based on the initial costs. In that case, there exists indication for slow diffusion of energy conserving technologies i.e. the energy paradox in the Finnish heating market of detached houses. It means in practice that households with higher income levels choose heating technologies that entail higher initial cost, whereas low income households would prefer low initial cost investment such as direct electric heating. However, the results are not unanimous and not significant for all parts of the regression models. The logistic model on direct electric heating implies clearer correlation between income and heating mode choices and backs up the hypotheses of the thesis. Nevertheless, the multinomial logistic model does not give substantial evidence for either rational behaviour in the sense of economic theory or the opposite. Therefore, strong assumptions or recommendations cannot be done based on the empirical analysis alone.

In the multinomial logistic model, the relation between income and choice of electric heating did not yield strong or significant evidence. For that part, the empirical results do not offer evidence on the effect of income on electric heating for low or higher income classes. However, in the logistic regression model, when deducing the probability to choose direct electric heating the results are clearer. The magnitude and direction in the probabilities vary as control variables are added into the regression estimation. In the first model, changing to lowest income category, the probability to choose direct electric heating is increased by more than 30 %. But in the model 6, as a household is switched to the second, third or fourth income class, probability to choose direct electric heating decreases by some 11-12 %, and the effect for the lowest income group is very small. In general however, the results would indicate that as the income level of a household increases, the probability to choose direct electric heating decreases too. That is, the lower the income level of a households, the greater the tendency to choose direct electric heating. The most probable reason for the lower income level households to choose direct electric heating is the low initial investment costs, which are the lowest for the direct electricity. If the electricity price development will be in the future similar to what it is today, the total costs of direct electric heating will be more expensive than that of for instance ground heating despite the difference in initial cost. The comparison of three different heating modes; direct electric heating, district heating and ground heat pump to a type consumer between 2008 and 2023, showed how the NPV of the total investment is sensitive for the electricity price development.

As control variables were added to explain the heating mode decision in the logistic regression model, the probabilities to choose direct electric heating in each income classes dropped. Age and occupation on the other hand appeared to explain relatively strongly the decision of direct electric heating. Interestingly, the probabilities to choose direct electric heating were negative for all age groups. Nevertheless, most importantly, the probabilities dropped more for younger households than for the older households indicating that older people are more likely to select direct electric heating. It might be due to younger peoples' environmentally oriented attitudes, openness for new technologies, or urban locations. Occupations, on the other hand, increased the probabilities to choose direct electric heating. Lowest income level occupations, farmers, had high possibilities to choose direct electric heating as would be expected by the hypotheses. Surprisingly, however, managers had the greatest probability to choose direct electric heating. As the managers are the most high income class, the results contradicts with the hypotheses and results from income and heating mode correlations. It might be due to the data problems related to the manual removal of overlapping answers.

For the relation of other heating types and income, the multinomial logistic regression yielded different types of results. Entering a medium income class, decreases the probability to choose district heating by 6 % and ground heat pump by 11 %, whereas the probability to choose a heat pump increases by 10 %. Whether or not a household chooses wood heating or furnace do not seem to have any relation with the income level. As a matter of fact, the model explains the decision of those heating modes very poorly. The most significant and interesting result is the impact of income on the ground heat pump. The probability to choose a ground heat pump drops quite drastically, by 24 %, as the income group changes from the lowest from the higher ones. The result would again provide evidence for the phenomenon, that those households in the lower income classes would not prefer choosing the ground heat pump. The initial investment cost of the ground heat pump is one of the highest of the heating modes, but the NPV of the total costs is lower than that of the direct electric heating or district heating.

Besides income, other socio-economic factors were included as the explanatory variables in the models. These other factors did not succeed in forecasting the heating mode choice much better than the income level. Many of the variables did not yield significant results in the multinomial logistic model. The residential area had clearer impact on the probabilities. The probability decreases by 9 % for choosing an electric heating and 10% for ground heat pump when a household is moving from rural to urban area. The strongest effect of the residential area is related to district heating. The probability to choose district heating increases by 21 % if a household moves into an urban area from a rural area, which is expected since district heating is available only in the densely populated areas. Interestingly, electric heating in general as well as direct electric heating seem to be favoured in the rural areas. It is quite likely, that these households heat their residences with not only electric heat, but also use ancillary heating modes such as wood heating, furnace and heat pumps. The finding is also in the line with the income factor. The households that live in the urban areas have on average higher income levels than those living in the rural areas, and direct electric heating was observed to be more popular among the lower income households. However, the probability of the direct electric heat drops substantially less, only by 8-5 % in the logistic models 4-6, when a household moves into an urban area from a rural area compared to electric heating in general. There is also a tendency, that households with the highest income level would prefer direct electric heating a bit more often than the medium income classes. Here the impact can be explained for example by the easiness and user friendliness of direct electric heating, or by the utilization of the ancillary heating modes. The probability of district heat increases substantially in urban areas, which is expected, as the district heat network is available mostly only in urban areas. The ground heat pump, according to the results, is more popular in the rural areas. One explanation might be, that there is often limitations in the urban lots for the ground heat pump infrastructure.

The descriptive analysis of the data might offer more information on the relation between income and other household-specific factors used to analyze the heating mode choice. When observing the simple correlations between the socio-economic factors and heating mode choices, clearer patterns can be found. Thus, the value of the descriptive analysis for the analysis of the energy paradox gives more valuable implications than the regression models themselves. It is evident that direct electric heating, ground heat pump and district heating are strongly correlated with the income levels whereas there is not clear pattern observed for wood heating, heat pumps and furnace.

The reasons for the regression models relatively poor explanatory power lies much in the data. First of all, the number of total observations in the model is very low covering only 793 households in the multinomial logistic regression analysis and 827 in the logistic regression analysis. Second of all, there were irrationalities in the data due to the household survey type of the collection method. There were no limitations on how many choices a respondent could choose for heating modes, income levels and so on. In order to be able to conduct multinomial logistic or logistic analysis, some data cleaning had to be done. A household can be represented only in one category in the categorical analysis. Therefore it was necessary to choose the right say, primary heating mode, from all those the respondent had chosen. The results could thus be different from the real life situations, since some heating modes selected as primary heating modes had to be categorized as the ancillary heating modes. If the number of the observations containing parallel choices would have been small, these could have easily been dropped off from the analysis. Unfortunately, the number of these observations was so high that it would have drastically reduced the total observations number of the model. Third of all, many of the variables in the model explained the same feature; the economic level the household. The variables namely income, occupation, and household size are correlated causing the explanatory power of the model to diminish. It would be important to assure that all the respondents give answers to the same questions in order to secure the number of observations in the model. In the future research, it would be interesting to conduct similar study by utilizing more accurate data.

7.3 Suggestions for future research

Misoptimization of the households' energy use could lead to substantial welfare losses at least on the aggregate level. Aside welfare losses, environment-political targets are important to be considered as well since the energy production is a remarkable source of carbon dioxide emissions. Households consume a large share of the net energy produced for heating. That fact for its part is cut out for bringing the private heat energy consumption in the interest of policymakers. If the amount of direct electric heating is higher than in the households' private optima, the energy or carbon tax would have less effective solutions than desired by the planner. It would be more efficient in this situation to erect energy efficiency standards aside cap-and-trade solutions. When conducting such research, however, it would be beneficial to take the economic counter effect phenomenon into account. If the energy standard improvements lead to more efficient energy solutions, it might not automatically mean that the net energy consumption drops. On the contrary, some studies have shown that as the use of the technology becomes more economical, it increases the net use. If this would be the case with the space heating as well, it would be interesting to include calculations or at least serious discussion of the rebound effect into the analysis. The question of technological improvements resulting to greater amount of adverse impacts that Jevons' paradox deal with, leads social planners to ponder how it would be possible to change consumer behaviour that would also lead producers to change their behaviour.

For the future research of the topic, it would essential to achieve data with more observations. It would also be important to acquire information that is accurate and identical in the manner it is gathered. It would be essential to capture what in reality is the primary heating mode of the detached house. Therefore, it might be fruitful to conduct the survey after the houses are built and the realisation of the heating modes in practice during a year or two. It would thus be easier for a household to estimate whether it in reality employs direct electric heating or other heating modes compared to possible ancillary heating modes. The ancillary heating modes would be also important to include in to the analysis since a household might cover substantial share of the total heat energy need with furnaces or heat pumps. To make the data even more accurate it would be beneficial to combine information of the households available in the registers, such as the income level, household size etc.

To discover, if households value today future euro to its full value in heating technology choices, a time-series approach would be useful. It would be interesting to conduct a study where heating technology choices would be observed over a long time period, for instance for 15 years. It would then be possible to include the energy price changes in to the model and ex ante discover what were the real total costs of each heating modes for households. By utilizing panel data, it would be possible to estimate households' valuation of energy efficient technologies and future energy prices by utilizing the price variation and energy efficiency ratings in a cross section of heating modes. The valuation could be estimated through changes in time-series of energy price expectations.

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Appendix A: Survey question form

OMAKOTIRAKENTAJA 2008 **08/09B RV**

LÄMMITYS

32. Mitä lämmitysvaihtoehtoja harkitsitte ja minkä valitsitte? Mitä täydentäviä lämmitystapoja taloonne tulee?

	Pääasiallinen Harkittu	Valittu	Täydentävät lämmitystavat
LÄMMÖNLÄHDE:			
Sähkö	1	1	1
Öljylämmitys	2	2	2
Kaukolämpö/kiertovesi	3	3	3
Pelletti / kiertovesi	4	4	4
Hake / kiertovesi	5	5	5
Puuklapi / kiertovesi	6	6	6
Puu-uuni	7	7	7
Maalämpöpumppu	8	8	8
Poistoilmalämpöpumppu	9	9	9
Ulkoilmalämpöpumppu (Esim. Panasonic)	.	.	1
Aurinkovaraaja	2	2	2
LÄMMÖNJAKOTAPA:			
Sähköpatterit	1	1	1
Kattolämmitys	2	2	2
Lattialämmitys sähkökaapeleilla			
- kosteissa tiloissa	.	.	3
- myös huonetiloissa	4	4	4
Vesikiertoinen lattialämmitys	5	5	5
Vesipatterit	6	6	6
Muu, mikä? ________________	7	7	7

33. Millä perusteella valitsitte lämmitystavan?

1 Helppohoitoinen
2 Edullinen hankinta
3 Huoleton/vaivaton

4 Asiantuntijan suosittelema
5 Talotehtaan suosittelema
6 Aiemmin rakentaneen / tuttujen suosittelema

7 Edulliset käyttökustannukset
8 Oma puu/muu polttoaine
9 Mahdollisuus vaihtaa myöhemmin
–

1 Ympäristöystävällisyys
2 Omat aikaisemmat kokemukset
3 Toimintavarmuus

4 Terveellinen lämmitysmuoto
5 Kaavamääräykset
6 Turvallinen lapsille

7 Ei näkyviä pattereita
8 Muu, mikä? ____________________________________

34. Kenen (vesikiertoisen) lattialämmitysjärjestelmän valitsitte?

1 Nereus
2 Uponor / Wirsbo
3 KWH-Pipe / Weho Floor

4 Greenline
5 Warmia
6 Muu, mikä? __________________________________

0 Ei vielä valittu

35. Miten tyytyväinen olette lattialämmitystoimittajaanne?

1 Erittäin tyytyväinen
2 Melko tyytyväinen
3 Melko tyytymätön
4 Erittäin tyytymätön

36. Mitä maalämpölaitemerkkejä tunnette? Minkä merkkiset laitteet valitsitte?

	Tunnen	Valitsin
Carrier	1	1
Haato / Nibe	2	2
IVT / Greenline	3	3
Thermia / Ari Term	4	4
Lämpöässä / Suomen Lämpöpumpputekniikka Oy	5	5
Geopro / Oilon	6	6
Muu, mikä? ____________________________	7	7
Ei vielä valittu	.	0

37. a) Minkä tyyppisen kattilan valitsitte?

1 Perinteinen öljykattila
2 Kaksoispesäkattila (puu + öljy)
3 Pellettikattila
4 Muu puukattila
5 Muu, mikä? ___________________________________

37. b) Lämmityskattilan merkki (jos tiedossa)

____

38. Miten tutustuitte lämmitystapaanne ennen valintaa?

1 Esitteiden / oppaiden välityksellä
2 Rakennusalan messuilla
3 Tuttavan luona / kautta

4 Omat kokemukset
5 Alan liikkeiden / urakoitsijan välityksellä
6 LVI- / sähkösuunnittelijan välityksellä

7 Talomyyjän välityksellä
8 Sähköyhtiön kautta
9 Internetistä

0 Muu, mikä? ___________________________________

39. Mihin lämmitystapoihin seuraavat hyvät ja huonot ominaisuudet mielestänne parhaiten sopivat?

	A Sähkö-Lämmitys	B Öljy-lämmitys	C Pelletti-lämmitys	D Muu puu-lämmitys	E Maa-lämmitys
HYVÄÄ:					
Helppohoitoinen/huoleton	1	1	1	1	1
Edullinen hankkia	2	2	2	2	2
Edulliset käyttökustannukset	3	3	3	3	3
Ympäristöystävällinen	4	4	4	4	4
Terveellinen lämmitystapa	5	5	5	5	5
Asiantuntijoiden suosittelema	6	6	6	6	6
Energiansaanti turvattu	7	7	7	7	7
Edullinen energia tulevaisuud.	8	8	8	8	8
Varmatoiminen	9	9	9	9	9
Nykyaikainen lämmitystapa	0	0	0	0	0
HUONOA:					
Ei helppohoitoinen/huoleton	1	1	1	1	1
Kallis hankinta	2	2	2	2	2
Kalliit käyttökustannukset	3	3	3	3	3
Ei ympäristöystävällinen	4	4	4	4	4
Epäterveellinen lämmitystapa	5	5	5	5	5
Epäsuositeltava lämmitystapa	6	6	6	6	6
Energiansaanti epävarmaa	7	7	7	7	7
Kallis energia tulevaisuudessa	8	8	8	8	8
Ei varmatoiminen	9	9	9	9	9
Vanhanaikainen lämmitystapa	0	0	0	0	0

Appendix A: Survey question form

OMAKOTIRAKENTAJA 2008 **08/09B RV**

TAUSTATIEDOT

94. Miten hankitte tontin?

1 Tontti ollut pidempään omana
2 Saatiin perintönä
3 Ostettiin kunnalta
4 Vuokrattiin kunnalta
5 Ostettiin yksityiseltä
6 Muuten, miten? ____________________

95. Kauanko tontti on ollut hallussanne? Noin _______ vuotta

96. Rakennuspaikan sijainti?

Kaupungin taajama	1
Kaupungin haja-asutusalue	2
Maalaiskunnan taajama	3
Maalaiskunnan haja-asutusalue	4
Asemakaava-alue	5
Ei asemakaava-alue	6

97. Mikä oli asuinkuntanne ennen rakentamista?

Entinen asuinkunta ________________________________

98. Oletteko osallistunut merkittävästi rakentamiseen aikaisemmin?

1 En ole 2 Olen rakennusalalla 3 Olen osallistunut

99. Oletteko aiemmin tai aiotteko tämän talon jälkeen vielä rakentaa uuden omakotitalon?

1 Olemme rakentaneet aiemmin ja aiomme myös tämän jälkeen
2 Olemme rakentaneet aiemmin, mutta emme aio enää

3 Emme ole rakentaneet aiemmin, mutta aiomme myöhemmin
4 Emme ole aiemmin rakentaneet, emmekä aio myöhemminkään

100. Mihin ammattiryhmään perheenne päähenkilö kuuluu?

1 Maanviljelijä
2 Työväestö
3 Toimihenkilö
4 Yrittäjä / liikkeenharjoittaja
5 Johtavassa asemassa oleva
6 Eläkeläinen

101. Perheenne päähenkilöiden ikäryhmä?

1 Alle 30 vuotta
2 30 – 39 vuotta
3 40 – 49 vuotta

4 50 – 59 vuotta
5 60 vuotta tai yli

102. Talossa asuvien lukumäärä ________ henkilöä yhteensä

103. Mitkä ovat perheenne yhteiset bruttoansiot vuodessa?

1 Alle 20 000 euroa
2 20 001 – 40 000 euroa
3 40 001 – 60 000 euroa
4 60 001 – 80 000 euroa
5 Yli 80 000 euroa

104. Mikä on uuden asuntonne huoneistoala ja kokonaispinta-ala? Entä tontin koko?

Huoneistoala uudessa asunnossa _________ m2

Lattiapintojen yhteenlaskettu (bruttoala) noin __________ m2

Tontin koko __________ m2

105. Arvioikaa rakentamisen kokonaiskustannukset ilman omaa työpanosta

Rakennuskustannukset ilman tonttia _____________ euroa

Tontin hinta noin _____________ euroa

106. Paljonko talossanne maksoi …

Arkkitehti, rakenne-, LVIS yms. suunnitelmat yhteensä?	Noin _____ €
LVI-urakka	Noin _____ €
Sähköurakka	Noin _____ €
Tulisijat	Noin _____ €

107. Miten hyvin talonne kustannusarvio on pitänyt?

1 Alittunut yli 10 %
2 Alittunut 5 – 10 %
3 Pysynyt ± 5 %:n haarukassa
4 Ylittynyt 5 – 10 %
5 Ylittynyt yli 10 %

108. Koska rakentaminen aloitettiin ja koska se valmistui / valmistuu?

	Vuosi	kk
Talopaketin valinta (vuosi/kk)	______ /	______
Rakentamisen aloitus (vuosi/kk)	______ /	______
Keittiömerkin valinta (vuosi/kk)	______ /	______
Valmistuminen (vuosi/kk)	______ /	______

109. Onko nyt rakennettava talo tarkoitettu nyt tai tulevaisuudessa…

	Nyt	Tulevaisuudessa
Vakituiseksi, pääasialliseksi asunnoksi	1	1
”2-kodiksi”	2	2
Loma-asunnoksi	3	3
Muu, mikä? ______________________	4	4

110. Vastaajan sukupuoli? 1 Mies 2 Nainen

KIITÄMME VAIVANNÄÖSTÄNNE!

Appendix B: Multinomial logistic regression

Multinomial logistic regression		Number of obs	793
		Wald chi2(35)	178.19
		Prob > chi2	0
Log pseudolikelihood	-1105.967	Pseudo R2	0,0893

Variable	Coef.	Robust Std. Error	z	P>|z|	[95 % Conf. Interval]	
1						
	(base outcome)					
2						
income_low	-1.05254**	0.4331726	-2.43	0.015	-1.901543	-0.2035371
income_med~m	-0.6216285*	0.3237165	-1.92	0.055	-1.256101	0.0128442
age_40_60	0.4211943	0.319609	1.32	0.188	-0.2052279	1.047616
age_40	-0.540344	0.3685608	-1.47	0.143	-1.26271	0.1820219
city	2.0763***	0.3465136	5.99	0.000	1.397146	2.755454
cost_sqm	0.0004859*	0.0002556	1.9	0.057	-0.0000151	0.0009868
number_inh~s	0.0781257	0.0859827	0.91	0.364	-0.0903973	0.2466487
_cons	-2.901795	0.6960989	-4.17	0.000	-4.266124	-1.537466
3						
income_low	-1.25721***	0.3197154	-3.93	0.000	-1.883841	-0.6305793
income_med~m	-0.4774113*	0.2597147	-1.84	0.066	-0.9864428	0.0316201
age_40_60	0.4907859**	0.2367951	2.07	0.038	0.0266759	0.9548958
age_40	-0.158459	0.2609941	-0.61	0.544	-0.669998	0.35308
city	0.0096697	0.1855421	0.05	0.958	-0.3539861	0.3733255
cost_sqm	0.0005342**	0.0002201	2.43	0.015	0.0001028	0.0009655
number_inh~s	0.0742557	0.0751741	0.99	0.323	-0.0730829	0.2215943
_cons	-0.7237818	0.549516	-1.32	0.188	-1.800813	0.3532498
4						
income_low	0.4613522	0.6171464	0.75	0.455	-0.7482325	1.670937
income_med~m	1.012685*	0.5609876	1.81	0.071	-0.0868309	2.1122
age_40_60	0.0473623	0.3597806	0.13	0.895	-0.6577948	0.7525194
age_40	-0.247226	0.3768924	-0.66	0.512	-0.9859215	0.4914696
city	0.3683513	0.2793702	1.32	0.187	-0.1792042	0.9159068
cost_sqm	-0.0003067	0.0003268	-0.94	0.348	-0.0009472	0.0003339
number_inh~s	-0.0763576	0.1045756	-0.73	0.465	-0.2813221	0.1286068
_cons	-1.540872	0.8303949	-1.86	0.064	-3.168416	0.0866722
5						
income_low	0.3685881	0.6791724	0.54	0.587	-0.9625654	1.699742
income_med~m	0.6198972	0.6591324	0.94	0.347	-0.6719786	1.911773
age_40_60	-0.0332353	0.4362877	-0.08	0.939	-0.8883435	0.8218729
age_40	0.2587739	0.4178505	0.62	0.536	-0.560198	1.077746
city	-0.0818953	0.3028032	-0.27	0.787	-0.6753787	0.5115882
cost_sqm	-0.0011848**	0.0004047	-2.93	0.003	-0.001978	-0.0003916
number_inh~s	0.0380184	0.096204	0.4	0.693	-0.150538	0.2265748
_cons	-0.689635	0.8695991	-0.79	0.428	-2.394018	1.014748
6						
income_low	1.420012	1.11297	1.28	0.202	-0.761369	3.601392
income_med~m	0.5329352	1.140744	0.47	0.64	-1.702882	2.768752
age_40_60	-1.230189*	0.6315297	-1.95	0.051	-2.467965	0.0075861

Appendix B: Multinomial logistic regression

age_40	-0.3638958	0.4597447	-0.79	0.429	-1.264979	0.5371874
city	0.1472096	0.4037424	0.36	0.715	-0.6441109	0.9385302
cost_sqm	-0.0003793	0.0005153	-0.74	0.462	-0.0013891	0.0006306
number_inh~s	-0.4254525*	0.2189137	-1.94	0.052	-0.8545153	0.0036104
_cons	-1.077749	1.43694	-0.75	0.453	-3.894099	1.738602

*** significant at 0.01 level

** significant at 0.05 level

*significant at 0.1 level

Appendix C: Logistic regression

Logistic regression		Number of obs	827
		LR chi2(16)	86.94
		Prob > chi2	0.0000
Log likelihood	-415.88415	Pseudo R2	0.1263

direct_electricity	**Coef.**	**Robust Std. Err.**	**z**	**P>z**	**[95% Conf.Interval]**	
income1	0.0141523	0.7599407	0.02	0.985	-1.475304	1.503609
income2**	-0.7342199	0.3223295	-2.28	0.023	-1.365974	-0.1024656
income3***	-0.7392757	0.285059	-2.59	0.01	-1.297981	-0.1805704
income4**	-0.7098065	0.2860302	-2.48	0.013	-1.270415	-0.1491976
age_30*	-0.5740639	0.3049384	-1.88	0.06	-1.171732	0.0236044
age_30_40***	-0.9133792	0.2901764	-3.15	0.002	-1.482114	-0.344644
age_40_50	-0.5119669	0.317487	-1.61	0.107	-1.13423	0.1102962
age_50_60*	-0.5688808	0.3203374	-1.78	0.076	-1.196731	0.058969
city*	-0.3081213	0.1740942	-1.77	0.077	-0.6493397	0.0330971
cost_sqm***	-0.0010337	0.0002426	-4.26	0.000	-0.0015092	-0.0005583
farmer***	1.287611	0.4855687	2.65	0.008	0.3359138	2.239308
worker***	0.8380397	0.314421	2.67	0.008	0.2217859	1.454293
clerical_w~r**	0.7390494	0.3152034	2.34	0.019	0.1212621	1.356837
entrepreneur***	1.006465	0.3387052	2.97	0.003	0.3426148	1.670315
manager***	1.260839	0.4744359	2.66	0.008	0.3309617	2.190716
housing_sqm***	-0.0144185	0.0028123	-5.13	0.000	-0.0199305	-0.0089066
_cons	3.150231	0.7492324	4.2	0.000	1.681762	4.618699

*** significant at 0.01 level

** significant at 0.05 level

* significant at 0.1 level