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ORIGINAL PAPER

Public Perception on the Sustainable Energy Transition in Rural Finland: A Multi-criteria Approach

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Abstract

Heating is the most energy-intensive sector worldwide as well as in Europe and Finland. About 37% of the heat produced in Finland is still produced with fossil fuels, including 5.5% with fossil fuel oil (FFO). Phasing out FFO from the energy mix in compliance to Finnish carbon neutrality target is complicated because of the decentralized use all over the country, especially in rural Finland. There have been policies and financial instruments targeted for replacement of FFO-fired heating systems, but the rate of heating system renovation has been slow as there are still about 300,000 FFO and gas-fired heating systems nationwide. In this study, we conducted a survey of homeowners with FFO heating systems and asked about their willingness to renovate their heating system. In addition, we asked them to prioritize their sustainability criteria and we ranked them using the analytical hierarchy process (AHP). The first part of the results show that younger homeowners are more interested in more sustainable modes of heating. Further, the results also show that the willingness to undergo an FFO heating system renovation is higher among respondents with university degrees compared to respondents with high-school and upper secondary educations. The second part of the results show that the economy and environment were given the equally highest priority ratings compared to technological and social criteria. However, older and university degree-educated respondents emphasized environmental criteria, climate change and renewable energy indicators more than their younger and high-school graduate counterparts.

Keywords Energy · Renewable · Heating · Sustainability · Fossil oil · Energy transition · Public perception

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Abbreviations

FFO	Fossil fuel oil
MCDA	Multi-criteria decision analysis
AHP	Analytical hierarchy process
EU	European union
LCA	Lifecycle assessment
CR	Consistency ratio

Introduction

Space Heating and Finnish Heating Sector

Heating is the largest energy-using sector in the world. Around 50% of the total energy consumption in the world is used for heating of space and water, industrial purposes, and other applications. Around 46% of the total heat produced in the world is used for space and water heating and cooking in buildings. On the other hand, only 10% of the heat production is attributed to renewable sources of energy other than traditional biomass use [1]. According to the report from 2016, in European Union (EU) households, the heating of space and water consumes 79% of the total energy use and approximately 75% of the energy used in heating and cooling is sourced from fossil fuel [2]. Similarly, in Finland, the heating of space and household water consumed about 82% of total household energy consumption [3], but unlike global or European statistics, in Finland, the share of renewably sourced heat was 63% [4].

In Finnish dwellings, space heating is primarily provided by district heating, direct electricity, wood, fossil fuel–oil (FFO), and ambient energy (Fig. 1). District heating is heat provided by a local energy producer or from waste industry heat. Hot water is distributed through insulated underground pipes predominantly to blocks of flats and small houses via heat distributors. There are about 15,000 km of district heating networks (for reference: the electricity network extends for 400,000 km) used by 106 district heat producers in Finland [5, 6]. Ambient energy is classified as the heat extracted with a heat pump from the environment such as the air, water, or ground [7].

As shown in Fig. 1, district heating covers around 30% of the total heat demand, followed by wood fuel (28%) and direct electricity (24%). The share of ambient heat is about 12% and has been growing rapidly in Finnish households [8, 9]. As a minority, FFO covers around 5.5% of the total heat demand. FFO heating systems are predominant in the sparsely populated areas dominated by detached and semidetached houses [8].

In Finland, about 61% of the total residential heating energy consumption happens in detached and semi-detached houses followed by 25% in blocks of flats. As shown in Fig. 1, wood fuel and direct electricity cover most of the heating energy mix for detached and semidetached houses, while ambient energy comes in third. District heating is a major source of heat in blocks of flats, but it is negligible for other types of residential buildings. The reason for this is that the blocks of flats are dominant in the district heat supply network and sparsely populated areas lack district heating [9]. Similarly, there are about 300,000 FFO and gas-fired heating systems in Finland, predominantly in detached and semidetached houses, which consume 85% of the total FFO-derived heat [8, 10].

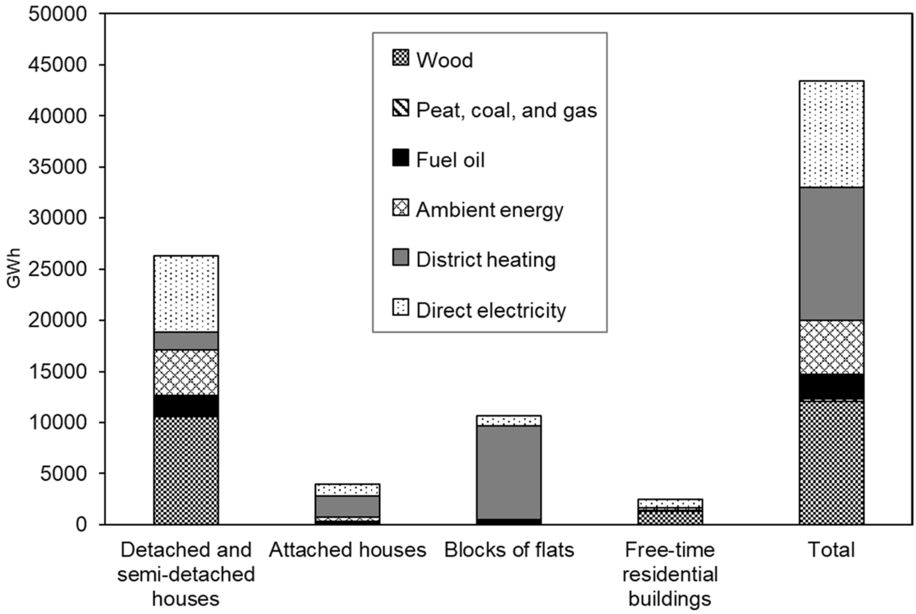

Fig. 1 Source of energy for residential heating classified according to the types of housing in Finland in 2019 [8]

Heating System Decarbonization and Finnish Energy Policy

The decarbonization of heating systems is highly challenging because it can be disruptive and comes with a high capital cost for relatively similar services that incumbent technologies provide [11, 12]. In addition to the economic hurdles, there are socio-technical challenges because of the complex problem which involves infrastructures, patterns of incumbency and path dependency, and socioeconomic factors such as income and poverty [13]. On the other hand, turnover in the housing stock is slow and it takes a long time for new investments to diffuse. Since there is very little unbiased and professional advice available, it could be confusing and risky for homeowners [11]. In addition, the urban region of Finland is growing faster than rural regions [14], and people from rural Finland continue to move to growing regions, mainly the southern region [15]. Potentially due to such reasons, rural homeowners often associate heating system renovation with the price of the house, and whether a new heating system would raise its market value.

For decades, Finnish energy policies have been focused on industries, but as the government aims to raise the renewable share of energy to more than 50% and simultaneously phase out coal from the energy mix, the policies are shifting toward the residential sector as well [9]. In Finland, regions have modest administrative power and they take a leading role in the development of their own region including the implementation of environmental and sustainable development policies. Examples of regional actions include setting up climate panels and working toward implementing the governmental climate act on a regional level [16] and the implementation of waste management [17].

As shown in Fig. 2, the share of fuel oil in residential heating is decreasing, falling from 11% in 2010 to 5.5% in 2019. However, FFO heating systems which are decentralized in

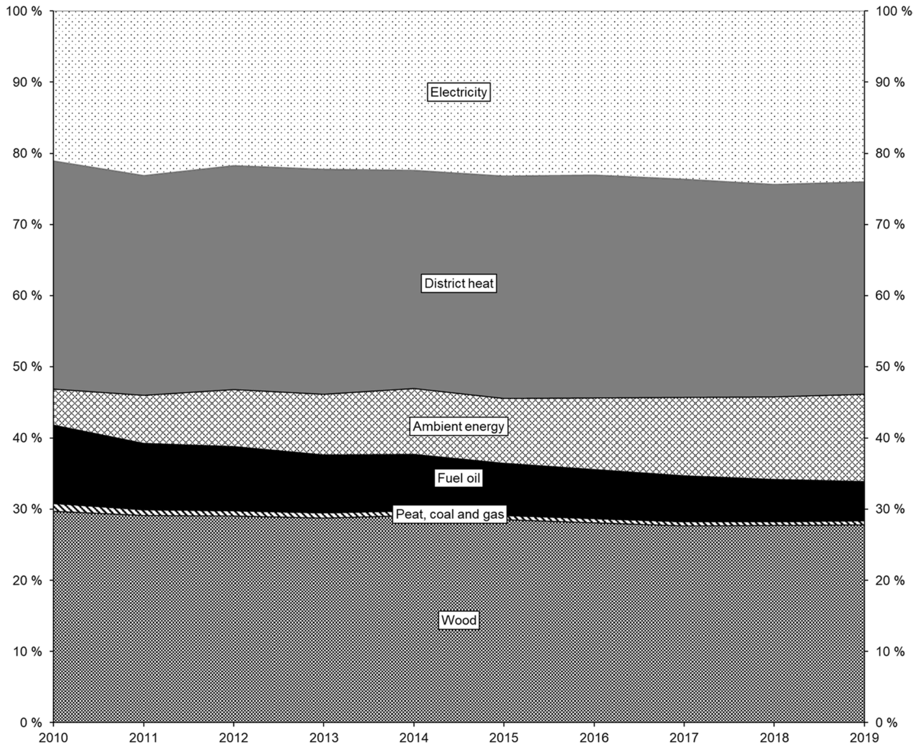

Fig. 2 Historical share of residential heating in Finland [8]

the rural areas [18] still may pose a barrier to the Finnish government's goal of achieving carbon neutrality by 2035 [19].

In the past, there have been efforts from the Finnish government to offer support to eliminate inefficient heating systems. During 2006–2008, low-income households could apply for a 25% grant for investment and other households could apply for a maximum of 6,000 euros of the labor costs for renovations, including heating system renovations [11]. Recently, the Finnish government through various institutions has been offering support mechanisms to replace FFO-heating systems with renewable sources of energy [20]. There are three kinds of financial support. For example, starting from 1.6.2020, the Ministry of Economic Affairs and Employment (through the Center for Economic Development, Transport, and the Environment, ELY-Center) began to offer a maximum of 4,000 euros as a one-time support package for homeowners who replace an FFO-heating system with a renewable source of heat [21]. Similarly, the Ministry of the Environment (through the Housing Finance and Development Center) offered up to 6,000 euros depending on the improvement in energy efficiency and offered disabled and elderly individuals up to 50% in repair costs for defective or end-of-life FFO heating systems [22]. Finally, the Finnish Tax Administration offers (and continues to offer until 2027) various kinds of support for the labor costs of such renovations [20].

According to the ELY-Center, in the 1.5 years since the public call for state support for elimination of FFO heating system, it received over 17,800 applications [21]. The number of planned renovations is relatively low as there are about 300,000 FFO and gas heating systems in the country. There may be various reasons for the slow start for the heating renovation plans. The Finnish public's attitude toward renewable energy is largely unknown as there are only a few scientific studies that have studied the factors that affect the decision making of homeowners concerning heating systems. A European survey found that the Finnish public are generally positive toward renewable energy [15]. Moula et al. [23] found that many of the respondents from the capital region of Finland wanted to save the environment. Jung et al. [24] also conducted a survey among the residents of the capital region of Finland and found that there is a strong willingness to invest in renewable energy technologies.

Survey and MCDA

In democratic societies, public participation is a critical element in energy restructuring or energy transition processes [25]. The public's perception of new technology, as well as their opinion of it, helps to close the communication gap between policymakers and the general population. In addition, such data help policymakers anticipate public reactions to new technologies [26]. Furthermore, public responses can be utilized to assess the risk associated with new energy technology [27]. Boudet, on the other hand, feels that, while awareness of public opinion and response does not guarantee the adoption of new technology, its absence is more likely to end in failure [28]. Similarly, Inglehart [29] also believes that policies design to solve environmental problem are unlikely to succeed without broad public support.

A survey is one method to gauge public opinion on a given subject. Surveys are especially useful because of the direct connection to the public at an individual level, and they can be geocoded to respondents to achieve the targeted responses at the local level. However, it is important to realize that surveys only provide response options and opinions at a specific point in time, and they rarely explain why respondents think the way they do or what led them to think that way. Boudet believes that researchers need to conduct detailed interviews and use focus groups and participant observations for detailed responses. The author also feels that the research on public perceptions and responses to shifting energy landscapes will continue to shed light on the ever-changing energy scenarios and broader society and that such a study is critical to achieving sustainable development in the energy sector [28].

The assessment of the way people make or ought to make decisions is an age-old concept. However, there are numerous scientific methods for these assessments and this number is growing with time [30]. Rational decision making for energy systems, their planning, management, and the economy are helpful for sustainable development, but as other factors come in to play such as policy, technology, local and global environment, it becomes complex and difficult [31]. Multi-criteria decision analysis (MCDA) is a tool that offers a technique to eliminate such complexities and difficulties and it has been successfully used in sustainable energy policies and decision-making processes as well. There are multiple methods for implementing an MCDA, such as: an analytical hierarchy process (AHP), the technique for order of preference by similarity to ideal solution (TOPSIS), elimination et choice translating reality (ELECTRE), and the preference ranking organization method for enrichment evaluation (PROMTHEE) [31, 32]. In addition, some studies [33, 34] have combined multiple methods in the same study. In the Finnish context, Kontu et al. [35] used a stochastic multi-criteria acceptability analysis (SMAA) to analyze the best and most suitable heating system for the city of Loviisa. Similarly, Jung et al. [24] used SMAA to gauge the public perception of renewable energy technologies among the residents of Helsinki. Grafakos et al. [36] used MCDA as a tool to gauge the sustainability preference of stakeholders on energy technologies.

There are handful of multidisciplinary research on sustainability criteria priority ranking using multi-criteria method. Väisänen et al. [37] conducted a survey among the local energy expert. In their study, they found that environment holds the highest priority followed by technology and economy. Abdelkader [38] conducted an online survey to gauge correlation between perception, willingness, and behavior of the respondents regarding green buildings. Their results show no significant relationship between educational background.

Komendantova [39] used multi-criteria decision analysis (MCDA) covering multiple countries including Finland to gauge the stakeholders' awareness of renewable energy sources and their preferences toward different criteria such as economic, technical, political, and environmental aspects. The stakeholders in the Finnish case included individuals who had an important role in the environmental impact assessment of local projects and members of local communities in northern Finland. The study found high levels of awareness of climate change and its being a consequence of human activities. The study also found that Finnish participants were highly concerned about the economic issues while subduedly concerned about environmental issues.

Analytical Hierarchy Process (AHP)

AHP is a tool developed by Thomas L. Saaty that helps in the decision-making process in complex systems. There are three phases which include: the identification and organization of the objectives of the system to be studied, criteria, constraints, and alternatives into the hierarchy; evaluation of the relevant elements using pairwise comparisons; and a synthesis of the results of the pairwise comparisons. The results of the process then show the relative importance of the elements [40]. According to Wang et al. (2009), AHP is the most popular MCDA tool in the sustainable energy decision-making process. It is more prevalent than others for rank-order weighting processes because of its understandability and simplicity [31]. For instance, Chinese et al. [41] applied AHP to the selection of a space heating system for an industrial building. Similarly, Väisänen et al. [37] combined AHP with a lifecycle assessment (LCA) to determine the sustainable means of energy for a local community in Finland. Datta et al. [42] used AHP to evaluate so-called green energies to identify the major challenges they pose to the future energy system. Zhang et al. [43], on the other hand, combined AHP with a comprehensive evaluation method called fuzzy comprehensive evaluation (FCE) to identify the most suitable and best-performing heating system in rural houses.

Sustainability Preferences and Aim of the Study

The preference on three pillars of sustainability may depend on the field and the demography of the stakeholders. For example, in a study on public mobility projects, social sustainability (safety, security, accessibility, etc.) got highest preference [44], whereas general public from Southern Spain gave all three pillars equal priority in sustainable agriculture [45]. However, similar study from Iran shows that ecological criteria are most important followed by economic prosperity for respondents from various professional backgrounds [46]. A sustainability maximization study on Dutch dairy farm found that ecological and economical sustainability score differently for different stakeholders [47]. Similarly, a meta-analysis by Ahtiainen et al. [48] supports the hypothesis that different stakeholders have their own interests and preferences on the same field. Their analysis of 34 empirical studies on the multi-functional agriculture deduces that general public emphasize on social policies such as cultural heritage, food security, and animal welfare, whereas expert and farmer emphasize on economic prosperity such as income, profitability, and employment.

As per the socioemotional selectivity theory, perception of time plays a significant role in selection and pursuit of social goals. The theory also suggests that social goals follow two general categories: pursuit of knowledge and emotions. When the remaining time is perceived as open-ended (i.e., younger generation), they tend to pursue knowledge and information. However, when the time is perceived as limited (i.e., older generation), the emotional goals are prioritized. [49]. In other words, young people may be likely to perceive that they have long time to live; thus, they may be concerned about the adverse effect of their environmental actions. On the other hand, older generation may think that they have short time-horizon thus may focus on emotional satisfaction and consumption of natural resources may not get the priority [50]. These theories may be applicable for environmental actions alone, but its scope is insupportable when two options such as economy and environment are given.

A willingness and ability to protect environment is positively associated with the level of education of decision maker [51]. Highly educated individuals are more likely to attach themselves with future environmental payoffs thus more knowledgeable on detrimental effects of environment, health, and lifestyles [52]. These hypotheses suggest that educated respondents are more likely to be more committed on activities that protects environment and purchase goods and services that reduce pollutions [51].

To understand what means the most to homeowners from different demography regarding the heating system preferences, this study aims to analyze the homeowners' priorities concerning sustainability. In this research, the priorities of homeowners are calculated using AHP. Further, the aim is to analyze the priorities or differences thereof in sustainability among different age groups and differently educated respondents. One of the reasons to segregate the results in different demographics is to lay the factual basis for the potential energy policies in future.

Further, this research aims to understand the ground reality of FFO heating systems in the South Savo region of Finland in addition to homeowners' backgrounds (age, education, FFO heating system age, and FFO consumption) and their interest in carrying out renovations for more environmentally sustainable means of heating their homes.

Thus, the research questions are formulated as:

-How willing FFO heating system owners are to renovate their heating system to more sustainable means of heating?
-What are the preferences of FFO heating system owners regarding sustainability criteria?
-How do the preferences differ among different age and differently educated demographics?

Materials and Methods

Survey

A two-part questionnaire was prepared, and the survey was conducted during October–December 2020 targeting owners of FFO-heating systems in the South Savo region of Finland. A paper version of the survey was sent to 1,614 households who subscribed to Lämmöllä magazine. Lämmöllä is a service magazine aimed at FFO heating system owners. The digital link to the survey was also shared via email lists and local public social media groups, with the total subscribers at the time of sharing being over 63,000. The reason for conducting both paper and digital versions of the survey was to be inclusive of all age groups.

The first part of the questionnaire contained general questions relating to respondents (home county, age, and education), their current heating systems, and their interest in renovating their heating systems to make them more sustainable. The second part of the questionnaire was thematic to AHP and contained sustainability criteria and indicators. The indicators for each criterion were set up for a pairwise comparison and as a summary for sustainability, the criteria were themselves set up for a pairwise comparison. The segregated categories provide an insight into an individual indicator at lower level. The summarized indicators on the other hand provide an overall priority in a bigger picture regarding sustainability of heating systems. The categories and the respective indicators were chosen from [53] and are shown in Table 1.

In the pairwise questionnaire setup, indicators were paired with each other and respondents were asked to evaluate the importance of one indicator over the other. For example, respondents were asked:

Between these two, which indicator is more important to you?

The fundamental scales and respective absolute numbers assigned to them according to [54] are shown in Table 2.

Table 1 Sustainable criteria and indicators

Criteria	Indicators	Comments
Technology	Suitability	Suitable for the target infrastructure
	Reliability	Reliability of the heating system
	Ease of use	Complexity for daily use
	Renewable energy	Source of energy used for the heating
	Efficient	Efficiency of the heating system
Economy	Job creation	Job creation in the region due to the implementation of the new heating system
	Affordable	Capital costs and daily operating costs
Society	Health	Effect on public health due to the outcomes of heating systems
	Local resources	Source of energy
	Acceptability	Acceptable in the community
Environment	Climate change	Greenhouse gas (primarily CO_2, CH_2, and N_2O) emission from the heating system
	Air pollution	Air pollution (NOx, SO_2, and particles) due to the heating system
	Ozone depletion	Ozone layer depletion due to the heating system
	Biodiversity	Effect on local biodiversity due to the heating system
Sustainability	Technology	A summary of technological indicators
	Economy	A summary of economic indicators
	Society	A summary of societal indicators
	Environment	A summary of environmental indicators

Table 2 Fundamental scales and absolute numbers

Fundamental scale	Absolute scale
Equally important	1
Moderately important	3
Strongly important	5
Very strongly important	7
Extremely important	9
2, 4, 6, 8 are the intermediate values	

In the pairwise matrices, the reciprocals of absolute scales were used to denote the opposing preference. For example: if A was extremely important (9) than B, then B was only 1/9 times important than A.

AHP

The responses were analyzed using the online tool 'AHP OS' developed by Goepel [55]. In the tool, the row geometric mean of the pairwise matrix a_{ij} is calculated using

$$r_i = exp\left[\frac{1}{N}\sum_{j=1}^{N} ln\left(a_{ij}\right)\right] = \left(\prod_{i=1}^{N} a_{ij}\right)^{\frac{1}{N}} \tag{1}$$

Then, the priority p_i is calculated by normalizing it as:

$$p_i = \frac{r_i}{\sum_{i=1}^{N} r_i} \tag{2}$$

The consistency ratio is calculated using Alonso & Lamata's linear fit [56]

$$CR = \frac{\lambda_{max} - N}{2.7699N - 4.3513 - N} \tag{3}$$

The aggregated decision matrix C of the selected individual participants 'k' is calculated using the weighted geometric mean of the decision matrices elements $a_{ij(k)}$ using the individual decision maker's weight w_k:

$$c_{ij} = \exp\frac{\sum_{k=1}^{N} w_k ln a_{ij(k)}}{\sum_{k=1}^{N} w_k} \tag{4}$$

Results and Discussion

Survey Results on Basic Information

The survey received a total of 133 responses from the study area, and they were characterized according to their age, education, their FFO heating system and interest in changing it (shown in Fig. 3). The respondents were primarily from the three largest municipalities

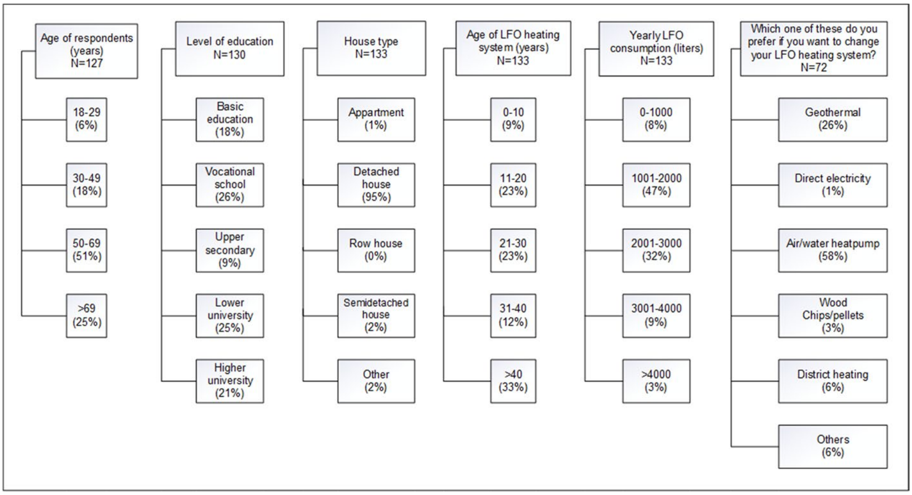

Fig. 3 Responses to questions related to respondents' personal information and self-reported characteristics of their FFO heating systems. The question regarding willingness to change to a sustainable heating system received a total of 133 responses, in which the share was: yes (72), no (44), and I don't know (17)

by population, Mikkeli (52,122), Savonlinna (32,547) and Pieksämäki (17,253) (Fig. 4A). More than 75% of the respondents who disclosed their age ($n=127$) were 50 years old or older (median age = 61)[1]. The age distribution of the respondents is shown in Fig. 4B.

Demographics and Willingness to Change

The respondents were asked whether they wished to change their FFO heating system, and the results show that most of them (54%) were interested, while 33% were not. The results also show that there was a significant age difference (p-value = 0.0021) between the respondents who were for (median = 59) and against (median = 67) the heating system change (Fig. 5A). On the other hand, the results also show that the level of respondents' education seems to have an impact on the interest in changing the heating system. As shown in Fig. 5B, about 42% of the high-school educated respondents were interested in changing their FFO heating system, while the corresponding share was 62% for respondents with a university degree.

Sustainability Priorities

The AHP results of summarized categories show that among the 4 sustainability criteria, economic and environmental sustainability were given equal priority, with 36% and 35%, respectively. Social and technological criteria were given 15% and 14%, respectively.

As per the technology criteria, renewable sources of heating energy were not significant for the respondents and came in third (18%) after reliability (30%) and efficiency (23%). Public health was rated as a significant priority (62%), more than local energy resources

[1] Includes gas-fired heating systems, which are negligible.

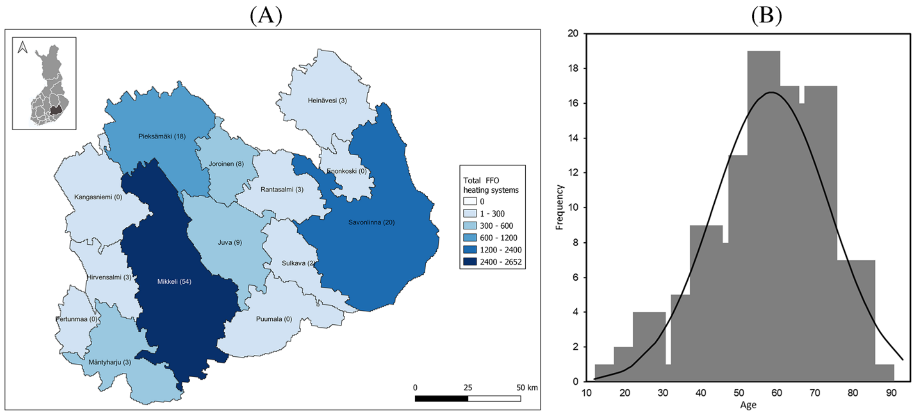

Fig. 4 Respondents from the South Savo region (in parenthesis) and total FFO heating systems in the region [57] (**A**) and distribution of respondents' age (**B**) (map license GADM.org CC-BY)

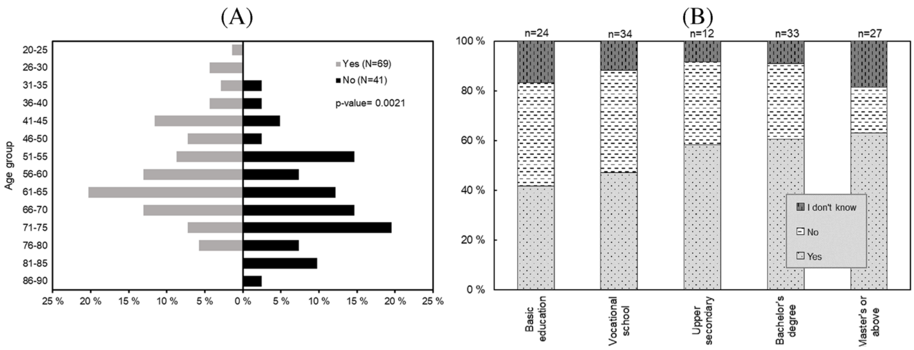

Fig. 5 The willingness of the respondents to change their FFO heating systems to a renewable source of energy classified according to the age categories (**A**) and education level (**B**) of the respondents. A basic education lasts for a minimum of 9 school years since the start of primary school, while vocational school and upper secondary degrees continue for 3 more school years after basic school education, and a bachelor's degree lasts for a minimum of 3 or 4 more years after vocational or upper secondary school. Master's degrees last for 2 years after a bachelor's degree

(23%) and public acceptability (16%) of the heating system. Further, respondents prefer affordable (55%) heating system than job creation (45%) in the society. In terms of environmental indicators, biodiversity (31%) gets the highest priority followed by climate change (26%), air pollution (24%), and ozone depletion (18%) (Fig. 6).

The priorities that the participants gave the sustainability criteria as well as their indicators were further analyzed for the different age groups, as shown in Fig. 7. The results show that renewable energy meant more to older respondents, whereas younger people prioritized reliability. Similarly, the results also show that older people emphasized job creation in the region, whereas younger respondents emphasized affordable energy. Further, climate change was more crucial for older people, but younger people felt biodiversity was more crucial. Finally, the economy was significantly more important for younger people than for older people, whereas older people prioritized the environment more than their younger counterparts.

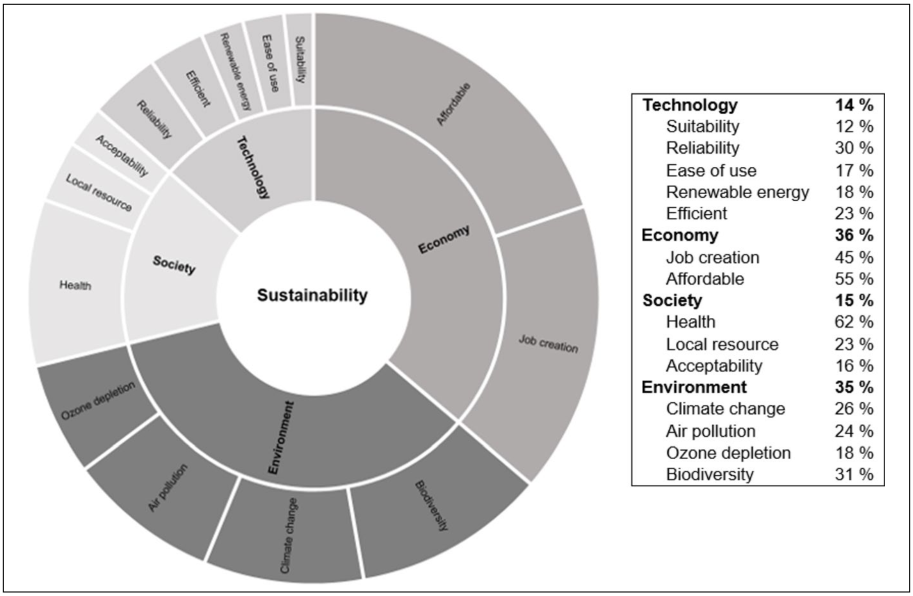

Fig. 6 Priorities of respondents with FFO heating systems ($N = 122$). CR (overall sustainability) = 0.003813

In the next stage, the priorities were aggregated based on the level of education of the respondents. The results (Fig. 8) show that renewable energy meant the most to vocational school educated respondents followed by respondents with a university degree. In contrast, it meant less to those high school educated respondents as efficiency was the highest of their priorities. High school graduates in this study prioritized the economy above other sustainability indicators, whereas vocational school graduates and the highest university graduates prioritized environmental sustainability.

Discussion and Limitations of the Study

The preferences on three pillars of sustainability differs on the field of research and the demography of the stakeholders. There are only handfuls of similar studies where preferences for sustainability criteria in heating system are ranked using multi-criteria method. Grafakos et al. [36] have conducted a study calculating priority weights for sustainability criteria. The authors used a constructive weighting methodology which involved criteria selection and initial ranking followed by pairwise comparisons. Unlike this study where indicators from different criteria were paired separately, the authors compared indicators from all sustainability criteria in the same pairwise comparison. In the case of low consistency, the procedure was simplified to reduce the cognitive burden. However, such a method was impractical in our study due to pseudo-anonymity of the participants and larger number of participants.

The priority weights in this study resemble the results reported by Komendantova [39], who found that economic concerns were the highest priority among the respondents from Finland and other countries involved in the case study. In the same study, energy costs and job creation in the region were among the highest priority for the

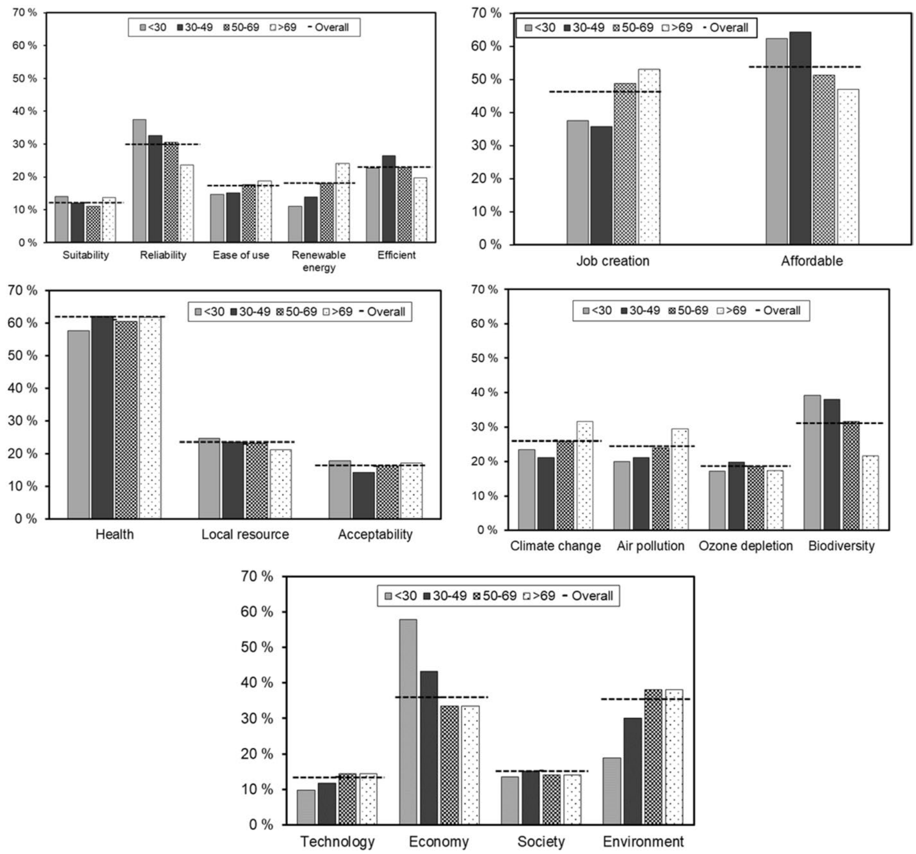

Fig. 7 Priorities of respondents ($N = 116$) for each criterion classified according to the age groups

respondents. Their study also found that environmental indicators which are directly associated with local environment and communities were given a higher priority than perceived global impacts such as climate change [39]. Conversely, a focus group of Hungarian adults prioritize environmental issues more than economic and social components of sustainability of energy sector [58]. In our study, among the environmental sustainability indicators, biodiversity was given a higher priority (31%) than climate change (26%) and air pollution (24%). The reason could be that respondents were concerned about immediate effect on them rather than climate change which is considered to have effect over a longer period of time. According to Väisänen et al. [37], the environment was the most important criterion for energy entrepreneurs and experts from Finland. Their study found that environmental criteria received a 31% priority weight followed by 21% by both technology and the economy. Similarly, contrary to our findings, the same study reported that greenhouse gas intensity (climate change) was given the highest priority (21%) followed by air pollution (18%) and water pollution (16%). Furthermore, economic indicators also contrasted with this study, as Väisänen et al. reported that job creation meant more (60%) to respondents than affordable energy (40%), compared to this study's results which showed 45% and 55%, respectively, for corresponding indicators. Like this study, health and the reliability of the heating system were given the highest priority according to their respective criteria. One should keep in mind that the respondents in their study were composed of experts in the field of energy sector. The authors conclude that AHP is a good tool to gather the local perspective. The contrasting results also indicate the importance of localized survey and subsequent conclusion.

A survey analysis from two states in the USA conducted by Hamilton et al. (2019) [59] found that renewable energy was a higher priority for younger people. Similarly, Salazar-Ordonez et al. [45] found that age is a significant factor in sustainability preference as their results show that younger citizens are likely to value environmental issues over economical ones. However in our study, reliability of the heating energy technology is highest on the priority ranking while renewable energy is the lowest for younger respondents. On the other hand, older respondents put reliability and renewable energy on equally highest priority. One could argue that unreliable technologies bring along the additional cost such as maintenance which is not preferred by young respondents. On the other hand, renewable energy even though more expensive than fossil-based are preferred by older respondents.

Education is one of the main determinants of environmental awareness [60]. According to Goetz et al. [51], highly educated populations express more concern about the environment. Hamilton et al. also showed that postgrad educated respondents rated renewable energy as a higher priority than high school educated respondents [59]. Similarly, Oluoch et el. also reported that respondents with a higher level of education in Kenya were more likely to have a positive attitude toward renewable energies such as solar, geothermal, and wind energy [61]. However, Abdelkader [38] found no significant correlation between differently educated respondents regarding perception and willingness to change to green buildings.

In our study, as shown in Fig. 5B, the willingness to change oil heating system to renewable source of heat is positively proportional to the level of education. Further, there is a significant difference in preference for among high school educated respondent and respondents with higher university degree. High school educated clearly prioritize economy over environment, whereas respondents with higher university emphasize on environment. Contrary to above-mentioned hypothesis, results also show that respondents with vocational degree prioritize on renewable energy and environment than other respondents. The socioemotional selectivity theory dictates that younger generation who perceive that they have long time to live thus are likely to think about environmental issues rather than economic gains, whereas older generations may prioritize on emotional goals such as physical luxury [49, 50]. Our study (Fig. 5A) shows that younger (median age 59) respondents said, ‘yes’ to the question whether they are willing to change to renewable source of heat, whereas older respondents (median age 67) said ‘no.’ However, in contrast, when given choice between economic and environmental criteria, their response (Fig. 7) shows that older respondents valued environment while younger respondents valued economy. One hypothesis can be deduced that younger respondents say ‘yes’ when asked whether they are willing to renovate their FFO but when given the choice between economic and environment sustainability (among others), they chose economy. The household financial burden could be one of the reasons why younger respondents prefer the economy over environment.

Lack of Financial Information

Inglehart [29] believes that public support for environmental protection is shaped by subjective cultural factors. People with postmaterialist values generally emphasize the quality of life, whereas people with materialist values tend to emphasize economic values and physical securities. The author found that people in the Nordics including Finland ranked support for environment protection highly and the number of people who were ready to sacrifice part of their income to reduce environmental pollution was high although they have the lowest levels of air and water pollution [29]. Salazar-Ordonez et al. [45] suggest that respondents who pay more taxes on food production place less value on environment than economy compared to those who pay equal amount of tax for trade, food production and non-trade function. However, Komendantova [39] observed that all participants regardless of their cultural background, emphasized economic and physical security, more than environmental protection. Similarly, Hast et al. found that financial affordability had a greater influence on consumer choice over environmental reasons [62]. Jung et al. found that the occupational status seemed to have impact on the willingness to invest in renewable energy technologies (RET) as employed respondents were more willing to invest in RETs [24]. Due to the procedural limitations, the incomes of the respondents' family were not collected in this study. The relationship between the homeowners' income and their preference for the sustainability criteria would provide a deeper understanding of homeowners' interest in energy transition.

Number of Participants and Consistency Conundrum

Consistency is an important aspect of AHP and Saaty [63] suggests that the consistency ratio (CR) should be 0.10 or less. In this study, the group CR of the entire respondents (n) varied from 0 to 0.05, depending on the criteria. However, the number of individual respondents with a CR score of 0.10 or less varied from 0–36% of the total respondents, depending on the criteria. According to Saaty, if the CR exceeds the threshold of 0.10 then participants should be asked to reevaluate their judgements [63]. In a study like this where a questionnaire was given to random participants, it is impractical to reconduct the survey to reassess the judgements.

In research, a small sample size can adversely affect multiple aspects of the study including interpretation of the results [64]. In the context of first part of this study, a higher number of participants would offer a realistic view of the study subject: FFO-heating systems and homeowners' perspectives on the energy transition. However, according to some research, the sample size in AHP does not have to be big, as even a single qualified expert could be representative [65, 66]. Cheng and Li believe that a large sample size may be counterproductive because of the 'cold call' respondents potentially providing arbitrary responses which may adversely affect the consistency of the judgement [67]. In their review study, Darko et al. found that many studies use small sample sizes ranging from 4 to 9 and there were only couple studies which had a sample size greater than 30 [64]. The authors suggest that it is imperative that researchers should pay special attention to the sample size to obtain the optimal judgements.

Scalability of the Research

According to the official statistics of Finland, the share of the population (15 or above) who have a bachelor's degree or above is 24%, which is 8% higher than the study area of this research, South Savo [68]. According to the results of this study (Fig. 5B), the willingness to transition to more environmentally sustainable heating systems was directly correlated to the respondents' education level and highly educated respondents were more likely to be interested in more environmentally friendly heating systems. Similarly, the group priorities were also fairly well correlated with the education level of the respondents: according to the priority results (Fig. 8), highly educated respondents were more likely (compared to high school educated respondents) to emphasize renewable energy and climate change indicators as well as the environment than others, including economic criteria. Thus, the group priority of the Finnish public nationwide may focus more on the environment, renewable energy, and climate change indicators. However, one should keep in mind other factors such as the level of education of homeowners with FFO-heating systems and the age of the FFO-heating systems and the incomes in the respective households.

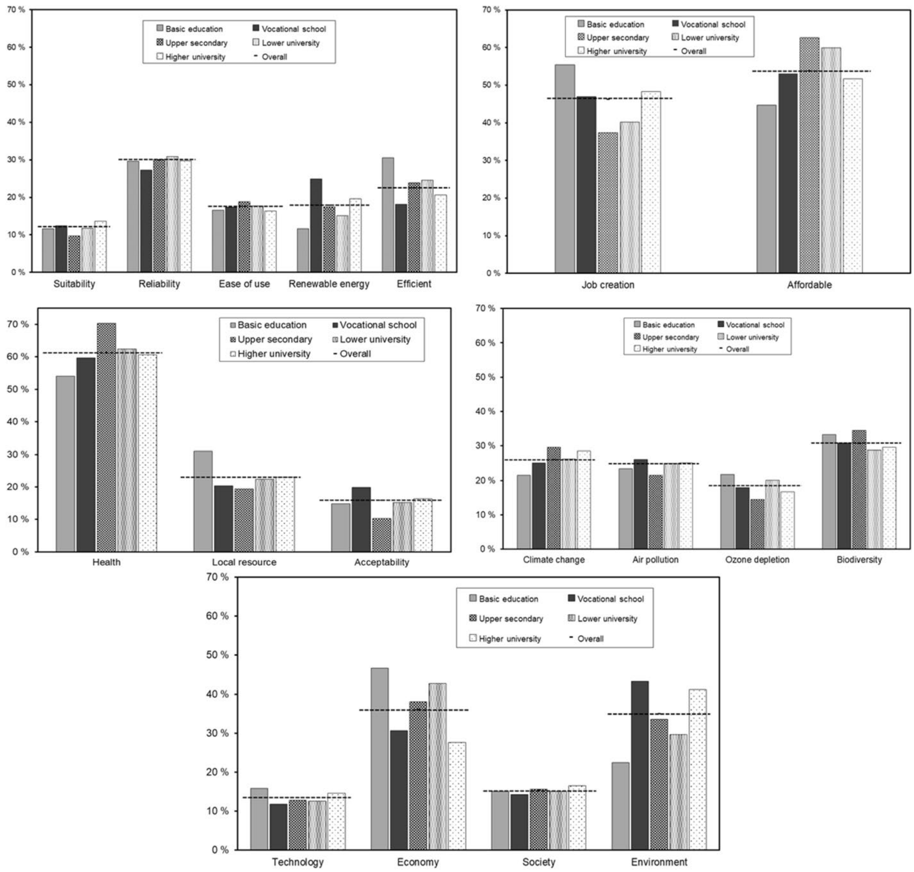

Fig. 8 Priorities of respondents ($N=119$) for each criterion classified according to the education level

The heating system renovation in rural Finland or even in smaller towns comes with a challenge as the homeowners evaluate the cost effectiveness of the renovation because the investment in renovations directly impacts the price of house and rural Finland is grows much slower than bigger cities. Further, the migration of residents to bigger cities like capital city is growing [15]. In this study, we segregated the criteria preferences according to the age and educational demographics but due to data privacy constraints, we did not collect the exact home address to pinpoint the type of settlement, i.e., urban or scattered settlement. It would be interesting and insightful to look at the preferences and difference there of respondents from urban area and scattered settlement.

Conclusion and Further Recommendations

The survey results show that the majority of FFO heating system owners were interested in changing their heating systems to a more sustainable source of heat. The results also show that the median age of the respondents who were interested in changing their FFO heating systems was 59 compared to 67 who were not. Air/water heat pumps were the preferred heating system followed by ground-source heat pumps (Fig. 3).

Based on an MCDA analysis, homeowners with FFO-heating systems placed an equal emphasis on economic and environmental sustainability. However, there was a difference in the emphasis between the age groups as older respondents prioritized the environment more than their younger counterparts. Similarly, overall, renewable sources of energy (a technology criteria indicator) came third in priority after reliability and efficiency. However, older respondents prioritized renewable sources of energy more than their younger counterparts. This trend further extended to environmental indicators as biodiversity was emphasized the most in overall. However, climate change was emphasized more by older respondents than by younger respondents. Economic criteria were the most important for the high school graduates, whereas the environment was emphasized by respondents who had a master's degree or above. Furthermore, climate change was slightly more important for respondents with a higher degree, whereas biodiversity was emphasized by high school graduates.

The willingness to transition to more sustainable modes of heating may be different on a national level and may be potentially higher as highly educated people are more willing. Similarly, the group priority may be in favor of renewable energy, climate change, and environmental criterion overall as more highly educated respondents tend to emphasize them.

Even though the group CR was well below 0.10, the share of respondents with 0.10 or less was very low (less than 36%). It would be wiser to conduct the AHP among a focus group or in a detailed meeting where reassessment of the responses would be practical and possible.

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Declarations

Competing Interests The authors declare that they have no known competing financial interests.

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