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The monetary value of convenience and environmental features in residential heat energy consumption, in particular its social determinants

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ABSTRACT

Environmental and comfort value of renewable energy sources is a less studied area. The article introduce the economic value of these characteristics, related to social determinants. The data basis is representative of the Hungarian population above 18 years of age, by gender, age and level of education. Our model estimation was developed by hybrid choice context in latent class modelling. In addition to the usual WTP (willingness to pay) calculation, we also used WTI (willingness to invest) calculations. The results show that the value of environmentally-friendly nature in Hungary exceeds the convenience factor. The latter cannot be significantly detected for the majority of the Hungarian population. This statement is supported by results for both fuels and boilers. Our findings show the strong attachment of the Hungarian average person to the use of firewood and natural gas, which are very typical in Hungarian heat consumption. Regarding socially selected consumer groups, strong correlation can be observed between social capital supply, income level, access to information and environmental awareness in Hungary. Regarding policy implications, our results in development of clusters may be useful for the establishment of a selective support policy and two clearly identifiable groups should be highlighted in the energy policy.

1. Introduction

The aim of this study is to analyse the social determining factors of the energy decisions on residential heating, one of the most important areas of energy consumption. Residential energy decisions are influenced by differences in social and economic position, which are responsible for unequal access to energy resources [1]. The value of comfortable and environmentally friendly energy consumption is becoming more and more important.

A previous research [2] assessed the attitudes and knowledge of the Hungarian population on energy consumption using a national, representative quantitative survey. An international comparative analysis of the specific characteristics of Hungarian households' energy use [3] and the preferences of the Hungarian population regarding heating systems and their socio-demographic background were examined on the basis of a) similar international researches, b) two types of data collection, c) expert opinions and d) the experience gained during previous pilot tests including similar questions. This study assumed that cost factors, the operation of the heating system, and the environmental impact are important considerations in the selection. A further assumption was that there are identifiable segments of the population where comfort and environmentally friendliness may play a key role in making such a decision, as opposed to those who, are unable to make such value-based decisions. In 2019, 69.8% of persons in the EU lived in an owner-occupied dwelling, but the Hungarian value is significantly higher (91.7%) [4]. In addition, mainly young people lived in rented apartments in Hungary, but most of them want to own a home in the near future.

The main research questions are the identification of the social components that most influence the decisions of the households included in the survey (e.g. income, age, education, occupation), and the examination of the willingness to pay and invest for the purpose of comparison. The research aim of this study is to seek groups of households with markedly different preferences for heating, but with a good fit, mapping the underlying factors of decision making using a hybrid latent class model. Our research use a new econometric model, evaluated a statistically reliable national survey, which considers the main elements of previous (Hungarian and international) surveys and in this

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way it shows the similarities and differences in energy decisions between the Hungarian and international energy consumers.

2. Literature review

2.1. Characteristics of household energy consumption in Hungary

In 2019, the global energy consumption was 13 975 Mtoe (585 EJ) (7), an increase of 43% compared to the turn of the millennium. This value represents an average annual increase of more than 2% since 2000. Households are responsible for 26.1% of final energy consumption in the EU, with heating accounting for the highest share at 63.6% (9). Residential buildings presents considerable energy savings potential [5] and strongly contribute to global CO2 emissions due to the high energy demand for electricity and heating [6]. Then the COVID-19 caused a fluctuation, but the worldwide energy consumption already reached 595 EJ in 2021 [7]. Several earlier studies showed the role of renewable energy consumption in economic growth [8] in the OECD countries.

In Hungary, the share of the household sector (34%) [9] and, more specifically, the utilization for heating purposes (75% [10]) in total final energy consumption are significantly higher. Regarding energy sources used for heating, it can be stated that the share of renewable energy and waste is the most significant in the EU and also in Hungary (27.0% and 32%, respectively), in addition to natural gas (38.0% and 56.3%, respectively) [11]. Although the share of renewables in Hungary is higher than the EU average due to biomass combustion, more than 56% share of natural gas use (in the absence of any significant Hungarian/national gas deposits) results in serious dependence on gas imports. In terms of costs, Hungarian households spent 20% of their total expenditures per month (EU average: 24%) on housing and household energy. More specifically, the share of household energy accounted for more than 60%, including gas, electricity and solid fuels, in this order [10,12]. However, Franceschinis et al. [13] stated, that the diffusion of RES (renewable energy sources) technologies still limited, while heating systems based on fossil fuels are still predominant [8,14]. The results of Ruokamo [5] reveal that Finish households view supplementary heating systems (especially solar-based) favourably. Besides, Brodny-Tutak [15] proved that higher ratio in RES results a positive impact on the economic growth, so more intensive use of RES could be a perspective way for the less developed countries [16].

In general, Hungarians link significant environmental pollution and high-cost requirements to the use of firewood in a stereotypical way [2]. On the contrary, heating with natural gas is associated with the stereotype of convenient and inexpensive heating, probably not independently of the subsidised residential pricing that has been in force for ten years. The perceptions of comfort and environmental considerations are nearly the same, although different social groups show significant differences. The public perception of firewood (i.e. it is uncomfortable and polluting) was also supported by a U.S. study [17]. It is important to note that regarding external costs of biomass is higher than natural gas and mineral oil, similar to the lignite, just the coal has higher value [18].

The housing stock in Hungary is predominantly outdated, i.e. most residential buildings are poor energy efficient, which leads to high overheads, carbon dioxide and air pollution. The most common type of housing - almost one in five - is a detached house built in the 1960s or 1980s. Heating such a building without insulation requires up to twice as much energy per square metre as a typical panelled dwelling, and four times as much as a (insulated) 2000s apartment block. Gas is the most common energy carrier in 2019, with solid fuel (e.g. wood, coal, briquettes) in second place and district heating in urban areas in third place. Almost 40% of households in the bottom quintile of income groups heat exclusively with solid fuels, compared to only 9% in the top quintile. In other words, wood heating is mainly the fuel of choice for the poorer classes, as opposed to gas heating. Residential solid fuel combustion is one of the main causes of air pollution in Hungary, due to outdated stoves and poor insulation of buildings [19,20]. Household solid fuel combustion is responsible for more than 80% of the seriously harmful particulate matter emissions in Hungary (the EU average is 41%, average particulate matter emissions per capita in the EU are less than a third of those in Hungary) [21].

2.2. Assessment of environmental awareness in international literature

Environmentally conscious behaviour is evaluated in the literature with the willingness to pay and willingness to accept [22]. To eliminate this problem, Kocsis-Marjainé [23] and Whittington [24] recommended examining the use of overtime instead of monetary value, especially in developing countries. Studies of various environmental problems in various developing countries showed that residents are less willing to spend money on environmental protection, but more willing to devote time to this purpose [25–28].

Even in developed countries, people prefer to offer their time as opposed to their money [29], but the value of their free time depends significantly on how they spend this time, their income, and their social position [30]. The authors of this paper tried to eliminate this problem by means of a nationally representative questionnaire survey and the formation of clusters that can be considered as characteristic in terms of thermal energy consumption, as well as by conducting a discrete choice experiment. The analysis of latent variables, such as attitudes, can now be included in the long-used discrete choice experiment. For this reason, the effect of environmental attitudes was incorporated into the model to answer the research questions [31]. Michelsen and Madlener [32] examined the preferences of German homeowners regarding the introduction of an innovative heating system, providing their estimates for the representative sample using a multinomial logit model. Based on the obtained results, there are different drivers for adopting an innovative heating solution for newly built and existing single-family homes. For the former, decisions are largely related to the characteristics of the given system, while for the latter, choices are greatly influenced by various socio-demographic factors. Rouvinen-Matero [33] examined the preferences of Finnish housing properties with regard to heating systems. The aim of their research was to reveal which properties most influence residents' decisions concerning the choice of heating system. A stated choice (SC) experiment involved six heating alternatives, including wood pellet boiler, solid wood-fired boiler, district heat, electricity, ground heat (pump) and oil boiler in a labelled form. Attributes included in their experiment included investment cost, annual operating cost, CO2 emissions, fine particle emissions, and personal presence/work. In addition, estimates were made using multinomial logit and random parameter logit specifications. The investment cost is the most important consideration when making a decision, and other (non-financial) characteristics also have a significant impact. The heterogeneity in preferences was caused on the one hand by the availability of district heating, the existing heating system, and forests owned by certain residents. In addition, the authors pointed out the significant role of non-observed preference heterogeneity. In their 2020 representative survey conducted in three countries (Poland, Sweden, UK), Mills and Schleich [34] aimed at assessing households' preferences for a new heating system and making estimates of willingness to pay. The attributes involved in their experiment included the heating bill (25%, 50%, 75% reduction), the duration of installation (half a day, three days, one week), the duration of warranty (2, 5, 10 years), the cost of investment (3–20 thousand EUR), the extent of subsidies in relation to the investment cost (0, 5, 15, 25%) and the form of subsidy (public agency, energy provider, no subsidy (if subsidy = 0%)). Based on Mixed logit model estimation, respondents generally have a positive judgement of discounts for a new heating system, although it depends on the given country, Poland being the most significant in this respect. In the case of Sweden, it was found that discounted prices were more effective if they were offered by a public rather than a private source of funding. In addition, it was shown that respondents do not prefer longer time of installation and show a higher willingness to pay for a longer warranty period.

The methodological guide of Mariel et al. [35] is a significant contribution to the literature. The hybrid choice modelling was used in the context of the traditional latent class specification, where classes were allocated based on latent attitudes. Young, low-income men who live closer to wind farms have a stronger pro-wind power generation attitude. Based on the performed latent class modelling, two groups with opposite attitudes were distinguished.

In the experiment of Achnicht (2011), the 400 sampled German house owners could choose either a modern heating system or an improved thermal insulation for their home and the results showed that environmental benefits have a significant impact on choices of heating systems. Based on Altnicht et al. (2014) results, those homeowners are more likely to undertake energy modernisation activities who are able to pay and who can see a return on this investment [36].

Research by Yu et al. [37] examined the combined effects of energy poverty, GDP, renewable energy consumption, natural gas consumption and free trade on carbon emissions in 25 developing countries between 2001 and 2019. This was interpreted in the context of access to electricity. The countries studied currently have the highest demand for oil and the lowest demand for renewables. The lack of access to electricity is significant. The results show a direct link between natural gas consumption and CO_2 emissions. Energy poverty, i.e. low access to electricity, causes an increase in CO_2. Increased economic activity in turn leads to a decrease in CO_2 emissions. The authors therefore recommend that governments concerned increase access to electricity through infrastructure investments to ensure that the energy grid is developed throughout all countries. This will help to displace the most polluting fuels (oil, natural gas, coal) in the developing countries studied. It would be necessary to extend electricity supply to rural areas and to provide low-cost or free household electrical appliances.

Khan et al. [38] studied the relationship between per capita carbon emissions from fossil energy consumption and the factors of renewable energy consumption, technological innovation, carbon dioxide taxes, GDP, industrialisation, foreign direct investment and government integrity in 19 high-income countries of the European Union. While the increase in technological innovation contributes to the reduction of carbon emissions, the regression analysis results show that the relationship is not significant at the highest quantiles. Carbon taxes reduce carbon emissions at initial pollution levels, but at higher levels, carbon taxes become a legal mechanism for continued pollution. Their empirical results confirm that renewable energy consumption contributes to carbon emission reductions.

Hu and Wang [39] investigated the relationship between environmental regulation and carbon production capacity in China. The results of empirical research based on the spatial spillover effect show that there is a positive spatial correlation between the carbon productivity of different regions and there is a threshold for the impact of environmental regulation on carbon productivity. As the intensity of environmental regulation changes from weak to strong, the impact on carbon productivity of local regions changes from negative to positive. Empirical research based on the spatial spillover effect shows that there is a positive spatial correlation between the carbon productivity of different regions in China and a threshold for the impact of environmental regulation on carbon productivity. Improved carbon productivity in local regions also improves carbon productivity in neighbouring regions. Based on the regression results of the control variables, it is found that an increase in GDP per capita contributes to an improvement in carbon productivity and that technological innovation is also a positive factor in improving carbon productivity. However, the industrial structure and energy structure are barriers to improving carbon productivity.

Wang et al. [40] also investigated spatial effects in China: the impact of green technological innovation on green total factor productivity (GTFP). Their results show that green technological innovation has a significant positive effect on the change in green total factor productivity. However, they obtained different results by region. GTFP is highest in the Eastern region and lowest in the Western region. The analysis results of the spatial Durbin model suggest that green technological innovation has a significant positive effect on its own change in GTFP, but a negative effect on that of its neighbours. Green technological innovations in the Eastern and Central regions have a negative effect on their own GTFP, while those in the Western regions have a positive effect.

Yin et al. [41] analysed the dynamic changes and influencing factors of forest carbon sequestration efficiency at the provincial level in China for 30 years. Their results showed that per capita gross domestic product (GDP), urbanization and length of highway network had significant positive effects on carbon sequestration efficiency, while total imports and exports had significant negative effects. Their results also show that urbanization, ecological forest cover, temperature, GDP per capita, population, and total imports and exports have spillover effects. Large cities have a spillover effect, which also promotes the development of surrounding cities. Urban communities are also affected by ecological afforestation, i.e. forest policy development, in neighbouring cities.

Xu et al. [37] studied the impact of highway infrastructure improvements on carbon emissions. In their study, they used the length of highways and CO_2 emissions and agglomeration as proxy variables based on panel data of 278 cities in China from 2003 to 2016. There is an inverted U-shaped relationship between highway infrastructure and CO_2 emissions, and the effect is driven by agglomeration as a route. Empirical results show that the development of highway infrastructure has an impact on CO_2 emissions. The development of motorway infrastructure has a threshold on its impact on CO_2 emissions, i.e. motorway infrastructure has an emission-reducing effect through its own positive externality if it exceeds the threshold.

Ponce et al. [42] analysed the long-run relationship between economic growth and financial development, non-renewable energy, renewable energy and human capital in 16 Latin American countries. The analysis was based on statistical data from the World Bank and Penn Word Table databases for the period 1988–2018. Their results show that there is a long-run equilibrium relationship between financial development, non-renewable energy consumption, renewable energy consumption, human capital and long-term economic growth. They show a positive relationship between the variables of financial development, non-renewable energy consumption, renewable energy consumption and human capital and economic growth, indicating that an increase in these variables leads to an improvement in long-term economic growth. A two-way causal relationship was found between financial development, human capital variables and economic growth. One-way causality was observed between non-renewable energy consumption and economic growth, and between economic growth and renewable energy consumption.

Many studies are available regarding correlations between utilization of RES and other macroeconomical indicators at country, or regional level. Peng et al. [43] found, that the use of green energy correlates with changes in GDP and inversely proportional to population density. According to an up-to-date study by Wang et al. [44], carbon emissions and income levels at the global level can be characterised by an inverted U-shaped curve. Before its peak (USD 19 203 per capita), renewable energy sources tend to play a dominant role in emissions reductions, and afterwards the role of human capital considered more important. A previous article of Wang et al. [14] based on data of 104 countries the findings show that the role of RES in economic development shows strong correlation in developed countries, while a U-shaped relationship emerges in developing countries. The energy needs of rising living standards in developing countries are usually based on non-renewable energy sources, so the effectiveness of energy saving measures there may outweigh the use of renewables [8,45,46]. Wang et al. [14] analysed the importance of composite, political, economic and financial risk in the OECD countries on economic growth. They found that RES has positive impact after a threshold (in case of the first two risk types) and between the two threshold (in case of the last two

Table 1
On the main results of the selected literature.

Author, year	Region	Variables	Methods	Results
Marjainé et al., 2011	Hungary	Survey	Choice experiment	"The local population has a zero willingness to pay for reduction of flood frequency, so this outcome is of no value to the local population. In relation to water quality changes, WTP is positive."
Kocsis T, Marjainé Szerényi Z. 2018.	Hungary	Survey	WTP	"Both WTP for saving the environment and WTA (willingness to accept) costing externalization to others increases when the parameters of the decision are described in temporal terms instead of in money." (p. 1.)
Whittington D. 2010	Less developed countries	Meta-analysis	stated preferences	The WTP is low in the analysed cases, apart from the services and goods provided.
Rai RK, Scarborough H. 2015	Less developed countries	Survey	Choice experiment	The WTP increases if participants can contribute also by labour.
Tilahun et al., 2015	Ethiopia	Survey	Contingent Valuation Analysis	Properly designed payments with complementary policy interventions support sustainable resource use and poverty reduction.
Lankia et al., 2014	Finland	Survey	WTP & willingness to contribute (WTC)	Both WTP & WTC are different among social groups.
Eom –Larsson, 2006	South-Korea	Survey	WTP	The authors compared the value of house-work time and market wage.
Kastner I, Matthies E. 2016	Germany	Survey	Choice experiment	The strategies to foster investment into renewable energies has to be adopted to the different social groups.
Michelsen CC, Madlener R. 2012	Germany	Survey	Choice experiment	The decision to invest in the modernisation of the heating system depends on the preference of being more independent from fossil fuels and on the age of the home (existing vs. new-built).
Rouvinen S, Matero J. 2013	Finland	Survey	Choice experiment	Financial and non-financial factors influence residents choices, also the availability of district heating and ownership od forest have an effect.
Mills B, Schleich J. 2012	EU & Norway	Survey	Statistical analysis	Family age composition, and educational level has an impact on energy-investment. East-West differences can be found also.
Yu et al., 2022	Developing countries	Statistical data	Quantile-on-Quantile (QQ)',	Low access to electricity, causes an increase in CO2 emissions, while increased access to electricity help to displace the most polluting fuels (oil, natural gas, coal) in the developing countries.
Hu and Wang (2020)	China	Statistical data	Statistical analysis	There is a spatial spillover effect and a positive spatial correlation between the carbon productivity of different regions in China, and there is a threshold for the impact of environmental regulation.
Ponce et al. (2021)	Latin-America	Statistical data	Statistical analysis	The results show that there is a long-run equilibrium relationship between financial development, non-renewable energy consumption, renewable energy consumption, human capital and long-term economic growth.
Wang et al. (2023)	208 countries	Long-term statistical data	Differential GMM estimation	Inverted U-curve between income level and CO_2 emission, before peak: impact of RES, after peak: human capital is determining.
Wang et al. (2022a)	104 countries	Long-term statistical data	Regression estimation	Relation between RES and economic development: strong in developed countries, U-shaped curve in developing countries
Wang et al. (2022b)	OECD	Long-term statistical data	Panel threshold model	Impact of RES on economic growth is differential in case of differential country risk types.
Wang et al. (2020)	G20	Long-term statistical data	Multiple co-integration estimation	Driving forces in spreading of RES: research and development (generally), policy, environmental pressure (high-income countries).
Wang and Wang (2020)	OECD	Long-term statistical data	Non-linear panel data analysis	RES has a positive effect on economic growth, especially in case of high energy consumption.
Vida et al. (2020)	World	Statistical data	Statistical analysis	Energy use of RES is limited by the factors influencing food consumption

risk types). The importance of strong connection between political stability and energy and food security was also emphasized by Popp et al. [47]. Regarding OECD countries, Wang et al. [8] proved that research and development considered the most important driving force in spreading of RES, however, contribution of policy and environmental pressure also have high importance in the highest-income countries. Wang and Wang [8] stated (based on data of OECD countries) that RES shows a clearly positive impact on economic growth, especially in case of high-level, or growing energy consumption. In our opinion it proves the competition between RES and energy saving methods. Important note, that due to food-energy-feedstock debate, the energy use of biomass is also highly dependent on factors influencing food consumption (population growth, urbanization, religious habits, changing dietary patterns) [48].

We present and overview the main points of the literature on environmental awareness in Table 1, which summarizes the main details of the reviewed studies by comparing the variables used, the method and main results achieved.

2.3. Social determinants of energy use

The literature on social determinants of energy use examines factors influencing energy efficiency in households [49,50]. The unequal social distribution of access to information and knowledge is a key research issue in this area [51–53]. In addition to reference groups, the network effect [54], various forms of knowledge [34] also play a key role in spreading sustainable attitude patterns [55]. The role of consumer habits [56] and energy poverty [57] are the main topics of another research focusing more on social inequalities. Another generally accepted pattern is that well-educated residents tend to be more interested in energy efficient technologies, retrofits and behaviours [58].

Cattaneo [59] examines the social determinants and limitations of energy use in the context of a possible form of favourable policy intervention. In relation to energy efficiency, two domains of consumer behaviour are distinguished. One of them is behaviour according to everyday routines, while the other is investor behaviour resulting in long-term energy efficiency. Schleich et al. identify external and internal boundaries as a guiding principle for consumer behaviour [60]. Consumers invest less in energy-efficient technologies [61], and Schleich et al. [62] include the factors in the theoretical framework of internal and external constraints that can explain low adoption behaviour.

External constraints include primarily institutional factors that limit the introduction of energy-efficient technologies, which are also commonly referred to as market failure explanations [63]. In the system described by Schleich et al. [62], external constraints include capital market failures, lack of information, asymmetric and ambiguous information, as well as financial and technological risks. According to Schleich et al. internal constraints include reference-dependence and

Table 2
Sociodemographic characteristics of the sample.

Sociodemographic indicators	Sample ($N = 1000$)	Sociodemographic indicators	HCSO
Gender			
Female	53.43	Female[2]	52.09
Male	46.57	Male	47.91
Age		**Age (2016)**	
18–29	18.14	20–29	15.47
30–39	19.47	30–39	17.48
40–49	16.26	40–49	19.26
50–59	17.75	50–59	15.44
60-	28.38	60-	32.36
Educational level			
Elementary or below	27.21	Elementary or below	20.85
Vocational training	22.60	Vocational training	24.52
Secondary school	32.09	Secondary school	32.74
Higher education	18.10	Higher education	21.89
Frequency of using the Internet (%)			
Daily	71.14	Almost everyday[3]	81.4
At least once a week	4.92	At least once a week	5.5
At least once a month	0.66	At least once a month	0.875
Less frequently than monthly	0.30	Less frequently	0
Never	22.98	Never	12.5
Frequency of shopping online (%)			
At least once a week	2.48	At least once in a quarter of a year[4]	49.3
At least once a month	11.57		
At least once a quarter	16.34		
At least once every six months	11.89	At least once 3–12 monthly	10.7
Less frequently	15.67	Less frequently the once a year	5.7
Never	42.05	Never	34.3
Type of residence			
Village	29.72	Village [5]	31.46
Rural town	35.79	Rural town	31.99
County centre	17.41	County centre	18.89
Budapest	17.08	Budapest	17.67
Employment status			
Employee	33.59	Employee [6]	58.13
Leader, entrepreneurial with employee	11.39	Leader, entrepreneurial with employee	4.55
Entrepreneurial without employee	24.95	Entrepreneurial without employee	2.38
Retired	25.50	Retired [7]	29.68
Other (unemployed, student)	4.57	Other (unemployed, student)	5.26
Financial status[8]			
0-2 asset	43.60		
3-5 assets	39.84		
More than 6 assets	16.56		

non-linear probability weighting, rational inattention, bounded rationality, present bias, and status quo bias [62]. Of external constraints, lack of adequate information is the primary reason for lack of investment in energy efficiency [64,65].

The interactions between social inequalities and household energy use were analysed in a study by Czibere et al. [3], according to which the attitude of individuals concerning energy use shows great differences based on social and demographic variables. There are also country-specific differences.

Heat energy demand also depends on age, since it is common for older people to spend large amounts of time in their home [66]. The effect of aging as a determinant of the use of renewable energy sources is that a growing proportion of households are spending more and more time in their own homes. As older people tend to lead more sedentary lifestyles, they are more sensitive to the temperature of their environment. As a result, older people tend to set higher temperatures for themselves at home. In other words, ageing is associated with an increase in household energy demand. As incomes fall after retirement, they no longer modernise heating systems, which were outdated by then. Owners of buildings with poor or no insulation, outdated heating systems, outdated glazing, draughty doors and windows will not accept expensive renewable energy sources that would require significant capital investment. Older people are also more afraid of change and of learning and using new technologies than younger people [67]. This is also true for the adoption of more energy efficient heating and lighting systems [68]. Willis et al. [69] used conditional logit and mixed logit models to examine the effect of age and showed that it does indeed affect the adoption of technologies that affect energy efficiency. Older households are less likely to install microgeneration technologies (solar thermal, photovoltaic, wind). In other words, an ageing population reduces the likelihood of adopting microgeneration technologies in each country [69].

3. Research questions, materials and methods

3.1. The sample

The data collection was carried out by Závecz Research[1] in November 2020, the sample is representative of the Hungarian population above 18 years of age, by gender, age, level of education and type

[2] https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_wdsd003c.html.
[3] 87.85 of the respondents have Internet access; https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_oni017.html.
[4] https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_oni019.html.
[5] https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_zhc060b.html.
[6] http://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_qlf001.html.
[7] https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_fsp001.html.
[8] Its distribution within society as a whole has not been examined.

[1] http://www.zaveczresearch.hu/.

Table 3
Attributes, their levels and coding.

Attributes	Description of attributes	Attribute level	Coding
Monthly energy cost (thousand HUF/month)	Includes the cost of energy use, the efficiency of use and, in the case of gas, the base charge (fixed cost) *	10 (coal) 18 (firewood, natural gas) 26 (biobriquette) 30 (firewood pellets)	Continuous variable
One-time investment cost (thousand HUF)	It includes the heater, its installation and space requirements.	200 (coal, normal firewood boiler) 300 (natural gas) 700 (firewood, biobriquette gasifier boiler) 1000 (pellet boiler)	
Environmentally- friendly nature	The impact of the chosen heating option on the environment during the entire life cycle	Very polluting (coal) Slightly polluting (natural gas, firewood) Slightly environmentally- friendly (biobriquette) Very environmentally- friendly (fire pellets)	1 2 3 4
Type of operation (convenience)	Manual or automatic feeding of fuel	Manual: coal, firewood, biobriquette Automatic: natural gas, fire pellets	1 2

Notes: * Excluding personnel costs and maintenance/repair cost, due to their subjective nature.
**The subjective assessment of firewood in Hungary is less favourable than its actual environmental characteristics.

of residence. The questionnaire was part of an omnibus survey, and the present study focuses on the correlations between attitudes related to energy use and environmental protection, in addition to the respondents' set of values and their opinions on climate change. In the questionnaire, questions related to energy use are followed by questions on environmental protection. The questionnaire shows well the trends in Hungary, its questions are suitable for comparison with the results of previous questionnaires in Hungary [2] and abroad [70], but also reflect the effects of the specific Hungarian residential energy price regulation ("reduction of residential energy bill"). Table 2 Presents the detailed description of the sampe.

The following limitations should be taken into account at interpreting our results. We did not ask how confident respondents were that they would actually buy the house with the options they had chosen, as this would have allowed us to filter out any unrealistic choices. It would therefore be worth measuring the proportion of uncertain choices in future surveys.

In the scientific literature, several authors have found that people often answer lower amounts [71–73]. Ladenburg and Olsen [74] suggest that it is possible that the use of so-called "cheap talk" (this involves describing the hypothetical bias and its causes in the questionnaire) before WTP questions could reduce this hypothetical bias, but the results of the literature on this are not clear. We therefore did not apply this technique.

Our method is a discrete choice experiment, which is a preference estimation method based on the theory of random utility, it assumes utility-maximising behaviour known in the field of microeconomics [75]. In addition, according to the theory of characteristics, utility levels of alternatives in a decision set are considered to be derived from their attributes [76]. Finally, it breaks down utility into a systematic and a random component [77]. In addition to the application being a frequently used procedure in many fields: transportation studies [78,79]; health economy [80,81]; marketing [82,83]; energetics [84,85] in recent decades, several novel methodological innovations were performed on it. In order to resolve one of the most significant limitations of the multinomial logit model associated with McFadden [86], a number of new specifications attempted to capture the heterogeneity inherent in taste in order to abolish the assumption of homogeneous preferences. Some of these specifications approach by including deterministic components, and others by including stochastic components [87]. In their work, Bujosa et al. [88] and Greene-Hensher [78], present a bi-directional approach. However, the latest trend is the use of so-called hybrid choice models, which supplement the standard choice model with a latent construct as a different member. The basic assumption of the model is that individuals' choices are greatly influenced by different attitudes and perceptions, which, although not directly observable, can be incorporated into the context of a hybrid choice model through related statements and a latent variable [87,89]. In the literature of recent years, researchers have generally argued that individuals' preferences are not only influenced by the characteristics and observable attributes they examine, but are also related to individuals' attitudes and perceptions [90–94]. An appropriate and widely used way to collect data on attitudes or perceptions is to ask respondents to indicate how much they agree with it [95–97]. The present study contributes to the literature with an approach that is becoming increasingly widely used today by specifying a latent class (LC) model that captures taste heterogeneity and simultaneously allocates individuals to classes according to underlying attitudes that also influence the answers to a number of attitudinal questions [98–100]. Hence, this article not only aims at determining the monetary value of convenience and environmental features in residential heat energy consumption but also aims at additionally incorporating individuals' attitudes toward energy consumption in a hybrid choice model.

Hybrid choice modelling became an increasingly researched topic in the early 2000s. One of its key methodological issues is described by Bolduc et al. [101]. The authors point out that the use of the specification has so far been restricted to small-scale models due to methodological limitations (solving complex, multidimensional integrals). At the same time, they point out that the development of computer technology already allows us to apply more complex models through the use of different simulation-driven methods. Bolduc et al. [102] analysed the choices of Canadian residents regarding passenger cars (when faced with technological innovations) using a hybrid choice model. Their analysis identified two latent variables, the first of which was "environmental concern" and the second was "appreciation of new car features". Based on their results, several socio-demographic factors (gender, age, and education of respondents) had a significant effect on the explanation of latent variables (among others, for example, women with a university degree over 56 years of age had a more positive environmental concern attitude). Daziano and Bolduc [103] used Bayesian estimation procedure to process their data from the stated preference approach, which analysed vehicle purchase decisions and environmental considerations. Their results highlighted that environmentally conscious consumers are willing to pay more for low-emission vehicles. From a methodological point of view, it was emphasized that the application of the Bayesian estimation technique is

Table 4
An example of a decision situation.

	1st heating method	2nd heating method	3rd heating method
Monthly energy cost (thousand HUF/month)	26	10	30
One-time investment amount (thousand HUF)	700	1000	200
Environmentally- friendly nature	Very polluting	Very polluting	Very environmentally- friendly
Type of operation	Automated	Manual feeding	Manual feeding

Data were processed and models were estimated using R: Apollo [107,108].

methodologically easier to implement in the context of hybrid models, and the definition of confidence intervals for willingness to pay calculations is also clearer. Daly et al. [104], on the one hand, provided an example of the applicability of hybrid modelling in transport study and highlighted the role of latent attitudes in the context of train travel, on the other hand, they provided methodological innovation. In contrast to previous studies (where responses to attitude-type statements were analysed as a continuous model), ordered logit structure was used to model indicators related to attitudes. Sarman et al. [105], analysed decisions on leisure trips through hybrid choice modelling, with a particular focus on the risks from life-threatening events associated with travel. The latent variable of their model was defined in the context of risk-taking. Their results highlighted the impact of different threats, their potential magnitude, and respondents 'risk-tolerant attitudes on decisions.

This study uses hybrid latent class modelling to examine the environmental and economic sensitivities of the population and to show how preferences differ across the population of the country under study. The aim of this approach is to adequately capture individual heterogeneity in tastes through attitude indicators. Some of the heterogeneity may be related to sociodemographic characteristics of the respondents, but unobserved attitudes may also be the main cause of heterogeneity. Therefore, using this case study from Hungary, we jointly estimate attitude and choice models, analysing the role of latent attitudes in an environmental context.

3.2. Experiment design

The research started with a detailed literature review and expert interviews, with the aim to be able to identify which properties individuals consider most important in choosing their heating method in Hungary, and what levels should be considered when comparing them.

Experts on both biomass energy processes and environmental protection with significant international publication activity were invited for the purpose of this task. In addition to the findings of the eight expert responses received, the methodology used so far in the international literature was also taken into account the findings of the authors' previously published paper regarding the Hungarian population's preferences [2]. Subsequently, based on a 50-person pilot study, the questionnaire, decision situation questions, and different levels of attributes were finalised. Four attributes were identified, the levels of which were determined at 4-4-4-2. The number of attributes was influenced by the characteristics of the energy sources taken into account and the technological solutions of the boilers to be considered during use.

In the case of economic factors, in addition to the above aspects, market and statistical data were taken into consideration, as follows:

Basic data for determining the monthly energy cost:

- The prices and price ratios of five energy sources per unit of calorific value, which cover almost 100% of individual heat consumption in Hungary, but differ from the point of view of comfort and environmental protection, were taken into account, as follows:
  - o Prices (thousand HUF/GJ, Internet 1–3)
    Coal: 2.55 Natural gas: 2.8 Firewood: 3.0 Biobriquette: 4.1 Firewood pellets: 4.9
  - o Price ratios (rounded):
    Coal: 1 Natural gas: 1.1 Firewood: 1.15 Biobriquette: 1.6 Firewood pellets: 2
- These values already include the typical energy efficiency values for combustion (and the base charge for natural gas to be paid regardless of consumption), which were as follows (Internet 4–5)
  - o Coal: 80% Natural gas: 95% Firewood: 80% Biobriquette: 85% Firewood pellets: 95%
- Finally, the two basic statistical data on individual heating in the population were also used to determine the values to be developed:
  - o Energy demand of a 100 m^2 family house with average insulation: 73 GJ/year (Internet-6)
  - o The amount of the annual household energy cost per capita according to income deciles (129–396 thousand HUF/year) and the average family size (3.01), (Internet 7–8)

Basic data for determining the one-off investment cost:

- Based on the price offers of the most important boiler manufacturers, the following boiler prices were taken into consideration (thousand HUF, Internet 5–6):
  - o Coal: 200 Natural gas: 300 Firewood: 200/700 Biobriquette: 200/700 Firewood pellets: 1000
  - o If there are two values, the first refers to a normal wood-fired boiler and the second to a more advanced wood-gasifier boiler.

Table 3 provides a summary of the attributes used and their details.

To compile decision alternatives and situations, the D-efficient experimental design was chosen and the decision situations (16 pieces) were arranged into two blocks. Ngene 1.2 [106] was used for implementation. In the final questionnaire, respondents faced eight decision situations, each containing three choices (none of which included "no answer" as an option, i.e., respondents were faced a so-called "forced choice" situation). An example of a decision situation is shown in Table 4.

3.3. Model specification

In this paper, in addition to traditional latent class modelling, a hybrid choice approach is used which, similarly to Mariel et al. [109], describes a latent class (LC) specification complemented with a latent

Internet-1: https://matrabrikett.hu/tuezeloanyag-valasztas.
Internet-2: https://tuzelocentrum.hu/puspokladany?gclid=EAIaIQobChMIybrk-9zq6gIVWxV7Ch2XvQbjEAAYASAAEgLoBfD_BwE.
Internet-3: http://pelletexpert.hu/.
Internet-4: https://netkazan.hu/.
Internet-5: http://www.kazanwebaruhaz.hu.
Internet-6: https://365.reblog.hu/majdnem-a-felere-csokkentette-a-hoszigeteles-egy-atlagos-csaladi.
Internet-7: http://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_zhc021b.html.
Internet-8: https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_zrk007b.html.

variable (hereinafter referred to as a hybrid latent class (HLC) model).

As a first step, the traditional multinomial logit (MNL) model is estimated in order to obtain basic information about the sign of the characteristics involved in the study, as well as their relative weight as a function of utility. As a next step, a latent class (LC) model was used, i.e., distinct heterogeneous classes were formed within which members have homogeneous preferences [110]. The class allocation equation of the LC model is supplemented with a latent variable and 12 attitude-related statements are modelled (in the context of environmental awareness) with measurement equations.

3.3.1. Multinomial logit model (MNL)

The biggest advantage of the MNL model attributed to McFadden (1973) is that its estimation process and interpretation of its results can be performed relatively easily. However, it also has several disadvantages, most notably the assumption of independence of homogeneous preferences and irrelevant alternatives. In the case of the model based on the RUT (Random Utility Theory) approach, the systematic part of the total utility (Equation (1)) can be written down according to Equation (2).

$$U_{n,i,t} = V_{n,i,t} + \varepsilon_{n,i,t}, \tag{1}$$

where $U_{n,i,t}$ is the total utility of decision-maker n related to alternative i in the decision situation t, $V_{n,i,t}$ is the systematic part of utility (arising from the observed characteristics), while $\varepsilon_{n,i,t}$ is the random (non-observable) part of utility.

$$V_{n,i,t} = \beta X_{n,i,t}, \tag{2}$$

where β is the coefficient related to the observed variable, and X is the observed variable.

In the model, the probability of choosing alternative i of the elements of the decision set J related to decision maker n in the decision situation t can be expressed according to *Equation (3)*:

$$P_{n,i,t} = \frac{\exp\left(\beta X_{n,i,t}\right)}{\sum_{j=1}^{J} \exp\left(\beta X_{n,j,t}\right)} \tag{3}$$

3.4. Latent class model (LC)

The LC specification is able to address one of the major disadvantages of the MNL model, the assumption of homogeneous preferences, through forming a discrete number of classes. Separate classes, within which member preferences are already homogeneous, have separate β parameters for the studied properties. In the case of the model, the systematic part of the utility can be expressed according to *Equation (4)* [111].

$$V_{n,i,t} = \beta_q X_{n,i,t}, \tag{4}$$

where β_q expresses the estimated coefficient for the observed variable and class q ($q = 1, \ldots, Q$).

In the model, the probability of choosing alternative i of the elements of the decision set J related to decision maker n in class q in the decision situation t can be expressed according to *Equation (5)*:

$$P_{n,i,t|q} = \frac{\exp\left(\beta_q X_{n,i,t}\right)}{\sum_{j=1}^{J} \exp\left(\beta_q X_{n,j,t}\right)} \quad q = 1, \ldots, Q, \tag{5}$$

It is clear from *Equation (5)* that it is structured according to a similar structure as in the case of the MNL model (*Equation (3)*), however, from the aspect of the LC, it is modified according to *Equation (6)* in order to determine the probability of individuals belonging to each class.

$$P_{n,i,t} = \sum_{q=1}^{Q} P_{n,i|q} H_{n,q}, \tag{6}$$

where $H_{n,q}$ is the probability of individual n belonging to class q [112].

In the case of the model, it is difficult to identify the ideal number of classes. This is usually decided on the basis of information criteria, mostly AIC (Akaike information criterion), CAIC (Consistent AIC) and BIC (Bayesian information criterion) [113].

3.4.1. Hybrid latent class model (HLC)

The purpose of estimating so-called “hybrid” or “latent variable” models is to incorporate directly non-measurable effects (e.g., attitudes, perceptions) into the model described in this paper, as they also form an essential part of individuals’ decision-making processes [114]. On the one hand, these effects appear through the standard choice model (*Equation (1)*), supplementing it in a way that corresponds to *Equation (7)*. On the other hand, they appear through measurement equations related to different attitudes (*Equation (9)*).

$$U_{n,i,t} = V_{n,i,t} + \lambda LV_n + \varepsilon_{n,i,t}, \tag{7}$$

where LV_n is the latent variable for individual n, while λ shows its effect.

Among other characteristics, hybrid models are built from structural (describing the structure of latent variables as a function of observable, explanatory variables, in a typical utility function formula) and measurement equations (linking the latent variable(s) to questions related to different attitudes). This research includes a very important latent variable that represents respondents ’attitudes toward environmental awareness, and its structure can be described according to *Equation (8)* [102,104].

$$LV_n = \gamma F_n + \eta_n, \tag{8}$$

where γ is the coefficient estimated for the observed socio-demographic characteristic; F_n is the variable related to the observed socio-demographic characteristic; while η_n is the random member that is assumed to have normal distribution.

The measurement equations related to the decision-maker n ($k = 1, \ldots K$), where the answers given to statements represent the dependent variable, can be expressed in the structure of *Equation (9)*.

$$ME_{k,n} = \zeta_k LV_n + \sigma_{k,n}, \tag{9}$$

where ζ_k is the coefficient estimated for the latent variable in question k, LV_n is the latent variable, while $\sigma_{k,n}$ is the random part of the measurement model in relation to decision-maker n and question k.

3.5. Utility function, class allocation, and structural equations

In the models described in this paper, the systematic part of the utility is constructed according to *Equation (10)*.

$$V_{n,i,t} = ASC_i + \beta_{Price} Price_{n,i,t} + \beta_{Cost} Cost_{n,i,t} + \beta_{Env_{Medium}} Env_{Medium_{n,i,t}} + \beta_{Env_{High}} Env_{High_{n,i,t}} + \beta_{Env_{Very\ high}} Env_{Very\ high_{n,i,t}} + \beta_{Comfort_{Manual}} Comfort_{Manual_{n,i,t}}, \tag{10}$$

〖ASC〗 _i is the specific constant value of the alternative for the i-th alternative (set to 0 for Alternative 1 in each case); Price, Cost, Env, Comfort denote the properties included in the study, of which Table 2 provides a detailed overview. The baseline levels (for discrete variables) always included Low (for Environmental friendliness) and Automatic (for Comfort).

Where ASC_i is the specific constant value of the alternative for the i-th alternative (set to 0 for Alternative 1 in each case); *Price, Cost, Env, Comfort* denote the properties included in the study, of which Table 2 provides a detailed overview. The baseline levels (for discrete variables) always included *Low (for Environmental friendliness)* and *Automatic (for*

Table 5
Descriptive statistics of the examined statements.

Statement	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Mean	Standard deviation
Statement 1	1.86	6.97	28.22	37.86	25.09	3.77	0.96
Statement 2	2.32	7.78	30.89	36.70	22.30	3.69	0.98
Statement 3	2.79	8.36	27.29	36.93	24.62	3.72	1.01
Statement 4	4.76	11.61	31.36	34.03	18.23	3.49	1.06
Statement 5	6.85	16.84	34.84	26.83	14.63	3.26	1.11
Statement 6	6.85	13.24	30.66	32.06	17.19	3.39	1.12
Statement 7	1.63	6.50	25.09	40.07	26.71	3.84	0.95
Statement 8	1.39	4.99	24.16	40.42	29.04	3.91	0.92
Statement 9	1.63	6.62	25.90	40.19	25.67	3.82	0.95
Statement 10	2.09	5.11	27.99	40.53	24.27	3.80	0.94
Statement 11	1.63	4.88	26.48	39.61	27.41	3.86	0.93
Statement 12	2.09	5.92	27.87	40.19	23.93	3.78	0.95

Comfort).

In the case of the latent class (LC) model described here, only one constant term was included in the class allocation equation according to *Equation (11)*, while in the case of the hybrid latent class (HLC) it was extended it with the latent variable (*Equation (12)*).

$$A_{n,q} = \delta_q, \tag{11}$$

where δ_q denotes the constant of the q-th class (one of them is set at 0, only q-1 constants are to be estimated).

$$A_{n,q} = \delta_q + \varphi_q LV_n, \tag{12}$$

where φ_q denotes the coefficient estimated as a result of the latent variable for the q-th class, while LV_n denotes the latent variable for the n-th individual.

The structural equation for the latent variable can be expressed according to *Equation (13)*.

$$\begin{aligned} LV_n = {} & \gamma_{Education_2} Education_{2_n} + \gamma_{Education_3} Education_{3_n} + \gamma_{Education_4} Education_{4_n} \\ & + \gamma_{Residence_2} Residence_{2_n} + \gamma_{Residence_3} Residence_{3_n} + \gamma_{Residence_4} Residence_{4_n} \\ & + \gamma_{Wealth_2} Wealth_{2_n} + \gamma_{Wealth_3} Wealth_{3_n} + \eta_n, \end{aligned} \tag{13}$$

where *Education*, *Residence* and *Wealth* are socio-demographic variables, as described in detail in Table 1.

The measurement equations in this paper were defined in the structure of Equation (9) and were estimated for the following 12 Likert-scale type statements [3,115]. The scales represent four different attitudes: the first three of them measure environmental identity, the fourth-sixth measure the role attributed to governments, the seventh-ninth help to understand the role of personal norms in energy use, while the last three focuses on the role of social norms in shaping attitudes influencing energy use. Individuals with a strong environmental self-identity consider active participation in environmental activities to be a key characteristic of their identity [116]. Personal standards represent how people feel about their moral commitment to energy-saving behaviour [117]. Corporate environmental responsibility means increasing the environmental performance of organizations and reducing their environmental impact [118]. Social norms, on the one hand, include how people considered as references reduce their energy use and how they think about what an individual can do [119].

Table 6
Results of the MNL model estimates.

Properties and data describing the model	Estimates	Robust t-values
ASC alternative 2	−0.0091	−0.32
ASC alternative 3	−0.2401***	−7.68
Price/1000	−0.0351***	−17.22
Investment costs/10 000	−0.0110***	−18.31
Slightly polluting	0.4452***	7.52
Slightly environmentally- friendly	0.7723***	12.61
Very environmentally- friendly	1.2202***	24.27
Manual	−0.2543***	−7.37
Individuals	861	
Observations	6888	
Parameters	8	
Log-likelihood (final)	−6310.684	
Pseudo R^2	0.1661	
AIC	12637.37	
BIC	12692.07	

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

- Acting pro-environmentally is an important part of who I am. (Statement 1)
- I am the type of person who acts pro-environmentally. (Statement 2)
- I see myself to be a pro-environmental person. (Statement 3)
- I think the government has a goal to minimise its impact on the environment. (Statement 4)
- I think the government has implemented policies and procedures to minimise its impact on the environment. (Statement 5)
- I think the government has stated its mission to implement a sustainable (pro-environmental) policy. (Statement 6)
- I feel morally determined to save energy. (Statement 7)
- It would fit my standards if I used sustainable energy. (Statement 8)
- I feel personally responsible to try to save energy. (Statement 9)
- Most of the people who are important to me think I should try to use as little energy as possible. (Statement 10)
- Most of the people who are important to me will approve if I try to use as little energy as possible. (Statement 11)
- Most people who are important to me try to use as little energy as possible. (Statement 12)

Descriptive statistics on responses to the statements are presented in Table 5.

Responses ranged from 1 (strongly disagree) to 5 (strongly agree) on a scale. The table shows that the average exceeded 3 in all cases, which means that respondents tended to be in agreement with the above statements. It can also be concluded that respondents are the least convinced of the government's commitment to the environment, as the proportion of those who agree is the lowest. However, there is also the greatest disagreement among respondents, as the standard deviation is the highest in the case of these questions. Personal standards and societal expectations regarding environmental protection are particularly high; there is less disagreement among respondents than in case of previous responses. A recently published paper arrives at similar results [3]'.[9]

4. Results and discussions

This chapter presents the results of the model estimates according to the structure presented in the model specification section. As a first step, the estimation of the multinomial logit (MNL) specification is

[9] Factors influencing environmental attitudes are examined in detail in a different study.

Table 7
Values of information criteria for LC models with different numbers of classes.

Information criteria	2 Classes	3 Classes	4 Classes	5 Classes	6 Classes
Parameters	15	22	29	36	43
Log-likelihood (final)	−5857.476	−5655.795	−5556.196	−5452.076	−5380.438
AIC	11744.95	11355.59	11170.39	10976.15	10846.88
BIC	11847.52	11506.02	11368.68	11222.3	11140.89
Class probability values	0.72	0.28	0.22	0.29	0.23
				0.19	0.17
		0.27	0.28	0.12	0.07
	0.28		0.28		0.12
		0.45	0.21	0.19	0.20
				0.22	0.20

Table 8
Results of the LC model estimates.

Characteristics and data describing the model	Neutral		Cost sensitive		Comfort and environmental concern		Sensitive to energy price		Environmental concern	
Class probability	0.19		0.19		0.29		0.12		0.22	
	Estimates					Robust t-values				
ASC alternative 2	0.0437					1.05				
ASC alternative 3	−0.4061***					−8.02				
	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values
δ	Base		0.0090	0.04	0.4276**	2.04	−0.4236*	−1.67	0.1394	0.59
Price/1000	−0.0155***	−2.72	−0.0847***	−3.72	−0.0424***	−5.08	**−0.1680*****	−9.19	0.0137	0.76
Investment costs/10 000	−0.0048***	−2.86	**−0.0580*****	−6.01	−0.0163***	−5.37	−0.0066**	−2.07	−0.0020	−0.64
Slightly polluting	0.1913	1.05	0.7128**	2.03	1.7284***	9.98	−0.0369	−0.12	0.3238	0.55
Slightly environmentally-friendly	0.5535***	3.54	1.3092***	3.08	1.8057***	7.84	0.2767	0.97	**2.4384*****	9.81
Very environmentally-friendly	0.1814	1.17	0.4181	1.28	**1.9949*****	8.60	0.4881**	2.04	**3.8230*****	13.03
Manual	0.0437	0.33	0.0719	0.60	**−1.3750*****	−4.96	0.1417	0.80	−0.4743	−1.58
Individuals	861									
Observations	6888									
Parameters	36									
Log-likelihood (final)	−5452.076									
Pseudo R^2	0.2795									
AIC	10976.15									
BIC	11222.3									

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

performed, followed by the latent class (LC) and hybrid latent class (HLC) models. It is important to mention that, due to filtering out incomplete respondents, a sample of 861 people is used during the model estimations.

4.1. Results of the multinomial logit (MNL) model estimation

The results of the estimates of the MNL model constructed according to the utility function specification of *Equation (10)* are shown in Table 6.

Based on the results of the MNL model, it can be concluded that there were some heuristics in the decisions, shown by the fact that Alternative 3 was chosen significantly less often than Alternative 1 at the base level (which is shown by the significant coefficient of the "ASC Alternative 3"). As previously expected, price and investment cost have a negative effect on individuals' sense of utility (with price having a more significant effect), i.e., an increase in these factors is accompanied by a decrease in utility levels. As the level of pollution decreases, consumers' sense of utility increases, and the manual heating alternative is considered less preferred to the automatic solution. All estimated parameters for the examined characteristics were significant (at the 1% level), suggesting that the characteristics that most influenced individuals 'decisions were included in the experiment. Our results show great similarity to the findings of Khan et al. [38] and Hu and Wang [39], highlighted the importance of automatized technologies in the reduction of carbon dioxyde emissions, the tendency in Hungary fits to the Western European characteristics. Considering Yu et al. [37] statements, spreading these technological innovations is also a great reserve in improving carbon productivity and GDP.

Results of the latent class (LC) model estimation.

To eliminate the homogeneous preferences assumed by the MNL model, LC model estimates were also performed in order to distinguish classes with different preferences. For this purpose, several cases with different numbers of classes were tested and the version considered to be the most ideal from the statistics aspect was further analysed. The values of the indicators forming the basis for the authors' choice are shown in Table 6. The structure of our model was based on the research method of Mills and Schleich [34] and Mariel et al. [35].

Based on the results of, It can be clearly seen that the values of the information criteria (log-likelihood (final), AIC, BIC) showed a decrease even in the 6-class case compared to the previous 5-class case (Table 7). Although this conclusion suggests a better fit of the 6-class model, the authors nevertheless decided to analyse the 5-class specification. This choice was justified by the fact that in the 6-class case, a group with a rather low (<10%) class probability value was already visible, the number of significant parameters decreased significantly in the case of the model. Based on these conclusions, the performed research focused on 5-class models (for both the LC and HLC models). The results obtained for the LC model are shown in Table 8.

The applied typology is necessary to understand how the different consumer groups will react on (1) energy policy legislation, (2) what kind of tools are necessary to reach the desired goals of energy strategy – considering the proportion of the cluster members (3) what are the effects of the energy policy decisions at country level.

Table 9
Sociodemographic characteristics of the respondents in the sample and latent classes.

Sociodemographic Factors	Sample (*N* = 1000)	Neutral (19%)	Cost sensitive (19%)	Comfort and environmental concern (29%)	Sensitivity to energy price (12%)	Environmental concern (22%)
Gender (%)						
Female	53.43	50.08	52.86	56.12	56.13	51.17
Male	46.57	49.92	47.14	43.88	43.87	48.83
Age category (%)						
18–29	18.14	16.67	19.39	15.96	13.37	22.21
30–39	19.47	26.24	18.95	16.93	15.38	18.88
40–49	16.26	18.84	11.52	19.16	14.68	15.75
50–59	17.75	15.50	16.40	18.96	14.48	20.69
60-	28.38	22.75	33.74	28.99	42.09	22.47
Highest level of education (%)						
Elementary or below	27.21	10.10	18.17	7.95	14.76	3.81
Vocational training	22.60	35.79	43.30	32.39	42.28	21.31
Secondary school	32.09	40.60	36.15	43.12	36.30	48.68
Higher education	18.10	13.51	2.38	16.54	6.66	26.20
Frequency of using the Internet (%)						
Daily	71.14	82.91	64.77	77.88	63.28	97.62
At least once a week	4.92	5.47	8.15	5.70	7.11	2.37
At least once a month	0.66	0.07	1.48	0.48	1.22	0.01
Less frequently than monthly	0.30	0.00	0.00	0.00	0.00	0.00
Never	22.98	11.55	25.60	15.94	28.39	10.00
Frequency of shopping online (%)						
At least once a week	2.48	3.81	2.34	2.52	3.82	2.07
At least once a month	11.57	15.34	7.13	14.30	8.12	15.57
At least once a quarter	16.34	18.78	14.36	18.95	14.46	23.43
At least once every six months	11.89	11.32	18.93	11.99	13.26	6.71
Less frequently	15.67	17.21	12.59	19.40	13.79	19.12
Never	42.05	33.54	44.65	32.84	46.55	33.10
Type of residence (%)						
Small town, village	29.72	17.11	13.29	13.32	14.52	33.84
City	35.79	17.74	15.16	22.94	18.12	14.07
County seat	17.41	35.59	36.28	35.53	38.74	32.50
Budapest	17.08	29.56	35.27	28.21	28.62	19.59
Financial situation (%)[10]						
0-2 assets, weak financial situation	43.60	38.28	53.17	31.3	53.01	32.28
3-5 assets, average financial situation	39.84	38.57	38.26	47.80	30.90	46.52
More than 6 assets, very good financial situation	16.56	23.15	8.57	20.90	16.09	21.20
Persons under 18 years of age in the household (%) (households with children)						
0	72.05	68.92	74.86	72.79	81.77	78.55
1	15.83	19.50	14.18	17.70	13.68	13.20
2	12.12	11.58	10.96	9.51	4.55	8.25
Occupation of the respondent (%)						
Employees	33.59	35.04	35.98	39.14	33.88	37.12
Leaders, or entrepreneurs with employees	11.39	11.96	4.02	13.60	7.67	14.88
Entrepreneurs without employees	24.95	32.12	27.69	22.88	18.18	24.65
Pensioners	25.50	17.77	30.47	21.97	35.76	21.04
Other (unemployed, student)	4.57	3.11	1.84	2.41	4.51	2.31

4.2. Social characteristics of LC

The latent classes are briefly described below based on socio-demographic aspects (Table 9).

The *Neutral* class is one of the youngest groups (class 1), with the lowest proportion of those over 60 and the highest of those under 40 years of age. The educational level of this group is average. Members of the group are above-average daily Internet users, as it is one of the most Internet-using groups (following class Environmental concern). There is a predominance of those who do not shop regularly online, but the proportion of those who never shop online is also below average (42% of the sample never shop online). These respondents mostly belong to the metropolitan population, they live in county seats and in the capital and they have the best financial situation in the sample. The average level of those in weak and average financial situation and the above-average level of those in very good financial situation is a good indicator, as the proportion of those who own the most assets is the highest in this class. Most of the members have no children, even though this class has the most households with one and two children. The employment structure of the group is mainly characterised by the high proportion of employees and individual entrepreneurs and the below-average proportion of pensioners.

The *cost sensitive* class is one of the oldest groups (class 2), with an above-average proportion of people over 60 (one-third of the group), but the proportion of young people under 30 is also one of the highest. This is the least educated class, with most respondents on an elementary school or vocational school level and there are no respondents with higher education degree in this class. Many (one in four people) never use the Internet, daily users are slightly below average, and people are more likely to use the Internet once a week or once a month than the average. Almost half of them never buy online, and those who do shop only very rarely. These respondents live mainly in larger cities (county seats and in the capital), with rural and small-town populations being

[10] The financial situation of the respondents was measured by the following items: owning a car (less then 10 years old), a second home, a motocycle, a LED TV, a play console, a video-camera, a printer, a dishwasher, a laptop, or an automatic coffee machine.

Table 10
WTP calculation for the LC model.

Levels of Attributes	Willingness to pay				
	Neutral – class 1	Cost sensitive – class 2	Comfort and environmental concern – class 3	Sensitivity to energy price – class 4	Environmental concern – class 5
Slightly polluting	n.s.	8419.0***	40 736.4***	n.s.	n.s.
Slightly environmentally-friendly	35 775.9**	15 463.7***	42 556.5***	n.s.	n.s.
Very environmentally-friendly	n.s.	n.s.	47 016.0***	2904.4*	n.s.
Manual	n.s.	n.s.	−32 405.4***	n.s.	n.s.

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

well below average. This class has the worst financial situation (similar to class Comfort and environmental concert). Only a few households have children, mostly one child. The proportion of employees and pensioners is almost identical (about 30%), but the presence of individual entrepreneurs is also the most typical in this class, in addition to the neutral class.

The *Comfort and environmental concern* class is one of the "most feminine" groups (class 3), with the highest proportion of women in addition to class Comfort and environmental concert. Among the women in the class, those above 60 years of age represent the highest proportion (29%), but all other age groups have a relatively proportionate presence of women. The comfort and environmental concern class is a relatively highly educated group, with the predominance of higher education and secondary education degrees, while the proportion of those with elementary degree is the lowest. The vast majority (77%) use the Internet on a daily basis. They do not shop online frequently, as one third of them never shop online, and others do so only very rarely. Most respondents in this class live in cities, county seats and in the capital, while small towns and villages are rare. They have relatively good financial situation, with the majority having a medium level of possessions, but the proportion of people in adverse financial conditions is also the lowest here (still about one third of the group). The majority have no children, and households with children typically raise one child. The proportion of employees is the highest in this class, while the proportion of pensioners and entrepreneurs is not outstanding, but rather around or below average.

The *Sensitivity to energy price* class (class 4) is also characterised by a slight predominance of women, with an exceptionally high proportion of those over 60 (this is the oldest group, 42%), but that of people under 30 years of age is also the lowest. Most of them have secondary education degrees, while the number of people with higher education degrees is minimal (6.7%) and the proportion of elementary education degrees is relatively high (15%). The share of daily Internet users is lowest (63%) and the proportion of those who have never used the Internet is also the highest (28.4%). Typically they are short of knowledge and - according to the findings of [27,32–34] – they are less interested in the investment into RES technologies. Furthermore, a significant number of people never shop online (47%). Class sensitivity to energy price consists of urban population, with people living mainly in county seats and in the capital, small towns and villages are not dominant. In addition to class Sensitivity to boiler price, it is the group with the weakest financial situation, more than half of them have no more than two assets. The majority are childless (82%), and those who have children usually raise one child. The proportion of pensioners is the highest (35.8%) in this class and that of employees and individual entrepreneurs is the lowest.

In the *Environmental concern* class (class 5), the proportion of those under 30 years of age and people in their 50's is above average, but that of the elderly is not significant. Elementary education degree is almost non-existent in the class, with the proportion of secondary education and higher education degrees being extremely high. This is the most educated group. Almost all respondents in the group use the Internet every day, although one-third of them never shop online, and those who do so usually shop online quarterly or less frequently. This class is characterised by the highest proportion of those living in villages (34%) and in county seats (32.5%). A significant part of the group is in a medium financial position (46%), but the proportion of those in weak financial conditions is also notable (32%). At the same time, people in good financial situation have the largest proportion in this group, although it is only 20%, but no other class have such high value, apart from class Comfort and environmental concern. The number of children is also low, with 79% of households not raising any children. The proportion of employees is high, but the proportion of individual entrepreneurs and joint ventures is also significant, while the proportion of pensioners remains below average.

4.3. Analysis of willingness to pay (WTP)

Based on the LC model estimates shown in Table 8, negative and significant coefficients were obtained for price and investment costs (consumer price sensitivity decreases with increasing price and investment cost) in the case of four classes (as expected) and no significant effect was shown on these factors for one class (class 5). In terms of environmental awareness, two classes (class 3 and class 5) have environmentally conscious behaviour. Within these classes, the sense of utility increases as the level of environmental protection increases. Regarding the amount of work required during heating, a significant effect appears only for one class (class 3). Members of this class prefer automatic operation to manual operation.

In the next step, the research focused on the willingness to pay (WTP) which characterises the different classes for the examined attributes. The results are shown in Table 10.

The results in Table 10 clearly show that significant willingness to pay values for all factors were obtained only in one class (Comfort and environmental concern – class 3). Members of this class would pay approximately 47 000 HUF extra per month for the very environmentally-friendly heating alternative, as opposed to the very polluting one; in addition, they would pay approximately 32 thousand HUF less in a month if they had to heat manually, as opposed to automatic feeding. These factors have a great significance in the modernisation of existing family houses [32].

The provided minimum and maximum values (10 and 30 thousand HUF/month, respectively) suggest that the members of Class 3 (Comfort and environmental concern), which makes up 29% of the population, would not burn coal in any way, but they would choose other, more environmentally-friendly energy sources, even in the case of a much larger price difference than the current one. At the same time, the difference between the other energy sources is small, but it follows an environmentally-friendly nature. It is noteworthy that there would be a potential demand for firewood pellets (as a convenient and also environmentally-friendly fuel) even in the case of a significant price increase of up to 100%. In the questionnaire, a higher-than-average proportion of wealthier and younger respondents occurred in this cluster, which may also explain higher willingness to pay, the importance of convenience, and environmental awareness. Under the current price

Table 11
WTI calculation for the LC model.

Levels of Attributes	Willingness to invest				
	Neutral – class 1	Cost sensitive – class 2	Comfort and environmental concern – class 3	Sensitivity to energy price – class 4	Environmental concern – class 5
Slightly polluting	n.s.	122 924.0**	1 059 665.0***	n.s.	n.s.
Slightly environmentally-friendly	1 154 470.0***	225 783.0***	1 107 012.0***	n.s.	n.s.
Very environmentally-friendly	n.s.	n.s.	1 223 014.0***	n.s.	n.s.
Manual	n.s.	n.s.	−842 953.0***	n.s.	n.s.

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

Table 12
Results of the HLC model estimates.

Characteristics and data describing the model	Neutral (class 1)		Cost sensitive (class 2)		Comfort and environmental concern (class 3)		Sensitivity to energy price (class 4)		Environmental concern (class 5)	
Class probability	0.20		0.18		0.30		0.12		0.21	
	Estimates					Robust t-values				
ASC alternative 2	0.0454					1.12				
ASC alternative 3	−0.4061***					−8.28				
	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values	Estimates	Robust t-values
δ	0.1994	0.82	Base		0.5242**	2.37	−0.3881	−1.44	0.1939	1.06
φ	0.3396**	2.08	Base		0.9411***	5.49	−0.0090	−0.05	0.8573***	5.42
Price/1000	−0.0174***	−3.07	−0.0902***	−4.56	−0.0399***	−6.21	**−0.1697*****	−9.85	0.0178	1.47
Investment costs/10 000	−0.0048***	−3.11	**−0.0605*****	−7.39	−0.0174***	−6.04	−0.0073**	−2.20	−0.0011	−0.51
Slightly polluting	0.1581	0.99	0.8630**	2.22	1.7499***	9.32	−0.0570	−0.20	0.2511	0.61
Slightly environmentally-friendly	0.5703***	3.90	1.3683***	3.45	**1.8657*****	7.92	0.2450	0.87	**2.4676*****	9.09
Very environmentally-friendly	0.1897	1.40	0.3145	1.11	**2.0627*****	10.06	0.5077**	2.25	**3.9111*****	13.98
Manual	0.0059	0.04	0.0796	0.66	**−1.3052*****	−7.40	0.1640	0.95	−0.5432***	−2.62
Individuals	861									
Observations	6888									
Parameters	72									
Log-likelihood (final) for the total model	−17038.21									
Log-likelihood (final) for the standard choice model	−5440.419									
Pseudo R^2 (for choice model)	0.281									
AIC	34220.42									
BIC	34712.73									

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

conditions, the use of natural gas (comfortable but slightly polluting) and bio-briquettes (slightly environmentally-friendly but inconvenient) and the transition to these fuels are also likely to occur in clusters that make up two-thirds of the population. This tendency is in line with Western European trends, where solvency is less of a constraint on actual purchases. It should be noted that, according to the authors' previous research [2], a significant part of the Hungarian population classifies firewood as "very polluting", therefore, the dissemination of knowledge and the distribution of high-efficiency equipment could be a step forward for this fuel type, especially when granting permits for new houses, as recommended also by Michelsen-Madlener [32].

After determining willingness to pay, calculations were performed to determine willingness to invest (WTI), based on the fact that, according to Rouvinen-Matero [33], investment costs are the primary influence on household decisions. The results of this research, covering several countries with significantly different economic status (Table 11).

Table 11 presents significant values for all characteristics were obtained for the same class (Comfort and environmental concern – class 3) as in the case of willingness to pay. Members of this class would invest more than 1 million HUF in order to ensure that their heating is not very harmful to the environment. In addition, they would invest less than approximately 840 thousand HUF if their heating required manual feeding, as opposed to the automatic solution.

These results essentially support the authors' findings regarding Tables 10 and i.e. members of Class 3 (Comfort and environmental concern) would prefer not only to burn the comfortable and very environmentally-friendly firewood pellets, but also to purchase a much more expensive boiler that allows to burn firewood pellets. In addition, the amount of money to be paid for boilers running on increasingly environmentally-friendly fuels shows little difference compared to coal-fired boilers.

As in the previous case, two-thirds of the population is willing to pay for slightly more expensive boilers capable of burning natural gas and biobriquettes. However, convenient use is not relevant for about 70% of the population, which can be explained by the existing natural gas boiler (that is not suitable for burning the other fuels studied here) and less favourable income situation (i.e. favouring the cheapest possible solutions). The latter explanation is supported by the maximum value of firewood boilers in the slightly environmentally-friendly category among the members of the "Neutral" class (Class 1) with the largest share. In addition, this finding is closely related to the fact that the importance of natural gas and firewood combustion and the proportion

Table 13
The results of the HLC model – structural equation, class allocation model and measurement equation parameters.

Structural equation parameters	Estimates	Robust t-values	Class allocation model parameters	Estimates	Robust t-values.
$\gamma_{Education_2}$	−0.376***	−4.09	δ (Class 1)	0.199	0.82
$\gamma_{Education_3}$	−0.173	−1.57	φ (Class 1)	0.340**	2.08
$\gamma_{Education_4}$	0.176	1.32	δ (Class 3)	0.524**	2.37
$\gamma_{Residence_2}$	0.173*	1.92	φ (Class 3)	**0.941*** **	5.49
$\gamma_{Residence_3}$	0.124	1.17	δ (Class 4)	−0.388	−1.44
$\gamma_{Residence_4}$	0.057	0.46	φ (Class 4)	−0.009	−0.05
γ_{Wealth_1}	0.180**	2.10	δ (Class 5)	0.194	1.06
γ_{Wealth_2}	0.232*	1.82	φ (Class 5)	**0.857*** **	5.42
Measurement equation parameters	Estimates	Robust t-values	Measurement equation parameters	Estimates	Robust T-values
ζ_{q_1}	0.763***	24.84	ζ_{q_7}	0.769***	26.07
σ_{q_1}	0.586***	28.61	σ_{q_7}	0.551***	25.94
ζ_{q_2}	0.784***	25.17	ζ_{q_8}	0.731***	24.24
σ_{q_2}	0.581***	30.26	σ_{q_8}	0.559***	24.40
ζ_{q_3}	0.826***	26.98	ζ_{q_9}	0.791***	25.15
σ_{q_3}	0.585***	30.72	σ_{q_9}	0.514***	28.24
ζ_{q_4}	0.483***	10.82	$\zeta_{q_{10}}$	0.709***	20.58
σ_{q_4}	0.948***	31.71	$\sigma_{q_{10}}$	0.607***	21.69
ζ_{q_5}	0.443***	9.61	$\zeta_{q_{11}}$	0.727***	21.97
σ_{q_5}	1.017***	38.54	$\sigma_{q_{11}}$	0.576***	24.81
ζ_{q_6}	0.426***	9.04	$\zeta_{q_{12}}$	0.668***	18.86
σ_{q_6}	1.038***	37.45	$\sigma_{q_{12}}$	0.667***	20.94

Note: ***, **, * indicate that the coefficients are significant at the 1%, 5% and 10% levels, respectively.

of heating costs in residential combustion are much higher in Hungary than the EU average [11].

In order to learn more about the underlying factors of decision making, we estimated a hybrid latent class (HLC) model in the next step (Table 12).

Based on the estimates of the HLC model (Table 12), similar conclusions can be drawn for the attributes as in the case of the LC model (Table 8). However, the comparison of models shows that a model with a better fit was obtained (Pseudo R2: 0.281) by including the latent variable. The additional information obtained from the HLC model appear in three parts (class allocation, structural, and measurement equations). These results are shown in Table 13.

The results in Table 13 clearly show that three socio-demographic variables (education level, residence type, wealth type) were included in the structural equation. Based on the obtained results, it can be concluded that the value of the latent variable (environmental awareness) will be more positive for people living in the city, who have more than three assets, higher education degree (college, university degree) or only elementary school level (although the conclusion on higher education was not significant in the model). The ζ values in the measurement equations (which represent the effect of the latent variable in the equations) have a positive value for each statement, indicating that these statements will be rated higher as the latent variable increases. As an example, the higher the level of environmental awareness among respondents, the more they agree with the statement "Environmental awareness is an important part of my self-image". According to parameters of the class allocation model, the φ values (which represent the effect of the latent variable in the class allocation model) show a significant effect in several cases. We can conclude that people with a higher latent variable value (higher environmental awareness) are more likely to belong to classes 3 and 5. This conclusion is clearly reflected in respondents' choices and in the coefficients estimated for the attributes (in the case of class 3 and 5, a clear increasing trend was observed in the level of utility, at the same time as the level of environmental pollution decreased).

The different classes were named according to their characteristics based on the LC and HLC model estimates, as well as the calculations of willingness to pay and invest. The estimated cost coefficients of the models were the highest in absolute terms in the fourth class, while the coefficients estimated for investment cost were the highest in absolute terms in the second class. For this reason, the fourth class was named "Price sensitive" and the second "Cost sensitive". The presence of environmental awareness can be clearly assumed for the third and fifth classes (this conclusion is confirmed on the one hand by the coefficients estimated for the attributes and on the other hand, in the case of the HLC model, by the parameters of the class allocation model). In the former case, there is also a clear need for automated operation, which is also confirmed by calculations of willingness to pay and invest. Accordingly, the third class was named "Comfort and environmental concern" and the fifth was named "Environmental concern". Since no clear trend could be observed in the first class, it was named "Neutral".

5. Conclusions

One of the vital question of future energy-use is people's willingness to pay for convenience and environmental friendliness, and the factors influencing their choices. The article identifies the most important social determinants of energy consumption, using a nationally representative data basis, determines groups of consumers with markedly different preferences and quantify their expectable financial decisions when purchasing energy and heating systems.

The value of environmental-friendliness nature in Hungary exceeds the convenience factor of the population in the assessment of energy sources. This finding is supported by results for both fuels and boilers cases with significant differences. The very environmentally-friendly alternative exceeds the extra cost of comfort by about 50% for fuels and by almost 20% for boilers.

Significant results indicate different values among members of the "Neutral" and "Comfort and environmentally concerned" clusters in the case of fuel and boiler purchases. The former would pay about 20% less for slightly more environmentally-friendly fuels than the latter, and about 5% more for the boiler that burns such fuel. The values of comfort cannot be significantly detected for the majority of the Hungarian population. These findings show the strong attachment of the Hungarian average consumer to the use of firewood and natural gas that are still significant in the heat consumption of the population.

We also found a segment that accounts for 29% of the total population where the need for environmentally-friendly and also convenient solutions is clearly identifiable. These people would in principle be willing to pay more for fuel and equipment that can be considered modern in both respects. For them, coal and firewood burning is not an alternative in practice.

Higher educated and financially upper classes are open to environmental values in terms of the use of heating energy. Young adults not yet raising a child and people over the age of fifty with independent children before retirement, belong to this social class. It indicates that strong correlation can be observed between social capital supply, income level and environmental awareness in Hungary. The "Neutral" class also has social indicators similar to the environment class, and it shows that strengthening their environmental awareness in the field of heating could be achieved through more active involvement and cooperation of the public and civil spheres. The "Comfort and environmental concern" group typically includes lower-middle-class city dwellers, where there is no lack of openness to environmental values in the assessment of heat energy consumption, but they are strongly influenced by limited access to livelihoods and social capital. In their case, mass social and material rise can bring a significant strengthening of environmental values in energy use. For the classes of "Sensitive for stove price" and of "Sensitive for energy price", scarce material resources also strongly limit the pursuit of environmental values. Both classes includes higher age of classes, the higher proportion of retirees with uncertain sources of income and the higher proportion of villagers disadvantaged in terms of access to information are unlikely to change their environmental values.

People living in poorer households typically live in lower quality, more energy-intensive properties and have no financial means to change this. External support is therefore needed to alleviate energy poverty. Energy poverty has a number of factors and impacts, including energy efficiency, public subsidy schemes or health risks. The main influencing factors are the price of energy, the type, condition, equipment and energy efficiency of housing and household income [20]. In Hungary, 75–80% of energy-poor households live in a family house. Energy poverty mainly affects low-income elderly people, unemployed people, families with many children and single-parent families. In rural, economically disadvantaged areas, family houses are on average larger than condominiums, and energy poverty is particularly high in these areas due to higher overheads. The housing stock in Hungary is predominantly outdated, i.e. residential buildings are typically of poor energy efficiency, which leads to high overheads, carbon dioxide and air pollution [120]. A series of legislative measures could reduce the consequences of energy poverty. The modernisation of heating systems in dwellings should be strongly promoted, in particular the replacement of solid fuel stoves, but this intervention mainly affects the poorest, needs to be designed in a way that does not cause serious negative consequences and therefore requires a large-scale programme of stove and chimney replacement [20]. Low-income households typically have lower energy consumption than better-off households, but at the same time have less access to modern, energy-efficient and environmentally friendly solutions. This further exacerbates differences in energy use levels between different social groups and long-term, predictable, interdependent and differentiated residential energy renovation programmes are needed.

The results of our study show that the role of environmental values in heating energy use is highly dependent on the level of material and social capital and inequalities in their access. This may be particularly true in countries and regions of the European Union where the middle class and the supply of material and social capital do not reach the level of development centres. Reducing national and regional disparities has shown a long-term process. In strengthening environmental values, therefore, a radical change can be achieved in the distribution of EU financial aids and of state subsidies, which provides much more resources and harmonizes the cooperation of the state, local government and non-governmental organizations, especially for the younger generations.

Our results in development of clusters may be useful for the establishment of a selective support policy. Meeting with the EU expectations regarding GHG emission and ratio of RES is impossible without relevant and selective support policy instead of the present system which is available for near any person. Based on our results, two clearly identifiable groups should be highlighted in the energy policy. Our recommendations for the most rapid progress:

- Significant investment subsidy for quality wood stoves and firewood (to avoid heating with non-wood wastes, which are highly dangerous for the environment), as well as energy saving investments (e.g. insulation) for the 60 year + persons, since they typically live in under-insulated houses, in order to save energy for the long run. It is important to inform them via television, radio, or local newspapers, since – according to Bai et al. [121] these are the primary source of information for them. They can not afford to buy effective stoves without any financial help, but able and ready to use the cheapest and less comfortable types of biomass, as well as eligible for social firewood, so price support would not be so effective. The more effective stoves in their homes can save a high external cost (by substitution of coal and reducing the firewood consumption). Priority support for old people is in line with current national social policy, too. It would be very important not just social, but also in health aspect, since according to Hughes et al. [122] there are indications related to the correlation of low temperatures and respiratory health of the elderly people.
- Spreading of pellet burners is not a question of financial matters, since 29% of the population able and ready to pay for both comfort and environmental protection. This group is well-educated, younger and typically at higher level of energy-efficiency retrofits, so the subsidy would not be efficient for them. It would be important to establish inland background of pellet stove production and pellet production with their spill-over effects. In this case the support should aim to the establishment of productive assets for enterprises. The effect of subsidization for these segments should improve economic activity and technological development as well as – in accordance with Yu et al. (2022) [37], Hu and Wang (2020) [39] and Khan et al. (2021) [38] results – can decrease the GHG emissions. High natural gas and electricity prices in these days result higher substitution value of renewable energies, which trigger price hiking also in the market of renewable equipments, in spite of the technical development. However, not only the fossil energy sources, but the energy saving investments can be taken competitors. According to practical experiences, energy saving investments should be implemented first, followed by renewable investments.

It should be emphasized that profitability of the RES technologies strongly depends on the price fluctuation of fossil energy sources (especially of oil and gas prices), which are affected many times by political decisions [123], general infrastructural progress [124], spatial [41] and financial [42] development and it makes uncertain the viability, effectiveness and planning of renewable systems, too. The best example is the years of 2021 and 2022, when extremely high price hiking was observed in the market of both above-mentioned fossil energy sources. Another important issue is considering country-specific factors in national/regional RES policy, since income level, energy consumption, differential risks, human capital, research and development has very divergent impact on the efficient use of RES, as it was proved by Wang et al. in several previous articles [14,14,44,94].

Model estimation in hybrid choice context is a relatively rarely used practice in latent class modelling. By incorporating environmental awareness as a latent attitude into the class allocation equation, we had opportunity to distinguish classes with different preferences for heating systems so that the grouping is based on the level of environmental awareness of the respondents. As a result, we were able to know what characteristics respondents actually have environmental awareness and whether they make consistent decisions in their choices. In addition to the usual WTP (willingness to pay) calculation, we also used WTI (willingness to invest) calculations, which also have significant information content and can provide further guidance.

Our paper has two important limitations. On the one hand radical changes of energy prices in recent years (due to epidemics, Russian-Ukrainian war) may also orientate the originally environmentally and comfort-oriented consumers towards economic preferences. On the other hand, the balanced operation of the world economy, the increasing information and education level of the everyday people, the energy effective innovations and the increased integration of environmental and energy storage considerations into energy prices are likely to bring about a positive change in environmental awareness in the long term. We therefore believe that future research should pay particular attention to comparing the impact of extreme and normal conditions on energy market as well as to continuing the estimation of short- and long-term energy trends and their driving forces in differential types of economies.

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Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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