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Article

Wood-Pellet Heating in Norway: Early Adopters' Satisfaction and Problems That Have Been Experienced

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Abstract: Given the vital role of early adopters during the early stage of wood-pellet heating development, this study aims to explore the factors that explain the overall satisfaction among the early adopters of this type of heating as well as the problems experienced with wood-pellet heating in Norway. Ordinal regression was used to analyze empirical data which was collected from a mail survey in autumn 2008. The response rate of 45% was composed of 669 early adopters of wood-pellet heating. Findings show that both economic factor (*i.e.*, cost) and technical factors (*i.e.*, pellet stove performance) have played a significant role in early adopters' overall satisfaction with wood-pellet heating. The most common problems experienced are igniter failure in the pellet stove, lack of committed and competent suppliers/vendors, more time and effort than expected during maintenance, and fines from pellets both during handling and combustion.

Keywords: early adopters; satisfaction; technical problems; wood-pellet heating; Norway

1. Introduction

Environmental problems, such as climate change, are important issues today. The question of how to meet present needs without sacrificing the ability of future generations to satisfy their needs is thus a central topic in the debate over sustainable development. The convergence toward a sustainability path depends to a great extent on the diffusion of environmentally friendly technologies. In fact, the diffusion of these technologies is often slow and tedious [1,2]. The diffusion of wood-pellet heating in Norway is one of the examples. Little attention has been paid to the empirical study of customers' perceptions of wood-pellet heating. Therefore, this study contributes to a better understanding of the case by meeting two objectives. First, it aims at revealing factors explaining early adopters' satisfaction with using wood-pellet heating. Second, this paper also presents subjective perceptions about maintenance time as well as problems related to wood-pellet stoves, suppliers of wood-pellet stoves and wood pellets. This paper provides empirical evidence about the factors influencing household satisfaction with wood-pellet heating and their typical problems so that intervention favoring further diffusion of wood-pellet heating could be appropriately designed.

2. Wood-Pellet Heating

Home heating accounts for approximately 50% of an average household's energy use, being the largest share of energy consumption in Norwegian residential sector. The Norwegian heat market is characterized by a dominance of individual heat sources, such as electric radiators, logwood stoves, and air-to-air heat pumps, rather than central heating using water-based heating systems. Approximately 5% of Norwegian households use common central heating and less than 1% have access to district heating [3,4]. The most important energy carrier in Norwegian households is electricity due to the public investment in hydropower construction from 1960 to 1990, which provided a large capacity of cheap electricity [5]. Figure 1 shows the market share of various types of heating systems in Norway [6]. Norwegian households generally combined different types of heating systems and the combination of electric heating and wood stove is the most popular system [7].

Norway's commitment to the Kyoto Protocol which restricts the increase of greenhouse gas emissions has led to policies favoring the increased use of heat pumps, wood-pellets, thermal solar energy, *etc.* [5]. Therefore, the Norwegian government plans to reduce and then phase out remaining oil-based heating systems by supporting alternative heating systems which are presumed to be environmentally friendly. Figure 1 illustrates the 65% reduction in oil-based heating systems in 2009 compared with 2006. However, among the Nordic countries, Sweden is the country that has significantly reduced oil use in the residential sector so that the level of oil use per person is about 30% of that of Norway [7]. This has been made possible by replacing oil-based heating systems with district heating, water-based heat pumps and pellet boilers [8].

The pellet market in Norway is currently only a niche market, in contrast to some European countries such as Sweden, Austria, and Denmark in which wood pellets have been well-developed and well-utilized for heating, mainly in the residential sector. At the moment, the main application of wood-pellets in Norway is small-scale heating in households. Wood-pellet heating is particularly interesting for the Norwegian market because wood-pellets are normally produced out of clean saw

dust and shavings, which are residues from the wood-based industry. A life-cycle assessment shows that wood-pellet stoves can result in overall environmental and climate benefits in Norway compared to oil-based heating system [9]. Furthermore, given the fact that wood is the second dominating heating system in Norway, replacing wood stoves with pellet stoves may contribute to lower emissions as pellet stoves burn significantly cleaner than wood log stoves [10]. Table 1 presents emission comparison of different wood log fireplaces and woodpellet stove which shows the large potential for low emissions achievement with woodpellet stove.

Figure 1. Heating system adopted by Norwegian households in 2006 and 2009, by percentage. Note: Norwegian households generally utilize more than one type of heating system. Source: [6].

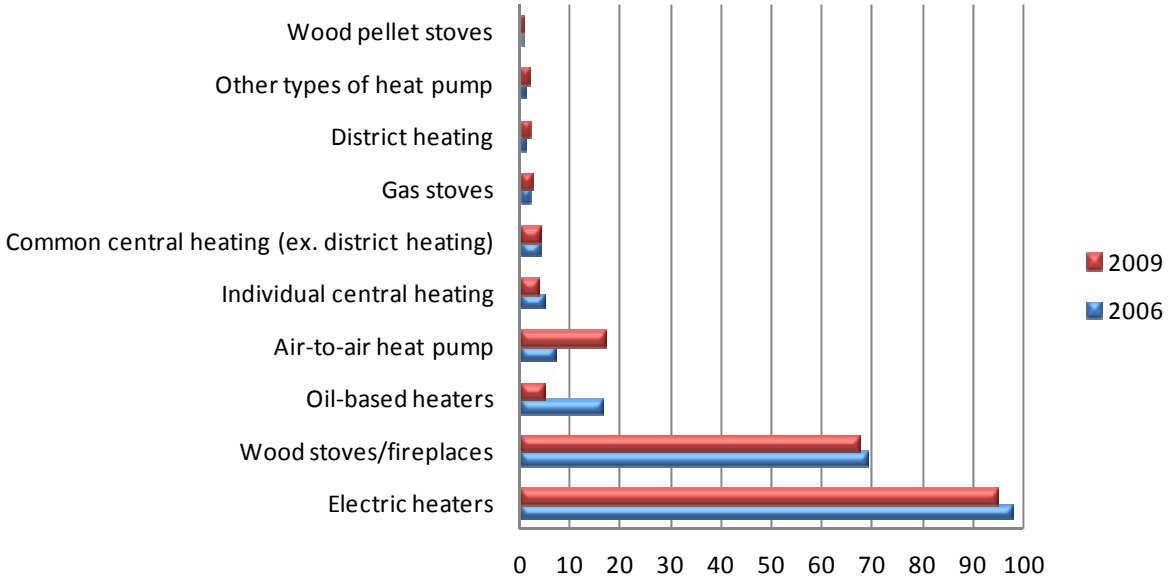

Table 1. Arithmetic average emissions levels in mg/m^3 at 13% O_2 from small-scale biomass combustion applications at standard reference conditions.

	Load (kW)	Excess Air ratio	CO (mg/m^3)	C_xH_x (mg/m^3)	Particles (mg/m^3)	NO_x (mg/m^3)	Temp (°C)	Efficiency (%)
Wood-stoves	9.33	2.43	4,986	581	130	118	307	70
Fireplace inserts	14.07	2.87	3,326	373	50	118	283	74
Heat storing stoves	13.31	2.53	2,756	264	54	147	224	78
Pellet stoves	8.97	3.00	313	8	32	104	132	83
Catalytic wood-stoves	6.00	-	938	-	-	-	-	-

Source: [11].

To persuade households to decide on wood-pellet heating, a subsidy scheme of up to 20% of total installation cost of wood-pellet heating was introduced in 2003. A study investigating the effect of this subsidy scheme to the adoption of wood-pellet heating indicated that only 1215 out of 3671 households who received grants had actually installed wood-pellet heating [12]. Therefore, the market for

wood-pellet heating remains low and is stagnating [3]. According to Statistics Norway, it was reported that the market share of wood pellets was 0.3% and 0.7% in 2006 and 2009 respectively (see Figure 1). A previous study of the opportunities and barriers for wood-pellet heating in Norway came to the conclusion that the largest barriers were in fact on the demand side [13]. The study found that plant pellet production plant was currently operating under-capacity due to lack of wood-pellet demand. This study therefore complements the previous study by exploring subjective perceptions from the end-users' perspective.

The present study however does not claim that an extremely high adoption rate of wood-pellet heating is desirable from an environmental perspective as research on the optimal balance of heating systems in Norway needs to be investigated beforehand. This study is merely focusing on how to improve a potential system, *i.e.*, wood-pellet heating that is under-utilized.

3. Background Theory

A low level of acceptance of new technology is actually not new phenomenon in adoption and diffusion studies. One particular technology may take less than a decade to diffuse while another technology may take more than a century to be well-accepted by society. Studies to stimulate and/or accelerate technology diffusion can be approached at either macro- or micro-levels, qualitatively or quantitatively. Some studies have focused on supply side of the process, e.g., Grübler [14]; others on the demand side, e.g., Rogers [15].

As the present study focuses on demand side, it therefore uses insights from Diffusion of Innovation (DoI) theory by Rogers [15] which has been widely used in various application domains such as agriculture and information technology. According to DoI, the adoption of innovation has generally been through different phases from initial slow growth to accelerating and eventually to maturity and decline. The first phase of adoption involves innovators and is then followed by early adopters once the benefits start to become apparent. Early adopters are vital because they provide information to other consumers that are critical before marketing release. After an innovation crosses the chasm, the early majority comes into play, followed by late majority and laggards respectively.

DoI theory also highlights that innovation decision is dependent upon individuals' perception of an innovation's characteristics; relative advantage, compatibility, complexity, trial ability, and observability. Jeyaraj *et al.* [16] demonstrated that perceived innovation characteristics determined the acceptance of information technology applications. Relative advantage referring to the degree to which an innovation/a technology is perceived to be superior to previous/existing technology can be measured in terms of social prestige, convenience or satisfaction. Using the concept of satisfaction as an indicator of adoption decision has been proposed and applied in some studies, e.g., Nyrud *et al.* [17]. The concept of satisfaction assumes that dissatisfaction towards a technology may lead to a need of a new technology type, whereas satisfaction with existing technology convinced consumers to keep their technology, exerting a significant impact on consumer loyalty [18]. Mahapatra *et al.* [8] demonstrated that when low quality and expensive pellet boilers appeared on the market this was leading to dissatisfaction among early adopters of pellet heating systems who might have passed this information to others, and ultimately to low market penetration. Sopha *et al.* [19] have indicated that those who would choose wood-pellet heating in the future seems to be satisfied with the existing wood-pellet

heating, stressing the importance of exploring factors contributing to the satisfaction /dissatisfaction of using wood-pellet heating. Furthermore, Nyrud *et al.* [17] demonstrated that satisfaction towards wood stoves could predict the future use and the willingness to recommend to others. Given the vital role of early adopters, it is thus important to investigate the early adopters' perceived satisfaction towards wood-pellet heating.

Furthermore, as the wood-pellet market is still at an early stage of development, there is a dynamic aspect in technology development which will then impact on the structure of the wood pellet system. For example, developments in pellet quality and the convenience of using wood-pellet stoves will shape the future wood-pellet market. Therefore, during this stage, not only economic factors but also technical factors are vital. This is demonstrated by Nyrud *et al.* [17]; satisfaction concerning wood stoves in Norway is mainly related to the performance of the device. With respect to technology, there are many factors involved. Time and effort required for operation and maintenance of wood-pellet heating was found to be significant and impacted negatively on satisfaction [17]. The pellet stove is a relatively new technology which was first marketed in the USA in 1983 [12]. One of the success factors of wood-pellet development in Austria is that Austrian legislation enforces stringent emission standards for boilers, guaranteeing the boiler quality and enforcing the R&D efforts of boiler producers to improve technical performance of installations [20]. On the other hand, one of the barriers of wood-pellet development in Finland is that there is no standard for combustion equipment, leading to the collapse of consumers' confidence [21]. Moreover, the lack of after-sales service has already been seen as a problem for wood-pellet development in Finland [21]. With respect to pellet quality, according to Nashoug and Pedersen [13] there was a varying quality of pellets in Norway. Pellet quality was also perceived as a barrier in Finland where the pellets did not endure the mechanical wear caused by storage and transport [21]. In contrast, the certification system of pellets has facilitated the development of wood pellets in Austria [20]. Considering the issues raised in the literature mentioned, this study focuses on technical factors; namely maintenance time, pellet stove performance, suppliers/vendors and pellet quality.

With respect to the economic factor, the generous subsidy is one of the driving forces behind the wood-pellet heating development in Austria. Conversely, cost was found to be barrier for wood-pellet development both in Finland and in Norway [11,21]. Therefore, the present study focuses on both technology-related factors (technical factors) and cost (economic factor) that explain consumer satisfaction.

4. Methodology

4.1. Data Collection

A mail survey was conducted in autumn 2008 to collect data. 1500 questionnaires were sent to wood-pellet users in Norway which represents almost all the users. The list was acquired from wood-pellet companies in Norway. The response rate after three weeks was 34.6%. After a reminder was sent out, additional responses from 150 were received and this makes a total response rate of 44.6% (669 responses). Several respondents did not answer the entire questionnaire, and therefore the response rate varies for each question. The quantitative survey for the present study is also used for the

study reported in Sopha *et al.* [19] and Sopha *et al.* [22]. The analysis in the present study is however built on different variables which have never been used in both the previous studies except for the cost measure (see Table 2).

Table 2. Name and definitions of variables used in the analysis.

Variable	Name	Description
Dependent	Wood-pellet satisfaction	Perceived overall satisfaction of wood-pellet heating (5-point Likert scale, high score = high satisfaction)
Independent	Maintenance time	Perceived maintenance time (5-point Likert scale, high score = less time)
Independent	Pellet stove	Perceived pellet stove performance (5-point Likert scale, high score = high satisfaction)
Independent	Supplier of stove	Perceived service provided by stove vendor/supplier (5-point Likert scale, high score = high satisfaction)
Independent	Pellet quality	Perceived pellet quality (5-point Likert scale, high score = high satisfaction)
Independent	Cost	Perceived cost of wood-pellet heating (7-point Likert scale, high score = very expensive)

A household is the unit of analysis, implying that the response from the questionnaire represents a household. Hence, one member of the household, on behalf of a household, answers the questionnaire.

To test if the sample varied significantly from the regional distribution of all households in Norway, sample analysis was conducted and indicated that the sample shows an insignificant difference with respect to age when comparing to age distribution of population registry (Chi^2 = 45.423; df = 73; p = 0.995). Even though the regional distribution of wood-pellet sample is significantly different from that of population registry (Chi^2 = 488.028; df = 18; $p < 0.000$), this sample is representative for all Norwegian wood-pellet users, as it accounts for roughly 80% of all wood-pellet users in Norway.

To test non-response bias, a Chi^2 test is performed to compare the original and the response sample by provinces/districts. The tests revealed that there is no statistical difference between the original samples and response samples for wood pellet sample (Chi^2 = 2.031; df = 13; p = 1.000). Thus, a self-selection bias could not be found with respect to regional distributions. Other data on the original population to test self-selection bias in the response samples are not available. It might, therefore, be possible that self-selection processes result in an undetected bias. In addition, given the higher number of satisfied adopters in this sample (see Table 3), dissatisfied adopters are under-represented.

Table 3. Profiles of respondents' response on both dependent and independent variables.

Dependent variable	**Frequency (%)**
Wood-pellet satisfaction	*N* = 456
1 = not at all satisfied	7 (1.5%)
2	3 (0.7%)
3	29 (6.4%)
4	172 (37.7%)
5 = very satisfied	245 (53.7%)
Independent variables	**Means (S.D.)**
Maintenance time	2.64 (1.39)
Pellet stove	3.99 (1.04)
Supplier of stove	3.69 (1.19)
Pellet quality	3.71 (1.02)
Cost	3.56 (1.60)

4.2. Analysis

The analysis is divided into two parts to meet two objectives. The first analysis is to identify technical factors explaining early adopters' satisfaction. Ordinal regression was then selected to deal with ordinal nature of the dependent variable, *i.e.*, overall satisfaction of using wood-pellet heating. The independent variables are perceived maintenance time, perceived performance of wood-pellet stoves, perceived service provided by suppliers/vendors and perceived pellet quality, which are treated as continuous variables. Table 2 present the names and definitions of variables used in the analysis.

The second part of the study is to document responses from open questions with respect to maintenance time and the most experienced problems related to pellet stove, suppliers/vendors and wood-pellets. This part provides a more detailed explanation of the specific issues investigated in the first part.

5. Results

5.1. Ordinal Regression—Early Adopters' Satisfaction

Table 3 presents profiles of the sample based on responses to the dependent and independent variables in the survey. Participants with missing values in predictive variables had to be excluded from the study so that the final analysis is based on a sample of 456 respondents. The table shows that 91% of the sample is satisfied with wood-pellet heating, whereas only about 2% shows dissatisfaction.

The tests shown in Table 4 were conducted to assess model fit and the model's ability to predict the dependent variable. Based on the results in Table 4, the regression model fits well to the empirical data.

The regression coefficients, Wald test statistics, and significance for each of the variables are presented in Table 5.

When applying a $p < 0.05$ criterion of statistical significance, perceived stove performance and cost are found to be significant whereas perceived maintenance time and perceived service by suppliers/vendors are found to be marginally significant. Pellet quality is found to be non-significant ($p = 0.882$).

The threshold of categories 3 and 4 is significantly different from zero, implying that they substantially contribute to the values of the response probability in different category. The threshold of categories 1 and 2 is found to be non-significant, implying that the cutting points are not truly different and thus these categories need to be combined. The result indicates that the overall satisfaction of wood-pellet heating was significant associated with pellet stove performance and cost, whereas pellet quality is found to be non-significant to explain overall satisfaction of wood-pellet heating.

Positive regression coefficients of maintenance time, pellet stove and stove suppliers/vendors indicate that households who rate higher levels on these variables are likely to be more satisfied with wood-pellet heating. Negative regression coefficient of cost shows that the household is likely to be less satisfied with the increase of wood-pellet cost.

Table 4. Regression analysis.

Test	Result	Remark [a]
Test of Parallel Lines	$Chi^2 = 12.954$; $df = 15$; $p = 0.606$	Non-significant result indicates a well fitting model
Model Fitting	$Chi^2 = 182.795$; $df = 5$; $p < 0.001$	A well-fitting model is significant by this test
Goodness of Fit: Pearson Deviance	$Chi^2 = 1189.127$; $df = 1431$; $p = 1.000$ $Chi^2 = 611.535$; $df = 1431$; $p = 1.000$	A well-fitting model is non-significant by these tests
Pseudo R-Square: Cox and Snell Nagelkerke	 0.330 0.385	The higher, the better (less than 1). Approximations to OLS R^2, not to be interpreted as actual percentage of variance explained

[a] Source: [23].

Table 5. Ordinal regression for wood-pellet users' satisfaction.

Variable	B	Wald χ^2	*df*	*p*
Threshold 1 *vs.* 5	−0.466	0.458	1	0.499
Threshold 2 *vs.* 5	−0.034	0.003	1	0.958
Threshold 3 *vs.* 5	1.778	8.171	1	0.004 **
Threshold 4 *vs.* 5	4.839	51.685	1	<0.001 ***
Maintenance time	0.153	2.909	1	0.088 [ms]
Pellet stove	1.123	67.038	1	<0.001 ***
Suppliers of stove	0.193	3.702	1	0.054 [ms]
Pellet quality	−0.016	0.022	1	0.882
Cost	−0.233	9.804	1	0.002 **

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; [ms] marginal significance (ms) $p < 0.1$.

Table 6 displays the accuracy of the classification results for the satisfaction response category against the actual response category. The model demonstrated moderate prediction accuracy (50%) for all five categories combined.

Table 6. Accuracy of the classification for response categories.

		Predicted response category					
		1	**2**	**3**	**4**	**5**	**Total**
Actual response category	**1**	1	0	3	2	1	7
	2	0	0	0	3	0	3
	3	0	0	6	21	2	29
	4	0	0	1	87	84	172
	5	1	0	1	46	197	245
	Total	2	0	11	159	284	456

5.2. Perceived Problems Related to Wood-Pellet Heating

5.2.1. Maintenance Time

Table 7 displays the maintenance time each week experienced by early adopters. Most users respond that maintenance time less than 50 minutes per week is required for wood-pellet heating.

Table 7. Perceived maintenance time (N = 609).

Maintenance time (minutes/week)	Number	%
Less than 50	487	80
51–100	103	17
101–150	18	3
Above 150	1	0

5.2.2. Stove-Related Problems

Table 8 depicts the main problems of wood-pellet stove experienced by early adopters. It seems that the most familiar problem is related to the igniter, an electrical element which is heated to about 300–400 °C to start pellets to fire. Other common problems are related to control system, fuel feeding system and noise.

Table 8. Stove-related problems (N = 443). Note: Respondents are asked to name only one the most experienced stove-related problem.

Problem	Number	%
Igniter failure	108	24
Inappropriate combustion	99	22
Control system	45	10
Fuel feeding system	27	6

Table 8. *Cont.*

Problem	Number	%
Noise	27	6
Operations (unstable, stop)	20	5
More work than expected	16	4
Users guidance—too complicated	10	2
Backfire	8	2
Expensive (service and/or spare-parts)	6	1
Glass windows (safety, dangerous for children)	4	1
No Problem	*73*	*16*

5.2.3. Supplier-Related Problems

Table 9 shows experienced problems related to suppliers/vendors. Lack of commitment to consumers refers to unwillingness to provide service or no response toward consumers' request. Discontinuation of pellet-stove sales could be due to that suppliers/vendors are either no longer selling pellet stoves or are in bankruptcy.

Table 9. Supplier-related problems (N = 324). Note: Respondents are asked to name only one the most experienced supplier-related problem.

Problem	Number	%
Lack of commitment to consumers	78	24
Lack of competence	76	23
Long delivery time for spare-parts	24	7
Discontinuation in selling pellet stoves	22	7
Long distance	8	2
No Problem	*116*	*35*

5.2.4. Pellet-Related Problems

Table 10 displays most problems related to pellets. About half of the reported problems are about fines/dust from pellets both during handling and combustion. Fuel properties of pellet include densities, length, fines and moisture that differ over time. This may result in a new adjustment of the pellet stove which is not suitable for consumers.

Table 10. Pellet-related problems (N = 408). Note: Respondents are asked to name only one the most experienced pellet-related problem.

Problem	Number	%
Dust	210	51
Non-stable fuel properties (over time)	35	9
Moisture	25	6
Too much ash	18	4
Varying pellet size (too long pellets)	10	2
Energy expectation in fuel	5	1
No Problem	*105*	*26*

6. Discussions

This study investigates the explanatory variables of early adopters' satisfaction concerning wood-pellet heating in Norway. The wood-pellet market in Norway is at the moment in the early development stage, the role of early adopters hence becomes important as they may either facilitate or hinder further adoption of wood-pellet heating. Early adopters, conveying subjective evaluation of wood-pellet heating, serve as a role model for potential adopters, thus reducing uncertainty (skepticism) about wood-pellet heating. Moreover, they may also provide feedback information on wood-pellet heating performance needed for improvement. Therefore, this study contributes to help policy makers to design effective intervention by providing empirical evidence about whether or not wood-pellet heating is satisfying from the households' perspective, providing information on factors leading to satisfaction, as well as providing facts on the most problems experienced by early adopters.

Results demonstrate that about 91% of early adopters are relatively satisfied with wood-pellet heating. Results also indicate that overall satisfaction toward wood-pellet heating is significantly influenced by both technical factors (*i.e.*, pellet stove) and economic factor (*i.e.*, cost). Studies have indicated that the lack of appropriate technology hinder the development of wood pellets, in addition to the economic barrier such as high investment cost [11,20,21]. Nyrud *et al.* [17] also emphasized the importance of superior system performance before a public campaign. Furthermore, Sopha *et al.* [22] simulating households' decision-making in response to various interventions, demonstrated that the relative advantage of wood-pellet heating should be realized not only in one area but also in many areas simultaneously with respect to functional reliability, supply security, indoor air quality, required work, and cost. The need for simultaneous development is also emphasized by Egger and Öhlinger [24] who suggested that key success for wood-pellet market establishment relied on all factors in market which functioned at the same time; from good quality pellet, standardized stove/boiler, distribution network, competent installers, until there was willingness among consumers to use wood-pellet heating. This actually corresponds with the design principles for effective carbon emission reduction programs for household sector by Vandenbergh *et al.* [25]. They suggest that program success critically depends on the combination of financial incentives and other design principles such as simplicity, quality assurance, and marketing.

The pellet stove is found to be a significant explanatory factor concerning the satisfaction of using wood-pellet heating. The most common problems with pellet stoves are related to igniter failure, inappropriate combustion, control system, fuel feeding system and noise. The problem with noise is also reported in the previous study on wood-pellet heating in Norway [12]. It implies that technology development for the pellet stove is urgently needed. It is also worthwhile to note that "glass windows" are perceived to be unfavorable by a few respondents due to safety considerations. Conversely, "glass windows" are preferred due to aesthetic concerns because the stove is not only serves its functional purpose but also performs a symbolic presentation of Norwegian homes [12]. For this reason, a neat design of the pellet stove is important to attract consumers [12,26]. Both maintenance time and vendors/installers reach marginal significance. The difficulty related to maintenance time and effort could be handled by fully automatic operation [26]. It seems that, based on the findings, maintenance time of wood-pellet heating should be less than 50 minutes/week to make wood-pellet

heating even more interesting. With respect to the problem related with service provided by suppliers/vendors, although 38% respondents show their satisfaction, it is worthwhile to mention that about 24% of responses confirmed their lack of commitment to the consumers, e.g., suppliers/vendors do not respond to consumers' inquiries and 23% confirmed that there was a lack of competence. Long delivery time for spare-parts, and discontinuation of selling pellet stoves are other problems mentioned as the third and fourth highest on the list. Lack of knowledge/skills was a barrier for wood-pellet development in Finland [21]. Therefore, improving suppliers' commitments and competences could be one of areas where action is required.

Pellet quality is found to be a non-significant variable for explaining satisfaction. 26% of responses allege to have no problem with pellet quality. However, this result is at odds with the work by Nashoug and Pedersen [13] who documented that the variation in the quality of pellets is one of the barriers for pellet development in Norway. The explanation could be that pellet quality has been developed and standardized. Hence, the quality of pellets is no longer perceived to be dissatisfying. At the same time, this result indicates that there exists dynamicity of technology development. Nevertheless, the main problem related to pellet quality is "dust" which is persistently perceived as a problem by adopters [13] and adopters of this study.

With respect to cost, our results imply that the higher the cost, the higher probability of dissatisfaction when using wood-pellet heating. It is necessary to note that the limitation of this study is that cost refers as a total cost which involves both investment and operational cost. It would be beneficial to differentiate between investment and operation costs so that appropriate intervention could be targeted to the specific area. Sopha *et al.* [22] used a similar sample as this study but analyzed a different part of the questionnaire. They confirmed that high investment cost is the highest barrier rated by the respondents. High investment cost was actually named by some works as a barrier to adopt wood-pellet heating. For instance, Bjørnstad *et al.* [12] documented that only about 33% of households receiving grants actually installed wood-pellet heating because of the high investment cost as well as the uncertain benefits. According to Nashoug and Pedersen [13], investment cost for pellet burning is about twice as high as investment in ordinary wood-burning stoves (in cost/KW). Moreover, some buildings lack the fundamental pre-requisites such as chimney, or room for pellet storage so that it is expensive to remodel them. The investment cost barrier was also experienced in Finland [21]. With respect to operational cost, Sopha *et al.* [22] indicated that operational cost is the third important attribute in a heating system decision which is in agreement, to some extent, with Nyrud *et al.* [17] who demonstrated that operational cost was not significant in explaining satisfaction with wood heating in Norwegian households.

Last but not least, this study concerns the subjective evaluation of the respondents which does not necessarily correspond to the actual/objective issue. For instance, the same price of a pellet stove may be perceived differently; some may consider it expensive and others may regard it to be cheap, depending on the contextual factors in which one is situated, thus providing richer insights.

7. Conclusions

This study uses the ordinal regression method to model the relationship between the early adopters' overall satisfaction with wood-pellet heating and the explanatory variables concerning both the

financial factor (cost) and the technical factor (maintenance time, pellet stove, suppliers/vendors, and pellet quality). Everything except pellet quality was found to be significant. The research findings provide the compelling evidence that both cost and pellet stove performance have played a significant role in early adopters' overall satisfaction with wood-pellet heating in Norway. Due to the significance of the pellet stove, technological improvements to alleviate the most common problems, *i.e.*, igniter, inappropriate combustion, control system, fuel feeding system and noise, are thus necessary. With respect to cost, it seems that financial support is still necessary; however, it should be complemented with intervention supporting technical factors. Although marginally significant, committed and competent suppliers/vendors as well as automation may stimulate a higher satisfaction level for wood pellet heating. The findings also indicate that pellet quality is no longer perceived to be a barrier as it was previously, implying the occurrence of technology dynamicity. Given the recent weak development of the wood-pellets market in Norway, *i.e.*, lack of vendor commitment and competence, immature technology and finally; low electricity prices, it seems that the market share of wood-pellets heating systems might not go any further than today's level.

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