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Firewood Heating in Rural Hungary: Survey Evidence on the Challenges and Controversies of Household Energy Transition

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Abstract

This study examines the drivers, practices, and challenges associated with firewood use through a survey of 603 rural households in Hungary. The results reveal that 97% of respondents use firewood exclusively for heating, primarily through mixed-fuel boilers and room heating systems, while advanced technologies such as wood gasification boilers are rare. A significant proportion (71%) of rural households that utilise firewood have access to alternative heating options, with natural gas being the most prevalent. In 27% of households in the survey, despite the availability of alternative heating options, firewood remains the primary heating energy source, while the same share uses it only as a secondary option. The vast majority (95%) of the households that use firewood, but no alternative energy sources are available, do not plan to change to alternative fuels, mostly because of the high costs entailed. It is anticipated that firewood will persist as a stable component of the rural energy landscape. The survey results indicate that household waste combustion is a current practice and remains an option in the future. Educational attainment has been demonstrated to correlate with heating choices, with lower education levels correlating with a greater propensity for the use of firewood.

Keywords: fuelwood; household waste burning; space heating; household energy; rural energy systems; fuel stacking

1. Introduction

Due to the inconsistent use of the terms firewood and fuelwood in the literature, the authors decided to use firewood exclusively. Instead of differentiating between firewood as cut and split pieces of wood that is used for combustion directly, and the fuelwood as all types of wood for energy generation (including roundwood, chips, pellets, twigs, etc.), firewood is used. This is justified by the fact that households typically use firewood that fits the description above.

Firewood is our most ancient fuel, as the use of fire has been part of human life for hundreds of thousands of years [1,2]. Its importance is still significant today, with more than 2 billion people worldwide using it for heating or cooking [3]. Globally, the volume of firewood production exceeded that of industrial roundwood every year until 2017 [4]. Firewood is the second most widely used heating fuel in Hungarian households after piped natural gas, providing heating for almost 1.4 million homes nationwide, which is 31% of the total housing stock [5].

Check for updates

Received: 29 January 2026
Revised: 25 February 2026
Accepted: 3 March 2026
Published: 6 March 2026

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1.1. The Role of Firewood in the Energy-Mix

Hungarian households most commonly use natural gas and/or firewood for heating. The choice between the two is strongly influenced by the relative price of one fuel compared to the other [6]. The importance of firewood has increased in the years since the turn of the millennium, especially after the sharp rise in natural gas prices after 2006. An increasing number of households switched from natural gas to firewood, and by 2013, residential biomass and natural gas consumption had reached the same level [7].

Energy costs play a significant role in the budget of households. As a measure to protect against drastic changes in energy prices, the government has introduced a policy to reduce household utility costs. The Act LIV of 2013 imposed a two-tier pricing on residential natural gas and electricity, which offers reduced prices in case of below-average consumption. According to the data from the Hungarian Central Statistical Office (KSH), the price of firewood continued to increase. As a result, gas consumption has started to rise again, while households' use of firewood has declined [7]. The outbreak of the Russian-Ukrainian war in 2022 led to a significant increase in uncertainty surrounding the natural gas supply from Russia. In response to this, households began to accumulate substantial reserves of firewood, thereby exerting upward pressure on the market and giving rise to a surge in firewood prices. This crisis prompted the Hungarian government to intervene again, starting a firewood supply campaign until mid-2023. This program allowed households to purchase a limited amount of firewood from state forest companies at a reduced price. In certain regions, this resulted in demand for firewood exceeding several times that of previous years [8]. In the following years, there was a significant drop in demand for firewood.

1.2. Firewood Production and Other Economic Aspects

Since Hungary's climate is mostly suitable for broadleaved species [9,10], and in some regions the forests are on the xeric limits [11], the share of low-quality products, such as firewood, tends to be high, while high-quality industrial wood tends to be low. Forest privatisation in the 1990s further enhanced firewood production as forest owners tried to obtain their firewood from their own forests [12,13]. Consequently, firewood production is pivotal to the economic output of the forestry sector [14].

The average (2005–2024) gross wood harvest of the country is 7.4 million m^3, which fluctuates in a ±12% range. The average wood harvest residue is 16%–17%, and the average roundwood production is 6.6 million m^3. Although the share of firewood and woodchips for energy purposes in the total production is 55% on average, it is significantly influenced by market disturbances and governmental policies described in Section 1.1. The firewood supply campaign from late 2022 to mid-2023 created a shift in production from pulp and paper wood to firewood. Despite the government program, the price of firewood continued to increase. From 2021 to 2023, the price of stacked firewood and ready-to-use firewood increased by 193% and 165%, respectively (Figure 1).

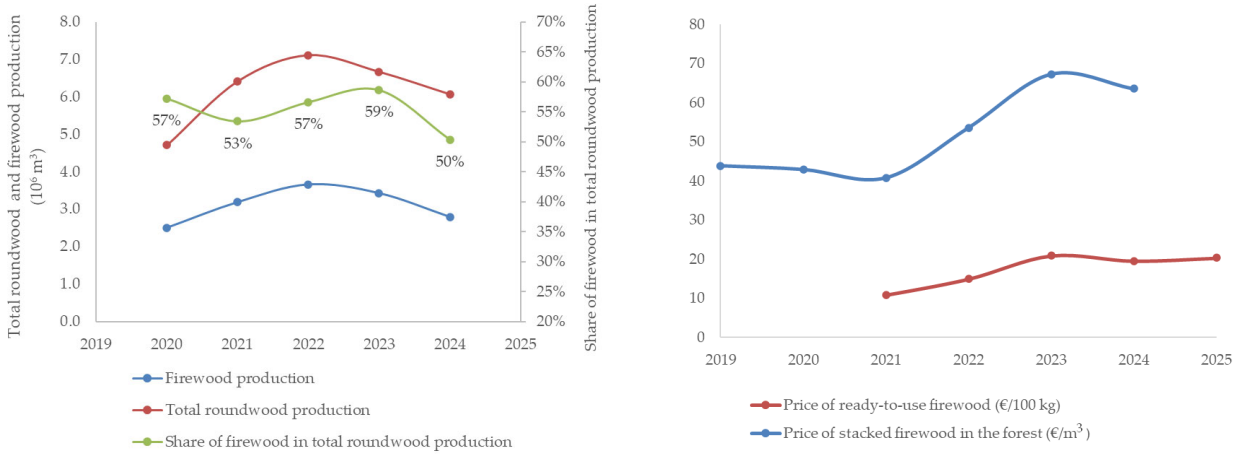

Figure 1. Roundwood and firewood production (**left**), Price of stacked firewood and ready-to-use firewood in Hungary (**right**) (data source: [15]).

1.3. Social Dimension of Firewood Use

Firewood use is often linked to energy poverty, which typically occurs when a household is unable to heat its home to an adequate level or when its energy costs exceed a certain percentage of its income [16]. According to researchers investigating the social dimensions of energy management, energy-poor households typically use solid biomass-based heating, and this firewood-using segment is likely to live in outdated family homes in rural and suburban areas [17]. Wood heating is generally more widespread in rural areas than in cities [18], as biomass-based heating is complicated to install in urban buildings and is prohibited in some countries [19]. In Hungary, wood burning accounts for 31% of the household energy mix and is most common among people living in rural areas (Table 1). 61% of village households and 35% of households in small towns use wood for heating. In contrast, only 3% of the households in Budapest and 13% of the households in towns with county status use firewood [5]. Wood burning occurs in all segments of society in Hungary. Although it is primarily an energy source, it can also be used as a mood element in wealthy households, or it can be seen as a secondary heating option that increases energy security [7].

Table 1. Heating energy sources used by Hungarian households in 2022.

Heating Method	Households	Proportion	
Heating with non-wood fuels	3,182,260	69%	
Heating with wood (total)	1,398,278	31%	100%
Of which heated exclusively with wood	706,889		51%
Of which heated with mainly gas and wood	570,141		41%
Of which heating with other fuels and wood	121,248		9%

Source: KSH [5].

1.4. The Role of Firewood in the Energy Transition

EU policies, and the subsequent national policies, aim at (1) a clean energy production that lowers environmental impacts, including pollution and decarbonisation, (2) affordable energy costs for households, and (3) a secure energy supply that reduces dependency on third country relations. In rural areas, firewood is one of the main traditional energy sources used for heating and cooking. Low combustion efficiency can result in heavy air pollution both in the neighbourhood and indoors. Despite its relative advantages: (1) local use of firewood provides affordable energy access, (2) requires no infrastructure development, (3) usually entails short transportation and low energy input in production and processing,

as well as (4) it contributes to the local economy, its overall judgment is negative. Therefore, firewood use for household purposes is a key element of energy transition.

There are strong barriers to energy transition, the significance of which may vary in different regions and cases. Lack of awareness of the end-users and their attitude and lifestyle can sustain habits of using solid fuels. Buildings may require improvements to reduce energy needs and to install new equipment for the energy sources that low-income households cannot afford. New energy sources, in general, are not necessarily cost-efficient, especially if the externalities of the traditional energy sources are not priced. Centralised energy supply requires investment in infrastructure so that households can have access. Maintaining grid stability on a large scale may be a challenge. There might be contradicting economic, societal and environmental considerations resulting in policies with mixed effects.

Energy transition does not take place as a linear and one-way development process, but rather new energy options exist together with old energy alternatives. Keeping the firewood heating and installing gas heating, for instance, can provide the opportunity for flexible adaptation to the energy prices and protection against supply failures.

1.5. Purpose of This Study

This study aims at examining (1) the drivers, practices and challenges associated with firewood use, (2) the status of firewood use compared to other energy sources, (3) the importance of firewood in the energy mix, (4) the users' experiences with firewood, and (5) the users' plans.

Given the importance of firewood in the rural energy mix in Hungary, and the fact that its level of utilisation as well as its prospects are indicative of the state of energy transition, this study offers survey evidence on the energy transition and fuel stacking in rural Hungary. Experiences of the firewood users provide insights regarding the driving forces and hindering factors of further transition.

2. Materials and Methods

2.1. Study Area and Target Population

In 2024, we conducted a questionnaire survey to assess firewood use practices, circumstances, and the user experiences. The target population consisted of adult Hungarian citizens residing in villages or small towns who use firewood. Small towns were defined as towns of no county status, and neither the capital, as defined in Act CLXXXIX of 2011. A sample of 603 completed questionnaires was compiled. Figure 2 illustrates the distribution of these responses across the counties.

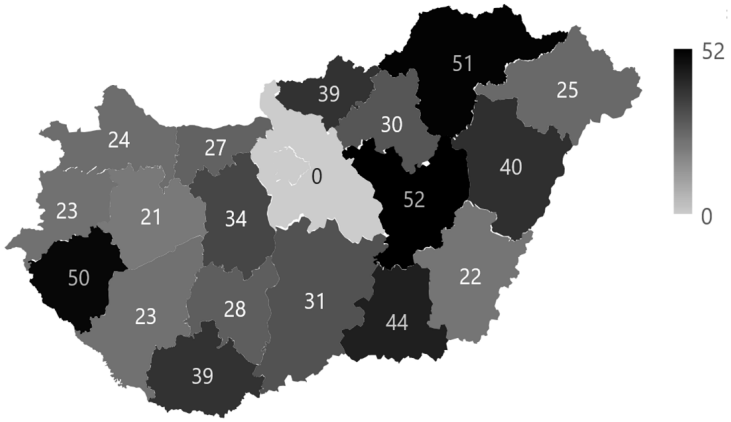

Figure 2. Number of complete questionnaires by county.

2.2. Data Collection Procedures

Data collection was conducted by M.Á.S.T. Market and Public Opinion Research Company using the C.A.T.I. (Computer-Assisted Telephone Interviewing) method. The sampling frame consisted of approximately 3000 individuals included on the company's contact list, which is representative by age, gender, education level, type of settlement and county of residence. From this frame, respondents (from villages and small towns) were randomly contacted until 603 firewood-using households were identified. A screening question at the beginning of each interview ensured that only firewood users were included, and only one respondent per household was interviewed. The final dataset comprises 603 completed questionnaires.

2.3. Data Protection

Participation in the interview and answering the questions was voluntary, and respondents got no reward of any kind. Responses were recorded anonymously by the market research company; therefore, the authors did not need to handle personal information.

2.4. Study Design and Survey Instrument

The questionnaire was designed by the authors in cooperation with M.Á.S.T. Market and Public Opinion Research Company. The questionnaire consisted of 25 survey questions and 9 demographic questions. The questions were closed questions, and respondents had to select one or more answers from a predefined list, but they were allowed to specify their answers if they were not on the list.

2.5. Sample and Participants

This study focuses on households that use firewood and are located in rural areas, i.e., small towns or villages. Because no descriptive statistical data is available for this population (e.g., household size, income levels, volume of firewood use, etc.), the sample cannot be further stratified. Consequently, representativity can only be understood in the sense that the sample reflects rural firewood-using households. Representativity is supported by the random selection of households to reduce systematic bias.

The demographic information collected from respondents does not directly describe the household in terms of gender, age, or education. Proper demographic characterisation of households would require significantly more complex classifications based on household composition, lifestyle, and other factors, none of which are available in population-level statistics. Therefore, an uneven distribution of respondents, for instance, does not necessarily indicate biased sampling, nor biased answers, considering that respondents represent their households, not themselves. The only exception we have found is the level of education, as explained in the Discussion. All findings in this study should therefore be interpreted within the limits that may arise from the sampling procedure.

Figure 3 illustrates the demographic characteristics of the sample. During the telephone survey, it was mainly members of the older generation who answered the questions, 73% of whom were over 51 years of age, and a significant proportion of whom were over 65 years of age. Women participated in the research in slightly higher proportions than men. Most of them do not have children and live in single-person or two-person households. There is a significant correlation between age and the number of household members based on the chi-square test (p = 0.00000). Members of the older generation typically live in smaller households. Half of the respondents have a secondary school certificate or higher education qualification. A smaller proportion of respondents (19%) are able to save money at the end of the month. It is worth noting that the question about their financial situation received the highest number of refusals to answer (7%).

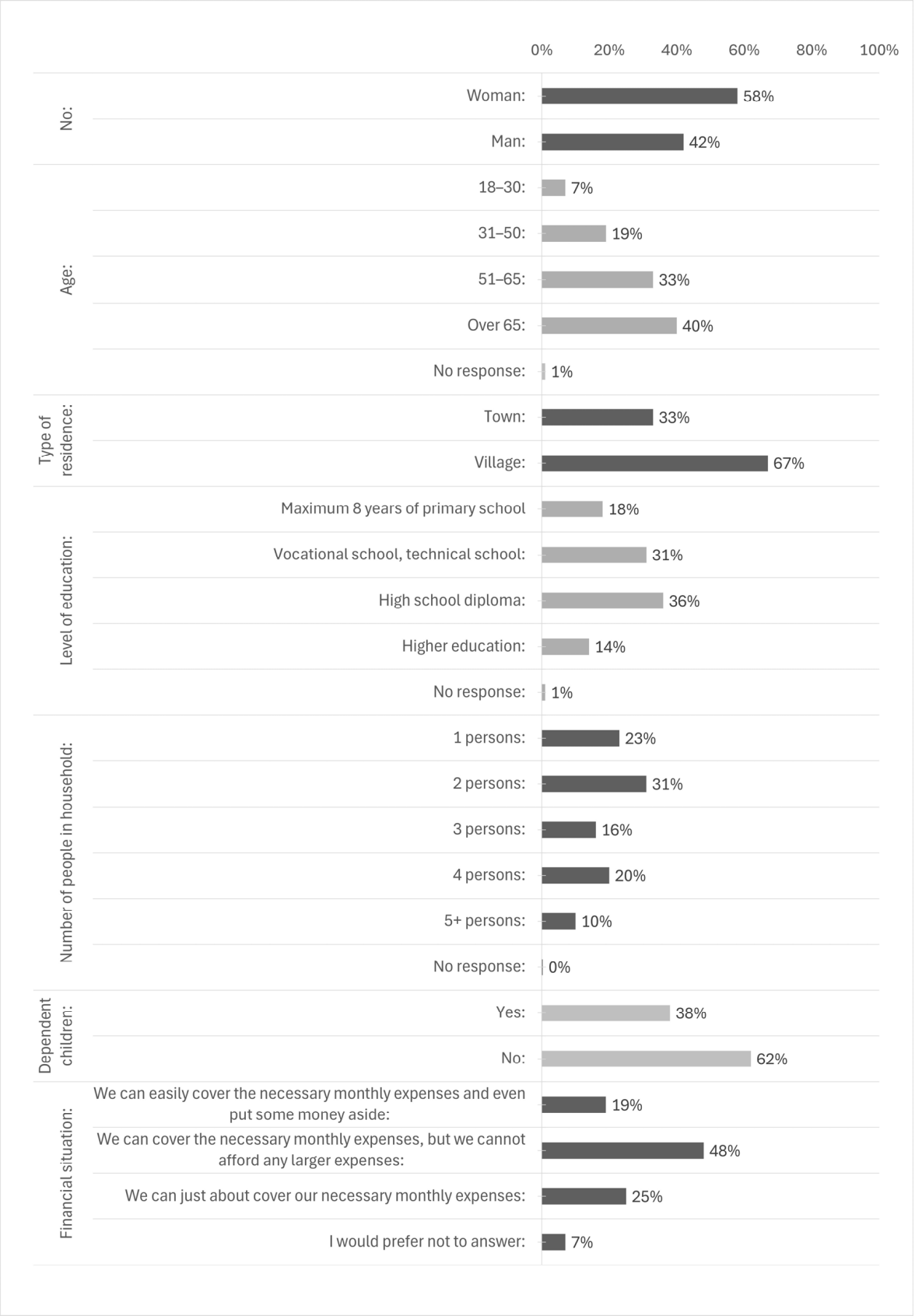

Figure 3. Demographic characteristics of the sample (N = 603).

2.6. Variables and Data Preparation

The analysis was performed using Microsoft 365 Excel (Microsoft Corporation, Redmond, WA, USA, 2025) and IBM SPSS (IBM Corporation, Armon, NY, USA, Version 27) software. The respondents' answers were summarised for each question, and the results are presented in tabular form and using traditional diagram types in the most appropriate way for illustration. Throughout the study, the response options "I don't know" and "no answer" were combined and reported as N.A. For certain analyses, N.A. responses were excluded, resulting in varying sample sizes across analyses. These differences are indicated in each case. In some cases, predefined answers were merged to better adapt to the aim of the analyses at hand and to simplify the presentation of the results.

The demographic variables were categorised based on the respondents' answers to the questionnaire. Additionally, we created a binary variable to identify households using both exclusive firewood heating and room-based heating, coded as 1 = yes and 0 = no. The significance of firewood in household heating was categorised on an ordinal scale that was derived directly from respondents' answers to a single question of the questionnaire. Firewood-use categories were derived directly from the questionnaire item "Please select the role of firewood or wood-based fuel within your heating system." The response options and their ordinal coding were:

- 1 = We heat exclusively with firewood.
- 2 = We primarily heat with firewood but also use other heating systems.
- 3 = We heat with both firewood and another system (e.g., gas), both equally important.
- 4 = We primarily heat with another system but also use firewood as a supplement.
- 5 = We use firewood only for ambience (e.g., fireplace, tile stove).

Because there are only two cases in the highest category, the 5th category was merged with the adjacent 4th category. Educational attainment was used as a categorical predictor with the following coded levels:

- E1 (code = 1): Maximum 8 years of primary school
- E2 (code = 2): Vocational or technical school
- E3 (code = 3): High school diploma
- E4 (code = 4): Higher education

Subjective income status was also included as a categorical predictor, coded according to the questionnaire responses:

- I1 (code = 1): We can easily cover the necessary monthly expenses and even put some money aside.
- I2 (code = 2): We can cover the necessary monthly expenses, but we cannot afford any larger expenses.
- I3 (code = 3): We can just about cover our necessary monthly expenses

2.7. Statistical Analysis

All analyses were conducted at a 5% significance level ($p < 0.05$) using IBM SPSS Statistics. We applied a multi-step approach to assess associations:

- Cross-tabulation and Chi-Square Tests: We tested the relationships between demographic variables and the type of heating system using Pearson's chi-square test. The strength of associations was evaluated with Cramér's V. For ordinal variables, we used the Linear-by-Linear Association test to detect trends.
- Ordinal Association Measures: We assessed the monotonic relationships between education and firewood dependence using Kendall's tau-b coefficient.
- Ordinal Logistic Regression: We modelled the effect of educational attainment on the firewood dependence scale using ordinal logistic regression. The proportional odds

assumption was verified with the Test of Parallel Lines, and we assessed model fit using Deviance χ^2 and goodness-of-fit statistics. The explanatory power was estimated with Nagelkerke's pseudo R^2, and odds ratios (OR) with 95% confidence intervals were reported for interpretation. OR values were obtained by exponentiating the logit coefficients ($OR = e^B$), and the corresponding 95% CIs were computed as exp(lower CI) and exp(upper CI).

- Binary Logistic Regression: We examined the association between income status and a combined heating pattern (exclusive wood use combined with room-based heating) using binary logistic regression. Model fit was evaluated with Omnibus χ^2 and Hosmer–Lemeshow tests, and the explanatory power was assessed using Nagelkerke's R^2.

2.8. The Classification of Heating Systems

The classification of heating systems and equipment considered in this study is listed and described in Table 2.

Table 2. Description of technical terms of heating systems and equipment.

Terms	Description
Central heating	Heat is generated in one location within the household and distributed to the other rooms.
Room heating (space heating)	The rooms are heated separately, and the heating equipment is not connected or formed into a system.
Mixed fuel	Firewood is typically used alongside household waste, such as paper and wood.
Stove, fireplace, tiled stove	Traditional space heating equipment that combusts fuel and radiates heat directly to the immediate environment. The oxygen required for combustion is taken from the atmosphere of the room, and the smoke escapes through the chimney.
Gas convector	A wall-mounted device that burns natural gas to heat the air. The oxygen required for combustion is taken from the atmosphere of the room, and the flue gases are either released into the room or exhausted to the outside through the wall.
Portable gas heater	Natural gas is supplied from a refillable metal tank (gas cylinder) and is burned in an open flame. The oxygen required for combustion is taken from the atmosphere of the room, and the flue gases are released into the room.
Electric radiator/heater	Radiators of various types that convert electricity to heat. Its operation is based on a filament that heats liquid in the case of a radiator or air in the case of a fan heater. Infrared panels emit infrared waves.
Air conditioner	Air conditioners with heating function.
Solar collector	Solar energy is collected and concentrated by prisms to heat water, which is then usually transferred to a heat storage tank via a heat exchanger.
Heat pump	A highly energy-efficient piece of equipment, which can transfer heat from the outside (air, ground or water) to the inside (water or air).
Boiler, furnace	A boiler burns fuel to heat water, which can then be used to provide heating for the household. Smoke then escapes through the chimney.

3. Results

3.1. Available Heating Systems

The overwhelming majority (97%) of the respondents in the survey use firewood for heating exclusively, and only a small fraction (3%) uses it also for cooking. Heating includes both room heating and hot water heating.

62% of the households that use firewood for heating have a central heating system, out of which 6% have a room heating option as well. while 36% have only room heating. The

most common heating equipment of the central heating systems is a conventional boiler, either fuelled solely with wood (8%) or fuelled with wood mixed with household waste such as paper and wood waste (47%). Only a small fraction (1%) uses a wood gasification boiler, and no cases were recorded with pellet or wood chip boilers, as presented in Table 3.

Table 3. Wood-based heating systems of households among the respondents.

		Number of Households	Share of Households
Central heating	Boiler, mixed fuel *	286	47%
	Boiler, wood only	51	8%
	Wood gasification boiler	4	1%
	Pellet boiler	0	0%
	Wood chip boiler	0	0%
Room heating (stove/fireplace)		217	36%
Central and room heating		39	6%
NA		6	1%
Total		603	100%

* Mixed fuel: wood and household waste such as paper and wood waste.

3.2. Alternative Energy Sources for Heating

There is little variance among the households surveyed with respect to their available alternative heating options based on their heating system. 71% of the households surveyed have at least one alternative energy source for heating, and the majority of them (86%) have only one option. The most common alternative energy source is natural gas, accounting for 72% of the total. This includes pipeline natural gas, which is used in central boilers and gas convectors, as well as natural gas cylinders, which are used in portable gas heaters. Electric heating is also available as an option in a significant proportion of households, which usually means portable electric heaters. Heating systems that use coal or solar collectors are rather rare, accounting for less than 1% each, as shown in Table 4.

Table 4. Distribution of alternative energy sources by heating systems of the households surveyed.

		Central Heating	Room Heating	Central and Room Heating	NA	Total
Households	Total number of households	341	217	39	6	603
	No alternatives (wood only)	88	52	12	3	155 (26%)
	NA	10	6	0	1	17 (3%)
	Households with alternatives	243	159	27	2	431 (71%)
	Share of households with alternatives	71%	73%	69%	33%	71%
Alternatives	Total number of alternatives	284	176	31	2	493
	Avg. Alternative/household	1.2	1.1	1.2	1.0	1.1
	Gas	75%	68%	77%	0%	72%
	Electric	24%	30%	16%	50%	25%
	Solar collector	1%	1%	3%	50%	1%
	Coal	0%	2%	3%	0%	1%

3.3. Importance of Firewood in Households with Alternative Energy Sources for Heating

155 households, which account for 26% of the sample, use firewood exclusively, and for an additional 159 households (27%), firewood is the primary energy source for heating. 121 households (20%), firewood is as important as other energy sources, while in 162 cases

(27%), firewood plays a secondary role. Only 2 households use firewood to create a unique atmosphere (Figure 4).

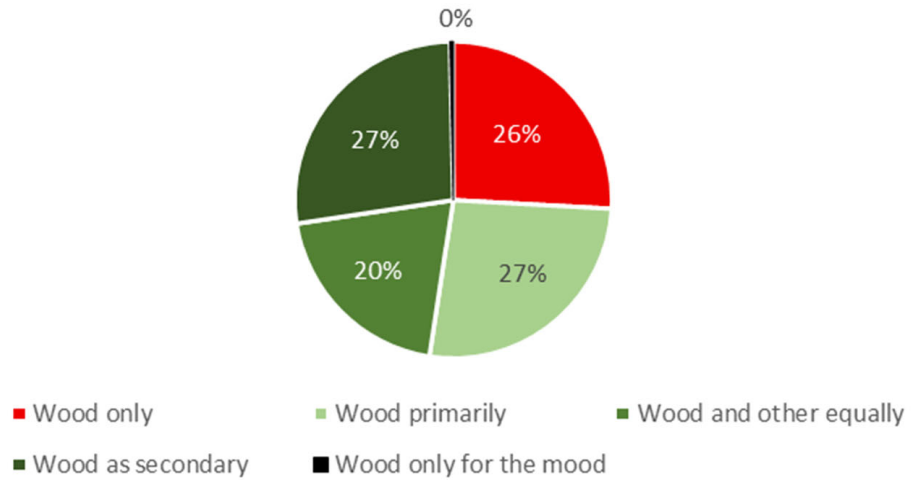

Figure 4. The role of firewood in the energy mix of households surveyed (*N* = 599).

3.4. Perceived Advantages and Disadvantages of Firewood Compared to Other Energy Sources

Firewood users with multiple heating options were asked to evaluate the advantages and disadvantages of using firewood. Based on the results, financial advantages are the most important feature, as indicated by 69% of respondents. The atmosphere created by firewood-based heating was also identified as a significant (35%) advantage. This refers not only to the sight of an open fire (fireplace), but also to traditional tile stove heating. 14% indicated that this method of heating fits well with their lifestyle, and almost as many (12%) believe that wood burning provides a pleasant feeling of warmth. The latter is closely related to the atmospheric element noted earlier. In addition, a further 4% mentioned other benefits, such as the fact that wood comes from their own land. 5% do not know what the benefits of wood burning are.

Among the disadvantages of using firewood, the most common issue is that it is inconvenient to heat with (59%). A significant proportion of respondents (30%) were unable to name a specific disadvantage. Environmental concerns were mentioned by 10%, which could be added to the 7% who are concerned about the forests. 9% said that the use of firewood is financially disadvantageous, and 2% indicated other unfavourable aspects (Table 5).

Table 5. The advantages and disadvantages of using firewood, as perceived by survey respondents with multiple heating options (multiple answers were permitted) (*N* = 431).

Advantages	Households	Proportion	Disadvantages	Households	Proportion
Financially favourable	297	69%	Inconvenient	254	59%
Atmosphere	152	35%	Environmental concerns	41	10%
Fits lifestyle	62	14%	Financially unfavourable	39	9%
Pleasant feeling of warmth	52	12%	Concerns regarding forests	30	7%
Other	16	4%	Other	6	1%
Does not know/NA	20	5%	Does not know	127	30%
			NA	6	1%
Total	431	-	Total	431	-

3.5. Plans of Households Heating with Wood Only

Of the 155 people who heat exclusively with wood, only 8 indicated that they would or probably switch to another energy source within the next three years. In all cases, the underlying reason was inconvenience, with 1 respondent adding that their age also played a role.

By contrast, the vast majority (94%) do not want to switch: 56% certainly do not want to, and 37% are unlikely to. Most of these respondents (66%) are satisfied with firewood heating, and a similar proportion (63%) responded that the cost of installing a new heating system is a deterrent. Closely related to this, 11% believe that switching to another energy source would not be financially advantageous. Only a small fraction (2%) responded that piped natural gas is not available in their settlement, while 1% is concerned about uncertainties regarding natural gas supply and the legal regulation of solar panels. 3% indicated other reasons, and 3% did not know or did not respond. (Table 6).

Table 6. Plans to switch from wood to another energy source, along with the reasons for doing so, among respondents who heat with firewood exclusively (multiple answers were permitted) (N = 155).

	Households	Proportion	
Heating exclusively with wood—total	155	100%	
No plan to change the energy source	145	94%	100%
Of which, because 'we are satisfied with wood heating'	96		66%
Of which, because of the high costs of installing a new system	92		63%
Of which, because it would still not be financially beneficial	16		11%
Of which, because piped natural gas is not available	3		2%
Of which, because of concerns about uncertainties in regulations	2		1%
Plan to change to another energy source	8	5%	100%
Of which, because of the inconvenience	8		100%
Of which, because of the advanced age of the user of	1		13%
No answer	2	1%	

3.6. Differences in Firewood Use Among Demographic Groups

We examined whether there was a correlation between the demographic characteristics of the participants and the extent to which wood played a dominant role in their heating systems. While most demographic variables did not show a significant relationship, we found a notable association with educational attainment, as indicated by the chi-square test (Table 7). Although the overall relationship showed a weak effect size, a clear pattern emerged: households with higher education levels tend to rely less on wood as their primary heating source. Ordinal association statistics and the linear-by-linear association test showed a significant monotonic relationship between educational level and the ordered heating categories. The ordinal logistic regression analysis reinforced this finding (Table 7). Education emerged as a significant predictor of a household's position on the firewood dependence scale, despite the model's modest explanatory power. The proportional odds assumption was satisfied, and goodness-of-fit statistics indicated that the model adequately represented the data.

Table 7. Association between educational attainment and the role of firewood in household heating: chi-square tests, ordinal association measures, and ordinal logistic regression results.

Analysis	Statistic/Parameter	Value
Sample size	N	592
Chi-square tests	Pearson χ^2 Likelihood Ratio Linear-by-Linear Association (df = 1) Cramér's V	χ^2 = 23.965 (df = 9; p = 0.004) χ^2 = 23.405 (df = 9; p = 0.005) χ^2 = 16.574 (df = 1; p < 0.001) V = 0.116 (p = 0.004)
Ordinal association	Kendall tau-b	tau-b = 0.142 (p < 0.001)
Ordinal logistic regression	Model fit Goodness-of-Fit Test of Parallel Lines Pseudo R^2	LR χ^2 = 18.538 (df = 3; p < 0.001) Deviance χ^2 = 4.867 (p = 0.561) * χ^2 = 4.867 (p = 0.561) * Nagelkerke = 0.033
Parameters (ref: E4)	E1 E2 E3	B = −0.958; OR = 0.384 (95% CI: 0.228–0.645; p < 0.001) B = −0.457; OR = 0.633 (CI: 0.398–1.009; p = 0.055) B = −0.138; OR = 0.871 (CI: 0.552–1.375; p = 0.553)

* The equality of the Goodness-of-Fit and Test of Parallel Lines χ^2 values (df = 6) is expected in this model specification, as the general model becomes saturated with a single four-level predictor.

The interpretation of odds ratios reveals that households with the lowest education levels have significantly lower chances of belonging to categories that exhibit reduced reliance on firewood compared to those with tertiary education. In contrast, intermediate education levels displayed weaker or non-significant differences.

We found no correlation between the financial situation of respondents and their heating systems. No significant association was found between income status and exclusive wood heating, nor between income status and room-based heating. However, the situation changes when these two variables are combined—whether a household relies exclusively on firewood and uses room-based heating. Households with lower income status were more likely to rely exclusively on firewood and use room-based heating (see Table 8). Binary logistic regression confirmed this association, indicating that income status significantly predicts this combined heating pattern, although the model's explanatory power was limited.

Table 8. Relationship Between Combined Heating Pattern (Wood only + Room heating) and Subjective Income Status: Chi-Square and Binary Logistic Regression.

Analysis	Statistic/Parameter	Value
Sample size	N	558
Proportion by income status	High (I1) Medium (I2) Low (I3)	3.4% 11.3% 13.1%
Chi-square tests	Pearson χ^2 (df = 2) Linear-by-Linear Association (df = 1) Cramer's V	χ^2 = 7.884 (df = 2; p =0.019) χ^2 = 6.549 (df = 1; p < 0.010) V = 0.119 (p = 0.019)
Binary logistic regression	B (subjective income status) Standard error p Odds ratio 95% CI for OR Intercept (Constant)	0.537 0.212 0.011 1.710 (1.129, 2.589) –3.332 (p < 0.001; OR = 0.036)
Model fit	Omnibus χ^2 Hosmer–Lemeshow Nagelkerke R^2	χ^2 = 6.679 (df = 1; p = 0.010) χ^2 = 2.770 (df = 1; p = 0.096) 0.025

4. Discussion

Opinions on firewood use are divided, as there are conflicting arguments regarding its environmental [20,21] and social impacts and circumstances [17]. In a separate study based on this survey [22] we already revealed that people's opinions about a complex environmental topic, such as the impact of firewood use, are mostly based on worries and other feelings about the environment in general. This is because people do not have much information about the subject, which makes it hard for them to develop a comprehensive standpoint.

The survey was conducted among the rural population, as this is where this method of heating is most widespread [5]. In addition to heating, firewood has many uses in households around the world, such as cooking or preserving traditions, but it can also have gastronomic or cultural dimensions [23,24]. In our domestic research, the households of our respondents primarily consider it as a heating option, and they may also use it for cooking to a negligible extent.

In our survey, 36% of the households use firewood for room heating, while the rest have more advanced central heating systems for firewood utilisation, which is consistent with the findings of previous studies [25]. Only 9% of the households use firewood for room heating and indicated no alternative energy sources.

We found that almost half (47%) of the households in the sample mix firewood with household waste. The amount of household waste burnt is so widespread in Hungary that it has a significant impact on national energy consumption [26]. The dominant alternative energy source for firewood users is natural gas (72%), electricity accounts for 25% of the households, and other energy sources, such as coal, are insignificant.

Alternative heating methods are not independent of the firewood technology used. Both mixed-fuel boilers and gas boilers can be used in central heating systems, making them logical alternatives to each other. At the same time, it is also quite realistic to have a tiled stove or even a fireplace as a decorative element in the household in addition to a gas boiler. Based on our results, both versions occur among firewood users, but their frequency is not the same. A gas boiler is a much more common choice alongside a mixed-fuel boiler than in the case of room heating. At the same time, gas convectors, electric radiators and heaters are more common in room heating. Based on our results, it appears that those without central heating often use multiple energy sources (electricity, gas and wood) for room heating.

The survey revealed that more than half of the households (53%) that use firewood use it exclusively or primarily, and 27% use it as a secondary option. In this respect, our sample does not reflect the results of the 2022 census conducted by the Hungarian Central Statistical Office, as half of the firewood users in the census heat exclusively with wood (Table 1). They are slightly more prevalent in our sample than in the national data [5].

We did not ask participants' income in numerical terms for two reasons. First, this is a sensitive topic, and many would not have answered. Second, household income is more relevant than that of the respondent; therefore a per capita income would have been necessary, which would have required time-consuming calculations, if it was possible at all. Instead, we asked them how well they could make ends meet at the end of the month. Even so, the proportion of non-respondents was relatively high. It can be concluded that the majority of our participants live in a balanced financial situation. Within the examined demographic characteristics, a clear pattern emerged only among respondents who heat exclusively with firewood and exclusively through room-based heating. In this case, households with lower subjective income status appeared more likely to rely on this heating configuration than those reporting a more favourable financial situation. Although the strength of the association was modest, the direction of the relationship suggests that

limited financial resources may steer some households toward heating strategies that are perceived as more economical or accessible.

Although the relationship between education and heating practices was weak, the patterns observed in the data suggest that households with the lowest educational attainment tend to rely more consistently on wood-dominant heating arrangements, whereas higher educational levels show more variability in heating choices. Taken together, our findings indicate a slight tendency for lower educational levels to correspond to higher firewood dependence. This is also suggested by research conducted in some developing and developed countries, which shows that lower educational attainment is associated with higher firewood use [27–29]. In the case of our research, however, it is fair to note that during our telephone survey, we only measured the demographic data of the respondent, who was not necessarily the head of the family or the decision-maker. In Hungary, however, people typically choose partners with the same level of education, and their proportion is also increasing [30,31]. Therefore, the educational attainment of one respondent is likely to reflect that of their partner. Homogamy, or the tendency to choose a partner with a similar educational background, is strongest in the lowest and highest categories [32]. We also found a significant difference between these two demographic groups in terms of the importance of firewood. Based on this, our results may indeed suggest that the importance of firewood use in Hungary decreases with increasing educational attainment.

Among those with alternative energy sources, the majority of respondents (69%) find firewood-use financially favourable, and a similarly large proportion (59%) find it inconvenient to use; 39% think both at the same time. This may refer to an earlier finding that, as a financially advantageous and energy-secure energy source, the use of firewood may become embedded in cultural practices over time and become a sociocultural norm [33]. The atmosphere of firewood heating, and its pleasant warmth, as well as its compatibility with rural lifestyle, contribute to a positive feeling connected to firewood use. These were mentioned by 35%, 12% and 14%, respectively. Environmental concerns and the concerns about forests as disadvantages appeared by 10% and 7% respectively, which signals that these aspects are seen as less important than the main advantages. This is also supported by the fact that 31% of the respondents did not indicate any disadvantages, and in total, firewood users associate 55% more advantages to firewood-use than disadvantages.

This generally positive attitude toward firewood-use is shared among the surveyed households without alternative energy sources, too. They overwhelmingly (94%) stated that they have no plan to invest in another heating option, partly because of their high rate (66%) of satisfaction, and partly (63%) because of the high investment costs that would be required, furthermore, 11% believe that other energy sources are not any better in financial terms. Apparently, this small share (26%) of firewood users who rely on firewood entirely, has neither intention, nor financial motivation and option to change to another energy source.

This sample is not suitable to draw a conclusion on how advanced this transition process is, because we only surveyed households that still use firewood, and did not survey households that once used it but do not use it anymore. The fact that 71% of firewood users already have alternative heating options and 47% of the firewood users do not use it as their primary heating energy source represents a modest step toward less polluting heating. However, it does not necessarily align with broader decarbonization goals, or some might even argue that it could be seen as a step backwards, given that natural gas combustion involves a one-way release of CO_2. The widespread occurrence of alternative heating methods is a prime example of fuel stacking, which suggests that firewood is gradually losing its importance, but it maintains a secondary option role.

The transition away from firewood use is primarily hindered by high investment costs, strong perceptions of the financial benefits and reliability of firewood, and cultural and lifestyle ties that legitimise its use.

5. Conclusions

This study explored firewood heating practices in rural households in Hungary, with particular attention to the availability of alternative heating options, the current habits and future plans of the firewood users and the factors hindering fuel switching.

Although this study focuses on rural Hungary, its insights into persistent firewood use, limited prospects of further fuel switching, and socio-economic constraints reflect challenges faced in many regions worldwide. As such, it contributes to global discussions on rural energy transitions by highlighting how entrenched habits, cultural norms, and structural inequalities can slow household-level energy transition.

There are three major findings of this survey. (1) Rural households that use firewood in a large proportion (71%) are equipped with alternative heating options, most commonly natural gas. This finding suggests that the firewood market in the future can flexibly react to changes in price fluctuations and possible government market interventions. The use of firewood and other energy sources is already balanced, as those heating with wood primarily, secondarily and equally to the other resources have a share of 27%, 27% and 20% respectively. They are mostly satisfied with the financial advantages, and they developed a positive attitude toward firewood heating.

(2) In terms of future usage trends, it is crucial that households that use firewood exclusively have very little motivation and possibility to invest in installing heating options other than firewood combustion. Only 5% of them plan to make such investments in the next 3 years. A large proportion (66%) of the rest of the households are generally satisfied with wood heating, and almost the same proportion (63%) find the necessary investment costs a deterrent. All this likely suggests that firewood will remain a permanent part of the rural energy mix, especially where access to modern systems is limited.

(3) Overall, our findings suggest that demographic factors play only a limited role in shaping firewood-related heating practices. Education emerged as the only demographic variable with a consistent, though not particularly strong, association: lower educational attainment was generally linked to a higher likelihood of relying on firewood. The modest tendency for lower-income households to rely exclusively on firewood with room-based heating may reflect energy-related constraints commonly associated with the 'poverty trap.'

This study provides a snapshot of rural firewood use, but more focused research is needed to reveal how households might react to future price changes, policy shifts, or technological developments. Longitudinal studies would therefore be needed to assess how stable these patterns are over time.

Author Contributions: Conceptualization, R.H., Z.K. and E.S.; methodology, R.H., Z.K. and E.S.; validation, E.S.; formal analysis, R.H.; writing—original draft preparation, R.H. and E.S.; writing—review and editing, R.H., K.R.-E. and E.S.; visualization, E.S.; supervision, R.H. and E.S.; project administration, R.H. All authors have read and agreed to the published version of the manuscript.

Funding: This article was made in the frame of the project TKP2021-NKTA-43, which has been implemented with the support provided by the Ministry of Culture and Innovation of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021-NKTA funding scheme.

Data Availability Statement: Data is available upon request. The authors wish to limit access to the survey data as long as it is fully published. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CO_2	Carbon-dioxide
KSH	Hungarian Central Statistical Office
PM	Particulate Matter

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