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Philosophiae Doctor (PhD) Thesis 2013:63

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School of Economics and Business
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Consumers and Bioenergy: The effects of behavioural factors on households' heating consumption choice in Norway

Forbrukere og bioenergi: Virkninger av atferdsmessige faktorer på energibruk til oppvarming i norske husholdninger

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“A fundamental concern of economics is understanding human choice behaviour”

-McFadden, 1974

“Information changes behaviour - all we need to do is make it transparent”

-Sviokla, 2008

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Shuling Chen Lillemo

Ås, September 2013

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List of Papers

This PhD thesis is based on the following papers, which are referred to by their roman numerals (I-IV):

- **Households' heating investments: The effect of motives and attitudes on choice of equipment** (Shuling Chen Lillemo, Frode Alfnes, Bente Halvorsen and Mette Wik, *Biomass and Bioenergy*, published)
- **Warming up with electricity, firewood, pellets or fuel oil? Modelling how perceptions and attitudes affect the share of biomass in household heating energy consumption** (Shuling Chen Lillemo, Bente Halvorsen, manuscript)
- **The impact of lifestyle and attitudes on residential firewood demand in Norway** (Shuling Chen Lillemo, Bente Halvorsen, *Biomass and Bioenergy,* published)
- **Measuring the effect of procrastination and environmental awareness on energy saving behaviours: an empirical approach** (Shuling Chen Lillemo, *Energy Policy,* Accepted)

Abstract

How energy consumers behave, namely, what type and how much of different energy products and services they consume, direct and indirect affects the environment, as well as personal (and collective) well-being. Understanding the decision-making process behind energy consumption is thus important if we want to influence people's energy consumption and achieve the goals of sustainable energy consumption. In this thesis, I study choices related to energy consumption for residential heating by using an integrated behavioural study approach that employs perspectives from economics, psychology and sociology. The analyses in this thesis are based on two Norwegian nation-wide household survey datasets, which are used in combination with a discrete choice econometric modelling framework. By modelling consumers' choices, we may identify barriers and drivers for sustainable energy consumption. The analytical approaches are innovative, and the research results should shed light on how Norwegian households use energy in their homes.

The dissertation consists of four empirical papers that have the following goals: (a) to evaluate the determinants of investments in heating equipment and investigate how motivations and environmental attitudes affect the heating investment choice in Norwegian households (paper I); (b) to explore a new methodology for modelling the consumption share of storable energy goods and examine the impact of perceptions of heating equipment and attitudes towards biomass consumption on the choice of the primary heat source in households (paper II); (c) to test the effect of lifestyle variables on households' firewood demand (paper III); and (d) to identify the role of procrastination and environmental awareness on energy saving activities (paper IV). As a methodological assessment, I also use household characteristics (age, income, education, household size, etc.) and residence characteristics (dwelling size, age, type, etc.) as variables in the modelling process.

The results indicate that perceptions concerning the appearance, efficiency, cost, required time and effort and environmental impact differ greatly between different types of heating equipment (woodstoves, pellet stoves, electric ovens and air-to-air heat pumps). Perceptions concerning the attributes of the heating equipment and attitudes towards different energy sources are both important in explaining the type of heating investment and the choice of primary heat source (paper I and II). People whose main motivation is to reduce costs are more likely to invest in heat pumps, whereas investors in pellet stoves are more concerned about the impact of the heating source on the environment (paper I). Furthermore, the annual

costs and effectiveness of the equipment are the most important factors in explaining firewood consumption, while access to firewood and pellets and environmental considerations are important factors in explaining the share of pellet stove use in residential heating (paper II). In paper III, urban lifestyle and comfort concerns are shown to be negatively associated with firewood demand. Moreover, access to cheap firewood has a significant positive effect on the demand for firewood (paper III). Lastly, results from the study on the effect of procrastination on energy saving behaviour reveal that the degree of procrastination affects people's heating energy saving behaviour. People with a higher tendency to procrastinate are less likely to engage in energy saving activities in general, especially with respect to activities that demand effort and time, such as investing in new equipment (paper IV).

The estimation results illustrate the importance of taking into account internal motivational factors, such as attitudes and perceptions, in explaining people's energy consumption. For example, it is important to employ measures that aim to reduce procrastination to realise the underlying energy saving potential in Norwegian households. The interdisciplinary study approach enriches our knowledge of individual decision making related to energy consumption. It can also improve the effectiveness of energy and environmental policy. We need more empirical studies that focus on energy end users' behaviour from different social science perspectives, especially a behavioural economics perspective.

Sammendrag

Hva slags energikilder forbrukerne velger og hvor mye de forbruker, har direkte og indirekte virkning på miljøet, så vel som på personlig (og kollektiv) trivsel. Å forstå beslutningsprosessen bak folks energiforbruk er viktig hvis vi ønsker å påvirke deres energiatferd og oppnå mål om mer bærekraftig energiforbruk. I denne avhandlingen bruker jeg integrerte atferdsstudier til å utforske valg av ulike boligoppvarmingsløsninger ved å benytte tilnærminger fra økonomi, psykologi og sosiologi. Studien er basert på datasett fra to landsdekkende husholdningsundersøkelser i Norge, og bruker økonometriske modeller for diskrete valg. Ved å modellere forbrukernes beslutninger kan vi systematisk identifisere hindringer og drivere for bærekraftig energibruk. De analytiske metodene er innovative og forskningsresultatene belyser hvordan norske husholdninger bruker energi i sine hjem.

Avhandlingen består av fire empiriske artikler som har følgende mål: (a) å identifisere faktorer som påvirker investeringer i oppvarmingsutstyr, og å undersøke hvordan motiver og miljøholdninger påvirker investeringsvalg relatert til oppvarming i norske husholdninger (artikkel I), (b) å utforske en ny metodikk for å modellere andelen av ulike energiformer brukt til oppvarming i husholdningene , og å undersøke effekten av ulike oppfatninger og holdninger til bioenergi på valg av husholdningens viktigste varmekilde (artikkel II), (c) å teste effekten av livsstilsvariabler på husholdningenes etterspørsel etter fyringsved (artikkel III), og (d) å undersøke i hvilken grad prokrastinering og miljøbevissthet påvirker iverksetting av energisparingstiltak (artikkel IV). Som kontrollvariabler har jeg også tatt in husholdningsegenskaper (alder, inntekt, utdanning, husholdningsstørrelse, etc.) og kjennetegn ved boligen (boligstørrelse, alder, type osv.) som variabler i modelleringen.

Resultatene viser at oppfatninger om utstyrets utseende, effektivitet, kostnader, tid og innsats som kreves for å bruke utstyret og miljøpåvirkning varierer sterkt mellom de fire oppvarmingsløsningene (vedovner, pelletsovner, elektriske ovner og luft-til-luft varmepumper). Oppfatninger om utstyrets oppvarmingsegenskaper og holdninger til ulike energikilder er begge viktige for å forklare investeringer i nytt oppvarmingsutstyr og valg av hovedvarmekilde (artikkel I og II). Folk som har som sitt viktigste motiv å redusere kostnadene har størst sannsynlighet for å investere i varmepumper, mens de som investerer i pelletsovner er mer opptatt av miljøet (artikkel I). Videre er årlige kostnader og oppvarmingseffektivitet de viktigste

faktorene bak økende forbruk av fyringsved, mens enkel tilgang til ved og pellets samt miljøhensyn er avgjørende for å øke andelen av pellets til boligoppvarming (artikkel II). I artikkel III fant vi at urban livsstil og ønsker om komfort var negativt assosiert med etterspørsel etter ved. Vi fant også at tilgang til billig brensel hadde en signifikant positiv effekt på etterspørselen (artikkel III). Til slutt viste resultatene fra studien av effekten av prokrastinering på energisparende atferd at graden av prokrastinering påvirker folks oppvarmings- og energisparende atferd. Folk som oppgir høyere tendens til å utsette ting har mindre sannsynlighet for å engasjere seg i energisparing generelt, og spesielt når det kommer til aktiviteter som krever innsats og tid som å investere i nytt utstyr. Det er derfor viktig å sette inn tiltak som tar sikte på å redusere prokrastinering for å realisere potensialet for energisparing (artikkel IV).

Resultatene fra denne oppgaven og deres implikasjoner viser viktigheten av å ta hensyn til interne forhold, som for eksempel beslutningstakernes holdninger og oppfatninger, når man forklarer folks energiatferd. Den tverrfaglige studietilnærmingen beriker vår kunnskap om individuell beslutningstaking og valg av energiløsninger. Resultatene kan også brukes til å utvikle en mer effektiv energi-og miljøpolitikk. Vi trenger flere empiriske studier som fokuserer på energiforbrukernes atferd fra ulike samfunnsvitenskapelige innfallsvinkler, spesielt fra et atferdsøkonomisk perspektiv.

Introduction

1. Introduction

1.1 *Background*

1.1.1 Energy consumption and climate change

There is a growing interest in improving energy efficiency and reducing energy consumption and the associated greenhouse gas emissions in every sector of the economy. The International Energy Agency (IEA) has stated that current trends in energy supply and consumption are patently unsustainable and must be altered (Van de Graaf and Lesage, 2009). In its efforts to stabilise and reduce emissions, the EU Commission has prioritised energy issues and set the so-called 20/20/20 targets: to obtain 20% of its overall energy from renewable sources, to reduce total primary energy consumption by 20%, and to cut greenhouse gas emissions by at least 20%, all by 2020 (EU, 2008). The residential sector is a substantial consumer of energy and, in most European countries, accounts for approximately one-third of the total energy consumption (EEA, 2008). The transition towards the use of more energy-efficient technologies and renewable energy resources requires people to make the desired choices and act upon these decisions. Thus, policies aimed at promoting renewable energy sources or increasing energy efficiency in the household sector heavily rely on individuals' daily choices and household routines (Sovacool, 2009).

The Norwegian government also aims to increase energy efficiency and the share of renewable energy use to achieve the greenhouse gas emission goals of the 20/20/20 targets (Klif, 2010). The government wants to reduce the dependence on electric heating, although Norwegian electricity production is almost entirely based on hydropower. The main reason for the government's desire to reduce the dependence on electric heating is the growing demand for electricity, especially during long and cold winters, such as in 2010. Occasionally, electricity needs to be imported, which is often generated from fossil or nuclear energy sources[1] (NVE, 2008). Therefore, households are encouraged to invest in heating equipment based on renewable energy sources to provide energy in addition to electricity, such as solid biomass (pellets). Investment in more energy efficient heating equipment is also supported by the

[1] However, some researchers argue that the electricity trading through the "Nord Pool" market likely cannot achieve the goals of CO_2 emission reduction by replacing imported fuel-based electricity with renewable energy in Norway. For more details, see research by Førsund et al. (2003).

government. In 2003, Enova (a public enterprise owned by the Ministry of Petroleum and Energy) introduced a programme to provide a subsidy of up to 20% of the total investment costs for all types of heat pumps (the programme stopped providing subsidies for air-to-air heat pumps in 2006), pellet stoves and central control systems (Miljøkomiteen, 2002–2003).

Since this time, the installation of heat pumps has increased tremendously, while the adoption of pellet stoves remains low (Bjørnstad, 2009). Thus, the dependency on electricity for heating has not changed. Hence, information about consumers' preference with respect to their choice of heating equipment and knowledge about how everyday activities influence energy use are essential for designing successful energy policy and developing efficient and sustainable energy consumption patterns (Brounen et al., 2012, Lopes et al., 2012, Swan and Ugursal, 2009). However, current studies on residential energy use usually focus on either technical factors or aggregate perspectives, based on time-series data for the entire sector. Furthermore, most of the existing economic literature on energy consumption focuses on economic factors, such as price or income (Cayla et al., 2011, Halvorsen et al., 2005, Vaage, 2000, Nesbakken, 1999). Only a few published papers focus on the role of attitudes when explaining energy consumption (Sopha, 2011). In particular, there is no study on the role of attitudes and perceptions on Norwegian households' current energy consumption choices.

The main aim of this thesis is to improve the understanding of Norwegian households' energy consumption choices. I use information concerning individual household behaviour and people's attitudes towards sustainable energy consumption to identify crucial behavioural barriers and drivers for accelerating the transition to an energy-efficient and low-carbon future.

1.1.2 Norwegian households' energy consumption for heating purposes

The household is regarded as a social unit in which its members collectively decide on the issues related to the indoor climate, energy consumption and appliance use. Norwegians value the heating performance of their heating equipment because of the cold and long winters. In contrast to most other European countries, in Norway, approximately 40-50% of stationary energy use in the housing sector is used for heating due to the cold climate (Enova, 2003, SSB, 2009). As a consequence, choices concerning energy use for heating purposes are considered very important economic decisions for households.

It is useful to divide choices regarding energy consumption for heating purposes into investment decisions and utilisation decisions. It is common for Norwegian households to have more than one type of heating equipment in their residence. A household's choice of heating equipment partly reflects the household members' cultural background and heating preferences. Moreover, some types of heating equipment serve functions other than heating. For example, many households install a woodstove or open fireplace for the purpose of home decoration. This may pose a challenge when studying Norwegian households' behaviour related to heating, especially with respect to investment decisions.

The most common types of heating equipment in Norwegian households are electric space heaters, electric floor heating, woodstoves and air-to-air heat pumps. Ninety per cent of all households have electric heaters and/or electric floor heating. Woodstoves (or open fireplaces) are the traditional and second most commonly owned type of heating equipment, and approximately 70% of households have a woodstove installed in the house (SSB, 2008). It is common to use different combinations of heating equipment; most common is the combination of an electric heater, a woodstoves and a heat pump. Because it is so common to use different heating sources in combination, in many cases, it may be difficult for the household to determine the main energy source that is used for heating. In the data used in this dissertation, approximately 70% of households rely on electricity and 20% rely on biomass (mainly firewood) as the primary heat source. The rest of the households either use fossil fuel or district heating as main heating source (Lillemo et al., 2013). More information about the Norwegian household profiles is provided in papers.

Regarding biomass heating, increased use of biomass for heating in Norway is perceived to have several advantages, such as reducing CO_2 emissions from fossil fuels (Lee et al., 2011) and achieving sustainable social development objectives by, for instance, increasing farmers' income and rural employment (Rosillo-Calle et al., 2007). Traditionally, Norwegians used to burn firewood to heat their houses, and people generally have positive attitudes towards using woodstoves. Approximately 50% of the households in the survey reported that they planned to invest in woodstoves in the next five years (Lillemo et al., 2013). Although a large proportion of Norwegian households have shifted to electric heating due to the low price and convenience of electricity, the potential to increase the use of biomass energy remains. From a supply perspective, biomass resources are abundant and have great potential for increased production in Norway (Tromborg et al., 2008, Even, 2005). The Norwegian government has set the goal to increase the share of biomass energy in the total energy consumption and, in particular, to increase the share of pellet stoves in the Norwegian heating market (Miljøverndepartementet, 2006, Norwegian-Strategy-Group, 2006). Therefore, studying households' heating energy choice behaviour is essential to achieve energy policy goals.

1.2 *Research questions and objectives*

Households' choices with respect to energy consumption are highly related to climate change, gas emission and consumer welfare. For example, when households decide what type of heating equipment to invest in, they simultaneously determine which energy sources they will use in the future as well as the efficiency of their energy consumption. Thus, to overcome consumer barriers or more effectively change consumer behaviour, knowledge of consumer's decision making related to energy consumption is of vital importance (Allcott and Mullainathan, 2010). In this thesis, I aim to answer following research questions:

1) Which factors are important when households choose to invest in new heating equipment?

2) What are consumers' preferences and attitudes towards using solid biomass energy for heating purposes?

3) What determines how much biomass energy households actually use, given their type of heating equipment?

4) Do perceptions and attitudes shape and constrain households' choice of a primary heat source?

5) How do an urban lifestyle and comfort concerns affect the demand for firewood in Norwegian households?

6) Do unobserved time preferences (measured by the degree of procrastination) affect the households' energy saving behaviour?

7) How can we encourage, motivate and facilitate sustainable behaviour in daily energy consumption?

For answering the above questions, improved data and empirical research are needed, as the causal links between factors related to consumer's energy consumption are not clear and no systematic studies have been conducted for such a purpose. This thesis adopts an innovative methodological approach in modelling heterogeneous households' decision making in terms of heating energy choice behaviour. I focus on how attitudes and perceptions can help explain heating choice behaviour. I aim to identify various factors, both external constraints and internal factors that affect households' heating choice behaviour. My research can be used to provide science-based recommendations for energy efficiency and biomass energy regulatory/incentive policy. Furthermore, it will improve the understanding of the current policy frameworks, dynamics and institutional barriers.

2. Methods

Decision making refers to the process of evaluating and choosing among alternatives. Household decisions regarding energy use can be complicated due to a large number of influential factors. Thus, analysing choices regarding energy consumption provides us with a very interesting empirical context for studying household or individual decision making. Before carrying out the empirical work, I briefly review various models and theories on individual decision making from an energy consumption perspective (see table 1).

2.1 *Theoretical framework (decision making models related to energy consumption)*

Theoretically, the research approaches for applied studies on energy consumption behaviour can be guided by disciplinary perspectives that range from economics to psychology and sociology. Numerous studies examine energy consumption behaviour across these disciplines (Lopes et al., 2012, Baddeley, 2011, Allcott and Mullainathan, 2010, Swan and Ugursal, 2009, Wilson and Dowlatabadi, 2007, Wei et al., 2007, Breemhaar et al., 1995, Maréchal, 2010, Lutzenhiser, 1993). In a detailed review of residential energy use literature, Wilson and Dowlatabadi (2007) group the decision models in five types: traditional economic models, behavioural economic models, technology adoption models, attitude-based decision models, and social and environmental models from psychology and sociology. They suggest that a more integrated approach is needed for applied research on the design of energy efficiency interventions.

Table 1 Comparison of disciplinary approaches to decision making related to energy consumption behaviour

Main features	Economics		Psychology		Sociology
	Conventional microeconomics	**Behavioural economics**	**Marketing models**	**Technology adoption models**	**social and environmental models**
Study focus	Purchase of products, household economics also includes the use of products in "household production"	Purchases behaviour, use and disposal behaviour	Purchases behaviour, use and disposal behaviour	Purchase and adoption of new energy technology	Purchase and ownership of products, the use of products in the household
Main research methods	Quantitative (observed behaviour)	Quantitative (Observed behaviour and controlled experiments)	Quantitative (observed behaviour)	Quantitative and qualitative (surveys, interviews, observed behaviour)	Qualitative (surveys, observed behaviour)
Main dependent variables	Preferences between decision outcomes	Preferences between decision outcomes	Preferences between decision outcomes	Rate of diffusion	Self-reports of behaviour and/or energy use
Main independent variables	Costs and benefits of outcomes and their respective weights	Aspects of the decision frame and context	Factors underlying preferences: personality, motivations, values, attitudes, norms, sociodemographics	Adopter role in social networks, communication channels, technology attributes, and leadership of adopter	Norms and roles, sociodemographics, economic incentives, lifestyles, family

Framework for influencing energy relevant behaviour	Provide information about benefits and incentives to improve cost-benefit ratio and improve cognitive capacity to assess benefits/utility; market transformation; internalising externalities; providing a public good or regulating the use of a public good	Focus on framing and reference points for decisions, influence heuristic selection by emphasising associations or emotive attributes, control choice sets and default options	Information and persuasion; empowerment	Exploit communication channels through social networks; target the social system surrounding the individuals; change agents or institutions; ensure desired technology or behaviour has key attributes	Identify and target barriers, design salient and personally relevant information, recognise the social role of routine or habitual behaviour, manage expectations
Empirical studies	Many	Very few	Many	Some	Many

Note: The table is a compilation based on several sources (Wilson and Dowlatabadi, 2007, Brohmann et al., 2009)

The various disciplinary approaches to decision making in the context of energy use are summarised and compared in table 1, based on two reviews (Brohmann et al., 2009, Wilson and Dowlatabadi, 2007). A detailed explanation of each approach is provided in the following sections. In general, energy consumption behaviour is divided into energy equipment investment behaviour and utilisation behaviour. The main study methods combine both quantitative and qualitative methods. Microeconomic approaches rely more on quantitative methods, while sociological studies more often use qualitative methods. The dependent variables are usually the preferences of choice outcomes, and they are quite similar across all approaches, except for sociological approaches, which primarily use self-report forms (such us focus group) to study people's energy consumption behaviour. The independent variables, or the factors that are used to explain energy consumption behaviour, often differ considerably among the approaches. For example, conventional microeconomic approaches often focus on monetary costs and benefit issues and seldom focus on the attitudes or individual differences of decision makers, while behavioural economics focuses on different aspects of the decision frame and context.

2.1.1 Conventional microeconomic and behavioural economic decision models

In conventional microeconomic decision models, the consumer's choice is described as a utility maximisation problem under a budgetary constraint, with a utility function characterising the consumer's preferences for consuming varying amounts of different types of commodities (Mas-Colell et al., 1995). Utility theory and rational choice are the building blocks for conventional microeconomic decision models. Utility theory is considered a framework for decisions that weight the utility of a particular outcome by its probability. The term "utility" measures preferences over some set of goods and services, and it is often regarded as a proxy for well-being, personal benefit, or the "betterness" of an outcome (Kahneman et al., 2003). The decision maker is assumed to behave as a rational actor in a normative sense of having preferences that are known, ordered and consistent. He or she seeks to choose the combination of consumption that gives the highest utility (Mas-Colell et al., 1995). The rational actor model can incorporate utility from many different sources (other than money), including the perceived fairness of the decision process itself (Thaler, 1985).

Regarding energy consumption, it is often assumed that consumers follow their stable and maximised preference in choosing amounts of consumption or identify the alternatives from the energy consumption choice set. Thus, most economics studies on household energy use or user behaviour are based on micro consumption data, and the cost and benefits of energy consumption outcomes are considered the most important factors (Berkhout et al., 2004, Bernard et al., 1996, Bin and Dowlatabadi, 2005, Brounen et al., 2012, Cayla et al., 2011, Deaton, 1997, Douthitt, 1989, Halvorsen and Larsen, 2001, Howden-Chapman et al., 2009, Liao and Chang, 2002, Nesbakken, 1999, Nesbakken, 2001, Dubin and McFadden, 1984). Although the decision context matters, perceptions, beliefs and attitudes are usually considered to be underlying factors of consumer preferences and have not been studied directly in a microeconomic model, because these types of data are usually not available within empirical consumption data.

Behavioural economists seek to integrate a psychological understanding of decision making into microeconomics. As noted above, utility theory and its applications rest on axioms of preferences that broadly define rational choice. However, many experimental and field evidence shows that individuals do not consistently make rational decisions (Camerer and Loewenstein, 2004). Often, people's decision making is determined by their perceptions of the information they receive, rather than actual facts. Time inconsistency, framing, reference dependence, and bounded rationality are common topics in this literature. In each case, individual choices violate one or more of the axioms of preferences on which utility theory is based. In recent years, many behaviour research findings have had important implications for public policy (Thaler and Sunstein, 2008, Shafir, 2012, Sunstein, 2013, Dolan et al., 2012). For example, in 2009, the US government set up the Office of Information and Regulatory Affairs (OIRA) to apply insights from behavioural economics into public policy making by pushing regulatory issues involving clean air and water, food safety, health care, energy and so forth.

In behavioural economics, decision making concerning energy consumption is more context dependent. The decision maker's preferences are not fixed and are not necessary consistent over time for intertemporal choice. More often, the decisions are made heuristically (by the rules of thumb)(McCalley, 2006, Baddeley, 2011). Some reviews have summarised the insights of behavioural economics related to energy consumption, focusing on the endowment effect or other decision heuristics (Lopes et al., 2012, Baddeley, 2011, Allcott and Mullainathan, 2010). These studies suggest that in order to reduce residential energy consumption or change individual energy consumption behaviour, the context in which the decision is made must be considered. Assessing this context entails using measures such as influencing heuristic selection by controlling choice sets and default options or emotive attributes (Baddeley, 2011, Dolan et al., 2012, Wilson and Dowlatabadi, 2007). For example, if government wants to encourage energy conservation, the information campaign which is framed in terms of losses is far more effective than is framed in terms of gains(Thaler and Sunstein, 2008). However, still, very few empirical studies have been conducted in the field.

2.1.2 Other behavioural decision models

There are also some other decision-making models that have been used to study individual energy use. They differ in terms of the dependent variable of focus and main research method.

The independent variables are usually psychological and demographic factors, which occasionally overlap.

Marketing models

The consumer marketing approach emphasises psychological factors combined with contextual variables. The literature on models studying consumer behaviour and behavioural change for the purpose of promoting sustainable consumption has been reviewed by Jackson (2005). Some models of consumer behaviour focus on the internal antecedents of behaviour, such as values, attitudes and intentions. Others focus more on external factors, such as incentives, norms and institutional constraints. Some models offer conceptual insights into the psychological antecedents of behaviour; others illustrate the way in which social norms are contextualised; still others highlight the impact of different value orientations on behaviour. Some behaviour studies of energy consumption are based on marketing approaches. These heuristic understandings help to identify points of policy intervention. The factors underlying energy consumption choice, such as personality, motivations, values, attitudes, norms and sociodemographics, are common explanatory variables in these models for energy consumption (Foxall et al., 2006, Zanoli and Naspetti, 2002, Niemeyer, Salmela and Varho, 2006).

Technology adoption models

Technology adoption models, occasionally also framed as agent-based technology diffusion models, mainly rely on attitude-based evaluations of technology adoption. In the study of technology diffusion, the adopter's role in social networks, the channels of communication, the attributes of technology, and the leadership of adopters are common dependent variables explaining the adoption of new technologies. Social networks and technological attributes are considered to be the key factors. The theory of planned behaviour (TPB) has often been applied in the area of environmentally relevant behaviour (Ajzen, 1991). It has been used to explain a wide array of energy technology adoption behaviour, for example, the adoption of heating equipment in Norway (Nyrud et al., 2008), use of energy-saving light bulbs and use of cars (Bamberg and Schmidt, 2003) and busses for commuting (Heath and Gifford, 2002).

Social and environmental models

Social and environmental decision models from psychology and sociology are used to explore the influences of information, pro-environmental attitudes, value-belief-norm characteristics, habits and external conditions, social constructs, organisational behaviour, sociotechnical systems and the energy decision maker's cultural and social context on energy consumption behaviour. The key assumption of the model is that personal norms play important roles in determining environmental or social consumption choices. The norm activation decision model was first introduced by Schwartz (1977) to explain helping behaviour from a sociological perspective. The intensity of moral obligation felt by an individual to perform a behaviour is an important immediate antecedent of behaviour (Akerlof and Kranton, 2000, Schwartz, 1977). This approach relies on the explaining power of norms and roles, sociodemographics, economic incentives, lifestyles and household characteristics. Usually, qualitative data analysis is employed by interviewing consumers (Wilhite et al., 1996, Vlek et al., 1995, Wei et al., 2007). Self-report forms are commonly used for empirical studies. By contrast, quantitative studies relating lifestyles to energy choices are scarce.

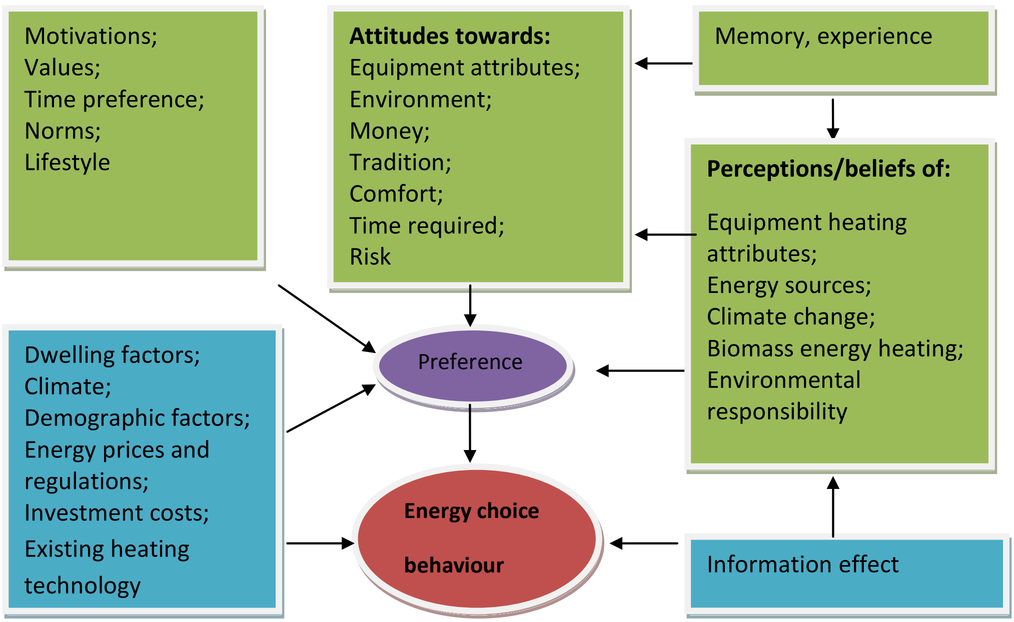
2.1.3 Integrated behavioural study approach

Jackson (2005) notes that decision models that are good for providing a heuristic understanding are not necessarily good for empirical testing, and vice versa. A good conceptual model requires a balance between parsimony and explanatory completeness. This thesis adopts an integrated behaviour approach based on conventional economics, behavioural economics, consumer psychology, attitude-based behavioural theory and sociological identity models. The dependent variables are the households' heating energy use, heating equipment purchases and energy saving behaviour. The use of different energy sources and behaviour related to energy savings appeared to be related to different sets of factors.

As McFadden (2001) mentioned in his Nobel Prize lecture, economic choices are shaped by both standard preferences and cognitive and psychometric effects. It is necessary to include more relevant choice data in order to better explain consumer behaviour. Consumer attitudes play an important role in this psychological decision-making process. Abrahamse and Steg (2009) also suggest that energy use is determined by sociodemographic variables, whereas changes in energy use, which may require some form of (cognitive) effort, appear to be related to psychological variables. Including psychological or sociological variables into conventional economic analyses would help to better explain the consumer's energy consumption.

Choices concerning which energy sources to use and how much of each to consume depend on both internal factors, such as people's attitudes towards the environment and energy use, norms, time constraints and comfort needs, and external factors, such as investment costs, energy costs and the type, size and age of the dwelling. Energy consumption behaviour can be considered to reflect the preferences of the household concerning heating energy consumption. For example, a household's choice to heat a particular room might reflect their attitudes to heating sources, time required and the environment. Tailored energy consumption recommendations and incentive policies thus need to consider both technical and consumer behaviour perspectives.

Figure 1. Determinants of household heating choice behaviour



Note: External factors are presented in the blue boxes, and internal factors are presented in the green boxes. Inspired by McFadden (McFadden, 1986, McFadden, 2001).

Figure 1 shows some important links in the process of household decision making with respect to particular heating consumption choices. The interrelationships between the different groups of variables and their influences on behaviour vary according to the specific situation of the consumer and their heating choice behaviour (i.e., investment in or utilisation of heating equipment). Energy consumption is directly determined by people's behaviour, which is shaped by consumer's preferences. Consumer's preferences are influenced both by internal and external factors. First, the decision is constrained by external factors, such as the dwelling characteristics, the climate, socioeconomic factors and governmental regulations. At the same time, the decision is shaped by various internal factors, such as the consumer's social identity, time preference, lifestyle, attitudes and perceptions of energy sources. In terms of attitudes, not only the direction but also the strength or degree of the attitude is important in influencing consumer behaviour. Meanwhile, information and experience play an important role in forming perceptions and thus affecting behaviour.

In this thesis, individual internal factors, such as consumers' attitudes and perceptions of the attributes of different heating equipment and energy sources, investment motivations, lifestyles and personal time preferences, are introduced into conventional economic analysis of consumer behaviour. In many cases, the internal factors are quantified using psychological measures and introduced into econometric models. The goal is to measure the influence of these factors on daily heating choice behaviour.

2.2 ***Household survey data***

The empirical studies in this thesis are mainly based on two Norwegian household survey datasets. The first data set is the Norwegian Survey of Consumer Expenditure (NSCE) for the years 1997 and 1998, conducted by Statistics Norway (Kleven and Roll-Hansen, 1999). The second is a self-collected data set from a web survey with 1860 participants. To measure the effect of temperature on household choices, information about annual local heating degree days (HDD) from the Norwegian Meteorological Institute is used. The annual HDD is the number of degrees that the average daily temperature is below 17^{o}C over a year. HDD is observed by municipality and merged onto our survey. Larger HDD values indicate colder temperatures and thus a greater need to use energy to heat a residence (Benestad, 2008).

2.2.1 Norwegian Survey of Consumer Expenditure

In paper III of this thesis, we apply the data set from the Norwegian Survey of Consumer Expenditure (NSCE) conducted by Statistics Norway. The sample in the NSCE is drawn randomly from the Norwegian population, and each drawn individual is attached to a family. The interview object in both the main survey and the supplementary questionnaire on energy is the househod member in charge of purchases. The Norwegian NSCE contains information concerning household expenditures on a wide range of goods, including firewood. It contains information about, among other things, the amount of firewood acquired (purchased, chopped by the consumer, or received as a gift) during the last 12 months, measured in volumes (sacks). The survey also contains information about the characteristics of the household and residence.

In both the 1997 survey and the 1998 NSCE survey, a supplementary questionnaire was included, containing questions about household attitudes towards energy consumption, as well as questions concerning lifestyle and environmental concerns. Of the original sample of 2,000 households, 1,361 households completed both the main survey and the supplementary energy questionnaire. Of these, 1,155 observations remained after excluding missing values and errors in the data.

2.2.2 UMB household heating energy survey

The second dataset is based on a nation-wide household web survey with 1860 participants, conducted in November 2010. These data are used in papers I, II and IV. The households are drawn from two different samples/populations: the first was drawn from TNS Gallup's web-panel, and the second was drawn from the database of applicants for grants from Enova SF, which is the Norwegian government's agency for handling subsidies for alternative heating equipment in households and businesses. Henceforth, I refer to the former subsample as the Gallup sample and the latter subsample as the Enova sample. The total sample is referred to as the Combined sample. The response rates were 46% for the Gallup sample and 43% for the Enova sample.[2]

The Gallup sample is a national, randomly selected sample, representing a cross-section of the Norwegian population. However, for the purposes of our analysis, the Gallup sample contains too few observations of less frequently used heating equipment, such as pellet stoves,

[2] Unfortunately, I do not have information about the respondents who chose not to participate, and therefore, I cannot conduct a non-response bias analysis on these data.

to identify why people do or do not choose these types of heating sources. I therefore supplemented the Gallup sample with the Enova sample, which includes households that have installed a pellet stove. The Enova sample is randomly drawn from the database of Enova applicants. For this reason, the Enova sample is not representative of the Norwegian population. To correct for this, in papers I and II, we generate sampling weights in the Enova sample to balance the proportional differences between the random Gallup sample and the choice-based Enova sample (Waldman, 2000). Weights are generated based on the different rates of pellet stove ownership in the Enova and Gallup samples.

The same questionnaire was administered to both the Gallup sample and the Enova sample. The questionnaire contains four parts. In the first part, respondents are asked about their current place of residence, including its type, age, size, ownership status and main heating source. In the second part, the respondents are asked about the existing heating equipment and their perceptions about the most commonly owned equipment. The respondents are asked to compare woodstoves, pellet stoves, electric heaters and air-to-air heat pumps with respect to the attributes of the equipment, such as the cost, effectiveness, environmental friendliness, indoor air quality, and time and effort required to use the equipment. The third part of the questionnaire elicits the respondent's attitudes towards using biomass for heating in terms of its environmental and socioeconomic contribution. The same seven-point scale is used for all attitude and perception questions. For each statement, the respondents indicate their perceptions on a seven-point scale, where 1 = strongly disagree and 7 = strongly agree. Lastly, in the last section, demographic factors, such as income, education and age, are recorded.

2.3 *Microeconometric modelling based on discrete choice analysis*

The data analyses in these empirical studies are mainly based on discrete choice analysis. Random utility maximisation theory is the core of discrete choice analysis in studying choice behaviour from an economic perspective. It assumes that the individuals maximise their (random) utility and choose the alternative that will give them higher utility than the available alternatives (Manski and Lerman, 1977, Ben-Akiva and Lerman, 1985).

Theoretically, the discrete choice model is based on a latent variable approach, which can be expressed as follows:

$$V_i^* = \beta_0 + \beta_i x_i + \varepsilon_i \quad (1)$$

where V_i^* is an unobservable magnitude, which can be considered the net benefit from taking a certain action, such as an investment decision, purchase or use of certain heating equipment (e.g., heat pump, wood stoves). In economics, we call this 'representative utility', while it is referred to as 'satisfaction' in psychology. x_i is a vector of relevant explanatory factors that we expect to influence the household's action. β_0 is a constant term. β_i represents the estimated parameters for choice models by using maximum likelihood techniques. We cannot observe the net benefit, but we can observe the outcome of the individual having followed the decision rule. For example, in paper IV, I observe whether the individual did (y=1) or did not (y=0) perform energy saving activities, such decreasing the room temperature when the room is vacant. For a Logit model, by modelling the probability that a household makes a choice, we can get:

$$\Pr(y = 1|X) = \frac{\exp(X\beta)}{1 + \exp(X\beta)} \quad (2)$$

The estimated coefficients β_i do not measure the marginal effects $\frac{\partial y}{\partial x_i}$ due to the non-linearity of the cumulative distribution function. However, one can deduce the marginal effects using certain transformation techniques. ε_i is the disturbance term, which is assumed to satisfy the standard assumption of the Logit model.

For the multinomial Logistic model, the dependent variable in the analysis consists of multiple choices rather than a binary choice. For example, in paper II, the household has to choose one particular energy source as their primary heat source from certain alternatives. The choice set consists of 5 unordered heating sources, such as electricity, firewood, pellets, fuel oil and other. Unordered choice models can be based on a random utility framework (Maddala and Flores-Lagunes, 2007, Train, 2003). A household i, i=1,…,n, chooses from a finite set of alternatives, j=1,…,m. The utility of alternatives j is

$$\mu_{ij} = \beta_{ij} x_i + \varepsilon_{ij} \tag{3}$$

where x_i are the explanatory variables, such as the household characteristics and dwelling characteristics, and ε_{ij} is the error term. Errors are specified as independently and identically distributed according to the type I extreme value distribution. A household is observed to have chosen alternative j when the utility from alternative j is the highest of all of the alternatives. The probability of household i choosing heating source j is given by

$$Prob(energy\ source_j) = P_{ij} = \frac{\exp(\beta_j x_i)}{1 + \sum_{k=1}^{j} \exp(\beta_k x_i)} \tag{4}$$

The marginal effect of a change in variable x_i is equal to:

$$\frac{\partial P_{ij}}{\partial x_i} = P_{ij} \left[\beta_j - \sum_{k=0}^{j} P_{ik} \beta_k \right] \tag{5}$$

Multinomial Logit models can be used when the alternatives in the choice set are mutually independent, i.e., the probability of choosing a particular alternative is irrelevant to the presence of other alternatives (it follows the independence of irrelevant alternatives (IIA) rule) (Train, 2003). If the IIA rule is violated, a mixed Logit model would be a better option. A mixed Logit model addresses the heterogeneity of consumer preferences via random coefficients (i.e., the preference coefficients are random variables that are distributed over the population) and avoids the restrictive substitution patterns of the multinomial Logit model (Train, 2003). We use this model in paper I.

The potential explanatory variables are related to not only external factors, such as socioeconomic incentives, buildings, and infrastructure that restricts the decision maker, but also internal factors, such as motivations, perceptions, attitudes and time preferences. Both psychological and sociological factors are used as explanatory variables in the discrete choice models, and I attempt to deduce their potential impact on energy consumer behaviour.

3. Thesis content, main results and implications

Different choice models were chosen according to the characteristics of the different dependent variables. By modelling the households' heating choice behaviour, the goals are to identify which factors matter with respect to households' heating choice behaviour, including their investment, utilisation and conservation decisions.

Paper 1: Households' heating investments: *The effect of motives and attitudes on choice of equipment*[3]

Research questions and method

This study investigates how attitudes, motivations, residence characteristics and socioeconomic factors relate to households' investments in four types of heating equipment: wood stoves, pellet stoves, electric ovens and air-to-air heat pumps. Based on the combined sample from the UMB household energy survey, we used revealed preference data, i.e., what households have already invested in, to study heating equipment choices.

The data from the Enova sample were adjusted according to the weights in the Gallup sample. Economic behavioural modelling was used to construct the analysis framework, and a mixed Logit model was applied in the analysis of investment choice among woodstoves, pellet stoves, electric heaters and air-to-air heat pumps.

Main results and implications

We found that 52% of the households had invested more than NOK 3000 in heating equipment in the previous 10 years and that 34% of those invested in at least two types of heating equipment. The perceptions concerning the appearance, efficiency, cost, time and effort required to use the equipment, and environmental impact differed greatly among the four types of heating equipment. Motivations, environmental attitudes, residence characteristics and demographic factors played an important role in the households' likelihood of investing in heating equipment and choice of heating equipment.

[3] This paper was co-authored with Frode Alfnes, Bente Halvorsen and Mette Wik and was published in a special issue of Biomass and Bioenergy: Bioenergy Market, 2013.

Decisions to invest in heating equipment are affected by both economic factors, such as cost and income, and noneconomic factors, such as residence characteristics, demographics, attitudes towards the environment, time preferences and willingness to dispose of old equipment. The motivation to save costs had a significant effect on the investment likelihood for heat pumps. Woodstoves are popular, both for heating and as house decorations. The majority of the households that had invested in new equipment were motivated by reducing heating costs. People whose main motivation is to reduce costs were more likely to invest in heat pumps, whereas investors in pellet stoves were more concerned about the environment. Woodstoves are the most popular of the four types of equipment, while pellet stoves are the least popular. This difference in the popularity of woodstoves and pellet stoves may be due to the perceptions of the two heating sources. Stakeholders in the pellet stove industry should improve their product in several ways. First, households must be able to obtain pellets easily. Second, the investment costs and annual heating costs must be competitive with other heating sources. Lastly, an improved aesthetic appeal will probably also increase the use of pellet stoves.

Being environmentally aware seems to reduce a consumer's likelihood of investing in new equipment. However, environmental awareness does seem to increase the likelihood that a household purchases biomass-based heating equipment if they decide to invest in heating equipment. It is thus not obvious whether increasing environmental awareness would boost market demand for biomass-based heating equipment.

Paper 2: Warming up with electricity, firewood, pellets or fuel oil? Modelling how perceptions and attitudes affect the share of biomass in household energy consumption[4]

Research questions and method

In this study, we investigate whether heating perceptions concerning different heating equipment, environmental attitudes and residence and household characteristics affect households' likelihood of selecting a particular heat source as the primary heat source. Norwegian households usually contain more than one type of heating equipment. It is common to use electricity together with firewood and/or other types of fuel to heat a residence. People often have a choice between different heating equipment to heat their residence, even in the short run with no new investment in heating equipment. Therefore, the particular energy

[4] This paper was co-authored with Bente Halvorsen.

sources that are used for heating depend on not only the heating equipment that is owned by the household but also the households' perceptions concerning the equipment and their usage behaviour.

The data were from the UMB household energy survey and were based on the Combined sample. In this study, we used a multinomial Logit model to model the choices among electricity, firewood, pellets, fossil fuels and other. The data in the Enova sample were adjusted according to the weights of the share of pellet stoves in the Gallup sample.

Main results and implications

When the respondents were asked about primary heat source, 70% reported using electricity as their primary heat source, 20% reported using firewood, 5% reported using fossil fuels, and less than 1% reported using pellets as their main heating source. Even in the households with a pellet stove installed, 28% reported that they use electricity as their primary heat source. We found that perceptions concerning the heating equipment attributes, such as the heating costs, effectiveness, time and effort needed to operate the equipment and indoor air quality, affect a household's choice of heat source. In particular, perceptions of the environmental friendliness of the equipment are important with respect to the choice of pellet stoves as the primary heat source. Heating effectiveness and low costs are reasons that many households still keep firewood as their primary heat source. The positive attitude towards the use of firewood and heat pumps as heating sources reduces the likelihood that households would use pellet stoves as the primary heat source. The heating equipment that is installed in the residence also plays a key role in the choice of the primary heat source. For example, an installed heat pump significantly reduces the likelihood that a household would use firewood or a pellet stove as the primary heat source.

***Paper 3: The impact of lifestyle and attitudes on residential firewood demand in Norway*[5]**

Research questions and method

After electricity, firewood is the second most important source of household heating in Norway, but its share in total energy consumption for heating has decreased significantly, now accounting for less than 20% of household energy consumption used for heating. The Norwegian government wants to reduce the reliance on electricity in residential space heating.

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[5] This paper was co-authored with Bente Halvorsen and was published in a special issue of Biomass and Bioenergy: Bioenergy Market, 2013.

We analysed the determinants of the demand for firewood in Norwegian households, focusing on intrinsic factors such as lifestyle and attitudes towards the environment, as well as household socioeconomic characteristics.

We used data from the Norwegian Consumer Expenditure Survey and a supplementary questionnaire on energy consumption and lifestyle. Social identity modelling was used to construct the analysis framework. We applied a zero-inflated negative binomial model to correct for over-dispersion and the excessive number of zeros in the data.

Main results and implications

The results indicate that an urban lifestyle and concerns for comfort are negatively associated with firewood demand. In addition, the price of firewood has had a strong negative effect on demand. However, the most important determinants of household firewood demand are the residence characteristics, including the location, and household characteristics, such as age and income of the household members. Households with a more urban lifestyle use significantly less firewood. We found that a one-unit increase in the urban lifestyle index results in about a 15% decrease in the number of sacks of firewood acquired. These results indicate that households that frequently participate in urban activities, such as going to the cinema or restaurants, use less firewood than other households, ceteris paribus. Households that score high on the comfort index are also likely to consume less firewood. Thus, woodstove technologies that require less labour may increase the use of biomass energy in Norwegian residences. Cheap access to firewood is one of the most important factors in explaining firewood consumption in Norwegian households; thus, economic considerations are very important when determining how much firewood is used for heating. Households in farmhouses in the countryside rely more on firewood for space heating.

Paper 4: Measuring the effect of procrastination and environmental awareness on energy saving behaviours: an empirical approach[6]

Research questions and method

A common finding in behavioural economics is that people often procrastinate, i.e., keep postponing tasks or decisions that have been planned and need effort to be executed. Procrastination may have an even greater effect on inter-temporal energy choices, since energy is an abstract, invisible and intangible commodity. This study evaluates how procrastination and

[6] This paper was written independently and has been resubmitted to *Energy Policy,* after revision.

environmental awareness influence people's heating energy conservation behaviour, either through curtailment behaviour or efficiency behaviour.

I used data from the UMB 2010 household energy survey, which includes information on households' heating energy saving behaviour, degree of procrastination, environmental awareness and other dwelling and household characteristics. Latent variables were generated by factor analysis. Binary choice models were chosen to deduce the factors that influence household heating energy saving behaviour.

Main results and implications

People with a higher tendency to procrastinate are less likely to engage in heating energy saving activities in general, especially with respect to activities that demand effort and time, such as investing in new equipment. More environmentally concerned people are significantly more likely to exhibit curtailment behaviours, such as reducing the indoor temperature when they are away and warming up smaller parts of their residence. Some measures to overcome procrastination are needed in policy design in order to encourage energy saving behaviour. For example, innovative measures aiming to increase awareness of the future gains of energy saving, such as feedback systems and commitment devices, are needed to increase people's energy saving behaviour.

4. Conclusions

The Norwegian government has made recent efforts to increase energy efficiency and the consumption share of renewable energy sources other than electricity in the residential sector. The successful implementation of environmentally friendly energy policies requires an understanding of consumer behaviour. By modelling the consumers' energy related decisions, we can identify the barriers to and drivers of sustainable energy consumption. This research provides a better understanding of energy consumption for heating purposes in Norwegian households. The selected equipment used in the papers in this research are either the most commonly used types of heating equipment (such as electric heaters, air-to-air heat pumps, woodstoves or fireplaces) or policy-relevant heating equipment (pellet stove) in Norway. Based on micro-level survey data and discrete choice modelling, the empirical studies cover topics such as decisions regarding heating equipment investments, determinants of the choice of the main heating source, demand level for firewood and the degree of energy saving.

Overall, behavioural factors play an important role in predicting the households' heating choice behaviour. This finding confirms what Sopha (2011) claims in her recent study in Norway, namely, that we need interdisciplinary studies in order to understand changes in households' energy consumption behaviour. The empirical results provide a better understanding of consumers' energy consumption behaviour. The major contributions of the research are listed below.

4.1 *Contributions*

1. *Interdisciplinary approach:* This study includes economical, psychological and sociological factors to understand consumer decision making related to energy consumption. Empirical analyses are carried out using perspectives from economic theory, consumer psychology, social science and behavioural economics. The results provide comprehensive insights into households' decision making.
2. *Methodological contribution of modelling multiple energy sources:* In paper II, we develop a method to deduce the factors that may increase the consumption share of various energy sources. This is important because most Norwegian households are already able to use several energy sources for heating, and the use of already existing heating equipment is important for explaining the consumption share of various energy sources in the short run. Moreover, because firewood, pellets and fuel oils are storable goods, their consumption shares are difficult to measure. By examining factors that increase the probability that a household chooses a particular energy source as the primary heat source, one can explain the determinants of changes in the consumption share of an energy source.
3. *Innovative explanatory variables:* We use behavioural factors (such as perceptions and attitudes) to model energy-related choices. For example, in paper III, we aim to explain households' firewood demand partly by consumers' lifestyle and comfort index. In paper IV, I use consumers' degree of procrastination to explain their energy saving behaviour. As far as I know, such research has not been done before. *Importance of attitudes and perceptions: Nor*wegian consumers have positive attitudes toward traditional biomass heating sources, such as woodstoves. However, the perceptions of various heating equipment attributes differ considerably among the four selected types of heating equipment. This finding explains in part why the market shares for these types of heating equipment vary so much.

The unpopularity of pellet stoves, for instance, could be due to the more positive perceptions of alternative heating equipment, such as woodstoves and heat pumps.

4. *Psychological variables explaining heating investment decisions:* Findings from paper I *s*uggest that some psychological variables are highly associated with households' heating investment decisions. For example, consumer's time preferences, willingness to discard old equipment and concerns for the environment significantly affect their investment decisions. Moreover, different purchase motivations are closely related households' heating equipment choice. For example, the motivation to save costs increases the likelihood that a household invests in a heat pump.
5. *Procrastination* is identified to negatively affect energy saving behaviour. The empirical analysis from paper IV reveals that people with a higher tendency to procrastinate are less likely to engage in energy saving activities in general, especially with respect to activities that require more time and effort, such as investing in new equipment. Being a procrastinator might also reduce the positive impact from environmentally motivated energy saving behaviour. Effective and innovative measures aiming to increase awareness of the future benefits of energy savings, such as feedback systems or commitment devices, are needed to increase energy efficiency and energy saving behaviour.

4.2 ***Future study suggestions***

This thesis provides noteworthy information about the behavioural determinants of households' energy consumption decisions. An examination of the determinants of heating energy consumption, or demand at the micro-level, would improve our understanding of the energy-related behaviour of households and aid the design of policies aimed at increasing alternative renewable energy consumption or lowering carbon intensity in energy consumption.

However, this thesis has certain limitations. In particular, this research focuses on individual choice data. It would be interesting to combine behavioural data and the accurate household energy consumption data to capture the effect of energy user behaviour. It also should be noted that this study primarily concerns energy consumption behaviour in Norway, which is among the countries with the highest income and labour costs. We should therefore be careful when generalising from these results and implications to other countries.

Furthermore, more studies aiming to incorporate insights from behavioural economics are needed to better understand peoples' energy consumption behaviour. For example, in paper IV, procrastination is identified to negatively affect heating energy saving behaviour. This finding could be further explored in studies in other types of environment-related behaviour. Furthermore, experimental economic techniques could also be applied to measure people's degree of procrastination more accurately or to determine how to design effective commitment devices. Generally, more empirical studies from a behavioural economics perspective are needed to evaluate additional measures that assess behavioural change. Studies focused on decision making related to energy consumption will help to improve policy frameworks and thus improve the effectiveness of policies aimed at improving energy efficiency and changing people's energy consumption behaviour.

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Paper I

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Households' heating investments: The effect of motives and attitudes on choice of equipment

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ABSTRACT

This paper reports on an online survey conducted in Norway to investigate how attitudes, motives, residence characteristics and socioeconomic factors relate to households' investments in four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps. First, we find that perceptions about characteristics such as appearance, efficiency, cost, time and effort required to use the equipment, and environmental impact differ greatly between the four types of heating equipment. Second, we find that 52% of the households invested more than €375 in heating equipment in the previous 10 years, and that 34% of those invested in at least two types of heating equipment. Third, using discrete choice models, we find that motive, environmental attitude, characteristics of the residence and demographic factors affect households' heating investment likelihood and choice of heating equipment. For example, we find that people whose main motive is to reduce costs are more likely to invest in heat pumps, whereas investors in pellet stoves are more concerned about the environment.

1. Introduction

In order to achieve sustainable development, the use of renewable energy carriers and improvements in energy efficiency have become high on the political agenda in many countries, including Norway [1,2]. In particular, the use of biomass has attracted great attention because of its perceived role in reducing CO_2 emissions by partly replacing fossil fuels while also achieving sustainable social development objectives [3]. Furthermore, the Norwegian government wants to reduce reliance on electricity in residential space heating [4] and improve energy saving and efficiency [5]. Therefore, Norwegian households have been encouraged to invest in heating equipment based on renewable energy sources, such as pellet stoves, efficient woodstoves and heat pumps [6]. Achieving these goals and developing an efficient environmental and energy policy require better understanding of consumers' choice of heating equipment, in terms of what affects their decisions on whether to invest in new heating equipment and on what type of equipment to invest in.

The choice process is shaped by both economic factors, such as cost and income, and cognitive elements, such as subjective norms, attitudes and perceived controls [7,8]. In the case of heating investments, consumers make their choices subject to a series of economic and noneconomic constraints. The latter could be physical constraints (e.g., characteristics of the residence such as its age or size) and/or legal constraints (e.g., ownership status, regulations and legislation). Heating investment behavior is also shaped by consumer attitudes regarding the expected performance of the equipment and the

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energy sources being used [9,10]. Although investing in new heating technology is a way to improve heating performance and energy efficiency, such investments can also fulfill other needs, such as increasing comfort and/or improving the appearance of the home.

Most previous heating equipment choice studies emphasize the effects of income and prices on household energy consumption [11–17]. However, a few Nordic studies have included consumers' attitudes when explaining household investment in new heating equipment [9,10] [17]. Nyrud et al. [9] documented that heating performance, perceived time and effort required to operate the stove, environmental effects and perceived subjective norms influenced households' choices of woodstoves. Sopha et al. [10] found that communication between households and the perceived importance of heating equipment attributes affected households' plans for future investments in heating equipment. Mahapatra and Gustavsson [17] showed that economic aspects, functional reliability and indoor air quality were the important influencing attributes when households were choosing a heating system. However, each of these three studies has several limitations. For example, Nyrud et al. [9] studied only households in the city of Oslo that had received a subsidy for replacing an old woodstove with an improved woodstove. Sopha et al. [10] and Mahapatra and Gustavsson [17], on the other hand, based their study on stated preference data, that is, what households would do if they were to invest in the future.

This study provides insights into consumer motives in purchasing energy efficient and environmentally friendly products, using a representative Norwegian sample and revealed preference data, that is, what households have already invested in. The empirical data are from a web-based survey that asked Norwegian households about their heating investment choices during the previous 10 years. We focus our analysis on investments in four types of heating equipment: woodstoves, pellet stoves, electric heaters and air-to-air heat pumps (hereafter called heat pumps). Woodstoves and pellet stoves use bioenergy, whereas electric heaters and heat pumps use electricity. First, we investigate households' perceptions regarding the characteristics of each type of heating equipment, such as appearance, efficiency, cost, time and effort required, and environmental impact. Second, we examine what proportion of households have invested in heating equipment in the previous 10 years, and how many invested in multiple types of heating equipment. Third, we investigate what influences households' decisions to invest in new heating equipment, and which factors determine what type of equipment they choose. In the investment analysis we take into consideration intrinsic factors such as motives, attitudes, perceptions and personality, in addition to socioeconomic factors and characteristics of the residence.

2. Material

2.1. *Online survey*

We use data from a household online survey conducted in Norway in November 2010. The total 1860 participants were drawn from two populations: the first sample was drawn from TNS Gallup's web panel, and the second from the database of Enova, the Norwegian government's agency for handling subsidies for alternative heating systems. Henceforth, we refer to the former subsample as the *Gallup sample*, the latter subsample as the *Enova sample* and the total sample as the *Combined sample*.

The Gallup sample is a national randomly selected sample, representing a cross-section of the Norwegian population. However, for the purposes of our analysis, the Gallup sample contains too few observations of investment in less frequently used equipment, such as pellet stoves. This makes it impossible to identify why people choose these types of equipment. We therefore needed to supplement the Gallup sample with the Enova sample, which includes information about households that have applied for a subsidy from Enova to invest in a pellet stove, large heat pump or other energy saving equipment. The Enova sample is randomly drawn from the database of Enova applicants.

The same questionnaire was administered to both the Gallup and the Enova samples. The questionnaire contained four sections. In Section 1, we asked about the respondents' current residence, including its type, age and size, and the resident's ownership status. We also asked about the preferred living room temperature. In Section 2, respondents were asked about the existing heating equipment and investment in heating equipment during the previous 10 years. If households did invest, we asked for more details about their investment motives, subsidies received and similar information. Section 3 of the questionnaire elicited responses on perceptions of types of heating equipment, attitudes toward the environment and personality traits. For example, respondents were asked to compare woodstoves, pellet stoves, electric heaters and air-to-air heat pumps with respect to equipment attributes such as cost, environmental friendliness, air quality, and time and effort required. For each statement, they indicated their perceptions on a seven-point scale where 1 = strongly disagree and 7 = strongly agree. We used the same seven-point scale for all attitude and perception questions. Finally, in Section 4 we asked about demographic factors, such as income, education, age and household size.

The response rates were 46% for the Gallup sample and 43% for the Enova sample.[1] The average age of respondents in the Combined sample is 47 years and the average household annual income before tax is €74,000–100,000 (1 Euro = 8 NOK; see Table 1). More men than women answered the questionnaire in both samples, and the share of men was significantly higher in the Enova sample than in the Gallup sample. The latter most likely reflects the fact that families applied to Enova for a heating investment subsidy in the name of the husband and that we therefore obtained the name of the man from the Enova database. In addition to the gender difference, there are also several minor, although statistically significant, differences between the two samples. Respondents in the Enova sample are younger and more

[1] Unfortunately, we do not have information about the respondents who chose not to participate, and therefore cannot conduct any nonresponse bias analysis.

Table 1 – Description of the survey sample.

Variables	Measurement	Combined sample		Gallup sample		Enova sample	
		Mean	Std	Mean	Std	Mean	Std
Family income	Eight-point scale	4.23	(1.58)	3.93	(1.56)	4.57	(1.54)
Household size	Five-point scale	2.73	(1.22)	2.32	(1.07)	3.21	(1.21)
Education	Five-point scale	3.44	(1.15)	3.37	(1.16)	3.52	(1.13)
Age of respondent	In years	47.87	(12.53)	48.96	(12.99)	46.59	(11.83)
Female	Dummy	0.33	(0.47)	0.46	(0.50)	0.17	(0.38)
Size of residence	Six-point scale	3.56	(1.14)	3.24	(1.13)	3.95	(1.02)
Age of residence	In years	38.99	(23.71)	40.51	(22.61)	37.21	(24.83)
Years in residence	In years	14.18	(12.74)	15.61	(13.33)	12.49	(11.79)
Sample size		1860		1004		856	
Response rate	Percent	45		46		43	

educated, have a higher income and bigger household, live in a newer house and moved to the current residence more recently than respondents in the Gallup sample.

To measure the effect of differences in climate on a household's choice of heating equipment, we use local heating degree days (HDD) from the Norwegian Meteorological Institute, defined as the accumulated difference in degrees Celsius between the daily mean temperature (when it is $< 17\ ^{\circ}C$) and a threshold temperature of $17\ ^{\circ}C$ over one year. HDD has been found to be a good indicator of heating requirements. The greater the HDD the greater the energy demand to heat the house [18].

In our samples, 78% of the households have electric *space* heating and 64% have electric *floor* heating. Woodstoves are the second most common form of heating equipment: about 69% of households have a woodstove and/or a fireplace. The proportion of households owning an air-to-air heat pump is 26%. Only about 5% of the households own an oil/paraffin stove and/or a central heating system fueled by oil. As the Enova sample is drawn from the database of prior applicants to Enova, the share of households owning pellet stoves in the Enova sample is 31%, which is much higher than the share in the Gallup sample (0.5%).

2.2. *Perceptions of the types of heating equipment*

Perceptions play a very important role in consumer decision making process [8]. It is usually the perceived attributes, rather than the actual attributes, that determine choices.

Table 2 provides information about households' perceptions of the attributes of each type of heating equipment. In general, woodstoves scored high on appearance, effectiveness in warming up the house and heating costs, but respondents perceive that woodstoves require more time and effort to operate, as do pellet stoves. Pellet stoves are considered to be environmentally friendly, although not as much as heat pumps. Households also think that it is more difficult to get hold of pellets than firewood. Electric heaters are perceived as the best choice in terms of low investment costs and indoor air quality. Households perceive heat pumps to be the best investment in terms of operating cost, indoor air quality, environmental friendliness and effectiveness in warming up the house; however, heat pumps are perceived to have high investment costs and they scored low on appearance.

Each type of heating equipment has its own advantages and disadvantages, and no one type scores highest for all attributes. Households are likely to choose the equipment they think will best meet their specific needs.

2.3. *Investment choices*

In the Gallup sample, 52% of survey respondents reported that they had invested in at least one piece of heating equipment in the previous 10 years.

Table 3 shows the frequency of heating investment by Norwegian households. Results from the Gallup sample and the Enova sample are reported separately. Column 1 reports the frequency of investment in each of the four types of heating equipment. Columns 2 to 5 give the percentage of households that invested in a second piece of equipment, having also invested in the equipment reported in column 1. The proportions of households investing in woodstoves, pellet

Table 2 – Mean scores of perceptions of attributes of each type of heating equipment.

Perception of attributes	Electric oven	Firewood stove	Pellet stove	Air-to-air heat pump
Investment cost is low	5.67 (1.63)	3.75 (1.65)	2.59 (1.49)	3.08 (1.70)
Annual heating cost is low	2.79 (1.58)	5.09 (1.67)	4.03 (1.68)	5.22 (1.55)
Effectively warms the house	4.32 (1.75)	5.39 (1.49)	5.17 (1.48)	5.85 (1.27)
Difficult to obtain heating fuel		1.83 (1.40)	3.67 (1.95)	
Environmentally friendly	4.23 (1.98)	4.29 (1.71)	5.12 (1.47)	6.09 (1.13)
Takes much time and effort	1.31 (0.84)	4.17 (1.74)	3.82 (1.53)	1.62 (1.16)
Worsens air quality	4.32 (1.84)	3.55 (1.71)	3.33 (1.48)	2.65 (1.69)
Its appearance fits the house	4.81 (1.87)	5.48 (1.69)	4.35 (1.94)	3.85 (2.01)

Note: Means with standard errors in parentheses. All items are measured on a 7-point scale, where 1 = strongly disagree and 7 = strongly agree. Gallup sample: $N = 1004$.

stoves, electric heaters and heat pumps were 20%, 0.5%, 15% and 17%, respectively. Many households invested in more than one piece of heating equipment; some had bought even three of the four types. For example, among households that invested in a woodstove in the Enova sample, 49% also invested in an electric heater, 29% invested in a heat pump and 24% invested in a pellet stove.

2.4. *Motives behind heating investments*

Table 4 lists the key reasons that respondents gave for their investment decision. Only households that had made at least one heating investment during the previous 10 years answered this question. They chose the relevant ones from a list of motives, and multiple motives were allowed.

The most common motive chosen was to reduce heating costs. In the Gallup sample, 61% of the respondents gave this as the purpose of their heating investment, while 38% of households said they invested in order to improve indoor air quality and 33% to replace worn-out equipment. This last response is closely related to a household's decision to renovate the house, which was a motive given by 32% of households. Saving time or effort in heating the house was selected as a motive for 22% of the households. Improving local air quality and reducing greenhouse gas emissions was a motive for 18% and 12%, respectively. This indicates that the environment is not an important consideration for most people when investing in heating equipment.

3. Econometric approach

To determine the importance of the perceptions, motives and characteristics of the households and residences to the households' investments in heating equipment, we estimate two discrete choice models. The first model is a binomial logit model exploring the decision to invest or not, and the second model is a mixed logit model exploring the choice of equipment to invest in. Both are random utility models [19].

In the first model, the heating investment decision is represented by a dummy variable, indicating whether the household invested in heating equipment during the previous 10 years. This decision is assumed to be influenced by a number of factors, including the investment motives, attitude toward environmental factors, personality traits (e.g., degree of procrastination, willingness to throw away old equipment, preferred room temperature) and characteristics of the household and residence (income, education, age of household members, residence type, ownership status, and size and age of the residence). The household is assumed to invest in new heating equipment if the investment increases its utility. In our estimation, the utility of the investment (which equals the difference in utility before and after the investment) is approximated by equation (1):

$$V_i = \beta_0 + \gamma' x_i + \varepsilon_i \tag{1}$$

where V_i is the utility that household i derives by investing relative to not investing; β_0 is the constant; x_i is a vector of residence factors, demographic factors, attitudes and perceptions and sample indicators associated with respondent i; γ is the corresponding vector of parameters and ε_i is the disturbance term, which is assumed to satisfy the standard assumptions of the logit model. For a detailed list of the explanatory variables, see Table 5.

In the second model, we estimate the probability that a household will choose a particular type of equipment once it has decided to invest. We restrict our choice set to four heating alternatives: woodstove, pellet stove, electric heater and air-to-air heat pump. As one household may invest in more than one type of heating equipment, we specify a panel version of the mixed logit model with random-effect alternative-specific constants (ASC). If a household invested in more than one type of heating equipment, we give each of the n choices a weight of $1/n$ in the estimation. Furthermore, because the Enova sample is not representative of the Norwegian population, we also generate sampling weights in the Enova sample to balance the proportional differences between the Gallup sample and the Enova sample [20,21]. The weighted Enova sample used in the estimations has the same

Table 3 – Investments and cross-investments in heating equipment (in percentages).

Investment			Cross-investment frequency[a]			
Equipment	Sample	Frequency	Woodstove	Pellet stove	Electric heater	Heat pump
Woodstove	Gallup	0.20	1.00	0.00	0.32	0.30
	Enova	0.20	1.00	0.24	0.49	0.29
Pellet stove	Gallup	0.005	0.00	1.00	0.20	0.60
	Enova	0.23	0.21	1.00	0.21	0.19
Electric heater	Gallup	0.15	0.42	0.006	1.00	0.21
	Enova	0.23	0.43	0.22	1.00	0.19
Heat pump	Gallup	0.17	0.35	0.012	0.19	1.00
	Enova	0.15	0.41	0.30	0.30	1.00
Investing households in total	Gallup	0.52				
	Enova	0.89				

[a] The first two rows of the cross-investment frequency report the conditional frequency of those in the Gallup and Enova samples that say they invested in a woodstove and also invested in one or more other types of equipment. The following rows indicate the same information for other equipment types, respectively.

Table 4 – Motives for heating investment (in percentages).

Heating investment motives	Combined sample	Gallup sample	Enova sample
To reduce heating costs	72.54	61.10	80.45
To improve indoor air quality	41.58	38.14	43.96
To replace broken appliance	30.02	32.64	28.22
To modernize equipment	33.05	32.45	33.46
To save time and effort in heating	29.17	22.20	33.99
To improve local air quality	22.96	17.65	26.64
To reduce greenhouse gas emissions	22.11	12.14	29.00
Previous one did not look good	7.76	9.49	6.56
To increase house sale value	7.60	3.98	10.10
N	1289	527	762

Note: All motives were asked as yes/no questions, and multiple motives were allowed.

investment distribution as the Gallup sample. The same holds for the Combined sample.

In the mixed logit estimation, we assume that the household chose to invest in the equipment that afforded the highest utility level. We assume that the utility derived from each type of heating equipment depended on personal characteristics such as the owner's investment motives and socioeconomic factors, as well as on external factors, such as residence characteristics and climate. For identification, we normalize the utility of electric heaters to be zero, and model the utility from choosing one of the three other types of equipment relative to the utility of the electric heater. We approximate this utility difference by equation (2):

$$V_{ij} = \beta_{0ij} + \gamma_j' x_i + \varepsilon_{ij} \tag{2}$$

where V_{ij} is the utility household i receives by investing in heating equipment j, where j represents woodstove, pellet stove or heat pump, relative to investing in electric heaters; β_{0ij} is the random-effect ASC for alternative j, which is heteroskedastic and independently normally distributed over alternatives; x_i is a vector of residence factors, demographic factors and investment motives for respondent i; γ_j is the corresponding vector of nonrandom parameters associated with alternative j; and ε_{ij} is the disturbance term, which is assumed to fulfill standard logit assumptions. For a detailed list of explanatory variables, see Table 6.

Stata 12 software [22] was used for the econometric analyses. Equation (2) was estimated using the Stata mixlogit command described in Hole [23], Cameron and Trivedi [24] and Long and Freese [25].

4. Results and discussion

4.1. *The investment choice*

Table 5 shows the results of the binomial logit model exploring the decision to invest or not, using the Combined sample, the Gallup sample and the Enova sample.

Table 5 – Results from a logit estimation on the heating investment choice.

Explanatory variables	Measurement	Combined sample	Gallup sample	Enova sample
Attitudes and perceptions				
Preferred living room temperature	Four-point scale	0.283**(−0.107)	0.438***(−0.128)	−0.068(−0.208)
Attitude to environmental responsibility	Seven-point scale	−0.109**(−0.053)	−0.132**(−0.064)	−0.080(−0.097)
Buyer of environmentally friendly products	Seven-point scale	0.142**(−0.046)	0.129**(−0.056)	0.189**(−0.083)
Procrastination	Seven-point scale	−0.083**(−0.037)	−0.087**(−0.044)	−0.091(−0.074)
Unwilling to dispose of old equipment	Seven-point scale	−0.067*(−0.037)	−0.079*(−0.044)	−0.031(−0.069)
Demographic factors				
Household income	Eight-point scale	0.087**(−0.036)	0.117**(−0.041)	−0.041(−0.079)
Education level	Five-point scale	−0.098*(−0.058)	−0.123*(−0.068)	−0.017(−0.116)
Age of respondent	In decades	0.054(−0.057)	0.0397(−0.068)	0.045(−0.115)
Household size	Five-point scale	0.112*(−0.067)	0.134(−0.084)	0.063(−0.116)
Residence factors				
Apartment	Dummy	−1.470***(−0.217)	−1.413***(−0.246)	−1.521**(−0.495)
Age of residence	In decades	0.177***(−0.029)	0.149***(−0.035)	0.238***(−0.055)
Own the residence	Dummy	1.222***(−0.241)	1.261***(−0.262)	1.054(−0.857)
Size of residence	Six-point scale	0.230***(−0.069)	0.281***(−0.082)	0.178(−0.137)
Sample factors				
Gallup sample	Dummy	−0.922***−0.175		
Received Enova subsidy	Dummy	1.344***(−0.253)		1.391***(−0.26)
Constant		−2.023**(−0.643)	−3.211***(−0.731)	−0.975(−1.51)
N		1742	943	799
Log likelihood		−787.099	−534.848	−243.753

Note: Dependent variable equals 1 if household has installed new heating equipment costing more than €375 in the past 10 years, zero otherwise. Standard errors in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.001$.

Overall, the results for the Combined sample and the Gallup sample are similar to each other, and the results for the Enova sample are slightly different. In general, residence characteristics, income, education, environmental attitudes, time preference and unwillingness to throw away old equipment significantly influenced households' heating investments. First, *attitudes and perceptions* provide a mixed picture. People who are more environmentally concerned are less likely to invest, but being a buyer of green products increases the investment likelihood. This indicates that environmentally aware consumers who express their concern through the products they choose are also more likely to invest in new and energy efficient equipment. For time preferences, we find that respondents who procrastinate have a reduced likelihood of investing, as do people who do not like to throw away old equipment. Finally, households that prefer higher room temperatures are more likely to invest in new heating equipment.

Second, *demographic factors* also play an important role in the investment likelihood. In the Combined sample and the Gallup sample, we find that higher income is associated with an increased likelihood of investment, while a higher education level is associated with a lower investment probability. There is no significant relationship between respondent's age and investment likelihood. Household size is only significant in the Combined sample, and it implies that larger households are more likely to invest.

Third, *residence characteristics* seem to be the most significant factors associated with investment likelihood. The results for all three samples imply that households living in an older house are more likely to invest. Living in an apartment significantly reduces the probability of investment, possibly because of the availability of common heating systems. Results for the Combined sample and the Gallup sample provide further evidence that the size of the house and being the owner of the house have significant positive effects on the investment likelihood. Bigger houses need more heating and ownership of the house increases the incentive to invest.

Finally, households *applying for subsidies* from the government had a higher investment probability than those that did not. This correlation is likely a result of applicants for subsidies having already decided to invest before applying for the subsidy.

4.2. *The choice of heating equipment*

Equation (2) focuses on the drivers behind the choice of each type of heating equipment. In this estimation, we use the Combined sample in order to explore the purchases of the less common equipment, such as pellet stoves. The model is estimated relative to investments in electric heaters, meaning that the coefficients measure the difference in utility of choosing another type of equipment relative to electric heaters, given that the household has decided to invest.

Table 6 – Results from a mixed logit estimation of investment in woodstoves, pellet stoves and heat pumps relative to electric heaters.

Explanatory variables	Measurement	Estimated coefficients			Differences and Wald test		
		Firewood	Pellet	Heat pump	F–P	F–H	P–H
Investment motives:	Dummies						
To reduce heating costs		−0.132	−0.118	1.015***	−0.014	−1.147***	−1.133***
To increase house sale value		0.458	−0.226	−0.637	0.684	1.095*	0.411
Previous one did not look good		0.090	−1.382**	−1.533***	1.472**	1.624***	0.151
To replace broken appliance		−0.558**	−0.853***	−1.412***	0.295	0.854***	0.558*
To modernize equipment		−0.183	−1.140***	−0.810***	0.958**	0.628**	−0.330
To save time and effort in heating		−0.075	1.673***	0.890***	−1.748***	−0.965***	0.783**
To improve indoor air quality		−0.334*	−0.212	0.602**	−0.122	−0.936***	−0.814***
To improve local air quality		0.185	0.288	0.179	−0.103	0.006	0.109
To reduce climate change gas emissions		0.498*	0.906**	−0.170	−0.408	0.668*	1.076**
Demographic factors							
Household income	Eight-point scale	−0.068	−0.122	0.041	0.054	−0.110	−0.164*
Household size	Five-point scale	−0.051	0.265*	−0.090	−0.316**	0.039	0.355**
Age of respondent	In decades	0.162*	0.125	0.197*	0.037	−0.035	−0.072
Education level	Five-point scale	−0.086	−0.078	−0.139	−0.009	0.053	0.062
Residence factors							
Detached house	Dummy	0.630**	0.372	0.820***	0.258	−0.191	−0.448
Size of residence	Six-point scale	0.102	0.247*	0.234*	−0.145	−0.132	0.013
Age of residence	In decades	−0.023	0.035	−0.035	−0.058	0.012	0.071
Mean heating degree days	In 100 HDD	0.015	0.060**	0.004	−0.045**	0.011	0.056**
ASC		−0.722	−9.081***	−2.214**	8.359***	1.492	−6.867***
Std of ASC		0.544*	1.276	0.141	0.731	0.686	1.417

Number of choice observations = 1220
Number of participants = 826
Log likelihood = −618.39
Wald $chi^2(54) = 396.37$
Prob > $chi^2 = 0.0000$
Note: Estimated with the mixlogit command in Stata 12. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.

Included in the estimation are 826 households that made a total of 1220 investments.

Column 1 of Table 6 lists the explanatory variables and column 2 details how they are measured. Columns 3–5 list the coefficients estimated by the mixed logit model in equation (2). Columns 6–8 show the difference in coefficients between woodstoves, pellet stoves and heat pumps. The significance levels are calculated using Wald tests of parameter equality.

The investment likelihoods for each type of equipment are significantly associated with the various explanatory variables. Starting at the top, we see that *reducing heating costs* is more important for households investing in heat pumps than for those investing in electric heaters, pellet stoves or woodstoves. This could be because of the perception that heat pumps are more energy efficient and cost saving, which is consistent with the equipment evaluation results in Table 2. The motive *to increase house sale value* is more important among households that invest in a woodstove than those that invest in heat pumps.

The next three motives focus on the replacement of old equipment. *The previous equipment did not look good* was a more important motive for households investing in electric heaters and woodstoves than for households investing in heat pumps and pellet stoves. This can be explained by the fact that electric heaters and woodstoves have been common in Norwegian houses for many years and that new and more aesthetically appealing ones have entered the market. Heat pumps and pellet stoves, on the other hand, are relatively new technologies and people have not started to replace them. Furthermore, heat pumps and pellet stoves tend not to be aesthetically appealing, as reflected in their relatively lower score for appearance in the perceived attributes reported in Table 2.

The motive *to replace a broken appliance* is most important for households investing in electric heaters and least important for those investing in heat pumps. Most households already have several electric heaters installed their home, and are more likely to buy a new one to replace old, broken equipment. It is more likely that the other three types of equipment, especially the heat pumps, are bought to supplement already existing equipment, and not as a replacement. Similar arguments can be used when investment behavior is motivated by *house renovation*.

The motive of wanting *to save time or effort in heating* was most important to households that invested in pellet stoves or heat pumps. This indicates that they wanted to replace old equipment that demanded more effort such as woodstoves in the case of pellet stove buyers and firewood or fuel oil stoves for heat pump buyers. This motive is most important for pellet stove buyers. Nyrud et al. [9] also identified maintenance work as an important determinant in the heating equipment investment decision.

As in Mahapatra and Gustavsson [17], we find that the motive of *improving indoor air quality* is important when choosing a heating system, and more important for households investing in heat pumps and electric heaters than for those investing in woodstoves and pellet stoves. Considering the dust generated during biomass-based heating processes and consumers seek for more comfort, these results seem reasonable. Our results suggest that the households that care most about indoor air quality are more likely to choose a heat pump. This finding is opposite to the findings of Sopha et al. [10], but the main difference between our study and their study is the time frame for the data collection: we collected households' actual investment data whereas they collected the stated preference data.

Interestingly, local air quality seems to be equally important for buyers of all types of equipment. Heating based on wood and pellets has a negative effect on the local air quality; however, upgrading an old woodstove to a modern wood or pellet stove has a positive effect on local air quality. As a consequence, the local government in Oslo has been subsidizing modernization of biomass-based equipment [9].

Motives concerning climate change seem to matter most for people investing in pellet stoves and woodstoves. In the case of woodstoves, this may be because people are replacing old stoves with new stoves that are more energy efficient. In the case of pellet stoves, this is consistent with households' high expectation of pellet stoves on good environmental performance (Table 2). Note that although heat pumps received the highest score on environmental performance, heat pump buyers were not motivated by environmental concerns.

Household income is positively associated with investment in heat pumps relative to pellet stoves; otherwise, household income is not significant. This minor impact of income is similar to the findings of Braun [16]. Household size is positively associated with investment in pellet stoves relative to the other three equipment types. Age is positively associated with woodstove and heat pump investments, possibly because older people are accustomed to using firewood and heat pumps are considered to be a convenient heating solution with little effort involved. These results are similar to those in Sopha et al. [10]. However, education level does not seem to be important in the choice of heating equipment in our study, in contrast to Sopha et al. [10], who found that education had an effect on the probability of choosing pellets.

Living in a detached house significantly increases the probability of investing in a woodstove or heat pump. House size is significantly and positively associated with the likelihood of investing in a pellet stove or heat pump. The age of the house is not a significant factor in the analysis. Findings from a recent German study [16] also concluded that residence features are significant in determining the heating choice.

As in Sopha et al. [10], living in a cold climate significantly increases the probability of investing in a pellet stove, compared with the other equipment types. These households typically have significant heating needs, and there are many days when it would be too cold for a heat pump to function efficiently. They are also more likely to invest in multiple types of heating equipment to reduce the risk of vulnerability to both blackouts and changes in electricity prices.

5. Conclusion

In this paper, we investigated the factors influencing households' heating investment decisions and choices of heating equipment. The aim was to improve our understanding of what determines household energy investment behavior. We carried out two estimations based on revealed preference data from a national household web survey. Our results have important policy implications.

Overall, the results suggest that several factors affect heating investment decisions and choices. First, the *decision* to invest is affected by both economic factors, such as cost and income, and noneconomic factors, such as residence characteristics, demographics, attitudes toward the environment, time preferences and willingness to dispose of old equipment.

Second, households' choices of equipment are influenced significantly by investment motives, residence characteristics, climate and some demographic factors. Our results suggest that Norwegians perceive different types of heating equipment very differently. We found that the cost saving motive had a significant effect on the investment likelihood for heat pumps. Woodstoves are a popular conventional heating choice and also decorate the house. Pellet stove buyers are more environmentally concerned and their investment may be influenced by the perceived environmental contribution of pellet stoves.

The majority of the households that had invested in new equipment were motivated by reducing heating costs. It is also worth noting that the two most popular types of equipment in the previous 10 years, woodstoves and heat pumps, were also the ones that the participants perceived to have the lowest annual heating costs, although not the lowest investment costs. This indicates that households are influenced not only by heating costs, but also by the investment cost, meaning that they consider the total cost of using the equipment over many years.

A comparison of the two forms of biomass-based heating equipment reveals that woodstoves are the most popular of the four types of equipment while pellet stoves are the least popular. The reasons for this difference may lie in the perceptions of the two technologies. Respondents believe it is easy to obtain firewood, while it is more difficult to obtain pellets. Woodstoves are also the favorite when it comes to cost; they are perceived to have a lower investment cost and lower annual heating costs than pellet stoves. In addition, woodstoves are more esthetically appealing than pellet stoves. Pellet stoves score better than woodstoves only in terms of the environment and the time and effort required for their operation. However, for these issues, heat pumps are considered far better than pellet stoves. Hence, if stakeholders in the pellet industry want to reach more than a small group motivated by environmental issues, they will have to improve their product in multiple ways. First, households must be able to obtain pellets easily. Second, the investment and annual heating costs must be competitive with other heating sources. Finally, improved esthetic appeal will probably increase the use of pellet stoves.

Environmental awareness appears to be a double-edged sword for biofuel-based equipment. On the one hand, being environmentally aware seems to reduce a consumer's probability of investing in new equipment. On the other hand, environmental awareness does seem to increase the probability of purchasing biofuel-based heating equipment. It is thus not obvious whether increasing environmental awareness will boost market demand for biofuel-based heating equipment. Our results indicate that information campaigns should focus more on savings in terms of money and time of using the new and more energy efficient equipment, rather than focusing on the environmental benefits.

Although this study helps us better understand Norwegian households' heating investment decisions and choices of heating equipment, we do not have information about the stock of heating equipment prior to investment, and whether the investment replaced one or more of the previous equipment types. Furthermore, we do not have information about the investment size; all we know is that each household had invested more than €375 during the previous 10 years. Finally, and perhaps most importantly, we do not have information about energy consumption. Thus, we are not able to conclude how these investments affect emissions from household stationary energy consumption. These are important topics for future research.

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Paper II

Warming up with electricity, firewood, pellets or fuel oil?

-Modelling how perceptions and attitudes affect the share of biomass in Norwegian household heating energy consumption

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ABSTRACT

One problem when evaluating the effectiveness of policies aimed at increasing the use of biomass for residential heating is that consumption is difficult to measure because of unobservable changes in fuel stocks. In this paper, we develop a method to estimate the changes in consumption shares based on information regarding the selection of the primary heat source. Applying data from a web survey on Norwegian households, we focus on how perceptions of types of heating equipment, attitudes towards different sources of heating energy and socio-economic factors affect this choice. We find that perceptions of the heating attributes of various types of equipment are important in explaining the choice of primary heat source. Positive perceptions of woodstoves and air-to-air heat pumps are among the most important factors for not choosing pellets as the primary heat source. We find that while annual cost and heating effectiveness are the most important factors in increasing firewood use, feedstock accessibility and environmental considerations are critical in increasing the share of pellets used in residential heating.

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1. Introduction

The role of domestic energy consumption in local and global emissions, as well as their effect on the environment, has gained increased focus in recent decades. The use of renewable energy carriers and increased energy efficiency have been high on the political agendas of many European countries, including Norway (Miljøverndepartementet, 2006, EEA, 2011). In particular, the use of biomass has attracted substantial attention because of its perceived role in reducing CO_2 emissions by partly replacing fossil fuels while also achieving sustainable development objectives (Rosillo-Calle et al., 2007 , Lee et al., 2011). In Norway, residential energy demand accounts for approximately one quarter of the total energy consumption, and the energy used for space heating amounts to approximately half of this figure (SSB, 2012). Residential energy use for heating purposes is thus high on the policy agenda, and a number of policies have been introduced to reduce Norwegian households' dependency on electricity, improve energy efficiency and increase the use of biomass for heating purposes (Miljøkomiteen, 2002–2003).

The results of the Norwegian government's efforts to reduce the reliance on electricity for space heating have been mixed. Despite investment subsidies and other measures, very few households have invested in equipment that exploits alternative heat sources, such as pellet stoves. Furthermore, a large percentage of households that have invested in pellet stoves do not use them as their primary heat source but rather as an additional heat source. However, the introduction of air-to-air heat pumps in Norwegian homes has been rapid. The share of households owning a air-to-air heat pump increased from less than one percent to approximately one quarter of Norwegian households over the last decade (SSB, 2009).[1] Additionally, traditional alternatives, such as woodstoves, remain highly popular and widely used, and approximately 20% of the respondents in our dataset reported that they used firewood as their primary heat source.

Most Norwegian households (more than 90% in our dataset) own more than one type of heating equipment and often heat their homes using multiple energy sources. It is common to have more than the necessary capacity installed, such that the household may choose between different heat sources even in the very short run. Thus, the energy mix used by an individual household may change with the relative energy prices, temperature, and other external factors, even without any investments in new equipment. Thus, the choice of energy source is very important with respect to energy policy, as most Norwegian households already

[1] Henceforth, we use the term "heat pump" to denote an air-to-air heat pump unless otherwise specified.

possess the necessary equipment to make the desired change in consumption. To ensure that the main goals of current environmental and energy policy are achieved in the most efficient way possible, it is thus important to have a good understanding of this utilisation choice at the micro level.

Analyses of residential energy consumption are numerous and cover both the analysis of energy demand and the choice of heating equipment (Lopes et al., 2012, Wilson and Dowlatabadi, 2007). The majority of studies are based on micro data on a country or regional basis. Dubin and McFadden (1984), Bernard et al. (1996), Lee and Singh (1994), Douthitt (1989) and Liao and Chang (2002) were among the first to simultaneously investigate both the choice and use of energy-using equipment by applying micro data. Some Norwegian studies based on household survey data have also been conducted, and they have primarily focused on household electricity consumption (Halvorsen and Larsen, 2001, Nesbakken, 2001, Vaage, 2000). Recent studies have analysed the adoption of pellet stoves to understand why Norwegian households do not favour this heat source (Sopha et al., 2011, Skjevrak and Sopha, 2012).

One main weakness in the existing literature on biomass consumption is that most studies focus on investments in heating equipment and firewood demand, rather than firewood or pellet consumption (Lillemo et al., 2013, Lillemo and Halvorsen, 2013, Sopha et al., 2010). The main problem with examining firewood demand is that we do lack information on actual consumption but instead have data on the amount of firewood acquired (purchased, received as a gift or acquired by own chopping). As most Norwegian households already own a woodstove or fireplace and have large stores of firewood that may last for many years, it is very difficult to draw conclusions regarding changes in current consumption based on these studies. Further, most studies only consider the consumption of one energy source at a time and do not analyse the simultaneous choice among different energy carriers. We thus need to find a method to identify and analyse factors that influence the use of the biomass heating equipment relative to electric heating equipment to obtain relevant information on how to shift household energy consumption away from electricity towards biomass in the short run.

In this study, we use information from a web-panel survey conducted in 2010 to analyse the household use of existing heating equipment. We theoretically demonstrate how we can estimate changes in the share of biomass consumption by studying the factors increasing the probability of choosing biomass relative to electricity as the primary heat source. Our focus is on the explanatory power of the perceived attributes of alternative heating equipment, attitudes towards biomass for heating, and socio-economic and building characteristics. We apply a multinomial Logit model to estimate the relative importance of these factors in selecting a primary heat source.

2. The data

In this study, we use data from a web survey of Norwegian households with 1860 respondents, which was conducted in November 2010. The households were drawn from two different samples. The first was drawn from TNS[2] Gallup's web-panel, and the second was taken from the database of applicants for grants from Enova SF, which is the Norwegian government's agency that is responsible for subsidies for alternative heating equipment in households and businesses. Henceforth, we refer to the former subsample as the Gallup sample, the latter subsample as the Enova sample and the total sample as the Combined sample.

The Gallup sample is a national, randomly selected sample that represents a cross-section of the Norwegian population. However, for the purposes of our analysis, the Gallup sample contains too few observations of the less frequently used types of heating equipment, such as pellet stoves, for us to be able to determine why households do or do not select these types of heat sources. We therefore supplement the Gallup sample with the Enova sample, which includes households that have installed a pellet stove. The Enova sample is randomly drawn from the database of Enova applicants.[3]

The Enova sample is not representative of the Norwegian population, as it is drawn from a sample of applicants to governmental grants for investments in heating equipment. To correct for this, we generate sampling weights in the Enova sample to balance the proportional differences between the random Gallup sample and the choice-based Enova sample (Waldman, 2000). Weights are generated based on the different rates of pellet stove ownership in the Enova and Gallup samples.

2.1 The questionnaire

The same questionnaire was administered to both samples. The questionnaire contained four parts. In the first part, the respondents were asked about their current place of residence, including its type, age, size, the ownership status and choice of primary heat source. In second part, the respondents were asked about their existing heating equipment and their perceptions of 4 types of equipment. The respondents were asked to compare woodstoves, pellet stoves,

[2] The firm was formerly known as Taylor Nelson Sofres.

[3] The response rates were 46% for the Gallup sample and 43% for the Enova sample. Unfortunately, we do not have information on the respondents who chose not to participate and therefore cannot conduct any nonresponse bias analysis.

electric heaters and air-to-air heat pumps with respect to equipment attributes such as costs, effectiveness, environmental friendliness, indoor air quality, and time and effort required to use the equipment. The third part of the questionnaire elicited the respondent's attitudes to using biomass in heating. The same 7-point scale was used for all attitude and perception questions. For each statement, the respondents indicated their assessments on a 7-point scale, where 1 = strongly disagree and 7 = strongly agree. Finally, in the last section, socio-economic factors, such as income, education and age, were recorded.

To measure the effect of climatic differences on a household's choice, information about local heating degree days (HDD) from the Norwegian Meteorological Institute was used. HDD are the number of degrees that the average daily temperature is below 17°C over the course of a year. HDD were estimated by municipality and merged into the respondents' survey accordingly. Larger HDD values indicate colder temperatures and thus a greater need to use energy to heat the residence (Benestad, 2008).

2.2 Descriptive statistics

Descriptive statistics of some key household and dwelling characteristics in the weighted combined sample are presented in Table 1. The average household's annual income before tax is approximately 4 on the scale considered, which is equivalent to between NOK 600,000 and 800,000 or €75,000–100,000 (see Table 1). There are 2.3 family members per household on average, the average age of the respondents is 49 years and the mean education level is 3.4 on the scale, which is equivalent to a high school education. The mean age of the dwellings is 40 years, and the respondents have, on average, lived in their current residence for 15.5 years.

Table 1. Descriptive statistics, weighted means and standard errors

	Mean	*Std. Err.*
Family income (1-8 scale)	3.96	0.05
Family members (1-5 scale)	2.33	0.03
Education (1-5 scale)	3.37	0.04
Age (years)	48.94	0.40
Size of house (1-6 scale)	3.59	0.03
Age of house (years)	40.44	0.71
Number of years lived in current house (years)	15.51	0.41

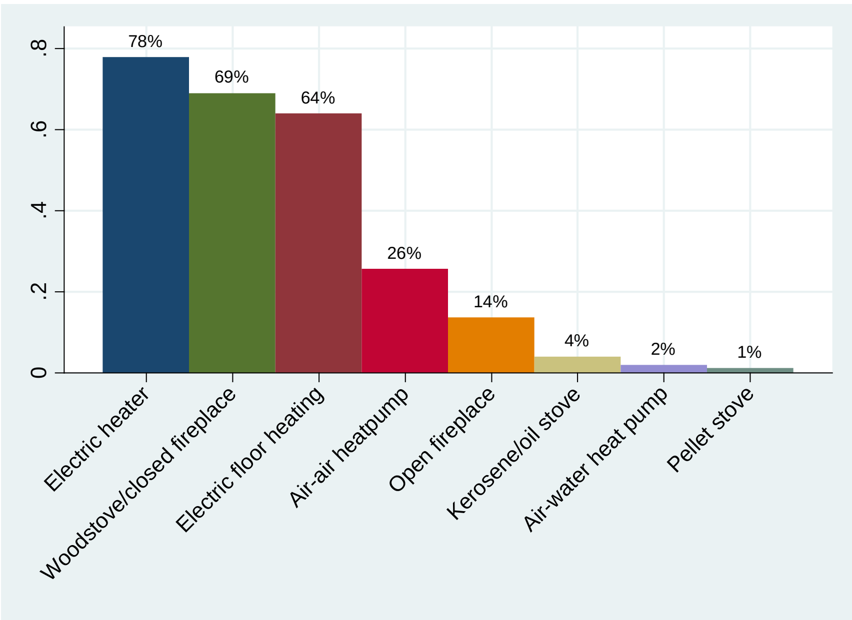
Sample size, N	1843

Sources: Household survey 2010, UMB

Norwegian households usually have more than one type of heating equipment installed in their homes. The most commonly used types of heating equipment are electric heaters, woodstoves, open fireplaces, and heat pumps. In the weighted combined sample, heating equipment running on electricity is the most common, with 78% of the households having electric heaters and 64% having electric cables (Figure 1). Woodstoves are the second most common form of heating equipment, and approximately 69% of households in our sample have a woodstove and/or an open fireplace.

The proportion of households owning an air-to-air heat pump is 26%. Only approximately 4% of the households own an oil/paraffin/gas stove. The shares of households owning pellet stoves or a ground source heat pump are both approximately 1%. Figure 1 indicates that the percentages sums to more than 100%, indicating that it is common for Norwegian households to have more than one type of heating equipment installed.

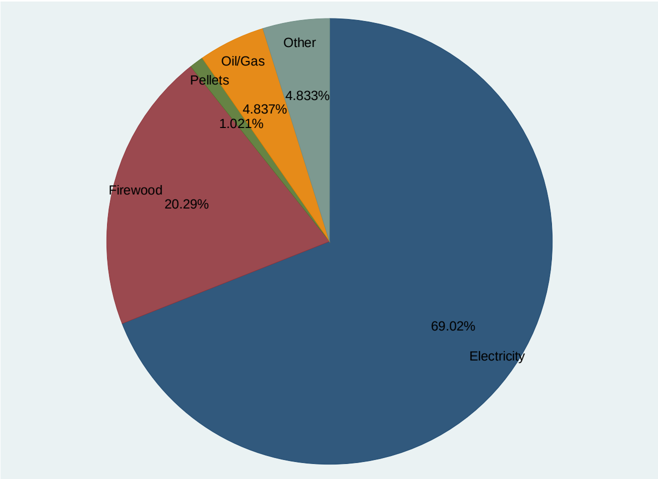
Figure 1 Ownership of heating equipment



Sources: Household energy survey 2010, UMB

Although many Norwegian households use alternative energy sources, they still rely heavily on electricity to heat their houses. In our survey, 70% of the households reported that electricity was their primary heat source (Figure 2). Firewood was the second largest heat source and was reported to be the main source by 20% of the interviewed households. Less than 1% of the respondents reported that their primary heat source was pellets. Approximately five per cent of the respondents reported that they still relied on fossil fuels to heat their homes[4]. The remaining 4% of respondents relied on other sources such as district heating.

Figure 2. The distribution of primary heat sources in Norwegian residences



Sources: Household energy survey 2010, UMB

Table 2. The distribution of primary heat sources among pellet stove owners

Primary heat sources	***Freq.***	***Per cent***	***Cum.***
Electricity	74	27.51	27.51
Firewood	18	6.69	34.2
Pellets	174	64.68	98.88
Other	3	1.12	100
Total	269	100	

[4] More households claimed to rely on fuel oil as their primary heat source than those reporting that they have equipment for using fossil fuels. The reason for this difference could be that some households have a central heating system based on fossil fuel but do not have an oil/paraffin/gas stove.

Sources: Household energy survey 2010, UMB.

This finding illustrates that even if a household uses alternatives to electricity for space heating, most households rely on electricity as their primary heat source. This is also partly the case for equipment, such as pellet stoves, that is targeted by the subsidies designed to reduce the use of electricity for heating. Table 2 shows that 28% of the households in our sample that owned a pellet stove reported using electricity as their primary heat source.[5] Of the households that invested in a pellet stove, only 65% reported that they used it as their primary heat source (Table 2).

3. The theoretical framework

In this section, we construct a theoretical framework to identify the factors that increase the share of biomass consumed relative to electricity in residential heating by modelling the households' choice of primary heat source.

3.1 The choice of primary heat source

Owning more than one type of heating equipment, Norwegian households can typically choose to heat a particular room with more than one heat source, even in the short run when no investment in new heating equipment is made. Understanding the choice of primary heat source from all available alternatives is thus important to understand the short run flexibility in household energy consumption and the factors that may shift consumption patterns in the short run.

In this analysis, we assume that households maximise their utility with respect to all consumption, including energy goods, subject to a budget constraint, given the stock of heating equipment installed in the residence. The maximisation problem for the household is given by:

$$\max_{x_1,..,x_N,F_1,..,F_E} U(F_1,\dots,F_E,x_1,\dots,x_N;K,\theta) \quad s.t. \quad Y \geq \sum_{i=1}^{N} q_i x_i + \sum_{j=1}^{E} q_j^e F_j \tag{1}$$

where F_j is the household's consumption of energy good j = 1, ..., E, x_i is the household's consumption of other goods i = 1, ..., N, q_j^e is the price of energy good j, q_i is the price on

[5] None of the respondents reported using oil or paraffin as their primary heat source.

other goods i, K is a vector of the stock of heating equipment, θ is a vector of tastes and characteristics of the household and residence and Y is household income. We assume utility to be strictly increasing in the consumption of all goods at a decreasing rate: $\frac{\partial U}{\partial F_k} > 0$, $\frac{\partial U}{\partial x_n} > 0$, $\frac{\partial^2 U}{\partial F_k^2} < 0$ and $\frac{\partial^2 U}{\partial x_n^2} < 0 \;\; \forall\, k = 1, \dots, E$ and $n = 1, \dots, N$.

Solving the maximisation problem in Equation (1) gives the demand for all goods and services, including energy goods, as a function of income and prices, given the characteristics of the household and residence, differences in individual tastes and attitudes given the current stock of heating equipment. Assuming an interior solution, the demand for energy good j is given by

$$F_j^* = F_j(Q, Y; K, \theta) \tag{2}$$

where Q is a vector of all prices Q$= \{q_1^e, \dots, q_E^e, q_1, \dots, q_N\}$. If the marginal utility of consuming a particular good is less than the marginal cost, the first condition will hold with the inequality for all consumption levels. In this case, the household will choose a corner solution with zero demand, even if the household has the opportunity to consume the good. Corner solutions are quite common with respect to the demand for energy goods other than electricity for space heating, such as firewood and fossil energy.

In this analysis, the primary heat source is self-defined by the household. Thus, the household makes an additional decision when answering the questionnaire, i.e., which of the energy sources they considered to be the primary heat source. This heat source may be the most applied as measured by energy (kWh) or the number of hours in use, or the household may use other criteria to determine that this source is the most important heat source, e.g., many households may use electricity to heat the residence to a temperature that is too low to be comfortable and then use firewood to raise the temperature to a comfortable level. Some of these households may consider firewood to be their primary heat source, even if they use more electricity, as measured both in terms of energy use (kWh) and use time. Thus, the choice of primary heat source is a result not only of the use of energy but also of the perceptions that the households have of the importance of their own choices. Here, we assume that the household chooses the energy good that yields the highest indirect utility increase to be the primary heat source.

The household's indirect utility is defined as the utility produced by the optimal consumption of all goods: $V = V(F_1^*, \ldots, F_E^*, x_1^*, \ldots, x_N^*; K, \theta)$. The contribution of the consumption of each good at the optimum can be found by differentiating the indirect utility function with respect to changes in the consumption of all energy goods consumed, given by: $dV = \sum_{j=1}^{E} \frac{\partial V}{\partial F_j^*} dF_j^*$. We assume that the household chooses to report as the primary heat source ($\tilde{F}$) the source that maximises the marginal change in indirect utility ($\frac{dV}{dF_j^*}$), that is, the source that satisfies the following problem:

$$\tilde{F} \equiv \max_{F_1^*,\ldots,F_E^*} \left\{ \frac{dV}{dF_1^*}, \ldots, \frac{dV}{dF_E^*} \right\} \tag{3}$$

3.2 Response to governmental policies

Governmental policy measures (or any other changes in factors exogenous to the consumption decision) will affect the optimal consumption of all energy sources and the share of total energy consumption of each source and will change the marginal indirect utility of consuming the different energy goods. If these changes are sufficiently large, they may also change which energy good the consumer considers the primary heat source. In this analysis, we only have information regarding whether an energy good is considered the primary heat source. Therefore, under what conditions can we infer changes in the consumption shares of different energy sources based on changes in what the household considers their primary heat source?

Assume that a change has occurred that has shifted the household consumption of energy sources at the optimum, including which energy source is viewed as the primary heat source. If we denote the situation before the change has occurred with the superscript 0 and the situation after the change with superscript 1, such that $\tilde{F}^0 = F_i^{*0}$ and $\tilde{F}^1 = F_j^{*1}$, the change in the optimal consumption of energy good k = i, j from state 0 to 1 is given by $\Delta F_k^* = F_k^{*1} - F_k^{*0}$ and the according change in indirect utility is given by $\Delta V = \Delta V^1 - \Delta V^0$. In this case, we have three potential outcomes with respect to the optimal consumption of the two energy goods: (i) the consumption of goods *i* and *j* both increase, (ii) the consumption of good *j* increases while the consumption of good *i* decreases and (iii) the consumption of both goods decreases.[6] Case (ii) implies that the consumption share of energy good *j* increases by definition, and we can deduce from the change in the primary heat source that the consumption share of the new primary heat source has risen. However, in cases (i) and (iii), this link is not as obvious.

First, assume that we are in case (i), where the change from state 0 to state 1 has increased the optimal consumption of both energy goods ($\Delta F_k^* > 0$, $k = i$ and *j*) and changed the primary heat source from *i* to *j* such that $\tilde{F}^0 = F_i^{*0}$ and $\tilde{F}^1 = F_j^{*1}$. As the marginal utility of consumption is assumed to be strictly increasing in the consumption of all energy sources at a decreasing rate, we know that the change in the optimal consumption of energy source *j* needs to be greater than the change in the optimal consumption of energy good *i* from state 0 to state 1 for the consumer to change his or her primary heat source. For $\tilde{F}^0 = F_i^{*0}$ and $\tilde{F}^1 = F_j^{*1}$ to occur, $\Delta F_j^* > \Delta F_i^*$ must meet the condition that $\frac{\Delta V}{\Delta F_i^*} < \frac{\Delta V}{\Delta F_j^*},\ \ i \neq j$.

The situation for case (iii), where the change from state 0 to state 1 has decreased the optimal consumption of both goods ($\Delta F_k^* < 0$, $k = i$ and *j*), is symmetrical. For the consumer to change his or her primary heat source from *i* to *j*, such that $\tilde{F}^0 = F_i^{*0}$ and $\tilde{F}^1 = F_j^{*1}$, the reduction in the optimal consumption of energy source *j* will have to be less than the change in the optimal consumption of energy good *i*: $\|\Delta F_j^*\| < \|\Delta F_i^*\|$.

Irrespective of the case that we consider, the optimal consumption of energy good *j* will increase more (or decrease less) than the consumption of energy good *i*, such that the share of good *j* consumed increases relatively more (decreases relatively less) compared to the share of energy good *i* when we move from state 0 to state 1 measured relative to total energy consumption in states 0. This finding implies that the consumption shares of energy goods *i* and *j* have the following properties: $\frac{\Delta F_j^*}{\sum_{k=1}^{E} F_k^{*0}} > \frac{\Delta F_i^*}{\sum_{k=1}^{E} F_k^{*0}}$ if $\Delta F_k^* > 0$, and $\left\|\frac{\Delta F_j^*}{\sum_{k=1}^{E} F_k^{*0}}\right\| < \left\|\frac{\Delta F_i^*}{\sum_{k=1}^{E} F_k^{*0}}\right\|$ if $\Delta F_k^* < \mathbf{0}$.

In both cases, this finding implies that all factors and policies that make the household change their choice of primary energy source from *i* to *j* will increase the consumption share of energy good *j* relative to the share of energy good *i*. This property is used below to evaluate the factors that may shift energy consumption in the context of current environmental policy goals.

[6] The fourth case, where the consumption of good *i* increases while the consumption of good *j* decreases, and what is perceived as the primary heat source changes from *i* to *j* is not consistent with the assumption that utility is increasing at a decreasing rate in the consumption of all goods and hence violates the condition in Equation (3).

3.3 Econometric specification

In the empirical analysis, the household may choose one of the following five heat sources as their primary heat source: electricity, firewood, pellet, fuel oil and others (including district heating and a *don't know* option). We assume that the household's marginal indirect utility from consuming energy good *j* (F_j^*) is given by

$$\frac{dV}{dF_j^*} = \mu_j + \varepsilon_j \tag{4}$$

where μ_j is the expected marginal utility of consuming F_j^* and ε_j is a stochastic error term that is assumed to be independent and identically Gumble distributed with zero expectation and constant variance.

As the household is assumed to choose the energy source that yields the highest increase in indirect utility as their main energy source, the probability that the household will choose energy source *j* as the primary heat source is given by

$$P(F_J = \tilde{F}) = P\left(\frac{dV}{dF_j^*} \geq \frac{dV}{dF_k^*}\right) = P(\widetilde{\mu_J} \geq \widetilde{\varepsilon_J}) \quad \forall \quad k \neq j \tag{5}$$

where $\widetilde{\mu_J} = \mu_j - \mu_k$ and $\widetilde{\varepsilon_J} = \varepsilon_k - \varepsilon_j$. The probability of choosing energy source *j* as the primary heat source may be estimated using a Multinomial Logit model. Multinomial Logit models can be used when the alternatives in the choice set are mutually independent, i.e., the probability of choosing a particular alternative is irrelevant in the presence of other alternatives (this follows from the Independence of Irrelevant Alternatives (IIA) rule) (Train, 2003). The difference in expected indirect utility $\widetilde{\mu_J}$ is approximated by a linear function, which is given by

$$\widetilde{\mu_J} = \alpha + \sum_{k=1}^{K} \delta_k \mathrm{DK_k} + \sum_{m=1}^{M} \beta_m \mathrm{HC_m} \tag{6}$$

where $\mathrm{DK_k}$ are dummy variables for whether the household owns a particular type of heating equipment based on *k* = electricity, firewood, pellets, fuel oil and other types of energy sources and HC is a vector of characteristics of the household and residence describing the taste factor θ. This finding means that all factors or policies that increase the probability of choosing the desired energy good (j), relative to the consumption of an unwanted energy source (i), will be viewed as desirable.[7]

As potential factors influencing the choice of primary heat sources, we include both perception and attitude variables (Mahapatra and Gustavsson, 2008, Nyrud et al., 2008, Sopha et al., 2010, Lillemo et al., 2013) and household and residential characteristics (Howden-Chapman et al., 2009, Cayla et al., 2011, Song et al., 2012, Nesbakken, 1999, Rehdanz, 2007, Druckman and Jackson, 2008, Vaage, 2000, Yohanis et al., 2008) because they are all found to be important determinants of household energy consumption decisions in the literature. A complete list of variables is provided in Table 3.

4. Results and discussion

The estimation results are presented in Table 3. Column 1 shows the estimated coefficients for the probability of choosing firewood over electricity as the primary heat source. Column 2 gives the estimated coefficients for choosing pellets over electricity, and columns 3 and 4 give the coefficients for the probability of choosing fuel oils and other heat sources over electricity as the primary heat source. Columns 5 to 10 list the comparative results of coefficient estimates for the other combinations of energy sources. We cannot apply the Hausman test for the IIA assumption because of the weights used in the regression (Long and Freese, 2006).

[7] We cannot conclude that an insignificant result will not affect the share, only that a significant result will affect the share.

Table 3. Estimation coefficients from MNL regression for the choice of primary heat sources

Explanatory Variables	F-E[a]	P-E	O-E	D-E	F-P	F-O	F-D	P-O	P-D	O-D
Perceptions of attributes (comparing to electric heater):										
Woodstove yearly heat cost is low	0.40***	-0.34	-0.05	0.33	0.74**	0.45**	0.07	-0.29	-0.67**	-0.38
Pellet stove yearly heat cost is low	-0.23	0.68*	0.02	-0.39	-0.92**	-0.25	0.16	0.66	1.07**	0.41
Heat pump yearly heat cost is low	-0.14	-0.59*	-0.05	-0.23	0.45	-0.09	0.09	-0.55	-0.37	0.18
Woodstove warms up house effectively	0.84***	-0.96**	0.50	0.20	1.80***	0.34	0.63	-1.46**	-1.17	0.29
Pellet stove warms up house effectively	-0.70**	1.18**	0.21	0.27	-1.88***	-0.91	-0.97	0.97	0.91**	-0.06
Heat pump warms up house effectively	-0.04	0.22	-0.69	-0.75	-0.26	0.65	0.71	0.91*	0.97	0.06
It is more difficult to obtain firewood than pellet	0.03	1.96***	-0.33	-0.04	-1.93***	0.36	0.07	2.29***	1.99***	-0.29
Woodstove is environmentally friendly	0.08	-1.48**	0.45	0.79**	1.56**	-0.38	-0.72**	-1.94**	-2.28***	-0.34
Pellet stove is environmentally friendly	0.01	1.89***	-1.21**	-0.79**	-1.88***	1.22**	0.80**	3.10***	2.68***	-0.42
Heat pump is environmentally friendly	-0.14	-1.95**	0.66**	0.16	1.81**	-0.80**	-0.30	-2.62***	-2.11**	0.50*
Woodstove requires a lot of time and effort	0.07	0.28**	0.14	-0.23	-0.21*	-0.06	0.30*	0.15	0.51**	0.36*
Pellet stove requires a lot of time and effort	-0.16	-0.42	-0.01	-0.25	0.25	-0.15	0.09	-0.40	-0.16	0.24
heat pump requires a lot of time and effort	-0.13	-0.10	-0.11	0.60***	-0.03	-0.02	-0.73***	0.01	-0.70	-0.71**
Woodstove makes poor indoor air quality	-0.15	-0.02	-0.22	-0.10	-0.13	0.07	-0.06	0.20	0.08	-0.12
Pellet stove makes poor indoor air quality	-0.54**	-0.12	-0.40	-0.89*	-0.42	-0.14	0.36	0.29	0.78*	0.49
Heat pump makes poor indoor air quality	0.501**	-0.12	0.32	1.04**	0.62	0.18	-0.53	-0.44	-1.15*	-0.71
Attitudes towards using biomass for heating:										
Increased use of bio-energy is important to reduce GHG emissions	0.13*	1.49***	-0.03	-0.13	-1.36***	0.16	0.26	1.52***	1.62***	0.10
Firewood produce a lot local air pollution	-0.16**	-0.16	0.12	0.23	0.01	-0.28**	-0.39**	-0.28*	-0.39**	-0.11
Friends and family use much firewood for heating	0.24***	0.27*	-0.05	-0.07	-0.03	0.29*	0.31**	0.32*	0.34*	0.02

Heating equipment ownership:										
Electric heaters	-0.06	-2.14***	-2.60***	-3.90***	2.07***	2.54***	3.84***	0.46	1.77**	1.30**
Electric floor heating	-0.25	-0.02	0.16	-1.18**	-0.23	-0.41	0.93*	-0.18	1.16**	1.34**
Firewood stove, closed fireplace	1.62***	-1.22**	-0.85	-0.27	2.84***	2.47***	1.89**	-0.36	-0.95	-0.58
Open fireplace	-0.28	-2.08**	-0.84	-4.76***	1.79*	0.56	4.48***	-1.24	2.69*	3.92**
Air-to-air heat pump	-1.40***	-2.89***	-4.67**	-5.60**	1.49*	3.27*	4.20**	1.78	2.79	0.93
Kerosene or oil stove	-1.38**	-0.50	2.74***	- 11.69***	-0.88	-4.13***	10.31***	-3.24**	11.19***	14.44***
Characteristics of the household and residence:										
Mean heating degree days, divided by 100	0.02	0.20***	-2.60	0.08	-0.18***	2.62	-0.06	2.80***	0.12*	-2.68
Living in apartment, 1= yes, 0= no	-1.14**	0.96	0.16	3.08***	-2.11**	-1.30***	-4.23***	0.803	-2.12**	-2.92*
Age of dwelling, divided by 10	0.14**	-0.004	-0.85	-0.06	0.15*	0.99	0.21**	0.85	0.06	-0.79**
Size of house, 1-6	0.28**	0.04	-0.84	-0.07	0.24	1.12*	0.34	0.88**	0.11	-0.78**
Household yearly income before tax, 1-8	-0.15*	-0.11	-4.67**	0.34	-0.04	4.52	-0.49**	4.56**	-0.45	-5.00
Education level, 1-5	-0.14	0.46**	2.75***	-0.17	-0.59**	-2.88	0.03	-2.29	0.63**	2.91
Age of household respondent, divided by 10	-0.03	0.08	0.05	-0.22	-0.11	-0.08	0.19	0.03	0.31	0.28*
Constant	-4.02***	-19.96***	1.685**	-2.00	15.94	-5.71	-2.02	-21.64	-17.96	3.69
Observations	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695

* Statistical significance is measured at three levels, denoted * for significance values better than 10 per cent ($p < 0.10$), ** for significance values better than 5 per cent ($p < 0.05$), and *** for significance levels better than 1 per cent ($p < 0.001$).

*a) Note: E: electricity; F: firewood; P: pellet; O: fossil fuel; D: district heating or other; the term represents odds comparing alternative 1 to alternative 2 (**E,F,P,O,D**), e.g., F-E means the odds of choosing firewood over electricity.*

The explanatory variables are organised into four groups: perceptions of the attributes of the heating equipment relative to the attributes of electric heaters; attitudes towards using biomass for heating; ownership of heating equipment; and the characteristics of the household and residence. The determinants of increased consumption shares of different energy goods are estimated by examining the factors that increase the probability of selecting a particular energy good as the primary heat source. Because there are many variables in this estimation and ten different combinations of heat sources, we focus the discussion on the effects of the variables describing the perceptions of the attributes of the various types of heating equipment and attitude variables. Other variables, such as those characterising the ownership of heating equipment, are highly significant for most choices. Thus, although variables such as heating equipment ownership and household and residential characteristics are very important in the estimation to control for heterogeneity in opportunities and needs, they will only be commented on briefly when they are of particular importance to our research question.

4.1 Perceptions

We begin by examining how perceptions of heating attributes affect the selection of primary heat sources. The variables describing the perceptions of heating attributes are measured in relative terms, as the scores (on a 7-point scale) assigned to any other type of heating equipment relative to the score received by an electric heater. If two heat sources have the same score, the relative score equals 1. A one-unit increase in these variables thus results in a doubling of the score on this attribute for a particular heat source relative to the score on the attribute for electric heating.

We expect a high/low score for the positive/negative attributes relative to electricity to increase/decrease the probability of choosing this source to be the primary heat source over electricity, e.g., we expect that if a household believes that firewood is relatively less expensive than electricity, this would increase the probability of selecting firewood as the primary heat source over electricity. However, because all of these heat sources are alternatives, we have no prior expectations regarding the signs of cross-attribute effects, e.g., how a high score for inexpensive firewood relative to electricity will affect the probability of choosing pellets over fuel oil as the primary heat source. These cross-attribute results are, however, very informative with respect to understanding the choices, as we need to view all of the factors affecting the household's decision, including the perceptions of other relevant alternatives.

Examining the effects of the relative perceptions of *annual heating costs*, we see that the perception that the annual heating cost of woodstoves is low relative to electric heaters has a significant and positive effect on choosing firewood as the primary heat source relative to electricity, pellets and fuel oil (Table 3). A low heating cost associated with firewood is thus an important reason that households rely on firewood to heat their residences. This finding is consistent with the results from another Norwegian residential firewood demand study (Lillemo and Halvorsen, 2013). We also see from Table 3 that the relative desirability of firewood heating costs relative to electricity reduces the probability of choosing pellets over district heating. The direct effect of perceiving the annual cost of pellets cost to be low relative to electricity has a positive and significant effect on choosing pellets as the primary heat source, over electricity, firewood and district heating (Table 3). The only significant effect for the perception that heat pump costs are low relative to electric heaters is that it reduces the probability of choosing pellets over electricity because heat pumps also run on electricity.

Second, we consider the relative perceptions of the effectiveness of the heat sources. The estimated direct effects of perceptions regarding the effectiveness of firewood relative to electricity have a significant and expected effect on the likelihood of choosing firewood as the primary heat source over electricity and pellets. This result is as we expected because woodstoves are widely recognised as effective heating equipment (Nyrud et al., 2008, Gibilisco, 2007). We suspect that a high score on the effectiveness of firewood is an important reason that many households continue to use firewood as their primary heat source despite all of the time and work involved. We also find that the more effective individuals believe firewood to be (compared to electricity), the less likely they are to choose pellets as their primary heat source, over both electricity and fuel oil. Furthermore, the more effective individuals believe pellets to be compared to electricity, the higher the probability of choosing pellets over electricity, firewood and district heating. It also increases the probability of choosing electricity over firewood. With respect to the perceived effectiveness of the heat pump, it only exhibits an indirect, positive effect on the choice of pellets over fossil fuel.

We also find that more easily accessible pellets, compared to firewood (the most commonly used fuel), have a significant positive effect on the probability of choosing pellets as the primary heat source. This coefficient is very large and significant; indicating that easy access to pellets is a major contributor to households choosing pellets as the primary heat source. The finding is consistent with the results of a recent pellet adopter study (Skjevrak and Sopha, 2012). If individuals perceive the acquisition of pellets to be difficult, this will severely reduce the likelihood of adopting pellets as the primary heat source.

With respect to perceptions regarding the *environmental desirability* of a fuel, we have several and very significant direct and cross effects, particularly relating to pellets (Table 3). When households believe that pellet stoves are relatively environmentally friendly, the probability of choosing pellets as the primary heat source increases significantly. This implies that pellet adopters are highly motivated by environmental concerns, which is consistent with previous heating studies in Norway (Lillemo et al., 2013, Sopha et al., 2010). Households believing that firewood is more environmentally friendly than electricity generally do not choose pellets as their primary heat source. One interpretation of this finding is that a positive attitude towards woodstoves may lead households to continue using traditional firewood instead of pellets. This perception might "crowd out" the potential pellet adopter because environmental concerns are considered a key motivation of pellet users in Norway, as we mentioned above. A relatively higher score on the perceived environmental friendliness of a heat pump relative to electric heaters seems to increase the probability of choosing electricity, district heating/other and firewood over pellets. That is, households that perceive heat pumps more environmentally friendly than electric heaters will have a less tendency to choose pellets compared other energy sources.

In particular, woodstoves and pellet stoves require considerable *time and effort* to use: acquiring the fuel, storing it, carrying it into the house, lighting a fire and cleaning up afterwards. We find that the perceptions of the additional time and effort required to use firewood relative to electricity significantly increase the probability of choosing pellets over electricity and firewood. The pellet heating is perceived as being more time- or labour-saving than firewood heating. Moreover, this perception is also associated with a higher probability of choosing fuel oil, firewood and pellets over district heating/other. Furthermore, if the heat pump is perceived as requiring a more substantial amount of time and effort than electric heaters, this increases the probability of choosing distinct heating/other over electricity, firewood and fuel oil.

As smoke and dust may affect *indoor air quality*, we find that the belief of indoor air quality concerning heating equipments is important in explaining the choice of the primary heat source and that some cross effects are significant. Perceiving pellets as resulting in relatively poorer indoor air quality than electric heaters is significantly associated with lower probability of choosing firewood relative to electricity. Although this result does not demonstrate a direct link between individual perceptions of pellet attributes and the choice of firewood and electricity consumption, it does imply that perceptions of poor indoor air quality reduce the attractiveness of biomass heating when individuals decide whether to rely on biomass or electricity for heating. Believing that the heat pump results in poorer indoor air quality than do electric heaters significantly increases the probability of choosing firewood over electricity as the primary heat source because the heat pump is driven by electricity (and is thus categorised under electricity as a type of primary heat source). This also increases the probability of choosing district heating/other over pellets or electricity as the primary heat source.

4.2 Attitudes

Examining attitudes towards the use of biomass for heating, we find that the belief that biomass use is important in fighting climate change significantly increases the probability of choosing both firewood and pellets as the primary heat source over other alternatives. Believing that firewood produces substantial local air pollution significantly reduces the probability of choosing firewood over electricity or district heating/other as the primary heat source. If friends and family use a substantial amount of firewood, this significantly increases the likelihood of using firewood as the primary heat source compared to other alternatives. It also increases the probability of choosing pellets over fuel oil and district heating. These results again suggest that environmental factors matter in Norwegian households' energy decisions.

4.3 Heating equipment ownership

The ownership of the different types of heating equipment is included in the estimation to control for heterogeneity. In general, the ownership of heating equipment directly determines the heat sources that households have the opportunity to use. However, what a household selects as the primary heat source not only depends on the ownership of a particular piece of equipment but also on all alternative types of heat equipment installed. Here, we are also interested in the cross effects, e.g., how the ownership of woodstoves affects the probability of choosing pellets as the primary heat source.[8]

Regarding the direct effects, we see that ownership of different types of heating equipment has the expected sign when significant. The ownership of electric heating equipment (heaters, floor heating and heat pumps) reduces the probability of using alternatives to electricity as the primary heat source, and ownership of firewood stoves/closed fireplaces and kerosene/oil stoves increases their respective probability of use as the primary heat source. In particular, owning a heat pump significantly reduces the possibility of using any energy source other than electricity as the primary heat source. It also increases the probability of choosing firewood when compared to alternatives other than electricity. The increased use of heat pumps in Norwegian homes over the last decade is thus likely to have increased the reliance on electricity as the primary heat source.

Examining the other cross effects in greater detail, we see that they are relatively significant and, in some cases, also strong. Owning a woodstove or closed fireplace decreases the likelihood of using pellets over electricity as the primary heat source. Finally, we see that owning a kerosene or fuel oil stove significantly reduces the probability of using firewood or district heating/other sources as the primary heat source relative to electricity and pellets.

4.4 Building and household characteristics

We also observe a number of significant and strong effects of building and household characteristics on the primary heat source decision. First, the local climate is important because the heating degree days variable has a significant impact on households' probability of choosing pellets over electricity, firewood, fuel oil and district heating/other as the primary heat source. In colder parts of the country, households are more likely to use pellets as the primary heat source.

The type of dwelling also significantly affects the choice because it determines the ability to have different types of heating equipment installed in the residence. For example, living in an apartment significantly decreases the likelihood of using firewood but increases the likelihood of choosing district heating/other as the primary heat source. The reason for the former result is that many apartment buildings do not have chimneys. The explanation for the latter result is that

[8] Owning a pellet stove is indirectly included in the analysis through a weighted index. The weight that we use is generated from the percentage difference in pellet stove ownership between the two survey samples

central heating systems based on district heating are much more common in apartment buildings than they are in separate homes.

The age of the dwelling is significantly associated with a higher possibility of relying on firewood to heat the residence, as firewood is the traditional heat source in Norway. Many households retain old heating equipment due to high renovation costs or to maintain the ability to switch between many different heat sources on short notice. The size of the dwelling also affects the choice of the primary heat source, e.g., a larger residence increases the probability of choosing firewood over electricity

We find that the probability of using district heating/other instead of electricity increases significantly with income, whereas the probability of using fuel oil instead of electricity decreases significantly. Second, we find that the probability of choosing pellets and fossil fuel relative to electricity increases significantly with the education level of the household head. This is consistent with the findings of Vagge (2000). The age of the household head significantly increases the probability of choosing fuel oils over district heating/other as the primary heat source.

5. Conclusions

The primary aim of this paper is to determine a method for evaluating the main drivers of and behavioural barriers to increasing the share of biomass and reducing reliance on electricity and fossil fuels in household stationary energy consumption, as this information is essential in understanding households' responses to various policy measures. Because most Norwegian households are able to use a combination of energy sources for heating, the use of previously existing heating equipment is important in determining the short run consumption shares of various energy sources. Because firewood, pellets and fuel oils are storable goods, their consumption shares are not directly observable from demand information. Thus, we developed a theoretical model to identify the determinants of increased consumption shares of various energy goods by examining the factors that increase the probability of choosing an energy good as the primary heat source. The model can also be used to represent other environmental choices: for example, it could be used to model consumption decisions concerning the main vehicle or fuel used by households.

In our application, we find that perceptions of heating attributes, such as heating cost, effectiveness, time and effort needed to operate the equipment and indoor air quality, guide households decisions regarding the primary heat source. In particular, we find that perceptions regarding environmental friendliness are important in choosing pellets as the primary heat source. Positive beliefs concerning the attributes of electric heating (especially for heat pumps) are important in explaining why households rely heavily on electricity for space heating. Furthermore, the perceived advantages of firewood are also important in explaining why firewood remains a major energy carrier in Norwegian homes, despite the high non-economic costs related to firewood consumption (carrying, chopping, storing).

We also find several important cross effects with respect to the perceptions of different types of heating equipment, in particular for pellets but also for district heating. For instance, the results indicate that a positive perception of firewood significantly reduces the probability of choosing pellets. In addition, positive perceptions of firewood and heat pumps in terms of environmental friendliness and cost significantly reduce the likelihood of using pellets as the primary heat source. Attitudes towards using biomass for heating also have numerous significant direct and indirect effects on the choice of the primary heat source. The belief that increased use of biomass for heating can reduce GHG emissions is particularly important in choosing pellets as the primary heat source. Traditions also seem to be important in the choice of firewood as the primary heat source.

Our results seem to indicate that households using a traditional mix of energy sources, e.g., a combination of electricity and firewood (and fuel oils), do not use pellets. Thus, the factors that support the more traditional energy sources seem to segment the traditional consumption pattern and are one of the main barriers to the spread of pellets in Norwegian households. However, this does not necessarily hamper the use of all types of new equipment. For instance, heat pumps are often used in combination with the traditional energy mix. We also see that different sources of biomass are seldom used in combination with each other, but rather in combination with electricity. Thus, an increased use of pellets would be in direct competition with an increased use of firewood.

Although both heat pumps and pellet stoves became easily available approximately 10 years ago, their market shares in Norway differ considerably. Heat pumps have become popular among the approximately one quarter of Norwegian households owning one, whereas less than one per cent own a pellet stove. Our results suggest that positive perceptions of woodstoves and heat pumps are some of the most important reasons that pellet stoves have not succeeded. It seems that choosing a pellet stove involves changing the entire method of heating one's residence, whereas the heat pump can be included in the traditional heating pattern.

The most important factor in our results is that of owning the different types of equipment. Ownership is also more easily affected by policy measures than perceptions. Thus, policies targeting investments will likely be the most effective. However, as our results and the Norwegian case show, investment subsidies are no guaranty for success because the choice of using a particular type of equipment relies not only on perceptions of that equipment but also on the perceptions of the alternatives. The heat pump became very popular, while pellet stoves are virtually non-existent in household energy consumption. This finding indicates that it may prove difficult to simultaneously increase both the share of new biomass energy, such as pellets, and energy efficiency through an increased use of heat pumps.

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Paper III

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The impact of lifestyle and attitudes on residential firewood demand in Norway

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ABSTRACT

In this paper, we analyze the determinants of the demand for firewood by Norwegian households, focusing on intrinsic factors such as lifestyle and environmental attitudes, along with household socioeconomic characteristics. The data are from the Norwegian Consumer Expenditure Survey and a supplementary questionnaire on energy consumption and lifestyle. We apply a zero-inflated negative binomial model to correct for over-dispersion and the excessive number of zeros in the data. The results indicate that an urban lifestyle and concerns for comfort are negatively associated with firewood demand. In addition, price has a strong negative effect on demand. However, the most important determinants of household firewood demand are the characteristics of the household residence, including location, and household characteristics such as age and income.

1. Introduction

Norwegians have a long tradition of using firewood to heat their residences, and historically firewood was the dominant source of heating for most households. However, in the last decades the use of other energy sources has increased, and electricity is now the main heating source for 70% of Norwegian households [1]. While firewood remains the second most important source of heating in Norwegian households, its share of total energy use has fallen significantly, and now accounts for less than 20% of household energy consumption [2]. Nonetheless, biomass energy resources remain abundant in Norway [3,4], and as a renewable energy source, biomass is expected to play a significant role in both reducing greenhouse gas emissions [5] and combating global warming [6]. The consumption of biomass, such as firewood and pellets, is encouraged by the Norwegian government as a means of reducing the dependency on electricity, develop rural areas and combating climate change [7].

To achieve the policy aim of increased use of biomass for residential heating, we need to better understand the factors affecting firewood demand. Economic costs are important when households make choices regarding energy use, but price and heating cost are not the only determinants [8,9]. Haas et al. [10], for instance, argue that behavior pattern plays an important role in explaining total energy consumption for space heating by private homeowners. In general, what we choose to buy or consume also reflects who we are, including our lifestyle and attitudes or preferences about time, comfort, and environmental concerns [11]. By lifestyles we mean a set

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of basic attitudes, values, and patterns of behavior that are common to a social group. In this study, we represent lifestyles in terms of consumption patterns and attitudes. Furthermore, the characteristics of the household and residence are also the key factors in explaining the total firewood demand for heating.

Several studies discuss the determinants of household energy consumption (or expenditures) for heating purposes in Europe [12–20]. Although most of these studies include household socioeconomic factors in explaining the demand, few consider household attitudes, lifestyle, or other identity statements. Furthermore, most of these studies focus on the demand for electricity, and very few include other energy sources in the analysis [12]. Even fewer specifically analyze the attitude or perception determinants of household firewood demand. As an exception, Nyrud et al. [17] adopts a structural equation modeling approach to examine the use of new and more energy efficient woodstoves in Oslo. They concluded that the key factors determining the inclination of households to invest in the new woodstove were economic benefits, heating performance, the perceived time and effort in operating the stove, and the environmental effects of heating, as well as the perceived subjective norm. However, in their study, they did not model the actual demand for or expenditure on firewood. Actual firewood demand is rarely being studied, partly because of the complexities in measuring and estimating firewood consumption [21].

Analyzing firewood consumption is generally complicated for a number of reasons. First, most households have problems accurately reporting their consumption of firewood as the feedstock may come from either purchases, gifts, or their own gathering and chopping. Fortunately, our data have information on all of these sources of firewood. In addition, the customary way of measuring firewood in cords (3.62 m^3 of well-stacked wood) is unfamiliar to most users, and firewood is instead often purchased in sacks of various sizes or on pallets. Thus, reporting the exact amount of firewood acquired by the household is difficult.

Second, in a representative sample, there will be many zero observations for firewood consumption, and this makes estimation difficult. Zero observations may arise for two main reasons. First, the household will not acquire firewood if it does not have a woodstove or fireplace in its residence (i.e. no opportunity for consumption). This group will never acquire firewood (hereafter referred to as "always zero"). Alternatively, the household may choose not to acquire firewood because it is either consuming firewood from an existing stock or because it chooses not to consume firewood at all (i.e. a corner solution). This second group of consumers may choose to acquire firewood depending on the price, income, or other factors.

The main aim of this paper is to estimate a model of firewood demand and to identify the characteristics of firewood use. Hopefully it can contribute to the development of improved policy measures aimed at increasing the utilization of solid biomass consumption in Norwegian households. The estimation draws on a unique data set, which includes data on both firewood consumption and household attitudes and lifestyles. By studying household consumption decisions, we can see how differences in lifestyle factors affect decisions on how much firewood to consume.

2. Modeling household lifestyle and energy use

Classical consumer theory assumes that consumers choose the consumption bundle that maximizes their utility subject to a budget constraint [22], such that consumption is a function of income and prices for a given set of preferences. Consumers often choose certain products, services, and activities because they are associated with certain lifestyle patterns or social identification [23]. In the current analysis, lifestyle refers to a pattern of consumption reflecting individual choices of how we spend time and money: that is, who we are and what we do [11]. We follow Akerlof and Kranton [24] and specify a demand function in which we can include, among other things, assumptions concerning attitude and identity statements. We assume the decision maker's utility function is given by:

$$U_i = U_i(a_i, I_i(a_i, k_i, l_i)) \quad (1)$$

where a_i is the action made by household i, in our case, the action of using firewood for heating. Note that the household is the observation unit. The variable I_i represents identity, which describes the household's lifestyle patterns and attitudes, and thereby reflects attitudes about time, comfort, cost, and the environment, etc. The variables k_i and l_i respectively represent the characteristics and lifestyle of household i. Note that the identity statements depend on the chosen actions, lifestyle, and characteristics of consumers. In this model, the consumers derive utility, not only through the consumption of goods or services, but also from the opportunity to express their identity. Household i is then assumed to select that action a_i and lifestyle l_i, which maximizes their utility U_i. We assume that all household preferences are given.

We expect household lifestyles and attitudes to be important determinants of firewood consumption. This is because relying on firewood for heating the residence requires considerable time and effort. First, the household has to acquire the firewood, by purchasing and/or chopping and piling the wood. This is hard and time-consuming labor. Second, heating with firewood also requires daily labor to feed the stove. Third, cleaning the ashes away after wood burning is also tedious work for most people. Finally, lighting the stove and keeping the fire burning at the desired intensity takes skill, particularly with older woodstoves. Thus, it takes a serious commitment to use firewood to heat the residence on a daily basis, especially when you take into consideration the comparative simplicity of operating electric panel ovens and heat pumps. Thus, we expect households that are traditional in their lifestyle and spend much time in the residence to have the highest firewood demand.

3. The data

In this analysis, we apply a unique data set containing information on household energy consumption, characteristics of the household and the household residence, as well as information about attitudes and lifestyle. The main source of data is the Norwegian Survey of Consumer Expenditure (NSCE) conducted by Statistics Norway. The NSCE contains information concerning household expenditures on a wide range of goods, including firewood.

In both the 1997 and 1998 surveys, a supplementary questionnaire was included containing questions about household attitudes towards energy consumption, as well as questions concerning lifestyle and environmental concerns [25].

Unfortunately, the NSCE did not include this supplement in any subsequent years, so we do not have access to more recent data. Conducting a similar survey by collecting firewood consumption information with the same accuracy as in the NSCE would be very costly, and as far as we are aware, Statistics Norway has no plans for repeating the survey in the near future. Even though heating practice has changed somewhat during the last 15 years, firewood remains the second most used energy source in Norwegian households, and we expect that the driving forces underlying household firewood consumption have not changed substantially.

The sample in the NSCE is drawn randomly from the Norwegian population, and each drawn individual is attached to a family. Of the original sample of 2000 households, 1361 households responded to both the main survey and the supplementary energy questionnaire. Of these, 1155 observations remain after deletions because of missing values and errors in the data. The main NSCE survey contains information about, among other things, the amount of firewood acquired (purchased, chopped by the consumer, or received as a gift) during the last 12 months, measured in volumes (sacks). The survey also contains information about the characteristics of the household and residence. The individual in charge of purchases in the household answered both the main survey and the supplementary questionnaire on energy.

To measure the respondent's attitudes towards the environment and comfort, time spent outside the residence, and the degree of urban lifestyle (frequency of going to theaters, cinema, eating out, etc.), We create several indices based on the responses to the supplementary questionnaire on these questions. This questionnaire also provides information about whether the household engaged in any form of electricity-saving behavior. We treat this variable as an indication of attitudes and lifestyle, as pronounced savings behavior is an indication of a desire to save energy.

Table 1 details the mean values of the main variables used in this analysis. In order to see how the variables vary across households with different lifestyles, we calculate the means for six different groups of households. Column 1 includes the means for all households in the sample. Column 2 reports the means for households engaged in electricity-saving behavior and Column 3 tables the means of households with a high score on the comfort index (scores greater than three). Columns 4–6 report the means of households in the upper quartiles of the distributions of urban living index, the time out of the residence index and the environmental concern indexes respectively.

As shown in Table 1, households living an urban lifestyle use relatively less firewood and households that are more environmentally conscious use relatively more firewood than other households. Environmentally conscious households also have a lower likelihood of a zero observation for firewood consumption. Households with an urban lifestyle face the

Table 1 – Mean values for the main variables used in the analysis.

Variable	All	Electricity savers	Comfort seekers	Urban lifestyle	Often outside residence	Concerned with the environment
Total acquired firewood consumed (sacks)	36.30	33.17	33.06	24.93	33.13	40.46
Zero firewood consumption (0, 1)	0.41	0.41	0.42	0.48	0.40	0.36
Price of firewood (Euro)	2.38	2.30	2.40	2.74	2.47	2.45
Involved in electricity-saving behavior (0, 1)	0.74	1.00	0.70	0.68	0.71	0.80
Urban living style index (1,..., 5)	1.96	1.94	1.99	2.87	2.11	1.90
Comfort concern index (1,..., 5)	3.41	3.40	4.32	3.50	3.52	3.29
Time spent outside residence (hours per week)	19.76	20.23	20.13	25.82	39.37	19.43
Environmental concern index (1,..., 5)	3.16	3.17	3.13	3.21	3.15	4.20
Living in detached house (0, 1)	0.62	0.62	0.63	0.55	0.61	0.57
Living in farmhouse (0, 1)	0.09	0.09	0.08	0.05	0.05	0.14
Living in apartment (0, 1)	0.10	0.11	0.10	0.19	0.14	0.14
Size of dwelling (m^2)	134.99	135.38	136.92	130.79	126.03	125.81
Time living in current residence (years)	13.60	14.38	13.49	10.19	11.93	16.02
Living in cities (0, 1)	0.21	0.23	0.22	0.28	0.24	0.23
Owning cottage in the mountains (0, 1)	0.12	0.12	0.13	0.11	0.13	0.12
Household yearly income after tax (125 Euro)	214.14	206.49	218.03	238.97	198.23	210.76
Education level (1,..., 8)	4.19	4.16	4.21	4.48	4.03	3.90
Age of household (years)	45.33	46.27	45.22	40.56	42.86	49.22
Number of observations	1361	503	757	202	248	322

1 Euro = 8 NOK.
Data source: Statistics Norway Survey of Consumer Expenditure for 1997–1998 with supplementary questionnaire on energy and lifestyle [25].

highest mean prices for firewood, which may in part explain their lower consumption.

The next group of variables is the score on the lifestyle and attitude indexes. We can see that households living an urban lifestyle are considerably less involved in electricity-saving behavior, particularly when compared with the group of environmentally concerned households. In turn, environmentally concerned households score lower on the comfort index compared with other households. Households with an urban lifestyle spend more time outside the residence than other groups. Given "time spent outside residence" also includes outdoor activities such as camping and hiking, this does not necessarily coincide with an urban lifestyle.

With respect to the choice of residence, two particular groups stand out: households living an urban lifestyle and environmentally concerned households. Households living an urban lifestyle are more likely to reside in apartments and less likely to live in detached houses or farmhouses than the average household. Compared with the average household, they also reside in smaller residences in the city and have lived in their current residence for a shorter period. In contrast, environmentally concerned households are more likely to live in either an apartment house or a farmhouse. Compared with the average household, they also typically reside in smaller residences and have lived there for a longer period.

With respect to household characteristics, households living an urban lifestyle have a relatively higher mean income, a higher level of education, and are younger. In contrast, environmentally concerned households are relatively old and have a lower level of education. We can also see that households that are seldom in their residence have a lower income and are younger than the average household.

4. Econometric modeling

The comparison of means in Table 1 provides some indication that lifestyle and attitudes are important in explaining the variation in household firewood demand. However, we also see that other characteristics of the household vary across the different lifestyles. Thus, the difference in firewood demand between these groups may result from the differences in the preferences for firewood by different lifestyles or differences in other important background variables, such as the size and type of residence or other household characteristics. In order to find the partial effect of lifestyle factors on firewood demand, we therefore need to conduct a regression analysis and undertake a comparison ceteris paribus.

4.1. *The distribution of firewood demand*

The dependent variable in our model is the amount of firewood the household acquired during a year, as measured in units of 70-L sacks. Fig. 1 illustrates the distribution of the number of sacks acquired by the households in our sample. As shown, the distribution of our data is strongly skewed to the left, with many zero observations: about 41% of the sample did not acquire any firewood during the previous 12 months (see also Table 1). In such cases, the ordinary least squares estimator of a linear regression is biased and inconsistent. Even if we were to use only positive observations of the dependent variable, we would be unable to reduce this bias [26]. Therefore, we need to use a model that can include a dependent variable with many zero observations. Furthermore, the unconditional variance of our dependent variable (56.34 sacks) is much larger than the mean (36.30 sacks). This is an indication of overdispersion, which is quite common for count data with excess zeros [26]. Both the overdispersion and the excessive number of zeros in our data suggest we may have an additional problem with unobserved heterogeneity.

As information on the ownership of a woodstove is not available in our data, we do not know whether the zero observations result from a corner solution or the lack of consumption opportunities. A standard Poisson model is not an appropriate choice in this case because it only accounts for observed heterogeneity and cannot deal with excess zeros and overdispersion. To account for the excessive zero problem, we require a zero-inflated model [27] with a negative binomial regression model to correct for the overdispersion. Thus, we apply a zero-inflated negative binomial (ZINB) model with a different probability model for the zero and nonzero counts.

4.2. *Zero-inflated negative binomial model*

The zero-inflated model assumes that there are two unobserved groups: "always zero" and "not always zero" [28]. In our case, the "always zero" group is equivalent to households that lack a (working) woodstove or fireplace. The "not always zero" group are households that have opportunities to consume and can then either choose zero (corner solutions) or any positive amount of firewood consumption. Zero-inflated models estimate two equations simultaneously, one for the count model of the number of sacks acquired, and one for the probability of belonging to the "always zero" group. The probability density of firewood consumption is thus a discrete–continuous mixture of consumers with positive consumption and consumers with zero consumption on firewood. By increasing the conditional variance and the probability of the zero counts, it can

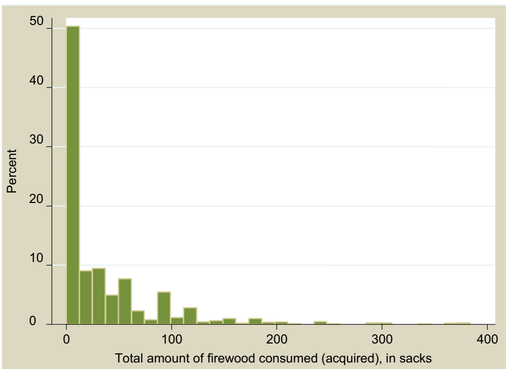

Fig. 1 – Amount of firewood consumed (acquired) by Norwegian households, in sacks[a].
[a]Histogram is drawn using percentages with Stata 12 (bin = 31, start = 0, width = 12.38).

take into account situations where the difference processes generate the zeros.

In the estimation, we refer to the "always zero" group as Group A. As shown in equations (2) and (3), a binary choice model determines household group membership, where π_i denotes the probability of belonging to Group A, and μ_i is the expected utility of firewood consumption:

$$\pi_i = \Pr(A = 1|z_i) \tag{2}$$

$$\mu_i = \exp(x_i\beta) \tag{3}$$

The z-variables are explanatory variables for the inflated model while the x-variables are explanatory variables for the count model. We specify different explanatory variables for the count equation and the inflated equation in our model. $A = 1$ means households do not have the opportunity to consume firewood. Equation (4) provides the overall probability of a zero count and a positive count in the data:

$$\Pr(y_i = k) = \begin{bmatrix} \pi_i * \Pr(y_i = 0|x_i, A_i = 1) + (1 - \pi_i) * \Pr(y_i = 0|x_i, A_i = 0) & \text{if} \quad k = 0 \\ \pi_i * \Pr(y_i = k|x_i, A_i = 1) + (1 - \pi_i) * \Pr(y_i = k|x_i, A_i = 0) & \text{if} \quad k = 1, 2, \ldots \end{bmatrix} \tag{4}$$

where y_i denotes the count number of sacks of firewood acquired and k is the observed count for all the households. Note that the overall rate of probability of zero and positive components mix according to their proportions in the population. The likelihood function is built to distinguish between consumers with different consumption opportunities [29].

4.3. *Specification of the demand for firewood*

Empirically, we specify the deterministic function for the count model in equation (5):

$$\begin{aligned}\mu_i = \exp\,(&\beta_0 + \beta_1\text{saving}_i + \beta_2\text{urban}_i + \beta_3\text{comfort}_i + \beta_4\text{time}_i \\ &+ \beta_5\text{environment}_i + \beta_6\text{detachedhouse}_i + \beta_7\text{farmhouse}_i \\ &+ \beta_8\text{apartment}_i + \beta_9\text{housesize}_i + \beta_{10}\text{livyrs}_i + \beta_{11}\text{city}_i \\ &+ \beta_{12}\text{cottage}_i + \beta_{13}\text{price}_i + \beta_{14}\text{income}_i + \beta_{15}\text{edu}_i + \beta_{16}\text{age}_i + \varepsilon_i)\end{aligned} \tag{5}$$

Column 1 in Table 1 lists the descriptions of the explanatory variables. In the model, we assume that each household's firewood consumption may reflect its lifestyle, social identification, and attitudes to comfort, time, and environment, and other demographic factors, such as income, education, age, etc. In equation (5), ε_i is the error term and $\exp(\varepsilon_i)$ is gamma distributed with a mean of unity and variance α [30].

5. Results and discussion

Tables 2 and 3 provide the estimation results from the ZINB continuous count and binary equations, respectively. The estimated parameters and the respective z-statistics are in columns 1 and 2. Asterisks indicate the levels of significance for the estimated parameters. In order to obtain a better understanding of the estimated coefficients in the ZINB model, we also report the percentage change in the expected count predicted by the estimation from a one unit and one standard deviation increase in the explanatory variables (see columns 3 and 4). Following Long and Freese [28], we use Stata 12 for all estimations and post-estimation calculations. We tested the model fit of the ZINB model against a zero-inflated Poisson (ZIP) model. While both models generated quite similar results, the ZIP results are more significant. However, not correcting for overdispersion normally results in consistent, yet inefficient estimation of the dependent variable. And the results are exemplified by spuriously large z-values and small *p*-values because of downwardly biased standard errors [31]. We suspect that this might be the case using our data. Thus, we only report the results of the ZINB model.

As shown in Tables 2 and 3, most of the estimated coefficients are statistically significant at the 5% level and with their expected signs. The overdispersion index, alpha (α), is statistically significant at the 1% level, which implies that applying a zero-inflated model is of benefit. In addition, the z-value of a Vuong test of the ZINB model vs. a standard negative binomial model is 15.51, suggesting that the ZINB better fits our sample than a standard negative binomial estimator [32].

Note that when the same variables are included in both the count model and the binary equation, the signs of the corresponding coefficients from the binary equation often lie in the opposite direction of those from the count equation (compare Tables 2 and 3). This is because a positive sign on a coefficient in the binary choice estimation implies a lower probability of the opportunity to use firewood, whereas a negative coefficient in the count model indicates low firewood consumption. As the binary estimation (reported in Table 3) only defines the likelihood for observations having strictly zero counts, our interpretation of the results will focus on the results from the continuous part of the estimation, as we are primarily interested in how various factors affect the amount of firewood households consume.

5.1. *Lifestyle factors*

The results generally indicate that several household lifestyle factors have a significant impact on firewood consumption. In particular, households with a more *urban lifestyle* use significantly less firewood, in that a one unit increase in the index of urban living style brings about a 15% decrease in the expected count of the number of sacks of firewood acquired. These results indicate that households that frequently participate in city life activities, such as going to the cinema, restaurants, etc., use less firewood than other households, ceteris paribus.

Table 2 – Estimation results from the continuous part of the zero-inflated negative binomial model (number of sacks acquired).

Explanatory variables	*b*	z	*p*-Value	%X	%StdX
Identifications and attitudes:					
Involved in electricity-saving behavior (0, 1)	0.116	1.520	0.128	12.3	5.2
Urban living style (1,…, 5)	−0.161**	−2.408	0.016	−14.8	−8.2
Comfort concern index (1,…, 5)	−0.058**	−2.122	0.034	−5.7	−6.3
Time spent outside house (hours per week)	−0.003	−1.279	0.201	−0.3	−3.9
Environmental concern index (1,…, 5)	−0.005	−0.103	0.918	−0.5	−0.3
Dwelling factors:					
Living in detached house (0, 1)	0.355***	3.688	0.000	42.7	18.7
Living in farmhouse (0, 1)	0.622***	4.582	0.000	86.3	18.6
Living in apartment (0, 1)	−0.333**	−1.951	0.051	−28.4	−9.2
Size of dwelling (10 m^2)	0.008	1.351	0.177	0.8	4.9
Total years in current residence (10 years)	0.086**	2.237	0.025	9.0	10.0
Living in cities (0, 1)	−0.318***	−3.231	0.001	−27.2	−12.2
Owning cottage in the mountains (0, 1)	0.228***	2.516	0.012	25.6	7.8
Demographic factors:					
Price of firewood (Euro)	−0.080***	−7.361	0.000	−7.7	−18.1
Household yearly income after tax (125 Euro)	0.0002	0.733	0.463	0.0	3.0
Education level (1,…, 8)	−0.085***	−3.449	0.001	−8.2	−11.7
Age of the main income contributor (10 years)	−0.109***	−3.030	0.002	−10.3	−13.0
Constant	4.923***	15.86	0.000		
Overdispersion factor	−0.445***	−7.93			
LR $\chi^2(16) = 216.83$	Prob > $\chi^2 = 0.0000$				
Log-likelihood	−4082.16				
N	1155				

$^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
b = raw coefficient. z = z-score for test of $b = 0$. $P > |z|$ = p-value for z-test. %X = percent change in expected count for one unit increase in X. % StdX = percent change in expected count for one standard deviation increase in X.

Households that score high on the *comfort* index are also likely to consume less firewood, such that when the comfort index increases by one unit, households use 5.7% less firewood. Firewood heating requires a number of daily labor inputs, including fetching the firewood, feeding the fire, and the cleaning out of ash and other residue. Even if some households experience that the fireplace brings comfort, this is not sufficient to make the overall effect positive.

The effect of being an *electricity saver* is not significant, contrary to our expectations, as using firewood to heat the residence is one of the most effective ways to save electricity. In addition, in the estimation, the index for *time used outside the house* is not significant. This is somewhat surprising, as we expected households that allocate more time on activities outside the house to consume relatively less firewood. In addition, it is also somewhat surprising that the coefficient for

Table 3 – Estimation results from the discrete part of the zero-inflated negative binomial model (probability of belonging to the "always zero" group).

Explanatory variables	*b*	z	P > z	%
Involved in electricity-saving behavior (0, 1)	−0.254*	−1.741	0.08	−22.3
Urban living style (1,…, 5)	0.082	0.630	0.529	8.5
Comfort concern index (1,…, 5)	0.074	1.293	0.196	7.8
Living in detached house (0, 1)	−0.382**	−2.188	0.029	−31.8
Living in farmhouse (0, 1)	−1.290***	−3.970	0.000	−72.8
Living in apartment (0, 1)	0.369	1.397	0.162	44.7
Size of dwelling (10 m^2)	−0.061***	−4.307	0.00	−5.9
Living in cities (0, 1)	0.152	0.875	0.38	16.5
Owning cottage in the mountains (0, 1)	−0.572**	−2.712	0.007	−43.6
Education level (1,…, 5)	0.138***	2.948	0.00	14.8
Age of main income contributor (10 years)	0.1521***	2.884	0.00	16.4
Constant	−0.735	−1.48		
N	1155			
Vuong test	z = 15.51 Pr > z = 0.0000			

$^*p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.
b = raw coefficient. z = z-score for test of $b = 0$. $P > |z|$ = p-value for z-test. %X = percent change in expected count for one unit increase in X. % StdX = percent change in expected count for one standard deviation increase in X.

the household's *environmental attitude* index exhibits a negative and insignificant effect on firewood use. This is interesting, as Table 1 showed that these households had higher firewood consumption than the average household. This indicates that we can attribute the higher firewood consumption in households with strong environmental concerns to differences in other variables, such as the age, type, and size of the residence. Thus, even if we observe that environmentally conscious households on average use more firewood, we cannot deduce that this is because of their environmental concerns (as we might have done if only considering the results in Table 1). This illustrates the importance of a multivariate estimation in assessing the partial effect of any variable.

5.2. *Household and residential characteristics*

The results show a large and very significant effect of the price of firewood on the demand for firewood, such that a one standard deviation increase in the price of firewood results in an 18% decrease in the expected number of sacks of firewood acquired. This is the third largest effect in the estimations as measured by a one standard deviation increase in the explanatory variable. This indicates that cheap access to firewood is one of the most important contributors to explaining firewood consumption in Norwegian households, and that economic considerations are very important when determining how much firewood is used for heating. However, the income variable is not significant, suggesting that the use of firewood is distributed over all income groups.

We can see from Table 2 that dwelling factors and household demographics are also very important determinates of household firewood consumption. These factors describe the heterogeneity in preferences across households, and the limitations in the opportunities of the household to choose between the various energy sources. In addition, they describe differences in the needs between households with respect to providing heating services for household members.

Variables describing the type of residence, residence characteristics, and the ownership of cabins all have a very strong and significant effect on firewood consumption. Living in *detached houses* and *farmhouses* and *owning a cottage* in the mountains all have a significant positive impact on total firewood consumption. The expected purchases of firewood increase by 43% and 86% respectively for households living in detached houses or farmhouses, while owning a cottage in the mountains increases the acquired amount of firewood by 26%. Conversely, households living in apartments acquire about 28% less firewood compared with other households. We can also see that living in one of the five largest cities in Norway reduces household firewood purchases by 27%. The results also indicate that households living longer in their *current place of residence* increase the number of sacks of firewood acquired, as does households living in larger houses.

With respect to the other demographic factors, we can see that firewood demand decreases with the *age* of the main income contributor in the household. This is a somewhat different finding from that in a US study by Liao and Chang [33]. They found that the space heating energy requirement increases as the aged become older, but with increased use of natural gas and fuel oil as alternatives to electricity. However, firewood consumption involves daily labor and hard work; older households may then prefer to reduce their use of firewood for heating as they age. *Education level* also exhibits a negative relationship with firewood consumption, and it is very significant and relatively large in magnitude. We do not know the exact reason for this observation, but one may be that households with higher education often work longer hours and therefore have less time available (or need) for burning firewood at home.

5.3. *Characteristics of the "always zero" households*

Table 3 provides the results from the ZINB model estimation for households that fall into the "always zero" group. Note that the estimated coefficients in this table have signs opposite to their equivalent coefficients in the continuous model reported in Table 2.

As shown, living in detached houses and farmhouses significantly reduces the probability of belonging to the "always zero" group. We also find that owning a large house and/or a cottage in the mountains has a significant and negative effect on the probability of "always zero" whereas this probability increases significantly with the age and education level of the household's main income contributor.

6. Policy implications and concluding remarks

By merely considering the mean amounts of firewood consumed in different types of households (see Table 1), it would appear that households living an urban lifestyle, that are comfort seekers or energy savers, and households that spend little time in their residence, use less firewood than the average household, whereas households that are environmentally concerned use more firewood than the average household. If we compare this with the results from the ZINB estimation, we find that only urban lifestyle and comfort concerns have significant effects on firewood demand, while environmental concerns do not influence firewood consumption in a significant way.

Based on our findings, we conclude that even if the results indicate that household energy demand is significantly associated with some lifestyle and comfort indices, dwelling factors and other household characteristics are of far more importance. Households in farmhouses in the countryside do rely more on firewood for space heating. Owning a cabin in the mountains is also very important for firewood demand, as the main heating source in these cabins remains predominantly firewood. Demographic factors are also important in explaining total firewood demand. Finally, price has a very strong and significantly negative effect on firewood demand, although it does not appear that the demand is very income sensitive.

As a result, it may be difficult to identify efficient policy tools for increasing firewood demand. Most information campaigns attempt to influence attitudes and/or lifestyles. According to our findings, this will only have a limited effect on firewood demand, whereas those factors that can change demand significantly are more difficult to target using conventional policy measures. For instance, the price incentive appears strong, but it is difficult to influence consumer prices, as there are currently no energy taxes on firewood consumption in Norway. This means that governmental intervention intended to influence household firewood consumption through changes in relative energy prices must be through indirect changes in the taxes on electricity and fuel oils. This will be much less effective than a change in the own price, even if electricity and fuel oils are alternatives to firewood in consumption, as the cross price elasticities are relatively small [34]. One alternative would be to apply policies aimed at changing the supply of firewood, resulting in a reduction in the price of firewood. This may indeed increase the demand for firewood, as we identify a high level of price sensitivity in our estimation. Whether this is an optimal solution, however, remains a topic for future discussion.

The results also indicate that comfort-seeking and older people are less likely to use firewood for heating. Thus, woodstove technologies that require less labor could possibly assist in increasing the use of bioenergy in Norwegian residences. In an effort to induce such a change, the Norwegian government is subsidizing investment in pellet stoves. However, Norwegian households prefer old-style woodstoves to the more modern pellet stoves [1], and even after almost a decade of subsidies, less than one percent of Norwegian households currently own a pellet stove. This indicates that it may prove very difficult to make bio-energy more accessible and easy to use in a way that Norwegian homeowners find attractive and desirable.

One limitation of this analysis is that the underlying survey is more than a decade old, and one may expect that relative prices, household behavior patterns and heating technologies have changed much since then. In particular, heat pumps have become popular in Norwegian residences during the last decade, with approximately one-quarter of all Norwegian homes now owning a heat pump [2]. However, the use of firewood remains very popular, and 70% of households have also upgraded or are still using their woodstoves [1]. This means that the underlying preferences for firewood consumption have been relatively stable during this period, even after the introduction of alternative new technology. The use of firewood also serves purposes not given by other heating sources, such as providing coziness in front of the fireplace.

In addition, we do not expect the effects of lifestyle on firewood consumption to change that much as the new technologies introduced have little influence on how lifestyle factors affect firewood consumption. The largest effect of the new technologies, particularly air-to-air heat pumps, is presumably through the effect they have on the cost of using electricity to heat the residence. Unfortunately, we do not have information about this cost nor the cost of using fuel oil for heating in this data set. However, we do know from other studies that these indirect price effects are not very large [34].

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Paper IV

Measuring the Effect of Procrastination and Environmental Awareness on Households' Energy-Saving Behaviours: An Empirical Approach

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Abstract: A common finding in behavioural economics is that people often procrastinate, i.e., keep postponing planned tasks or decisions that require effort to execute. The effect of procrastination on inter-temporal energy choice behaviours could be even more serious because energy is an abstract, invisible and intangible commodity. This paper uses a web survey to investigate how people's procrastination propensity and environmental awareness affect their heating-energy-saving behaviours. The results indicate that people who state that they have a higher tendency to procrastinate are significantly less likely to have engaged in most of the heating energy-saving activities, especially regarding larger purchases or investments in equipment and the insulation of doors and windows. I also found a positive relationship between environmental awareness and engaging in everyday energy-saving activities such as reducing the indoor temperature. The findings suggest that measures aimed at reducing procrastination are needed to realise energy-saving potential. It is important to find ways to either bring future benefits closer to the present or to magnify the costs of delayed action. For example, one can employ certain feedback systems and commitment devices to make current gains and future costs more visible or tangible.

Keywords: Behavioural economics; Energy-saving behaviour; Procrastination

1. Introduction

The energy used in family homes accounts for one-third of the total energy use in Europe (EEA, 2008). Reducing households' energy use is a target for energy and environmental policies (Gardner and Stern, 2002). The European Energy Efficiency Action Plan estimates that there is a large saving potential in the household sector and that households could save up to 27% of their current energy use by 2020 by making more energy efficient choices (European Commission, 2006). In a household study encompassing 12 European countries, de Almeida et al. (2011) estimate that an annual savings of 1300 kWh per household can be achieved by a combination of more energy efficient technologies and behavioural changes. Furthermore, in countries with a temperate climate, such as Norway, over half of the household energy is used for heating (IEA, 2004). The total energy saving potential for the private building sector is estimated to be approximately 12 TWh in Norway (Wachenfeldt, 2009). Energy-saving practices for space heating can therefore significantly reduce the energy use in households (Darby, 2000; Guerra Santin, 2011).

Household energy use depends on factors such as climate, energy price, and residence and household characteristics but also on the householders' energy-saving behaviours (Barr et al., 2005; Branco et al., 2004; Fabi et al., 2012; Lindén et al., 2006). Changing the households' behaviour is the focus of many of the proposed policies and measures to achieve energy-saving potential (European Commission, 2006). Households' energy-saving behaviours cover energy behaviours directed at both curtailment and efficiency. The former refers to daily engagement in energy-saving, such as turning off the light when leaving a room, and the latter refers to investment behaviours, such as buying new equipment or insulating the house (Oikonomou et al., 2009). Most studies on energy-saving behaviour focus on either cost issues or normative concerns (Allcott, 2011; Steg, 2008). However, several studies have found household energy-saving behaviour to be influenced both by cost factors and by other behavioural factors such as the available information on energy saving, the effort needed, everyday routines, demographic factors and the preference for thermal comfort (Steg, 2008). In particular, certain drivers or barriers behind energy investment behaviours could be due to sociocultural and psychological reasons (Brohmann et al., 2009; Lillemo et al., 2013; Wilhite and Lutzenhiser, 1999; Wilk and Wilhite, 1985; Wilhite et al.,1996).

Furthermore, people do not always behave consistently with their intentions and plans, especially in the case of pro-environmental behaviours (Kollmuss and Agyeman, 2002). Therefore, we need to pay more attention to behavioural factors to improve the policy effectiveness of the interventions aiming to encourage energy-saving behaviours (Abrahamse et al., 2005). Identifying the barriers to energy-saving behaviours could help to bring about the intended behaviour change. Some behavioural studies have mentioned potential psychological drivers and barriers including procrastination (postponing planned tasks or decisions that need the input of effort) (Baddeley, 2011; Grubb et al., 2009; McNamara and Grubb, 2011). As Rabinovich and Webley (2007) note, in general, moving from saving intentions to actual saving is not straightforward and may require careful planning and efforts in self-control. More empirical studies aiming to incorporate such behavioural economics principles are needed to sharpen energy policy (Wilson and Dowlatabadi, 2007).

The effect of procrastination has often been studied as it relates to health and financial savings topics (Thaler and Benartzi, 2004; Laibson, 2005; Akerlof, 1991; Kooreman, 2010). However, to the best of my knowledge, there are still no empirical studies about how procrastination affects people's energy-saving behaviours. The effect of procrastination on energy inter-temporal choice (choice over time) could be even more serious because energy is an abstract, invisible and intangible commodity. Based on survey data from Norway, I sought to explore the relationship between people's energy-saving behaviours and their level of environmental awareness and how this relationship is moderated by their tendency to procrastinate. The objective of this study is to provide empirical evidence of procrastination affecting households' energy-saving behaviours. This evidence will provide insights into why households fail to achieve their energy-saving potential and will help policy-makers to broaden their approaches to encourage energy saving.

2. Procrastination as a self-control problem

Economists usually incorporate exponential discount rates to represent peoples' impatience when they evaluate choice outcomes over time. The same exponential discount rate applied to all future moments implies that people have time-consistent time preferences. However, behavioural economists have found that more often people have inconsistent time preferences. And applying hyperbolic discounting or quasi-hyperbolic discounting may be more appropriate and consistent with the empirical findings than is using exponential discount rates (Laibson, 1997; O'Donoghue and Rabin, 2001; Phelps and Pollak, 1968). The reason is that when a decision-maker considers trade-offs between two future moments, he or she usually gives a stronger relative weight to the earlier moment as it gets closer; i.e., one is more impatient for the near future than for the distant future. In this case, the preferences are inconsistent along the time change. A consequence of this inconsistency is that people have a tendency to delay costs and desire rewards sooner.

Procrastination is defined as the tendency to keep postponing tasks or decisions that have been planned and that require effort for execution (Steel, 2007; Ainslie, 1975; Loewenstein, 1996). For example, one plans to do a task (such as changing heating equipment, dieting, exercising, stopping smoking, or saving) tomorrow (or next week, etc.), but in the next period, further postponement appears likely to occur. People have the inclination to procrastinate because they are impatient and usually put too much weight on the "here and now" when evaluating the costs and benefits of action (Laibson, 1997; Loewenstein and Prelec, 1992). Notably, not all procrastination leads to bad outcomes. Some economists would argue that there is an "inconsistency" or negative procrastination only if the procrastination actually leads to subsequent regret. I only focus on negative procrastination in this paper. For unwanted postponed behaviour, if people are not (fully) aware of the influences from their present biased preferences, the consequences could be serious. In this case, people usually refer to procrastination as a self-control problem.

Some researchers try to explain the procrastination phenomenon using a dual-self theory (Benabou and Pycia, 2002; Thaler and Shefrin, 1981). Thaler and Shefrin (1981) have stated that in an inter-temporal decision making process, people are guided by a "Doer self," who only cares about the present moment, and a "Planner self," who also cares about the future. The intrapersonal conflicts between the Doer and the Planner make people unwilling to take action if the costs are immediate and the payoff more distant. There are two ways to help people toward consistency: promote patience (Planner) or restrain impatience (Doer). In practice, one can either bring future benefits closer to the present or magnify the costs of delayed action. O'Donoghue and Rabin (2001) have indicated that the way to manage self-control problems such as procrastination depends on how aware the decision maker is of their problem. Sophisticated persons are partly aware of their self-control problem but naïve persons are not. The former would be able to use some commitment devices to enforce the Doer's planned actions, such as depositing some amount of money or goal setting, to ensure implementation of the plan.

Furthermore, when planning ahead, people usually underestimate the influence of procrastination, although it may have a large effect on their inter-temporal choice behaviour (O'Donoghue and Rabin, 2001). Decision-making is affected by procrastination in several ways such as wandering attention and peripheral factors that subconsciously influence decisions and perceptions (Allcott and Mullainathan, 2010). Procrastination is particularly a problem for our planned environmental activities because the future gain from environmental activities often looks small or unclear in the present (Steel, 2010). In the case of engaging in energy-saving behaviours, the short-term benefits in the form of economic and environmental gains may appear to be small even when the long-term effects are substantial. Therefore, procrastination can easily result in a gap between planned and actual environmental behaviour. Even when long-term gains are substantial, people do not want to sacrifice their current comfort and convenience in exchange for future gains. In many cases, the total welfare gain from energy-saving actions would have been much larger if the actions were performed earlier (Costanzo et al., 1986). Based on survey data and an econometric approach, this empirical study provides evidence for how procrastination plays a role in householders' energy-saving behaviours.

3. Material and methods

3.1. Data

The data were collected from a web survey with 1004 participants drawn from the TNS Gallup web-panel in Norway. The sample is considered to be nationally representative. The survey was conducted in the fall of 2010 and the response rate was approximately 46%[1]. It is worth noting that the average electricity use for Norwegian households is among the highest in the world (de Almeida et al., 2011). Due to the cold climate, approximately 50% of households' energy consumption is spent for heating purposes (SSB, 2012).

Table 1. Descriptive statistics for the sample

Variables	**Measurement**	**Mean**	**SD**
Family income before tax	1-8 scale	4.0	1.5
Education	1-5 scale	3.4	1.2
Age of respondent	Years	48.9	13.1
Being young	>24 and < 30 years old, 1 = yes, 0 = no	0.1	0.3
Female	1= female, 0 = male	0.5	0.5
Living alone	1 = yes, 0 = no	0.2	0.4
Own house	1 = own, 0 = rent	0.9	0.3
Size of house	1-6 scale	3.2	1.1
Age of house	Years	40.5	22.6
Preferred living room temperatures	1-4 scale	2.6	0.6
Sample size	1004		

Note: for the variables measured by scales, the larger number means a higher level of measurement; details on the scale information can be provided on request.

Information about education, age, income, gender and other characteristics of the respondents was collected. The sample means for the respondent characteristics are listed in Table 1. Income is measured on an 8-point scale, and the mean is 4.0. This result indicates a mean family income of around NOK 700, 000 or approximately € 87, 500 (using NOK 8 = € 1). Education is measured using a 5-point scale, and the mean is 3.4, indicating a mean education level of high school or some college. The share of men (54%) is slightly higher than that of women, and the average age is 49 years. One out of ten respondents are between 24 and 30 years old, which is defined as young in the study. Twenty-one percent of the respondents live alone, and eighty-seven percent of the respondents own the in which they reside.

3.2. Heating energy-saving behaviour

Table 2 presents five categories of energy-saving behaviour. The behaviour is measured by binary variables: the respondent has either been involved in a particular saving behaviour (1) or not (0). As noted previously, curtailment energy behaviour refers to active daily engagement in energy saving, such as turning down room temperatures (2) or turning off the heat in less frequently used rooms (3). Energy efficiency behaviour refers to the insulation of walls, roofs, doors and windows (4) or investments in more efficient heating equipment (5). The first category (1) is engagement in heating-saving behaviours in general and is "Yes" (i.e., 1) if the respondent has engaged in any of the energy-saving behaviours from category (2), (3) or (4). Notably, not all energy efficiency behaviours are for the purpose of reducing energy use, because increased efficiency, and thereby reduced cost, might lead to more frequent use of equipment, ultimately resulting in higher energy consumption (Berkhout et al. 2000). For this reason, I excluded (5) from category (1).

Table 2. Share of households involved in different types of energy-saving behaviour

Variables	Measure	Percentage	Observations
(1) Engaged in saving behaviours in general	1 = yes	80%	800
	0 = no	20%	204
(2) Reduction of room temperature when away	1 = yes	60%	606
	0 = no	40%	398
(3) Warming of a smaller part of residence	1 = yes	35%	350
	0 = no	65%	654
(4) Insulated residence, such as doors and windows.	1 = yes	27%	273
	0 = no	73%	731
(5) Purchased heating equipment (>€375)	1 = yes	52%	527
	0 = no	48%	477

1 Euro=8 Norwegian Kroner. Calculated on survey 2010

In the survey sample, 80% of the interviewed households have been involved in at least one of the category (2), (3) or (4) energy-saving behaviours. Many of the respondents have been involved in several of these. Reducing room temperature is the most common measure and was undertaken by 60% of the households. The second most common saving behaviour is investing in heating equipment; 52% of households report that they have invested in at least one piece of heating equipment with a value of over 3000 NOK (equals €375) in the last 10 years. Thirty-five per cent say that they warmed up a smaller part of their residence for the purpose of energy saving.

Twenty-seven per cent report that they have insulated their residences, which is the activity with the highest initial cost and effort but likely the highest long-term gains. The time, effort and money required to do these activities differ. Curtailment behaviour such as changing the room temperature requires small daily efforts, but purchases or investments require money and a greater effort today, but once the act is performed, it is in place for a long time.

3.3. Latent variables generated by the factor analysis

To identify the respondents' degree of procrastination and environmental awareness, the survey participants answered questions from an 8 item-pool covering different relevant dimensions of the attitude or behaviour. I used a 7-point Likert score scale (1=I strongly disagree to 7=I strongly agree) to evaluate each single item. Then, using exploratory factor analysis, the attribute space is reduced from a larger number of highly correlated variables (item pool) into 2 unrelated, independent factors. The first latent variable contains the items that measure the respondents' degree of procrastination. This variable includes 3 statements describing the degree of procrastination. The second latent variable is an index of the respondent's level of environmental awareness and sums up 5 statements regarding attitude toward environmental protection, climate change, personal responsibility and environmental behaviour. The criteria for determining the number of factors were a principal component analysis, varimax as the rotational strategy and the Kaiser criterion[2]. My results show a meritorious KMO-value of 0.78. The p-value of the Bartlett test is <0.01. The Cronbach's alpha is the measure for the internal consistency of items. These results support the identified factors. Details about the survey questions included in the factors and the test results are reported in Table 3.

Table 3. Factor analysis of latent variables

	Rotated factor loadings (pattern matrix) and unique variances	Cronbach's alpha
Latent variable 1: Degree of procrastination		0.60
Constantly postpone things to do until tomorrow	0.80	
Must hurry to finish things at the last minute	0.83	
To save time, often choose a more expensive solution than necessary	0.55	
Latent variable 2: Level of environmental awareness		0.84
We must reduce energy consumption to solve climate problems	0.77	
I am very concerned about climate change	0.78	
I have a personal responsibility to help to solve environmental problems	0.84	
Everyone should do whatever they can to protect the environment	0.76	
I buy environmentally friendly products if possible	0.76	

Rotated component matrix (varimax rotations). Calculated by Stata 12. Overall KMO=0.78

3.4. Econometric approach

In this paper, I test the following hypotheses under the assumption that the study subjects perceive that there are positive gains from engaging in energy-saving behaviours. *There is a negative relationship between the degree of procrastination and the undertaking of energy-saving activities. There is a positive relationship between the level of environmental awareness and executing planned actions to save energy. Nevertheless, due to the procrastination, the positive effect of environmental awareness might be reduced.* This reduction occurs because energy-saving behaviours, such as insulating a door or window or updating heating equipment demand money, time or effort. People choose the time to execute the saving tasks depending on the net benefit of doing it immediately relative to doing it later. People who show a higher tendency toward procrastination tend to value the cost of doing the task higher than they value the immediate benefit. Therefore, they are less likely to implement it.

I applied a binomial logit model to each of the reported energy-saving activities (1-5 in Table 2). The heating-saving decision was represented by a dummy variable indicating whether the household has performed saving activities. The decisions were assumed to be influenced by a number of factors associated with the respondents including: the degree of procrastination; the level of environmental awareness; the respondent's income, age, education, or gender; living alone and residential ownership (Barr et al., 2005; Steg, 2008). In addition, house size was included when modelling the behaviour of warming up small parts of the house, and house age and temperature preferences were included in the modelling of investment behaviour (Wachenfeldt, 2009; Wilhite et al., 1996). People were assumed to execute the saving behaviours if it would increase their utility. In my estimation, the utility of performing saving activities (which equals the difference in utility between doing and not doing) is approximated by the following equation:

$$v_i = \beta_0 + \beta_i x_i + \varepsilon_i$$

where v_i is the utility that household i derives by performing the energy-saving behaviour relative to not performing it; β_0 is the constant; x_i is a vector of the degree of procrastination, the level of environmental awareness, residence characteristics, and demographic factors associated with respondent i; β_i represent the estimated parameters for choice models by using maximum likelihood techniques; and ε_i is the disturbance term, which is assumed to satisfy the standard assumption of the Logit model. For a detailed list of the explanatory variables, see Table 1.

4. Results

The econometric analysis was performed using the Stata 12 software (Stata, 2009). Table 4 shows the results of the 5 binomial Logit models using the survey data to explore the different heating energy-saving activities. Column 1 reports the estimated results of engaging in heating energy-saving behaviours in general. Columns 2 through 5 list the rest of the estimated results for the particular saving behaviours that are listed in Table 2.

In general, the households' degree of procrastination, the level of environmental awareness and most of the socio-economic factors are significantly associated with the respondents' heating energy-saving behaviours. First, people with a higher degree of procrastination are less likely to engage in energy-saving activities in general and especially in those activities requiring more money and effort, such as investing in new equipment. *Second*, people with a higher level of environmental awareness are significantly more likely to have curtailment behaviours, such as reducing the indoor temperature when they are away or warming up smaller parts of their residence. However, the effect of environmental awareness does not appear to be an important driver of energy efficiency behaviours (such as investing in new heating equipment). This result may be because there are many other reasons that Norwegian households may invest in new heating equipment other than environmental awareness, such as saving money, acquiring more warmth, or increasing residential value, etc.

Table 4. Results from Logit estimations on five types of heating energy-saving behaviours

	(1) Any of (2)(3)(4)	(2) Reduced indoor temperature when away	(3) Warming up smaller parts of the house	(4) Insulation of doors, windows, etc.	(5) Have purchased heating equipment (> €375)
Explanatory variables					
Degree of procrastination	-0.18**	-0.13*	-0.02	-0.24**	-0.15**
	(-2.19)	(-1.83)	(-0.19)	(-2.93)	(-2.16)
Environmental awareness	0.37***	0.36***	0.23**	-0.03	0.01
	(4.52)	(5.08)	(2.97)	(-0.30)	(0.15)
Family income before tax	0.01	-0.01	-0.13**	0.15**	0.20***
	(0.17)	(-0.26)	(-2.16)	(2.32)	(3.46)
Education	0.22**	0.19**	0.19**	-0.08	-0.14**
	(2.91)	(2.94)	(2.91)	(-1.05)	(-2.09)
Being young	-0.80**	-0.49**	-0.84**	-0.45	-0.68**
	(-3.19)	(-2.07)	(-2.88)	(-1.38)	(-2.56)
Female	-0.19	0.02	0.08	-0.41**	-0.12
	(-1.13)	(0.11)	(0.56)	(-2.49)	(-0.86)
Living alone	-0.23	0.09	-0.13	0.09	-0.61**
	(-1.01)	(0.46)	(-0.63)	(0.36)	(-3.01)
Own house	0.08	-0.12	-0.38*	0.96**	1.26***
	(0.33)	(-0.54)	(-1.67)	(3.17)	(5.15)
Size of house			0.28***		
			(4.16)		
Age of house				0.04***	0.01***
				(10.52)	(4.22)
Preferred living room temperatures				0.30**	0.36**
				(2.20)	(3.03)
Constant	0.71*	-0.02	-1.36***	-4.61***	-2.60***
	(1.90)	(-0.06)	(-3.64)	(-7.75)	(-5.19)
Observations	970	970	969	966	966

NOTE: Dependent variable equals 1 if the household has engaged in the particular heating energy-saving behaviour, zero otherwise. Standard errors in parentheses * p<0.10, ** p<0.05, *** p<0.001

Finally, household demographic factors such as income, education and living alone also influence heating energy-saving behaviours. As one could expect, there are positive effects of income on investment behaviour. Higher income households make more investments related to heating. It is also interesting to see that people with more income are actually less likely to warm up smaller parts of the residence. Education appears to play an important role in practicing curtailment heating energy-saving behaviours but not in practicing investment behaviours. The results also show that young people are less likely to take action for all types of heating energy-saving behaviours. Interestingly but not surprisingly, being female reduces the likelihood of practicing insulation-saving behaviour. Furthermore, it appears that people living alone are less likely to invest in new heating equipment. Owning the residence can significantly increase the investment likelihood of new heating equipment and insulating the house. The older the residence and the higher temperature the respondent prefers, the more likely it is that the respondent has invested in new heating equipment or new insulation on doors or walls. Because the primary purpose of this paper is to address the effect of procrastination and environmental awareness on heating energy-saving behaviour, the following discussion section will focus on the policy implications of these two factors.

5. Discussion

5.1. Procrastination is a barrier to energy-saving behaviours

First, the results supported my hypotheses and identified procrastination as one of the barriers for heating energy saving. People's tendency toward procrastination is confirmed to have an influence on their heating energy-saving behaviour, especially in regard to behaviours that require significant money and effort such as investments in heating equipment and insulation. This result is consistent with a study by McNamara and Grubb (2011), who noted that substitution towards more energy efficient consumption is most likely delayed by procrastination because energy is an abstract, invisible and intangible commodity. Energy-saving activities always require some resource and/or time input that may cause some disutility. People keep postponing the planned saving tasks or decisions because they have a false belief that they will get to them sooner or later. Consequently, they are less likely to carry out their plans or decisions.

Second, considering that being environmentally friendly could be one of our motives for engaging in energy-saving activities, it is important to note that procrastination might work against the capacity to execute environmentally friendly behaviours. As Steel (2010) has noted, procrastination could be one of the more important barriers in fighting climate change at either a policy level or in people's daily practices. Environmental issues such as climate change are often concerned with future costs or benefits. If people put too much weight on the present moment, it will make the benefits from environmentally friendly behaviour look small from today's perspective. As a result, the positive effect of environmental awareness on energy saving can most likely be moderated by the negative effect of procrastination.

Furthermore, my results suggest that procrastination hinders energy efficiency energy behaviour more than curtailment energy behaviour. This finding is important because it is usually argued that the energy-saving potential of energy-efficiency behaviours is greater than that of curtailment energy behaviours (Gardner and Stern, 2002). The primary reason for this result could be that investment energy behaviour requires much more effort and input than does curtailment saving behaviour at any given time. I should note that the current study was performed in Norway, which has the highest labour costs in the world (SSB, 2008). Many Norwegians choose to perform insulation or installation work themselves because it is too expensive to hire others to do it. The resulting immediate need for personal labour may strengthen the negative effect of procrastination on the energy efficiency energy behaviour.

The results indicate that the government not only needs to motivate people to save energy, but it also needs to help people follow up on or execute their saving plans. In particular, the measures aimed at increasing households' investments in energy savings should focus on reducing procrastination rather than increasing environmental awareness. It is necessary to introduce some innovative behavioural approaches to encourage energy saving by reducing the effect of procrastination.

5.2. Behavioural approaches to overcoming procrastination and improving energy saving

Considering that most people are likely not fully aware of the negative effect of procrastination, we should *first* raise this issue and allow the public to become more aware of the influence of procrastination on their energy consumption behaviour. Thaler and Sunstein (2008) suggest that people should be given a gentle "nudge" or push when it is necessary, especially in the fields that have not been well noticed, to increase policy effectiveness and change people's behaviours. One practical policy to help people speed up their energy-saving plans could be to provide information regarding saving benefits through the public media such as TVs or newspapers. The benefits can be framed in terms of economic and/or environmental gains. Detailed, manifest and frequent messages about the positive gain from energy-saving will help people to become more involved in these activities. This involvement is particularly critical for environmentally motivated energy behaviours.

Second, from an individual perspective, good feedback systems can make the future benefits of energy-saving efforts more obvious and thus help people perform saving actions. Because procrastination is a problem of weighing present versus future costs and benefits and because most domestic energy use is invisible; the focus is to find ways to either bring future benefits closer to the present or to magnify the costs of delayed action. Energy users can learn about their usage patterns and moderate their behaviours if the consumption feedback is easily accessible (Fischer, 2008). Effective feedback can make energy use more visible and more amenable to control (Darby, 2006). The research policy agents or related marketing firms can put sufficient effort into suggesting or providing particular feedback systems. For instance, one can provide more accurate information on the consequences of saving over the long term with regard to environmental and/or economic returns through smart grid systems. Smart metering provides instant feedback and continuous and visible information to the energy consumer about actual electricity consumption (Hargreaves et al., 2010). Smart metering can also help the visualisation of the returns from inputs devoted to energy saving and has become a very powerful tool to reflect energy use information (Darby, 2006). The design of this type of system may need contributions from engineers/computer scientists with social science skills. For example, it will be useful to design room temperature control systems. With this type of temperature control system, one can specifically program the temperatures in different rooms at different times of the day. Further, one can obtain an estimate of how much it is possible to save over a year by reducing the room temperature by one degree, even by the timing of room temperature programming. In this way, smart metering could function as a reminder or “nudge” for households’ saving plan or decisions. The calculation of net benefits will allow such benefits to enter into people’s decision making processes and help to change their choices over time.

Finally, we can use effective commitment devices to help magnify the future net benefit. The results suggest that some concrete commitment devices are needed to help people follow through with their saving plans, especially for investment behaviours. Commitment devices represent the pre-commitment management that planners adopt for the implementation of their saving plans or actions. Commitment devices can promote constructive choices and enable effective planning (Dolan et al., 2012). Practical suggestions for designing commitment devices can be challenging and are beyond the research scope of this paper. However, the proposed devices should essentially fit the daily practices of households and be easy to implement, although the best device could vary from case to case. Inspired by research findings from smoking, health training and obesity, a commitment device such as goal setting or a money deposit device could be suggested to households to encourage them to fulfil their saving plans or decisions. One can introduce goal setting to increase energy-saving behaviours, as suggested in a study performed in the Netherlands (McCalley and Midden, 2002). One can also use visual indicators to help people compare their energy behaviours with others such as similar household owners or neighbours, which will lead them to update their beliefs about their own ability to follow through with goals setting (Battaglini et al., 2005). Alternatively, one can deposit some amount of money in a particular bank account. If the saving plans or decisions are implemented, such as investing in more efficient heating energy equipment or performing residence insulation, the deposited money will be returned; otherwise, it will be donated.

5.3. Too poor to save or too little to save?

One interesting result from this research is that it appears that young people are less likely to engage in all types of heating energy-saving behaviours. This result is similar to the findings from a household study that found that the higher age groups were more likely to be energy savers in the UK (Barr et al., 2005). A lack of financial resources could be one reason that younger people are less likely to invest in energy saving, but it should at the same time motivate them to turn down the temperature to save heating costs. The reasons for not saving could most likely be that the perceived benefits are too small or that they value comfort more. Most likely young people put even more weight on the immediate moment than do senior people when facing inter-temporal choices (Steel, 2007). For future studies, it would be worthwhile to investigate whether the effect of procrastination on people's saving behaviour varies with age.

The policy implications of this finding are twofold. First, information campaigns should distinguish between different age groups. For example, information can be specifically tailored to the younger owners of residences. Second, the government may need to evaluate financial support for those intending to invest in new heating technologies. The goal is to encourage improvement in heating equipment efficiency and more engagement in energy-saving activities in general.

6. Conclusion and policy implications

Saving energy can increase the welfare of individuals, contribute to sustainable economic development and reduce greenhouse gas emissions. To acquire more knowledge about the barriers and drivers of energy-saving behaviours, I conducted a national household web survey and studied the residential owner's heating energy-saving behaviours from a behavioural economics perspective. I focused on the important but less noticed behavioural factor of procrastination and measured the effect of procrastination on people's inter-temporal energy-saving choices. The results imply that people's tendency toward procrastination did reduce their involvement in energy-saving activities in a statistically significant way. There is a positive relationship between environmental awareness and engaging in everyday energy-saving activities such as reducing indoor temperatures. Therefore, the positive effect from being environmentally friendly might be moderated by the tendency to procrastinate in daily energy-saving practices.

To overcome procrastination in energy saving, the key is to find ways to either bring future benefits closer to the present or to magnify the costs of delayed action. On one hand, from the policy maker's viewpoint, it is important to make people more aware of their procrastination problem. The findings suggested that energy-saving campaigns should be purposely tailored to overcome procrastination. The policy agents can develop some effective reminders or "nudges" to reduce the negative effect of procrastination. For example, one can design saving schemes with clear goals and easily functioning reminder systems, through which people can move their energy-saving plan into action. The findings also suggest that measures aimed at increasing households' investments in energy saving should focus on reducing procrastination rather than increasing environmental awareness.

However, households should also put more effort to bring saving plans or decisions into action. For example, it is necessary to employ some good feedback mechanisms and commitment devices to make current gains and future costs more visible or tangible. Feedback systems allow the household to better visualise the benefits from saving activities. For example, feedback systems can be designed to increase the energy consumers' perceived gain from executing their saving plan. A room temperature control system using smart grid systems is suggested for this purpose. Alternatively, some effective commitment devices such as goal setting or money deposit devices could also help people to follow through on their saving plans or decisions.

In all, this empirical study identified procrastination as a barrier to heating energy saving. The empirical findings can be used to increase the effectiveness of policies that seek to encourage energy efficiency within Norwegian households. These results are not only relevant for energy saving in the private household sector but could also be extended to other saving campaigns and other environmentally friendly activities such as encouraging public transportation. By applying the research findings from behavioural economics, one can better achieve insight into people's behavioural changes. Further studies on this topic are needed, such as identifying effective commitment devices and introducing commitment devices or goal setting devices to increase energy saving.

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Footnote

1 I do not have information about the respondents who chose not to participate and therefore cannot conduct any nonresponse bias analysis.

2 The Kaiser criterion is a common rule of thumb for dropping the least important factors from the analysis. The Kaiser rule is to drop all components with eigenvalues under 1.0 (Kaiser, 1960). I generated a two-factor solution based on the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett test statistics. The KMO measure takes values between 0 and 1. Larger values indicate that the variables have more in common to permit a factor. Heuristically, the values of the KMO are interpreted such that 0.00 to 0.49 is unacceptable, 0.80 to 0.89 is meritorious, and 0.90 to 1.00 is excellent (Kaiser, 1974).

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Annex

6. Annex

A 1. The definition of main terminology used in the thesis

Perception (from the Latin perceptio, percipio) is the collection, identification, organization, and interpretation of sensory information in order to represent and understand the environment (Schacter et al., 2009).

Attitude means an expression of favor or disfavor toward a person, place, thing, or event (the attitude object) (Wikipedia).

Behaviour means the range of actions and mannerisms made by organisms, systems, or artificial entities in conjunction with their environment, which includes the other systems or organisms around as well as the physical environment (Wikipedia).

Intervention: any regulation, policy, program, measure, activity, or event that aims to influence behaviour (Wilson and Dowlatabadi, 2007).

Wood pellets are a type of wood fuel made from dry and finely grinded wood material (sawdust). The pellets are formed under high pressure into cylinders with typical diameter 6–10 mm and length 2–4 cm. Wood pellets "run" and can conveniently be fed from a storage unit to a combustion chamber. A wood pellet stove is a stove for space heating based on the combustion of wood pellets, typically for residential use. When a wood pellet stove is loaded with pellets, it can operate automatically and maintain a pre-set temperature for several days. (Reference: Sopha et al, 2010)

Woodstove is a heating appliance capable of burning wood fuel and wood-derived biomass fuel. Generally the appliance consists of a solid metal (usually cast iron or steel) closed fire chamber, a fire brickbase and an adjustable air control. The appliance will be connected by ventilating stove pipes to a suitable chimney orflue, which will fill with hot combustion gases once the fuel is ignited (Wikipedia).

An air-to-air (or air-source) heat pump typically extracts heat from the outdoor air and transports it to the inside of a building (home). It is used in colder climates for space heating and works in the "opposite direction" of the air conditioners used in warm climates. Many air-to-air heat pumps can be reversed and used as air conditioners. (Reference: Sopha et al, 2010)

A 2. Questionnaire used for 2010 household energy survey

Norwegian Heating and Energy Survey 2010

TNS Gallup has been commissioned by the Department of Economics and Resource Management, Norwegian University of Life Sciences (UMB) to implement the Norwegian heating and energy survey 2010. In this study, we want to identify which factors are important for Norwegian households' choice of heating equipment. The survey takes about 12 minutes to answer. There are no right or wrong answers. The data in this study will be treated confidentially. It will not be possible to link your responses to your e-mail address. All information should be used only for research purposes. Your answers will help to provide knowledge of Norwegian homeowners opinions about the advantages and disadvantages of heating based on different energy sources. The results will provide useful information in the development of a sustainable energy policy.

1. **What kind of house do you live in?**

- Detached
- Townhouse
- Two-, three-or four-family house
- Apartment Block
- Combined residential and commercial buildings
- Farmhouses
- Other, notér____________
- Do not know

2. **Which year was the house built? If you do not know, estimate approx. when the house is built.**

2010 to before 1930

3. **Which year did you move into your home?**

2010 before 1930

4. **What is the net living area of the dwelling?**

- Under 50 m²
- 50 to 99 m²
- 100 to 139 m²
- 140 to 199 m²
- 200 to 299 m²
- Over 300 m²

5. **To what extent do you agree or disagree with the following statements about your house?**

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
The windows are leaking	❍	❍	❍	❍	❍	❍	❍
The house is well insulated	❍	❍	❍	❍	❍	❍	❍
The floor is often cold	❍	❍	❍	❍	❍	❍	❍

6. **If your household wanted to make major changes to the heating equipment in the home, such as installing a new heat pump, is this something you could decide?**

- Yes, we can decide both the internal and external changes (for example, new heat pump)
- Yes, but only internal changes (for example, new stove, or new electrical equipment)
- No, the type of heating equipment in the home is determined by the housing cooperative / landlord
- Other, notér____________
- Do not know

7. **Does your household pay energy bills by yourself?**

- Yes
- Partly
- No
- Other, notér____________
- Do not know

8. **Has your household made any of the following efforts to reduce energy consumption for heating during the last ten years?** *Several answers possible*

- Reduced indoor temperature when you / you are gone and / or night
- Added isolation to doors, windows, walls or ceilings
- Warming up smaller parts of the house
- Installed Varmegjenvinningsanlegg
- None of these
- Other____

9. **What internal temperature do you prefer?**

	Under 18 C	18 to 21 C	21 to 23 C	Over 23 C
Living Room	❍	❍	❍	❍
Bathroom	❍	❍	❍	❍
Bedrooms	❍	❍	❍	❍
Kitchen	❍	❍	❍	❍
Porch, entrance hall, corridor	❍	❍	❍	❍

The next question comes to heating solutions in your home.

10. Which heating equipment do you have in your home? *Several answers possible*

- Electric heaters
- Elektriske varmekabler Electric heating cables
- Firewood stove, closed fireplace
- Open fireplace
- Pellet stove
- Own central heating with electric boiler
- Own central heating with oil boiler
- Own central heating with pellets boiler
- Own central heating with firewood boiler
- Combined oven (wood and oil / kerosene)
- Air-to-air heat pump
- Ground heat Pump
- Air-to-water heat pump
- District Heating
- Common central heating (with other households)
- Kerosene or oil stove
- Varmegjenvinningsanlegg
- Central Control system for electric heaters
- Other, notér____________

11. Which energy source do your households use mostly to heat up your home?

- Electricity (incl. Heat Pump)
- Firewood
- Oil and kerosene
- District Heating
- Pellets
- Other, notér____________
- Do not know

12. How satisfied or dissatisfied are you overall with the following type of equipment?

Overall how satisfied or dissatisfied are you with the following type of equipment?

	Very dissatisfied 1	2	3	4	5	6	Very satisfied 7
Electric heaters	❍	❍	❍	❍	❍	❍	❍
Electric heating cables	❍	❍	❍	❍	❍	❍	❍
Firewood stove, closed fireplace	❍	❍	❍	❍	❍	❍	❍
Open fireplace	❍	❍	❍	❍	❍	❍	❍
Pellet stove	❍	❍	❍	❍	❍	❍	❍
Own central heating with electric boiler	❍	❍	❍	❍	❍	❍	❍

Own central heating with oil boiler	❍	❍	❍	❍	❍	❍	❍
Own central heating with pellets boiler	❍	❍	❍	❍	❍	❍	❍
Own central heating with firewood boiler	❍	❍	❍	❍	❍	❍	❍
Combined oven (wood and oil / kerosene)	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍
Ground heat Pump	❍	❍	❍	❍	❍	❍	❍
Air-to-water heat pump	❍	❍	❍	❍	❍	❍	❍
District Heating	❍	❍	❍	❍	❍	❍	❍
Common central heating (with other households)	❍	❍	❍	❍	❍	❍	❍
Kerosene or oil-fired stove	❍	❍	❍	❍	❍	❍	❍
Varmegjenvinningsanlegg	❍	❍	❍	❍	❍	❍	❍
Central Control system for electric heaters	❍	❍	❍	❍	❍	❍	❍

13. How often do you use these heating equipments in the winter?

	Daily	Weekly	Monthly	Less	Never
Electric heaters	❍	❍	❍	❍	❍
Electric heating cables	❍	❍	❍	❍	❍
Firewood stove, closed fireplace	❍	❍	❍	❍	❍
Open fireplace	❍	❍	❍	❍	❍
Pellet stove	❍	❍	❍	❍	❍
Own central heating with electric boiler	❍	❍	❍	❍	❍
Own central heating with oil boiler	❍	❍	❍	❍	❍
Own central heating with pellets boiler	❍	❍	❍	❍	❍
Own central heating with firewood boiler	❍	❍	❍	❍	❍
Combined oven (wood and oil / kerosene)	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍
Ground heat Pump	❍	❍	❍	❍	❍
Air-to-water heat pump	❍	❍	❍	❍	❍
District Heating	❍	❍	❍	❍	❍
Common central heating (with other households)	❍	❍	❍	❍	❍
Kerosene or oil-fired stove	❍	❍	❍	❍	❍
Varmegjenvinningsanlegg	❍	❍	❍	❍	❍
Central Control system for electric heaters	❍	❍	❍	❍	❍

For Q10_3 or 4

14. How old is the wood stove / fireplace? *If you have several, answers the one you use most*

- 10 years or less

- More than 10 years
- Do not know

15. Have the wood stove / fireplace second burning function?

- Yes
- No
- Do not know

16. How does your household manage to get all the firewood you use?

- Does not use firewood
- Buy all the firewood
- Buy a part of what we use and hugger the rest
- Buy a part of what we use and get the rest from other
- Hugger all the wood itself
- Get all the firewood from other

17. Did your household spend more than 3000kr to purchase some new heating equipment in the home during the last 10 years?

- Yes
- No

18. Which of these types of heating equipment has your households purchased? *Check only for purchases of over 3000kr. multiple answers possible.*

- Electric heaters
- Electric heating cables
- Firewood stove, closed fireplace
- Open fireplace
- Pellet stove
- Own central heating with electric boiler
- Own central heating with oil boiler
- Own central heating with pellets boiler
- Own central heating with firewood boiler
- Combined oven (wood and oil / kerosene)
- Air-to-air heat pump
- Ground heat Pump
- Air-to-water heat pump
- District Heating
- Common central heating (with other households)
- Kerosene or oil-fired stove
- Varmegjenvinningsanlegg
- Central Control system for electric heaters

19. What is the reason (s) of your household chose to invest in new heating equipment? *Multiple answers possible.*

- To reduce heating costs
- The previous equipment did not look pretty
- The previous equipment was worn
- To spend less time and effort on heating
- To improve the environment locally
- To get a better indoor climate
- To reduce greenhouse gas emissions
- General upgrading of equipment due to refurbishing the house
- To increase the sales value of the dwelling
- Other____________

20. After the installation of the new heating equipment, which of the former equipment do you use less today? *Multiple answers possible.*

- Electric heaters
- Electric heating cables
- Firewood stove, closed fireplace
- Open fireplace
- Pellet stove
- Own central heating with electric boiler
- Own central heating with oil boiler
- Own central heating with pellets boiler
- Own central heating with firewood boiler
- Combined oven (wood and oil / kerosene)
- Air-to-air heat pump
- Ground heat Pump
- Air-to-water heat pump
- District Heating
- Common central heating (with other households)
- Kerosene or oil-fired stove
- Varmegjenvinningsanlegg
- Central Control system for electric heaters
- Other, notér____________

21. After the installation of new heating equipment, the indoor temperature in your home on average lower or higher than before?

- Lower than before
- Same as before
- Higher than before

22. After the installation of new heating equipment, warm you up more or fewer rooms than before during the winter?

- Less room than before
- The same number of rooms as before
- More room than before

23. Did you apply a subsidy grant from Enova when you invested in new heating equipment?

- Yes, my household did
- Yes, housing cooperative / landlord did
- No
- Do not know

24. Did you get the subsidy grant from ENOVA?

- Yes
- No
- Do not know

25. Did you use the subsidy grant?

- Yes
- No
- Do not know

26. What was the reason(s) you did not use it? *Multiple answers possible.*

- The total investment costs were too high, even with the subsidy
- Applications for grants was an impulsive act
- The house is too small for the investment would be paid off
- Other types of equipment were nicer and fit better with the rest of the house
- Enova's grant did not cover the equipment I would rather have
- It was too much extra paperwork to receive the grant
- I heard that others had negative experiences with the equipment I was considering buying
- Other____________

27. Why didn't you apply for a grant from Enova? *Multiple answers possible.*

- The heating equipment I chose is not covered by Enova grant
- I knew nothing about Enova grant
- I had no time to apply for funding
- Someone I know had a bad experience of receiving support from Enova
- I do not like to fill out so many forms
- I installed before the scheme was introduced
- Other
- Do not know

28. How likely is it that your household is going to invest in new heating equipment during the next five years?

- 1 Very unlikely
- 2
- 3
- 4
- 5
- 6
- 7 Very likely

29. How much would your household likely to spend for buying new heating equipment?

- Up to 10 000 kr
- 10 000-29 999 kr
- 30 000-49 999 kr
- 50 000-100 000 kr
- More than 100 000 kr
- Do not know

30. If your household were to invest in new equipment, which one would you choose most likely?

	Very unlikely 1	2	3	4	5	6	Very likely 7
Electric heaters	❍	❍	❍	❍	❍	❍	❍
Electric heating cables	❍	❍	❍	❍	❍	❍	❍
Wood stove, fireplace or fireplace	❍	❍	❍	❍	❍	❍	❍
Pellet	❍	❍	❍	❍	❍	❍	❍
Heat pump	❍	❍	❍	❍	❍	❍	❍
Other, notér_____________	❍	❍	❍	❍	❍	❍	❍

31. How important would the following factors to be if you were to invest in new heating equipment during the next 5 years?

	Not important 1	2	3	4	5	6	Very important 7	Do not know
Investment costs	❍	❍	❍	❍	❍	❍	❍	❍
Annual heating costs	❍	❍	❍	❍	❍	❍	❍	❍
Effective heating up the house	❍	❍	❍	❍	❍	❍	❍	❍
Appearance of the equipment	❍	❍	❍	❍	❍	❍	❍	❍
Time and effort required to operate the equipment	❍	❍	❍	❍	❍	❍	❍	❍
Indoor air / air quality	❍	❍	❍	❍	❍	❍	❍	❍
Greenhouse gas emissions	❍	❍	❍	❍	❍	❍	❍	❍
Increase the value of the dwelling	❍	❍	❍	❍	❍	❍	❍	❍
Secure access to fuel	❍	❍	❍	❍	❍	❍	❍	❍

A different type of heating equipment has different advantages and disadvantages. How much do you agree or disagree with the following statements about the different heating equipment?

32. The investment costs are low.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
wood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

33. The annual heating costs are low.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

34. The residence is heated efficiently.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

35. It is difficult to obtain fuel.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍

36. It is an environmentally friendly alternative to heat up the house.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

37. It requires a lot of time and effort to use.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

38. It gives poor indoor air quality (odor, dust, dry and poor air)

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍						❍	❍

		❍	❍	❍	❍	❍		
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

39. Appearance of equipment fits into the home.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Electric heaters	❍	❍	❍	❍	❍	❍	❍	❍
Firewood Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Pellet Stoves	❍	❍	❍	❍	❍	❍	❍	❍
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍	❍

40. How much you know about the following heating equipments?

	Know nothing1	2	3	4	5	6	Know very well 7
Air-to-air heat pump	❍	❍	❍	❍	❍	❍	❍
Ground Heat Pump	❍	❍	❍	❍	❍	❍	❍
Air-to-water heat pump	❍	❍	❍	❍	❍	❍	❍
Wood stove, fireplace	❍	❍	❍	❍	❍	❍	❍
Electric heaters	❍	❍	❍	❍	❍	❍	❍
Electric heating cables	❍	❍	❍	❍	❍	❍	❍
Pellet Stove	❍	❍	❍	❍	❍	❍	❍
Central heating with pellets boiler	❍	❍	❍	❍	❍	❍	❍

41. How much do you agree or disagree to the following statements about heatpumps?

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
ENOVA subsidy was crucial when I chose to purchase a heat pump	❍	❍	❍	❍	❍	❍	❍	❍
The heat pump works well even on the coldest winter day in my district	❍	❍	❍	❍	❍	❍	❍	❍
I have received many positive comments from friends and family that heat pumps are a good heating alternative	❍	❍	❍	❍	❍	❍	❍	❍
My household will continue to use t heat pump in the future	❍	❍	❍	❍	❍	❍	❍	❍

I can recommend others to use heat pump for heating	❍	❍	❍	❍	❍	❍	❍	❍

42. How much do you agree or disagree to the following statements about pellet stoves?

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
ENOVA subsidy was crucial when I chose to purchase a pellet stove	❍	❍	❍	❍	❍	❍	❍	❍
The cost of pellets is as expected	❍	❍	❍	❍	❍	❍	❍	❍
Pellet stove heats up my house efficiently	❍	❍	❍	❍	❍	❍	❍	❍
Pellet stove heat up my house in a pleasant way	❍	❍	❍	❍	❍	❍	❍	❍
Pellet stove creates more dust than I thought	❍	❍	❍	❍	❍	❍	❍	❍
Pellet stove is a reliable heating source	❍	❍	❍	❍	❍	❍	❍	❍
Operation of the pellet stove takes less time than I expected	❍	❍	❍	❍	❍	❍	❍	❍
It is easy to obtain pellets	❍	❍	❍	❍	❍	❍	❍	❍
I am satisfied with the appearance of the pellet stove	❍	❍	❍	❍	❍	❍	❍	❍
I have received many positive comments from friends and family that pellets stoves are a good heating alternative	❍	❍	❍	❍	❍	❍	❍	❍
My household will continue to use the pellets in the future	❍	❍	❍	❍	❍	❍	❍	❍
I can recommend others to use pellet stove	❍	❍	❍	❍	❍	❍	❍	❍

Now, we will ask you some general questions about your attitudes and opinions.

43. How much do you agree or disagree to the following statements?

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
New technology will solve the environmental problems	❍	❍	❍	❍	❍	❍	❍	❍
We must reduce energy consumption to solve climate problems	❍	❍	❍	❍	❍	❍	❍	❍

I am very concerned about climate change	❍	❍	❍	❍	❍	❍	❍	❍
Many claims about climate change is exaggerated	❍	❍	❍	❍	❍	❍	❍	❍
Solving environmental problems is the government's responsibility	❍	❍	❍	❍	❍	❍	❍	❍
Electricity prices will increase significantly over the next few years	❍	❍	❍	❍	❍	❍	❍	❍
Everyone should do whatever they can to protect the environment	❍	❍	❍	❍	❍	❍	❍	❍
Rich countries should be expected to do more to improve the environment than poor countries	❍	❍	❍	❍	❍	❍	❍	❍
I buy environmentally friendly products if possible	❍	❍	❍	❍	❍	❍	❍	❍
Most Norwegian households could reduce their heating costs by increasingly using other heating sources other than electricity.	❍	❍	❍	❍	❍	❍	❍	❍
I have a personal responsibility to help solve environmental problems	❍	❍	❍	❍	❍	❍	❍	❍

44. How much do you agree or disagree to these statements of bioenergy? With bio-energy, we mean wood, pellets, wood chips, etc.

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
Increased use of bioenergy for heating is an important contribution to reducing adverse climate change	❍	❍	❍	❍	❍	❍	❍	❍
Firewood produce a lot local air pollution	❍	❍	❍	❍	❍	❍	❍	❍
Increased production of pellets leads to loss of biological diversity	❍	❍	❍	❍	❍	❍	❍	❍
Subsidized production of bio-energy is a good way to give farmers a higher income	❍	❍	❍	❍	❍	❍	❍	❍
Norwegian authorities should encourage the use of wood, pellets or other biomass for heating	❍	❍	❍	❍	❍	❍	❍	❍
I grew up in a house which use much firewood	❍	❍	❍	❍	❍	❍	❍	❍
I use firewood with main purpose of being cozy	❍	❍	❍	❍	❍	❍	❍	❍
My household uses a lot of firewood for heating	❍	❍	❍	❍	❍	❍	❍	❍
Friends and family use a lot of firewood for heating	❍	❍	❍	❍	❍	❍	❍	❍

I can recommend others to use firewood for heating	❍	❍	❍	❍	❍	❍	❍	❍
I think my friends and family consider firewood as a good heating option	❍	❍	❍	❍	❍	❍	❍	❍

45. I see myself as someone who ...

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7	Do not know
like to maintain the traditions and culture	❍	❍	❍	❍	❍	❍	❍	❍
always participate in volunteer activities	❍	❍	❍	❍	❍	❍	❍	❍
like to be among the first to buy new technology when it is introduced in the market	❍	❍	❍	❍	❍	❍	❍	❍
believes that the quality of a product is more important than how it looks	❍	❍	❍	❍	❍	❍	❍	❍
discuss a lot with friends and family before I take important decisions	❍	❍	❍	❍	❍	❍	❍	❍
constantly postpone things for tomorrow	❍	❍	❍	❍	❍	❍	❍	❍
usually must hurry to catch what I should do before the last minute	❍	❍	❍	❍	❍	❍	❍	❍
in order to save time, often pay others to do things that I could have done	❍	❍	❍	❍	❍	❍	❍	❍
often buy things on sale	❍	❍	❍	❍	❍	❍	❍	❍
do not throw away the old stuff if they can still be used	❍	❍	❍	❍	❍	❍	❍	❍
like to do risky things	❍	❍	❍	❍	❍	❍	❍	❍
prefer to buy known products rather than the ones with newest technologies	❍	❍	❍	❍	❍	❍	❍	❍
to save time, often choose a more expensive solution than necessary	❍	❍	❍	❍	❍	❍	❍	❍
Always compare prices from different vendors when I buy expensive things	❍	❍	❍	❍	❍	❍	❍	❍

46. Where do you live in?

- Østfold
- Akershus
- Oslo
- Hedmark
- Oppland

- Buskerud
- Vestfold
- Telemark
- Aust-Agder
- Vest-Agder
- Rogaland
- Hordaland
- Sogn og Fjordane
- More og Romsdal
- Sør-Trøndelag
- Nord-Trøndelag
- Nordland
- Troms
- Finnmark
- Utlandts

47. Are you male or female?

- Man
- Woman

48. Which year were you born?

49. What is your highest completed education?

- Elementary Education
- Secondary education
- Professional school
- Universitets-/college education with up to 4 years duration
- Universitets-/college education with more than 4 years duration

50. How many people usually live in your household (including yourself)?

- 1 person
- 2 people
- 3 people
- 4 people
- 5 people or more

51. Approximately how large is the household's total gross annual income (before taxes and deductions)?

- Under 200,000 kroner
- 200,000 to 399,999 NOK
- 400,000 to 599,999 NOK
- 600,000 to 799,999 NOK
- 800,000 to 999,999 NOK
- 1,000,000 to 1,199,000 NOK
- 1,200,000 to 1,399,000 NOK
- 1,400,000 NOK
- Do not want to answer

52. Do you own or rent your current residence?

- Own
- Rent

53. Did you vote in the election in 2009, and which party did you vote?

- Det norske Arbeiderparti
- Fremskrittspartiet
- Høyre
- Kristelig Folkeparti
- Kystpartiet
- Rød Valgallianse
- Senterpartiet
- Sosialistisk Venstreparti
- Venstre
- Andre partier og lister
- Stemte ikke
- Husker ikke/vet ikke
- Vil ikke oppgi parti
- Hadde ikke stemmerettEr du aktiv eller passiv medlem av noen av følgende miljøorganisasjoner?

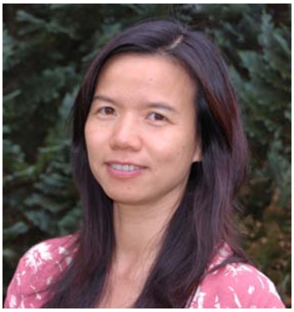
54. Are you active or passive member of any of the following environmental organizations?

- Bellona
- The Future in Our Hands
- Nature and Youth
- Greenpeace
- Norwegian Nature Conservation Association
- Norway's Environment Federation
- Environmental Home Guard
- WWF
- Agent21
- No, not a member
- Do not know
- Do not reply

Do you have any opinions or comments on the survey you have now answered?

Thank you for participating in the survey

Shuling Chen Lillemo



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Shuling Chen Lillemo was born in Liuzhou, China. She holds a Bachelor degree in Economics from Guangxi University in China (1996) and a Master degree in Development and Resources Economics from Norwegian University of Life Science, Norway, (2007).

Understanding the decision-making process behind energy consumption is important if we want to influence people's energy behaviours and achieve the goals of sustainable energy consumption. This thesis study factors affecting residential heating energy investments and utilization choices by integrated behavioural approaches.

The dissertation consists of four empirical papers that have the following goals: The first paper evaluate the determinants behind investments in heating equipment; it investigates how investing motives and attitudes towards environment affect the heating investment choice in Norwegian households; The second paper is to explore a new methodology for modelling the consumption share of storable energy goods; it examines the impact of heating equipment perceptions and attitudes towards biomass heating on the choice of the household's main heating source; The third one is to test the effect of life style variables in households' firewood demand; The last paper identify the role of procrastination and environmental attitudes in involvement of heating saving activities.

The estimation results from this thesis and their implications show the importance of taking into account internal factors, such as decision makers' attitudes and perceptions, in explaining people's energy consumption behaviour. The interdisciplinary study approach enriches our knowledge about individual energy decision making and consequent choices. It can aid to improve the energy and environmental policy effectiveness.

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