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Household preferences of hybrid home heating systems – A choice experiment application

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HIGHLIGHTS

- Study of hybrid heating where supplementary and main heating systems are combined.
- Choice experiment is applied to study the determinants of hybrid heating adoption.
- Hybrid heating appears to be generally accepted among households.
- Households exhibit differing attitudes toward hybrid heating.
- Policy makers should not underestimate the potential of hybrid heating.

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ABSTRACT

The residential heating sector presents considerable energy savings potential, as numerous heating solutions for reducing electricity consumption and utilizing renewable energy sources are available in the market. The aim of this paper is to examine determinants of household heating system choices and to use this information for policy planning purposes. This paper investigates residential homeowner attitudes regarding innovative hybrid home heating systems (HHHS) with choice experiment. Heating system scenarios are designed to represent the most relevant primary and supplementary heating alternatives currently available in Finland. The choice sets include six main heating alternatives (district heat, solid wood, wood pellet, electric storage heating, ground heat pump and exhaust air heat pump) that are described by five attributes (supplementary heating systems, investment costs, operating costs, comfort of use and environmental friendliness). The results imply that HHHSs generally appear to be accepted among households; however, several factors affect perceptions of these technologies. The results reveal differing household attitudes toward the main heating alternatives and show that such views are affected by socio-demographic characteristics (age, living environment, education, etc.). The results suggest that households view supplementary heating systems (especially solar-based) favorably. The other attributes studied also play a significant role in decision making.

1. Introduction

Sustainable energy usage is a key element and driver of the modern world. This decade, the European Union (EU) has sought to tackle three key objectives known as the '20–20–20' targets, which emphasize the reduction of greenhouse gas emissions, growth in renewable energy usage and improvements of energy efficiency. Residential energy demand plays an essential role in achieving these targets. Households consume a quarter of all energy consumed in the EU (European Commission, 2013). More specifically, a large fraction of this energy consumption is attributed to the residential heating sector, which focuses on heating household spaces and water (Pardo et al., 2013).

The residential heating sector presents considerable energy savings potential. Several technical heating solutions that utilize renewable energy sources and/or that reduce energy consumption levels are available in the market. These energy efficient heating solutions serve as relevant and cost-efficient alternatives in all climate conditions around the world. However, households have been slow to switch to heating systems of superior environmental performance (see Connolly et al. (2013)).

A major share of residential energy consumption is used for heating, especially in cold climate conditions. In Finland, over 80% of

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annual household energy consumption is dedicated to heating household spaces and water (Statistics Finland, 2012b). Additionally, approximately 50% of Finns live in privately owned detached houses (Statistics Finland, 2012a). The Finnish residential heating sector thus presents the capacity to meet renewable energy targets and to reduce overall energy demand levels and greenhouse gas emissions.[1]

Vihola and Heljo (2012) detected trends in heating methods used in Finnish buildings between 2000 and 2012. They discovered that the residential heating sector and the technologies that are used are changing. They identified a rapid decline in oil and direct electric heating usage alongside an increase in ground heat pump usage. While it has traditionally been common to rely primarily on one heating system, households are now beginning to utilize a combination of complementary heating technologies as a result of technological advances. This emerging trend warrants our study of innovative hybrid home heating systems (HHHS) and of household views of these technologies. Such analyses are needed, as knowledge of household preferences facilitates the promotion of HHHSs.

In combining more than one energy source for household space and water heating, HHHSs serve as an alternative to traditional heating systems (e.g., oil, gas or direct electric heating). HHHSs use a supplementary heating system alongside a primary heating system and can utilize several sources of renewable energy to generate heat (e.g., solar, solid wood, wood pellet and ground heat) as well as outside air and exhaust air.[2] Generally speaking, hybrid heating is flexible, cost effective and environmentally friendly for its users. HHHSs can also offer further protection from unpredictable fuel cost increases, as such heating systems do not rely on a single form of technology or fuel source. Moreover, HHHSs are easily adjustable. For example it is feasible to add supplementary heating technologies to central heating system. HHHSs can also be operated via automatized control systems and can thus automatically use the most efficient fuel source available.

While hybrid heating systems are growing more popular among households, there are only few studies (see Michelsen and Madlener (2013) and Scarpa and Willis (2010)) on determinants of household HHHS adoption that have simultaneously considered the effects of primary and supplementary heating systems on decision making processes. Previous studies have mainly focused on socio-demographic and motivational factors that influence the adoption of various heating technologies (see Section 2). Furthermore, previous studies have largely examined house renewal activities (both refurbishment and renovating activities), whereas the preferences of individuals who are building new detached houses have not been examined thoroughly (see Section 2). The heating literature lacks a thorough investigation of HHHSs. Most studies have focused on individual heating alternatives; in turn, the hybrid nature of space heating has been given little or no attention. This paper addresses this gap.

We used a stated preference (SP) method referred to as the choice experiment (CE) method (see Hensher et al., (2015)) to analyze individual preferences of HHHSs. The CE method is a widely used quantitative statistical approach that is employed to analyze individuals' discrete choices (see Adamowicz et al. (1994); Boxall et al. (1996); Phillips (2012); Viney et al. (2002)). The method has two important features: it allows one to examine hypothetical heating scenarios and to identify trade-offs between different heating alternative attributes.[3] Using this method, individuals were presented with a hypothetical setting involving energy efficient heating alternatives and were asked to select their preferred alternative among a predetermined choice set. Each heating alternative was described by a number of attributes and attribute levels. Thus, individuals implicitly made trade-offs between attribute levels related to different heating alternatives presented in choice sets.

This study has several objectives. First, it presents general information on household attitudes and perceptions of HHHSs. Second, it examines heating mode choices that households make when presented with various scenarios that involve currently used heating technologies. Moreover, this paper investigates the role that attributes play when households select one type of heating system over another. This study specifically focuses on the hybrid nature of each heating mode. The third goal is to explain patterns of preference heterogeneity among households. Different socio-demographic and behavioral household characteristics are expected to play a significant role in explaining household heating system choices. Finally, an account of how the study results may help facilitate the development of a greener residential heating sector is presented.

To examine these issues, the paper is organized as follows. After introducing previous studies related to household heating system choices, the survey design is presented in Section 3. The results are presented in Section 4 and the main findings are discussed in Section 5. Section 6 concludes with policy implications.

2. Previous studies

Numerous studies in the field of energy economics have examined household heating system choices. Michelsen and Madlener (2013) divided these empirical studies into three categories based on the nature of preference information used. In this paper, we follow their method and update it. The first category focuses on household-specific data (e.g., socio-demographic, housing or geographic characteristics) by relating such characteristics to heating system choices and energy demand (see Braun (2010), Dubin and McFadden (1984), Nesbakken (2001) and Vaage (2000)). Dubin and McFadden (1984) investigated U.S. household residential energy demand and developed a modeling approach that has been later utilized in many studies (Braun, 2010; Nesbakken, 2001; Vaage, 2000). Vaage (2000) and Nesbakken (2001) examined Norwegian households' heating mode choices and energy consumption. These studies showed that the electricity and fuel prices have a significant impact on the choice of heating system. The analyses also revealed a high degree of heterogeneity among households. Braun (2010) focused on the determinants of the heating mode choices in Germany. The results implied that regional effects and dwelling features are important for heating system choices.

The second category includes empirical data on real adoption actions and on planned decisions that focus on behavioral aspects of heating system adoption (see Bjørnstad (2012), Decker et al. (2010), Decker and Menrad (2015), Mahapatra and Gustavsson (2008, 2009, 2010), Michelsen and Madlener (2012, 2013, 2016) and Sopha et al. (2010)). Sopha et al. (2010) studied Norwegian households' perceptions of electric heating, heat pumps and wood pellet heating, whereas Bjørnstad (2012) examined levels of investment satisfaction among Norwegian households that use heat pumps and pellet stoves and that have participated in a subsidy program. The latter study showed that economic factors (electricity prices) affect investment satisfaction levels, but importantly, households also value their investments based on multiple dimensions (e.g., heat comfort and technical service availability levels). Mahapatra and Gustavsson

[1] Finland's goal is to achieve the EU's "20–20–20" targets and to further increase its share of renewable energy use to 38% by 2020.

[2] We mean by exhaust air the waste air leaving the house.

[3] With other techniques, we can only study events that have already occurred. Additionally, when we compare the Contingent Valuation (CV) method with the CE method, the latter can be used to identify trade-offs between different attributes. CE studies are conducted to examine an individual's response to changes in attributes of the chosen situation and in the chosen situation as a whole.

(*footnote continued*)