Diffusion of Energy-Saving Innovative Heating Systems in Sweden: A Consumer Survey Approach

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ABSTRACT

In Sweden, considerable energy efficiency and greenhouse gas mitigation could be achieved through the conversion of 500,000 detached houses from electricity-based heating systems to district heating, heat pumps or pellet boiler systems. House owners are central in the diffusion of innovative heating systems as they make the adoption decision. Hence, we carried out an empirical analysis of the factors affecting house owners' decisions to adopt a heating system. In June 2005 we sent out questionnaires to about 700 Swedish house owners residing in the city of Östersund, whose houses were originally built with resistance heaters. The results reveal that about 84% of the respondents had no plans to install a new heating system. Economic aspects, functional reliability and indoor air quality were the important factors in respondents' choice of a heating system. A district heating system has advantages with respect to functional reliability, indoor air quality, maintenance cost, system automation and time required for collection of information. A bedrock heat pump system has advantages with respect to annual cost of heating, indoor air quality, security of fuel supply, environmental benignity and market value of the house. A pellet heating system has an advantage with respect to investment cost.

Introduction

Swedish energy policy is aimed at phasing out oil and electric heating and increasing energy efficiency and the use of renewable energy resources in the residential and commercial premises sectors (STEM, 2004). In 2004, about 15.8 TWh of electricity was used for space heating of detached houses, mostly by the 33% of the 1.6 million Swedish detached houses exclusively using electricity for heating (STEM, 2005). Electricity-based heating systems can be replaced by innovative heating systems such as district heating, heat pumps or pellet boiler systems[1]. System analyses of small-scale heating systems for detached houses have shown that primary energy use and the emission of greenhouse gases (GHGs) are lower for district heating, heat pumps and pellet boiler systems than electric boilers and resistance heaters (Karlsson and Gustavsson, 2003; Joelsson and Gustavsson, 2005). In particular, there is a win-win situation in the conversion of electricity-based heating systems to a biomass-fired district heating system based on combined heat and power (CHP) production using steam turbine technology. The use of electricity is reduced and the increased district heat load increases the potential to co-generate electricity with high efficiency. The primary energy savings could be around 70% and 55% with district heating and bedrock heat pumps[2], respectively (Joelsson and Gustavsson, 2005).

[1] "Innovative heating system" is used here to refer to heating systems such as district heating, heat pumps and pellet boiler systems, and various stoves used to replace or complement the electric and oil boilers and resistance heaters that are more widely used and that have been in use much longer.

[2] Two basic configurations of geothermal heat pumps are bedrock heat pumps and ground source heat pumps. In the former case, a closed loop pipe containing an antifreeze solution extracts heat from a deep borehole of 50 – 250 meters, while in the latter case the pipe is laid horizontally 1-2 meters below the surface (Lund, 2003).

As with most innovations, widespread diffusion of innovative heating systems takes time. One way to pave the way for policies aimed at stimulating and accelerating the diffusion of such systems is to analyse the factors affecting the speed of diffusion. Factors affecting the diffusion of heating systems can be studied at different levels. At the macro-level the diffusion of a single heating system can be investigated by using the "systems of innovation" concept, according to which it is important to analyse the whole system including the role of supply- and demand-side actors, institutions and the technology. However, it is complex to explore these issues simultaneously, when there are many heating systems competing on the market. A simpler approach is to investigate the potential adopters' perception of the competing heating systems vis-à-vis their existing system. An innovative heating system with a greater perceived advantage will be adopted by more house owners than systems with less perceived advantage.

In a recent study it was found that about 75% of Swedish house owners had no plans to install a new heating system within next four years (Gustavsson and Mahapatra, 2005). In particular, the owners of houses with resistance heaters were less likely to install a new heating system. An earlier study carried out in the late 1980s also found similar results (Hallin, 1988). The aim of the present study is to gain a deeper understanding of the behaviour of the owners of houses with resistance heaters regarding their adoption of innovative heating systems.

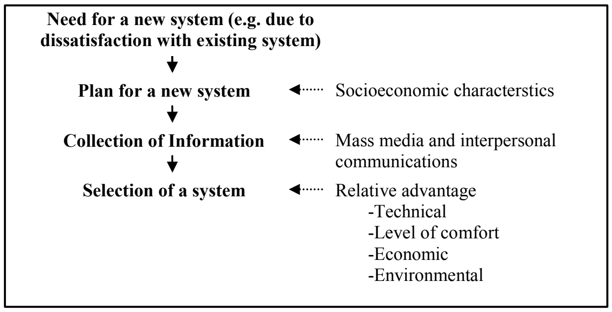
In order to understand the resistance heater owners' perception of different innovative heating systems we carried out a questionnaire survey, during June-August 2005, of 691 Swedish house owners residing in the city of Östersund, whose houses were originally built with resistance heaters. The survey was conducted prior to a market campaign initiated by the municipality-owned energy company *Jämtkraft*, which is planning to connect its local biomass-fired district heating network to these houses. The district heating production is mainly based on a wood-fired CHP plant. However, house owners may choose other heating systems and some may not install any new heating system at all.

In this paper, we present an assessment of the respondents' perception of various innovative heating systems that require a water-based heat distribution system (or a "hydronic system"). In Section 2 we discuss various factors that affect the diffusion of heating systems, based on the diffusion of innovation theory of Rogers (2003). In Section 3 we discuss the methodology and in Section 4 we present the results of the questionnaire survey. Finally, conclusions are presented in Section 5.

Factors Affecting Diffusion of Heating Systems in Swedish Detached Houses

Rogers (2003) has presented a diffusion of innovation model, where the decision-making process is central. The innovation-decision model essentially has the structure shown in Figure 1. In this section we apply this model to discuss various factors affecting the diffusion of heating systems in the Swedish detached house sector.

Figure 1: Stages in Innovation-Decision of a Potential Adopter



Need for a New Heating System

A need for an innovative system is created by dissatisfaction with the existing system, which may be because the existing system does not live up to expectations or because an innovative system, better than the existing system, is available (Rogers, 2003). House owners start to search for information on innovative heating systems when they are no longer satisfied with their existing system, e.g. due to high heating cost or breakdowns. Users of existing, well-functioning heating systems are likely to be satisfied with their heating systems, particularly if they are accustomed to using these systems. Adoption of an innovative system may involve a change in the user's routine behaviour to which it may be difficult to adapt. Also, new heating systems are associated with uncertainties related to performance, physical or economic lifetime, availability of service and support, etc. House owners averse to taking risks may prefer to continue to use their existing resistance heaters as the technology is mature and there is a well-established service and support system.

Socio-economic aspects such as income and age are closely linked to the likelihood of adoption of an innovation. House owners with higher incomes are expected to be more inclined to install a new heating system. Typically, older house owners find it more difficult to change their behaviour, as they have become accustomed to their existing heating system. Furthermore, they will be less likely to install a new heating system if they do not expect the investment to be paid back during their lifetime.

Sources of Information

House owners, who plan to install a new heating system will gather information from the mass media, interpersonal sources and change agents. According to Rogers (2003), the impact of mass media is more pronounced at the early stages of diffusion since the innovators, followed by early adopters, try the product first and they are influenced by mass media more than any other group of adopters. The main forms of mass media are television (TV), newspapers, the internet and fliers sent to the home. In the later stages of diffusion, adopters from other categories follow the early adopters, typically yielding a bell-shaped curve in the distribution of adopters. In this stage of diffusion, information spreads more through interpersonal communication, and the main sources of information are neighbours, relatives, friends and colleagues. Furthermore, the change agents (Rogers, 2003), such as the Swedish Energy Agency (STEM), the local energy office at the municipality level, magazines such as "Vi i Villa" (one of the Sweden's largest circulated publications exclusively covering aspects related to detached houses) and the installers of heating systems, influence the decision of potential adopters.

It is, however, difficult to ascertain which heating systems are recommended/promoted by different sources of information. Nevertheless, recommendations and promotions highlight the advantages of various system-related factors, e.g. cost and convenience that house owners consider in their decision. Information obtained from various sources, together with personal judgment is reflected in the house owner's perception of the advantages associated with a product. A system perceived as being more advantageous is preferred and will be recommended to others through interpersonal communication, leading to an increased number of adoptions. The perceived advantages are, nonetheless, compared with respect to various system-related factors and are discussed below.

System-Related Factors Affecting the Choice of Heating System

Technical factors. In the absence of a water-based heat distribution system (or hydronic system), house owners may supplement resistance heaters with an air-based heat pump or other kinds of stove. With the installation of a hydronic system, they can chose between district heating, a bedrock/ground source heat pump or a pellet boiler system. In addition to a hydronic system, the availability of a chimney and space for fuel storage is necessary for the installation of pellet boilers. Heat pumps require a suitable heat source, and connection to a district heating system depends on the heat demand in the area.

The performance (functional reliability) of a new heating system affects house owners' adoption decision. In Sweden, district heating systems are very reliable as they have been in use for many decades. House owners are usually not worried about the functional reliability of such systems, since the district heating company is responsible for supplying heat. The diffusion of pellet boilers (Westholm, 1986a) and heat pumps (Westholm, 1986b) was very slow during the 1980s, possibly due to several breakdowns in the systems, the main causes of which were poor quality of the systems and mistakes in their installation. These problems still exist.

Level of comfort. District heating and heat pump systems require no manual operation or maintenance. In particular, with a district heating system, the production and distribution of heat is managed by the district heating company. Swedish pellet boilers often require weekly manual cleaning of the burner and ash removal (Fiedler, 2004). Apart from the physical work, time is a major concern, especially when both spouses work.

Generally, the type of heating system does not affect the indoor air quality. However, the indoor air is usually dry with resistance heaters. With a pellet heating system dust may present a problem, particularly when pellets are fed manually into the boiler.

Economic factors. A hydronic system is necessary for conversion from resistance heaters to district heating, bedrock heat pumps and pellet boiler systems. For a typical Swedish detached house the investment cost for the installation of a hydronic system and radiators is about €4,400[3] (STEM, 2003). Investment costs for different heating systems mentioned hereafter exclude this investment. The investment cost for a bedrock heat pump of 5-6 kW capacity (efficiency of about 300%) is about €13,000, while the investment cost for connection to a district heating system is about €4,000 (STEM, 2003). The investment cost for a pellet boiler is about €5,000 (STEM, 2003). In addition, there is an investment cost of about €1,000 or €3,000 for building an

[3] €1 = 9.2 Swedish kronor (SEK) in August 2005.

indoor or outdoor storage area, respectively, to store pellets. Also, an investment of about €2,400 is necessary for the installation of a chimney.

The annual cost of heating also influences house owners' choice of new heating system. The cost of electricity in Sweden in 2003 was about 90 €/MWh. For a typical Swedish detached house with an annual heat demand of 20 MWh, the annual cost of heating with a bedrock heat pump with a system efficiency of 300%, is about €600. The annual cost of heating with a district heating system is about €1,450 (STEM, 2003). The cost of pellets in Sweden in 2003 was about 50 €/MWh (STEM, 2003). The annual cost of pellets for a pellet boiler with 80% conversion efficiency is thus about €1,250.

The market value of the house may be another factor affecting the choice of heating system. Heat pumps have the highest investment cost but lowest annual heating cost. This means that a house with a heat pump installed may have a higher market value than one with other systems. On the other hand, the house owner may be reluctant to install a heat pump as the market value may not increase in accordance with the investment cost of the heat pump.

Environmental and supply security issues. District heating, heat pumps and pellet boiler systems are considered to be environmentally benign. However, district heating systems may use fossil fuels. Heat pumps use electricity although the consumption in heating a house is reduced by two thirds in comparison to resistance heaters or electric boilers. Electricity production might be associated with polluting coal-fired power plants. There could also be fears about the environmental impact on underground water when using a bedrock heat pump. Similarly, house owners may have the impression that the use of forest resources to produce pellets disrupts the ecological balance.

With fossil-fuel-based systems there is a risk of supply disruption and price fluctuation in countries like Sweden. Such risks can be avoided through the sustainable use of domestic wood resources. However, a perception that the availability of pellets will be limited in the future due to raw material scarcity could act as a barrier in the adoption of pellet systems.

Methodology

The Questionnaire

The questionnaire has six parts. Section A includes general questions related to existing heating system. A particular question was directed at the respondent's level of satisfaction with the heating system which could be indicated on a 5-point Likert scale (1=not satisfied at all, 5=completely satisfied). Throughout the questionnaire all negative options were given a low ranking and positive options a high ranking. Other questions concern the respondent's plans for installing a new heating system, sources of information and type of heating system he/she would recommend. Section B includes questions specific to each heating system, e.g. the presence of a vendor in the vicinity, monetary savings upon switching to a new system, etc. In Section C, respondents grade the level of importance of different system-related factors. For each factor respondents indicate their choice on a 4-point scale (1=not important at all, 4=most important). In Section D, respondents were asked to rank the different heating systems on a 5-point Likert scale for each factor included in Section C. For example, for the factor "annual cost of heating at present", respondents could indicate on a 5-point scale (1=very high and 5=very low) the annual cost of heating with different heating systems. Sections E and F include questions on energy and the environment, and socio-economic variables, respectively.

The Survey

A total of 691 respondents originally having resistance heaters and residing in an area in the city of Östersund were sent the questionnaire in June 2005. After two reminders, one 3 weeks, and one 6 weeks, after the first dispatch, we obtained a response rate of 59%. Several respondents did not answer all the questions, and therefore the response rate for each question varies and is less than the survey response rate.

Analysis

In Section A of the questionnaire respondents were asked to express their level of satisfaction with their existing heating systems on a 5-point Likert scale (1=not satisfied at all, 5=completely satisfied). For the purpose of easy interpretation we restructured the five response levels into three. Level 1 (not satisfied at all) and level 2 (dissatisfied) were combined, as were levels 4 (satisfied) and 5 (very satisfied).

The mean and standard error (S.E.) were used in ranking the factors included in Section C. A higher mean indicates that the factor is of greater importance. As the mean is not the recommended measure of central tendency for ordinal variables (Nachmias and Nachmias, 1996), non-parametric tests, such as the Friedman test and Wilcoxon signed ranks test (Green and d'Oliveira, 1982), were conducted. The Friedman test compares all factors and indicates whether the ranking of at least one factor is significantly different from the others. The Wilcoxon signed ranks test compares the ranking of two successive factors.

In Section D the mean value of the respondents' ranking of the heating systems is presented in descending order. A system with a higher mean is better than the others. The Friedman test compares all heating systems regarding each system-related factor and indicates whether the ranking of at least one heating system is significantly different from the others. The Wilcoxon signed ranks test compares the ranking of two successive heating systems.

Results

Dissatisfaction with an existing heating system motivates a house owner to look for a new heating system. Out of the 389 house owners who responded, 61.2% were satisfied, 26.5% neither satisfied nor dissatisfied and 12.3% dissatisfied. There is a significant relationship between respondents' level of satisfaction and their plans to install a new heating system (Table 1). Respondents' plans for the installation of a new heating system follow a decreasing trend with increasing satisfaction.

Table 1. Percentages of Respondents Indicating When They are Planning to Switch to a New Heating System According to Level of Satisfaction (Pearson chi sq.=33.191, N=389, d.f.=8, p<0.001)

Respondent category	Respondents' plans to install a new heating system (% of each category)				
	Not yet planned	Yes, within 1 year	Yes, with in 1-2 years	Yes, with in 2-4 years	Yes, 4 years or later
Dissatisfied (N=48)	58.3	10.4	8.3	12.5	10.4
Neither satisfied nor dissatisfied (N=103)	81.6	3.9	2.9	6.8	4.9
Satisfied (N=238)	90.8	2.5	1.7	2.9	2.1
Total (N=389)	84.3	3.9	2.8	5.1	3.9

There is a significant relationship between respondents' age and their plans to install a new system in the near future (Table 2). The percentage of respondents planning to install a new heating system decreases with increasing age. However, the respondents in the age group 36-45 are more likely to install a new heating system than those in other groups.

Table 2. Percentage of Respondents in Different Age Groups Indicating Whether They had Plans to Install a New Heating System (Pearson chi sq.=38.143 , N=385, d.f.=16, p<0.001)

Age group (years)	Respondents' plans to install a new heating system (% of each category)				
	Not yet planned	Yes, within 1 year	Yes, with in 1-2 years	Yes, with in 2-4 years	Yes, 4 years or later
≤35 (N=15)	66.7	6.7	0.0	13.3	13.3
36-45 (N=64)	64.1	7.8	4.7	12.5	10.9
46-55 (N=75)	85.3	4.0	4.0	4.0	2.7
56-65 (N=153)	90.2	2.0	2.0	3.9	2.0
>65 (N=78)	92.3	3.8	1.3	1.3	1.3
Total (N=385)	84.4	3.9	2.6	5.2	3.9

There is a significant relationship between respondents' income and their plans to install a new heating system (Table 3). The percentage of respondents with plans to install a new heating system increases with increase in income, with one exception. Respondents in the income group 450,000-600,000 SEK are more likely to install a new heating system than other income groups.

Table 3. Percentage of Respondents in Different Income Groups Indicating Whether They had Plans to Install a New Heating System (Pearson chi sq.=32.202, N=369, d.f.=16, p=0.009)

Income group (1000 SEK)	Respondents' plans to install a new heating system (% of each category)				
	Not yet planned	Yes, within 1 year	Yes, with in 1-2 years	Yes, with in 2-4 years	Yes, 4 years or later
≤150 (N=6)	100.0	0.0	0.0	0.0	0.0
150-300 (N=63)	95.2	0.0	1.6	0.0	3.2
300-450 (N=117)	92.3	4.3	0.9	2.6	0.0
450-600 (N=129)	72.9	6.2	4.7	10.1	6.2
600 (N=54)	79.6	3.7	1.9	7.4	7.4
Total (N=369)	84.3	4.1	2.4	5.4	3.8

House owners consult several sources of information on new heating systems, albeit to varying degrees (Table 4). Installers/vendors are able to give on-site information about the suitability of different heating systems and are the most frequently consulted source. "Vi i Villa" is the second most consulted source. Interpersonal communication channels such as friends (41%), neighbours (27%) and colleagues are given greater preference than mass media channels such advertisements in newspapers (25%) and TV (5%). The local authority energy advisors (27%) are not such an important source of information as could be expected.

Table 4. Percentages of Respondents Indicating Their Sources of Information on Heating Systems (N=391)

Source	%*	Source	%	Source	%
Installers/vendors	63	Local authority energy advisors	27	Advertisements on TV	5
"Vi i villa"	46	Advertisements in newspapers	25	Chimney sweeper	4
Friends	41	Home-delivered fliers	25	Library	4
Internet	38	Colleagues	24	Other+	3
Visiting a house with a new installation	31	Exhibitions and trade fairs	19	Researcher	2
Neighbours	27	STEM	17		

*Many respondents indicated multiple sources of information, so the sum of the percentages exceeds 100.
+includes Jämtkraft - the local CHP plant, family members and own experience

The importance given to interpersonal communication channels as sources of information has implications for the diffusion dynamics of innovative heating systems. Later adopters usually take an adoption decision based on the recommendations of these sources (Rogers, 2003). Hence, it is of importance which heating system is recommended by the house owners in general. Out of the 291 respondents who responded, about 41% and 38% would recommend heat pumps (including water- and air-based) and district heating systems, respectively (Table 5). Only 2% would recommend a pellet heating system.

Table 5. Percentage of Respondents Indicating Type of Heating System They Would Recommend (N=291)

System recommended	%*	System recommended	%
Heat pump	41	Depends on type of house	2
District heating	38	Solar	2
Do not know	17	Pellet boiler	2
Other+	5	Wood boiler	1
Resistance heater	4	Electric boiler	1

*Many respondents indicated multiple choices, so the sum of the percentages exceeds 100.
+Other includes different types of stoves and fire place

System-Related Factors in the Choice of Heating System

Technical requirements for installation. District heating, heat pumps and pellet boiler systems require a hydronic system, while pellet systems also require a chimney and pellet storage. The survey results revealed that about 96.2% respondents (382 in number) do not have a hydronic system. In the absence of such a system, house owners may install an air-based heat pump or a wood-based stove. In fact, about 5.6% of the 393 respondents have already installed an air-based heat pump since 1994. Also, about 8.4% of the respondents have installed a wood-based stove or a fireplace. About 15 respondents (3.8%) have installed a hydronic system and 11 of them have already installed a bedrock heat pump. With the installation of a hydronic system, about 43% of the respondents could install a pellet boiler as they already have a chimney. Among these 169 respondents about 30% indicated that the space requirement for pellet storage was an obstacle in the adoption of a pellet-based heating system.

Other important factors. We have compared different factors that affect house owners' decisions to adopt a new heating system (see Section 2.3). The mean values for the different factors investigated (Table 6) showed that respondents consider, in decreasing order of importance, the annual cost of heating, investment cost, functional reliability and indoor air quality to be the four most important factors in heating system choice. Respondents attach less importance to factors like system automation, environmental benignity, and increase in market value of the house. The time required for the collection of information is given the least importance. The significance of the non-parametric Friedman test (Pearson chi square = 805.158, N = 239, degrees of freedom = 11 and p <0.001) confirmed the ranking of the factors based on the mean values and indicates that at least one variable is ranked significantly differently from the others. However, this test does not indicate whether any of the two successive factors in Table 6 are ranked significantly differently from each other.

Table 6. System-Related Factors Affecting Respondents' Choice of Heating System (in Decreasing Order of Importance)

Factor	N	Mean+	S.E.	Wilcoxon signed ranks test
Annual cost of heating	336	3.63	0.033	N.S.
Investment cost	358	3.59	0.032	*
Functional reliability	323	3.46	0.042	**
Indoor air quality	306	3.24	0.044	**
Maintenance cost	314	3.03	0.043	N.S.
Security in fuel supply	278	2.94	0.055	**
System automation	304	2.76	0.051	N.S.
System is environmentally benign	291	2.74	0.051	N.S.
Market value of the house increases	295	2.64	0.049	N.S.
Time required for maintenance of the system	282	2.59	0.048	N.S.
Low GHG emission	288	2.53	0.051	**
Time for collection of information	281	2.01	0.046	

+1 = not important, 2 = less important, 3 = important, 4 = most important.
N.S. = not significant, **significant at $p \leq 0.01$, *significant at $p \leq 0.05$.

We therefore conducted the Wilcoxon signed ranks test for each pair of successive factors in Table 6 and the results are presented in the last column of Table 6. The first entry in the column indicates that there is no significant difference in the respondents' ranking of the first factor (annual heating cost) and the factor that followed (investment cost). Similarly, the third entry in the column indicates that there is a significant difference in the house owners' ranking of the third factor (functional reliability) and the factor that follows (indoor air quality).

Comparison of Heating Systems with Regard to System-Related Factors

A higher percentage of the respondents indicated that they would recommend heat pumps than would recommend any other heating systems (Table 5). Such an attitude might be interpreted as respondents' expression of perceived relative advantages of heat pumps over other heating systems with respect to the most important factors that they take into account when deciding on a new heating system. In Table 7, we compare the respondents' perception of different heating systems with respect to the various factors outlined in Table 6. If the mean value of any factor for one heating system is higher than for another system then the system is considered better with regard to that factor. For example, for the factor "annual cost of heating", bedrock heat pumps have a mean value of 3.71, which is higher than the comparable values for other systems. This means that most respondents rank bedrock heat pumps better than a pellet boiler or a district heating system when considering the annual cost of heating. This factor is also divided into heating cost at present and in the future. The annual cost of different heating systems may change in the future, which may influence house owners' decisions to adopt a particular system at present. For each system-related factor, the Friedman test for ranking of different heating systems was significant ($p<0.001$). For each system-related factor, the results of the Wilcoxon signed ranks test for successive heating systems (arranged according to decreasing mean value) is presented in the last column of Table 7.

Comparison of mean values for the innovative heating systems (Table 7) indicates that bedrock heat pumps have advantages with respect to annual cost of heating, security of fuel supply, environmental benignity and increased market value of the house. A district heating system has advantages with respect to functional reliability, maintenance cost, system automation and time required for collection of information. There is no difference between the two systems with respect to indoor air quality. Pellet boilers are ranked lowest for every factor except for investment cost.

The percentage of respondents who answered "Do not know" to any particular aspect of a heating system ranged from 4.9% to 51.9%. The percentage of "Do not know" responses was lowest for resistance heaters and highest for pellet boilers. Also, "Do not know" answers are higher for bedrock heat pumps than for district heating systems.

Table 7. Comparison of Different Heating Systems with Respect to Various System-Related Factors

Factor and type of heating system	No. of observations (N)	Do not know^{+} (% of N)	Mean^{++}	S.E.	Wilcoxon signed ranks test
Present annual cost					
Bedrock heat pump	358	32.4	3.71	0.07	**
District heating	358	29.1	3.13	0.05	*
Pellet boiler	357	42.0	2.93	0.06	**
Resistance heater	373	5.9	2.13	0.05	
Future annual cost					
Bedrock heat pump	357	33.3	3.73	0.07	**
District heating	360	30.6	2.92	0.06	N.S.
Pellet boiler	355	41.1	2.89	0.06	**
Resistance heater	377	15.6	1.70	0.05	
Present investment cost					
Resistance heater	381	20.2	3.78	0.06	**
Pellet boiler	362	41.4	2.33	0.06	**
District heating	366	22.4	1.93	0.05	**
Bedrock heat pump	364	25.8	1.54	0.05	
Functional reliability					
District heating	352	29.0	4.52	0.04	*
Resistance heater	379	6.9	4.44	0.04	**
Bedrock heat pump	351	38.2	4.09	0.06	**
Pellet boiler	351	46.7	3.39	0.06	
Indoor air quality					
District heating	352	31.5	4.19	0.05	N.S.
Bedrock heat pump	353	39.7	4.18	0.06	**
Pellet boiler	349	46.4	3.72	0.06	**
Resistance heater	383	6.0	3.40	0.06	
Maintenance cost					
Resistance heater	380	9.5	4.33	0.05	N.S.

Factor and type of heating system	No. of observations (N)	Do not know+ (% of N)	Mean++	S.E.	Wilcoxon signed ranks test
District heating	359	32.6	4.21	0.06	**
Bedrock heat pump	358	38.0	3.54	0.07	**
Pellet boiler	357	42.6	3.07	0.06	
Security of fuel supply					
Bedrock heat pump	240	32.4	4.41	0.05	**
District heating	256	27.3	4.18	0.05	**
Resistance heater	377	7.2	4.09	0.05	**
Pellet boiler	206	41.5	3.47	0.06	
System automation					
District heating	358	30.4	4.58	0.05	N.S.
Resistance heater	386	4.9	4.45	0.05	**
Bedrock heat pump	357	37.5	4.28	0.06	**
Pellet boiler	357	44.0	2.86	0.06	
Environmental benignity					
Bedrock heat pump	355	24.8	4.47	0.05	**
District heating	354	23.2	3.90	0.05	**
Resistance heater	382	7.3	3.56	0.07	**
Pellet boiler	354	31.1	2.93	0.06	
Market value of the house					
Bedrock heat pump	355	26.2	4.52	0.05	**
District heating	356	20.2	4.24	0.05	**
Pellet boiler	351	38.2	3.01	0.05	**
Resistance heater	379	13.7	2.29	0.06	
Time required for maintenance of the system					
Resistance heater	385	4.7	4.74	0.04	*
District heating	356	28.4	4.68	0.05	**
Bedrock heat pump	356	37.9	4.39	0.06	**
Pellet boiler	353	43.9	2.81	0.06	
GHG emission					
Bedrock heat pump	348	29.9	4.64	0.05	**
Resistance heater	377	22.0	4.45	0.05	**
District heating	347	28.5	3.75	0.06	N.S.
Pellet boiler	346	39.0	3.17	0.28	
Time required for collection of information					
Resistance heater	377	27.9	4.12	0.07	**
District heating	353	42.2	3.58	0.07	**
Bedrock heat pump	354	46.0	3.13	0.08	**
Pellet boiler	351	51.6	2.98	0.07	

++"Do not know" responses were treated as missing values.
+A system with a higher mean value is interpreted as better than a system with a lower value
N.S. = not significant, **significant at $p \leq 0.01$, *significant at $p \leq 0.05$

Conclusions

The survey of 691 house owners with resistance heaters revealed that about 61% of the respondents are satisfied with their heating system. However, about 84% of the respondents have not planned to install a new heating system within next four years. This means some respondents dissatisfied with their existing systems have not planned to install a new heating system. This is because their socio-economic conditions do not motivate them to do so. The percentage of respondents planning to install a new heating system increases with decrease in age and increase in income. In particular, respondents in the age group 36-45 years and in the income group of 450,000-600,000 SEK are more likely to install a new heating system than those belonging to other groups. About 60% of the respondents are above 55 years old. About 90% of the respondents of this age have no plans to install an innovative heating system, probably because they expect the existing system to function during their remaining time in the house.

For house owners installers/vendors are the most important source of information related to heating systems. An effective way of influencing the diffusion of innovative heating systems may thus be to train installers/vendors to inform house owners about different heating systems.

Annual heating cost, investment cost, functional reliability and in-door air quality are the most important factors in heating system choice. Since economic factors are most important in house owners' decision making, economic instruments to internalise the external costs of heating systems would be useful in promoting environmentally benign heating systems. House owners perceive that bedrock heat pumps have advantages with respect to annual cost of heating, indoor air quality, security of fuel supply, environmental benignity and market value of the house. A district heating system has advantages with respect to functional reliability, indoor air quality, maintenance cost, system automation and time required for collection of information. A pellet heating system has an advantage with respect to investment cost. Hence, house owners giving priority to annual cost of heating will install a bedrock heat pump. Those giving additional importance to investment cost and functional reliability will install a district heating system.

The survey results are based on 59% of the respondents and we have not investigated whether the non-respondents varied from the respondents in any significant way. Also, from 1 January 2006, the Swedish Government is providing investment support to house owners for conversions from resistance heaters or oil boilers to district heating, heat pumps or biomass-based heating system (Swedish Government, 2005). The support is 30% of the total investment cost, but not more than €3,400. The investment support policy might have some influence on house owners' decision to adopt a new heating system, which is not reflected in the present survey.

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