Exploring regional and settlement patterns of residential energy awareness in Hungary

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This study investigates energy awareness in Hungary, focusing on households significantly contributing to final energy consumption and greenhouse gas emissions. It aims to identify regional and residential differences in energy efficiency and energy conservation measures implemented by households. The authors achieve this goal by establishing two new composite indicators quantifying the energy awareness of residential consumers: (1) the energy efficiency measures (EEM) index, and (2) the energy conservation measures (ECM) index separating investment-based activities and non-investment-based actions. Targeting the Hungarian population aged 30–69 years (N = 5,337,860), the study used a weighted sample (n = 3,651) based on gender, age categories, regions, and settlement types, ensuring representativeness. Data were collected using an online survey in November 2022. The most common measures included upgrading lighting, replacing windows and doors and choosing energy-efficient appliances. Although regional differences in the EEM index were not significant, cities with county status scored higher. ECM were also analysed, showing a wide acceptance across Hungary. There were no significant regional differences for the ECM index; however, cities with county status also scored at the top. A limitation of the study is its reliance on self-reported data collected through an online survey, potentially introducing biases and limiting the findings' accuracy. The study's findings can guide policymakers in designing targeted energy efficiency programmes and incentives that address the specific needs and motivations of different regions and settlement types in

Hungary. Socially, the insights into energy awareness and behaviour can help raise public awareness and encourage adopting energy-saving practices, contributing to reduced energy dependency and environmental impact. This study's originality is due to its unique methodological approach and focused examination of population energy awareness within regional and settlement contexts.

Keywords:
energy conservation,
energy efficiency,
household energy consumption,
regional and residential differences,
Hungary

Introduction

The problems caused by the 2022 energy crisis and climate pollution are spreading to all areas of life. The high volatility of energy prices and concerns about the security of energy supply, coupled with tightening climate regulations, pose significant challenges for all economic actors. The Paris Agreement on Climate Change is a significant milestone in climate protection, with 194 countries committed to keeping the global average temperature increase well below 2°C, targeting 1.5°C above preindustrial levels (United Nations 2015). In this regard, the European Union has established a target of reducing greenhouse gas emissions by 55% by 2030 and achieving climate neutrality by 2050. The FIT for 55 measures establishes the efforts planned to achieve these targets (European Council 2024), guiding strategic (and operational) action at all levels of the economy in the future. A significant share of CO_2 emissions is related to energy production and use, and the CO_2 intensity is strongly influenced by energy intensity and promoting policies to increase energy efficiency (Jaber 2022). Therefore, most measures aim to reduce energy use, increase energy efficiency, green the energy mix, and increase renewable energy source penetration. The targets established are very ambitious and can only be achieved through a concerted effort involving all economic stakeholders.

This study investigated the Hungarian population's energy awareness, as households contribute significantly (approximately one-third) to both final energy consumption and greenhouse gas emissions in Hungary (Eurostat 2022, KSH 2022a). According to the Energy Balance of Hungary (Eurostat 2022), household energy use decreased by approximately 2.5% between 2015 and 2022, and its share in total final energy consumption decreased from 35.5% to 32.4%, partly due to the 2022 energy crisis. According to 2022 data, households consumed mainly natural gas (49%), renewables (23%), electricity (18%), and heat (8%) in their daily lives. Solid fossil fuels and oil and oil products account for a minimal share (around 2%). Compared to 2015, a shift towards natural gas and electricity has come at the expense of renewables. Notably, the use of renewables in the residential sector is dominated by fuel wood, with solar energy and heat pumps representing a much smaller share. Thus, this shift in the energy mix in which wood for fuel use has decreased is a positive trend. In contrast, the use of other renewables (solar, heat pumps), natural gas, and electricity has increased (Eurostat 2022).

Household GHG emissions (23,869 thousand tons in 2021, of which approximately 96% is CO_2) decreased slightly by 1.1% between 2015 and 2021 (KSH 2022a). A positive trend in household energy use and GHG emissions is observed; however, it is still a slight and slow improvement. More progress is needed to achieve ambitious energy and climate policy targets.

In Hungary, the household energy costs to disposable income ratio fell from 7.1% in 2010 to 3.4% in 2021, putting the country in the midfield of the European Union (EU). This indicator shows how much income is spent on paying energy bills (KSH 2022a). Hungary's household gas prices were the lowest in the EU, and only the Netherlands was cheaper in electricity in 2022 (Eurostat 2022). This is largely because household energy prices in Hungary are subject to price regulation by the authorities and are kept artificially low by the government's policy of cutting overheads. 'The Hungarian government launched a utility cost reduction programme in 2013–2014 (Act LIV. 2013), which significantly, by a quarter (Weiner−Szép 2022) lowered residential energy prices, including electricity, natural gas, and district heating.' For this reason, the residential sector did not face energy market price movements between 2013 and 2022. However, from 2021 onwards, world energy prices rose, exacerbated in 2022 by the Russian–Ukrainian war. By the end of summer 2022, natural gas prices had risen 10–12 times (from below 30 EUR/MWh in January 2021 to over 330 EUR/MWh by the end of August 2022) (EEX 2024), while electricity prices also increased significantly. This unprecedented increase in energy prices made it increasingly clear that freezing residential energy prices cannot be maintained and that citizens face increasing challenges due to the energy crisis. In July 2022, the government was forced to change residential energy prices. According to the new rules, the frozen price would not automatically apply to the total residential consumption from August 1, 2022 but up to a certain level of consumption (2,523 kWh/year for electricity and 1,729 m^3/year for gas). Above the designated consumption level, households would have to pay the 'market price'.[1] (Government Decree 259/2022. (VII. 21.), 2022). This change has ensured that the movements in energy prices in the global energy market are partially passed on to consumers, thereby encouraging energy savings.

[1] The 'residential market price' does not reflect the actual market price. It can be lower and, in some cases, even higher than the actual market price. The 'residential market price' (in the case of natural gas, the 'price reflecting competitive market costs') shall be determined by the President of the Hungarian Energy and Utility Regulatory Office in a decree after consultation with the universal service provider. The office shall review and, if necessary, amend the price set out in its decree in the event of significant changes in market conditions (Government Decree 259/2022 (VII. 21.), 2022).

In late autumn 2022, we conducted a survey to assess household energy awareness in Hungary. This study examines the actions households have implemented or intend to implement to reduce energy consumption, their motivations, and their perceptions of their role in tackling energy challenges. It also highlights regional and settlement type differences. Our research questions were as follows:

- How widespread are energy efficiency measures (EEMs) in the household sector? How can different regions and types of settlements be characterised based on energy efficiency measures? (RQ1)
- How widespread are energy conservation measures (ECMs) in the household sector? How can different regions and types of settlements be characterised based on ECM? (RQ2)
- What are the sources of financing for EEM among households, and do these vary by region and type of settlement? (RQ3)
- What motivates energy users to implement energy-saving measures? What are the differences by region and by type of settlement? (RQ4)
- How does the population perceive its responsibility for solving the problems caused by the 2022 energy crisis? Are there differences by region and by type of settlement? (RQ5)

We answer these research questions by developing two composite indicators that assess the energy awareness of residential consumers, distinguishing between investment- and non-investment-based actions. Our survey focused on the Hungarian population aged 30–69 years and utilized a weighted sample to ensure representativeness across genders, age groups, regions, and settlement types. Data collection was conducted through an online survey in November 2022.

This study is structured as follows: first, it starts with the literature review. Then, the methodology is presented, followed by the results of the analysis and the answers to the research questions. The study continues with the discussion, and ends with the conclusion.

Literature review

There is a large literature on household energy use. Some studies examine household energy use, energy awareness, and their determining factors from different perspectives using different models. The authors typically start from different models of behavioural economics, such as the theory of reasoned action, the theory of planned behaviour, social cognitive theory, and the technology acceptance model, with the aim of identifying the determinants of household energy consumption through significant relationships or by using regression models (Brounen et al. 2013, Duan et al. 2023, Kasavan et al. 2021).

These studies conclude that household energy use is determined by the complex dynamics and synergistic interaction of socio-economic, demographic, and regional factors, with multiple explanatory factors (Borozan 2018). The most commonly studied factors are household demographic and social characteristics, such as size, income status, age, and educational attainment (Brounen et al. 2013, Canepa et al. 2023, Duan et al. 2023, Kasavan et al. 2021) or building characteristics (size, comfort level, technical equipment, energy characteristics) (Santin et al. 2009, Yohanis et al. 2008).

Several studies have examined the role of public subsidies and regulation changes in reducing energy use based on the assumption that a well-designed system of government subsidies and incentives can achieve energy targets. Cabrera et al. (2024) investigate the lasting effects of Swiss energy efficiency programmes on household electricity use and continuing energy-saving practices. Their results show a sustained reduction in electricity use and continued adoption of EEM among programme participants, demonstrating the role of subsidy programmes in promoting long-term energy-saving behaviour. Szép (2017) examined the impact of the utility cost reduction programme introduced by the Hungarian government in 2013–2014 (mentioned above) on energy consumption. The analysis showed that the frozen residential energy prices increased household energy consumption, i.e. additional energy consumption induced by price reductions.

Gróf et al. (2022) focused on identifying the aggregate effect of different constraints on housing energy renovations, with a particular emphasis on understanding the energy performance gap (prebound and rebound effects), renovation costs, creditworthiness, and credit possibilities of the population. They found that the nationwide energy renovation programme might be hindered by factors such as pre- and rebound effects and credit constraints. The government's residential energy price policy also reduces housing renovation efficiency (Gróf et al. 2022).

Csoknyai et al. (2022) analysed the impact of the change in regulating household energy prices (mentioned in the introduction section) on the gas consumption of Hungarian residential buildings. The authors point out that the change will encourage households to reduce their energy consumption and make energy-efficient and renewable investments. By surveying the country's building stock, they found that modern, new or renovated properties typically fit within the state subsidy. The buildings most affected by the rule change are detached houses built before 1990, where only 41–56% of annual gas consumption is in the quantity supported by the reduced price, the remainder falling into the market price category. The overheads for these buildings can be 7–10 times higher than for other types of buildings. Given that more than half of all gas-heated buildings fall into this category and that they consume 67% of the total housing stock, the authors estimate a significant potential for reducing gas consumption if these buildings reduce their consumption to the subsidised level. They identify a range of possible measures, assessing their implementation time, payback period and energy savings, and conclude that if all the buildings concerned were to implement the measures, 6.6% of total national gas consumption could be saved with measures that could be implemented immediately with minimal investment, and the potential savings could be increased to 17.1% with retrofit investments. Also highlighted is the rebound effect, reducing the potential of EEM somewhat (Csoknyai et al. 2022).

As part of the FIT for 55% package, the European Union plans to introduce a new, separate emissions trading scheme (EU ETS2) for buildings and road transport, which is expected to come into force in 2027. The scheme will also affect the residential sector by increasing heating costs and fuel prices (service providers/distributors are expected to include the costs of quota purchases in their prices) (EC 2024). The measure aims to encourage households to devise more energy-efficient solutions. In connection with the scheme's introduction, it is essential to mention revenue recycling, in which states recycle ETS2 revenues for various purposes, such as climate protection measures, energy efficiency programmes or support for the population. Muth et al. (2024) investigated public acceptance and willingness to pay carbon pricing among the Hungarian population and whether revenue recycling mechanisms influence acceptance. The research results indicate that revenue recycling increases public acceptance and that Hungary's acceptance of the carbon tax is low, slightly increased by revenue recycling mechanisms. In the latter area, revenue recycling for public health, education, and green investments has triggered higher acceptance (Muth et al. 2024).

Thus, different types of support schemes affect energy use differently. In addition to the general analysis of factors influencing household energy use, assessing whether there are regional differences in household energy consumption patterns and energy awareness and, if so, which factors contribute to these regional differences, is essential. Spatial differences in energy use are often analysed in cross-country comparisons, while regional and county (NUTS 2, NUTS 3) level analyses are less common in the literature. The complexity and multidirectional interactions of the determinants of household energy use described above make obtaining a clear picture of spatial differences challenging. For example, the impact of income may also show regional differences due to differences in average income levels across regions. In addition to geographical location, climate, and topography, a region's socio-demographics and economic situation can also determine regional energy use differentiation. Borozan (2018) developed a more integrated approach to separate these multiple influences. He distinguished general socio-economic–demographic factors (e.g. education, income status) and context-dependent factors (e.g. economic development, climate). The author assumed that households make energy consumption decisions based on the synergistic interaction of these two factors. He researched 64 European regions between 2005 and 2013. The results show there are common factors (impacting in the same way in each region) and factors that determine energy consumption depending on the level of regional development.

A frequent academic research focus is the causal relationship between economic development and energy use in the context of regional differences. Kashour (2023) has shown that a positive relationship exists between economic growth (GNI growth) and residential energy use in EU member states, i.e. the decoupling process between energy consumption and economic growth is not fully reached in EU member states. In addition to economic development, analysing the relationship between human well-being and energy use is also coming to the fore. Szép et al. (2022) found a moderate positive relationship between per capita energy use and human well-being (measured with human development index [HDI]) based on EU-27 data. A positive trend is that at least 19 countries have decoupled per capita energy use from HDI. This suggests that socio-economic development has been achieved less energy intensively due to technological progress, climate policies and changing attitudes. Energy consumption per capita shows moderate and decreasing spatial differences, consistent with differences in economic development (Szép et al. 2022).

Several authors highlight the impact of economic development on regional disparities. Duan et al. (2023) found that households in more-developed countries are more willing to use clean energy, meaning economic development plays a role in translating awareness into action. Lin et al. (2014) highlighted regional inequalities in China, which found significant differences in energy use between richer and poorer provinces. According to the study, population, economic development, energy resource availability, and climate conditions were the main drivers of household energy consumption. Using electricity consumption indicators of NUTS 2 regions of Turkey, Türkan–Ozel (2019) concluded that regional economic development led to an increase in electricity consumption, i.e. a positive relationship exists between electricity consumption and the level of regional development. The research's primary conclusion is that electricity consumption in NUTS 2 regions can be modelled as a function of economic indicators using panel data regression models. Kostakis (2020) showed significant regional heterogeneity in household electricity consumption in Greece related to climatic and demographic characteristics and household energy consumption patterns.

Few sources deal with regional comparisons in Hungary. Nagy et al. (2018, 2019) investigated regional differences in urban energy use (electricity and natural gas consumption) in Hungary between 2010 and 2015 (based on data from 23 Hungarian cities with county status and Budapest), showing no significant inequalities or large regional differences in the per capita and per household electricity and natural gas consumption indicators. Additionally, the spatial disparities have been further reduced over the period under review. In addition to the spatial differences, the research has shown a strong positive correlation between per capita income and energy use. The area-based Gini (AR-Gini) index also showed no significant difference in energy use between rural and urban areas in the study. The assumption that populations of more developed cities use energy more consciously and efficiently was not confirmed by the study. The authors explain this through the rebound effect (the additional increase in energy use resulting from energy efficiency improvements, i.e. the lost potential energy savings) and the high HDI (Nagy et al. 2018, 2019).

In addition to regional differences in residential energy use, researchers have focused on regional differences in renewable energy potential. Hungary's renewable energy potential shows significant regional differences in the country's different renewable energy sources (Hartmann et al. 2017). These studies can guide decision-makers on renewable investments. A key issue related to this is the potential for decentralised energy production using local renewable sources, which is explored by Kulcsár (2020). His analysis shows that approximately 30 settlements in Hungary could meet 100% of its annual electricity demand from local renewable sources (mainly solar and biogas) and even export the excess energy to neighbouring settlements. In this way, the yearly electricity demand of 29 additional settlements could be met entirely from local renewable energy sources, and the supply of some 30 settlements could be supplemented to varying degrees. There are regional differences in the settlement locations. The study draws an optimistic picture of Hungary's theoretical feasibility of decentralised local renewable energy supply systems.

Our study aims to fill a literary gap and to answer whether there are regional differences in energy efficiency and ECM implemented by Hungarian households.

Material and method

Development of indicators

Our research established two composite indicators to quantify the energy awareness of residential consumers. We aimed to assess the population's energy awareness in light of the energy efficiency and conversation measures taken or those they plan to take. As a first step, we reviewed the indicators that some authors use to describe household energy use and energy savings. Several household sector energy use indicators can be found in the literature. For example, according to the IEA (2014) summary, these can be indicators measuring energy use in absolute or specific terms (e.g. per floor area, per capita or per dwelling). Energy carriers (e.g. electricity, gas, district heating, etc.) or mode of use (e.g. heating, cooling, lighting, appliances, etc.) can calculate these indicators. Our research aim was not to quantify the savings achieved; however, rather to explore the types of measures households have taken or plan to take to reduce their energy use. We sought composite indicators that measure households' energy awareness. We found that researchers use composite indicators in different areas, for example Kelly et al. (2020) for energy poverty, Murias et al. (2020) for household energy vulnerability, Drago–Gatto (2022) for energy efficiency, Bhattarai et al. (2024) for energy security, Gupta et al. (2024) for household building energy efficiency, and Kong et al. (2020) for household energy efficiency composite indicators. However, no previously used indicator measured residential energy awareness, considering the energy efficiency and conservation measures implemented by the population. Dabbous et al. (2023) attempted to measure environmental awareness, Stragier et al. (2012) to measure energy-efficient behaviour in households, Allen et al. (2015) to measure household energy efficiency behaviours and behavioural plasticity, and Baidoo et al. (2024) to measure household energy conservation and efficiency awareness practices. The latter studies only partially applied the factors we examined, focusing primarily on behavioural and straightforward measures that do not involve investment. For instance, drawing on the work of Pierce et al. (2010), Stragier et al. (2012) categorised household energy conservation behaviour into five types: cutting, trimming, switching, upgrading, and shifting. Cutting refers to completely deactivating devices, such as turning off television sets or placing them in a low energy-consuming mode. Trimming involves reducing the operational intensity of an appliance, such as lowering the thermostat by one or two degrees. Switching denotes substituting one appliance with another to achieve a similar outcome with potentially lower energy consumption. Upgrading entails replacing outdated appliances with newer, more energy-efficient models. Shifting refers to adjusting appliance usage to off-peak hours. This practice does not necessarily reduce overall energy consumption but alters usage timing. From this, the energy-efficient behaviour scale was created using principal component analysis and confirmatory factor analysis.

On this basis, we decided to create our own indicators: (1) the EEM index, and (2) the ECM index. The indices were created considering there are two main ways to achieve energy savings: first, through EEM, where the same result (e.g. output, comfort level) is achieved using less energy, and second, through ECM, where less energy is used by reducing the output (e.g. quantity or quality of a product or service) or individual comfort levels (e.g. by setting a lower heating temperature to save energy) (Sebestyénné Szép 2013). The former typically requires some kind of investment (e.g. new technology, insulation, more modern equipment), while the latter can be achieved with minimal or no investment. *'Energy efficiency is about maintaining the same level of economic activity or services using less energy, energy saving is a broader concept that includes behavioural changes and restrictions on economic activity'* (EC 2011: p. 2, cited in Sebestyénné Szép 2013: p. 14). Increasing energy efficiency typically requires some investment and is more costly; however, it allows for greater energy savings that are sustainable in the longer term, and, thus, have higher cost savings. It also increases property values. According to Ertl et al. (2021), homes with near zero energy demand (energy class A) are, on average, 52% more valuable than similar buildings in the worst energy efficiency class (I–J). Upgrading a single-family home with average energy performance (E–F) can add 20–30% to a home's market value. According to the experts, this trend is also observed in condominium renovations (Beleznay−Huszár 2023, Ertl et al. 2021). In contrast, ECM (reducing energy consumption typically through behavioural changes and savings) achieve smaller, short-term results. They can be implemented quickly, at minimal or zero cost, and may have an immediate impact; however, contribute less to sustainability.

We identified eight investment-based activities that significantly enhance the energy performance of residential dwellings to formulate the EEM index. These activities include:

- EEM1: Modern heating/heating upgrades (e.g. replacing radiators, creating controllability, condensing boilers).
- EEM2: Alternative heating/fuel (e.g. CHP boiler or multiple heating modes).
- EEM3: Modern lighting/lighting upgrades (e.g. selective switching, motion-sensing switches, energy-saving light sources such as LED).
- EEM4: Renewable energy sources (e.g. solar panels, solar collectors, heat pumps).
- EEM5: Insulation and window and door replacements.
- EEM6: Building insulation (walls, slabs, roof).
- EEM7: Smart devices (e.g. remote-controlled heating, smart home systems).
- EEM8: Energy-efficient appliances (home appliances).

We established four categories to assign scores to each activity: (1) Completed prior to the survey (2022) = 30 points; (2) Completed (in progress) = 20 points; (3) Planned to start within 1–2 years = 10 points; and (4) Not planning = 0 points. Respondents were asked to rate each activity according to their completion status or estimated timeframe. The total score for each respondent was calculated by summing their scores for the relevant activities and dividing by the maximum possible points. All eight measures were considered for those residing in family houses or semidetached houses, whereas only six measures (excluding EEM4 and EEM6) applied to residents of flats or condominiums.

For this index, the need for weighting has been raised, as different EEM require different levels of investment and energy savings. However, similar dilemmas to those raised by Allen et al. (2015) on weighting were raised here, namely:

- The weights could be determined according to the potential energy savings of each measure. Still, these savings depend on the technological solution chosen (as each measure can be implemented with several technical designs), the size of the house, the building characteristics, the number of occupants in the household, their behaviour, the way energy is used, the structure, the climate, and many other interacting factors. In other words, it would be challenging to quantify the real impact of each measure in isolation.
- Another solution is to assess respondents' subjective perceptions of the energy savings they think they could achieve with each measure. However, this would presumably be very different from the results of engineering calculations for most respondents.

- The next possible consideration in developing the weights is the effort (physical and financial) required from households to implement the measure, i.e. considering how 'difficult' it is to implement the measure (Allen et al. 2015).

Finally, sought data on whether there are accepted averages or estimates in the building energy and energy management literature to estimate the potential of a measure. For example, based on the MVM Home & Pro (2024), energy savings for retrofitting façade insulation are estimated at 25%, for upgrading attic slab or roof insulation at 20%, for replacing windows (triple glazing) at 10%, and for replacing the heat generating equipment with modern heat pump heating at 30%. Considering that heating accounts for the largest share of household energy use, this would justify weighting the measures and giving more weight to insulation and heating retrofitting. Additionally, however, several other estimates of the specific investment costs, payback period, and potential energy savings of measures have been published; however, these estimates vary according to the type of building, its age, the technology chosen and if they are not implemented individually but, in some combination, (see for example Beleznay–Huszár [2023]). The lack of precise data is research limitation, and the omission of weighting may somewhat distort the results.

The same methodology was employed to construct the ECM index, focusing on non-investment-based actions that individuals can freely undertake. These actions include[2]:

- ECM1: Tracking the property's energy use.
- ECM2: Utilizing natural lighting.
- ECM3: Turning off lights when there is sufficient daylight or in unoccupied rooms.
- ECM4: Switching off (unplugging) electronic equipment when not in use.
- ECM5: Turning off equipment not in use (e.g. TV, radio, computer).
- ECM6: Saving energy at the expense of personal comfort (e.g. lowering heating temperatures, closing off parts of the house, minimising lighting).
- ECM7: Keeping informed about energy market news and monitoring opportunities.
- ECM8: Participating in awareness-raising programmes.

The response options and scoring for the ECM index mirrored those used for the EEM index. Scores for each respondent were summed and divided by the maximum possible points (8 activities * 30 points = 240 points).

[2] While ECM1, ECM7, and ECM8 are not specific energy conservation measures, they have been included in the analysis as they reflect behaviours that contribute to energy awareness and engagement. These actions support informed decision-making and proactive participation, which are integral to fostering a culture of energy conservation.

Sample composition

The study targeted the Hungarian population aged 30–69 years (N=5,337,860). The sample (n = 3,651) was weighted according to four criteria – gender, age categories, regions, and settlement types – to ensure that the sample is cell representative of the Hungarian population aged 30–69 years. Consequently, the results of our study have general validity at a 95% confidence level, with a maximum sampling error of ±1.62 percentage points. Table 1 presents the population's composition and internal proportions, as well as the unweighted and weighted samples.

Table 1

Population and sample composition

Denomination	Population		Unweighted sample		Weighted sample	
	N	%	n	%	n	%
			Gender			
Male	2,613,628	49.0	2,141	58.6	1,788	49.0
Female	2,724,232	51.0	1,510	41.4	1,863	51.0
			Age categories			
30–39 years	1,250,273	23.4	567	15.5	855	23.4
40–49 years	1,578,989	29.6	1,048	28.7	1,080	29.6
50–59 years	1,268,625	23.8	1,024	28.0	868	23.8
60–69 years	1,239,973	23.2	1,012	27.7	848	23.2
			Regions			
Southern Great Plain (SGP)	665,515	12.5	427	11.7	455	12.5
Southern Transdanubia (STD)	476,580	8.9	298	8.2	326	8.9
Northern Great Plain (NGP)	769,111	14.4	405	11.1	526	14.4
North Hungary (NH)	591,585	11.1	414	11.3	405	11.1
Central Transdanubia (CTD)	591,434	11.1	440	12.1	405	11.1
Central Hungary (CH)	1,678,133	31.4	1,380	37.8	1,148	31.4
Western Transdanubia (WTD)	565,502	10.6	287	7.9	387	10.6
			Settlement types			
Capital	950,220	17.8	671	18.4	650	17.8
City with county status[a)]	1,043,746	19.6	778	21.3	714	19.6
Town	1,745,615	32.7	1,220	33.4	1,194	32.7
Village	1,598,279	29.9	982	26.9	1,093	29.9
Total	5,337,860	100.0	3,651	100.0	3,651	100.0

a) City with county status is a city in Hungary with its own county functions and powers. From 2022, there are 25 cities with county status in Hungary: all county capitals except Budapest, and seven other cities (Act CLXXXIX. 2011).

Data was collected through an online survey conducted by NET Media Zrt. in November 2022. The primary tools used for data analysis were Excel and JASP programmes.

General characteristics of Hungarian regions

Before presenting the results, we briefly summarise the NUTS 2 regions' main characteristics in Hungary. Seven planning statistical regions (NUTS 2) have been created in Hungary, comprising counties with similar natural and geographic characteristics and levels of development. The most developed regions are Central Hungary, Central Transdanubia and Western Transdanubia. The Central Hungary region is home to the capital and where the country's economy is concentrated, while the Central Transdanubia region and the West Transdanubia region have a higher concentration of industry and better indicators due to their favourable geographical location and natural conditions. The regions with the weakest indicators are the Northern Great Plain, Northern Hungary, and Southern Transdanubia, where the decline of heavy industry and their less favourable natural and geographical conditions are the main reasons for their lagging behind.

Economic performance is characterised by gross domestic product (GDP) per capita indicator, a good proxy for the differences in economic development and performance by region (Kovács 2000, KSH 2022b, 2024). In 2022, Budapest accounted for 37% of (GD), with an additional 12% contributed by Pest County (KSH 2024: p. 54).[3] Budapest has the highest per capita GDP (11,812 thousand HUF/person, 208% of the national average), followed by Central and Western Transdanubia with values above 5,000 thousand HUF/person, 91–93% of the national average). The lowest values in relation to the national average are observed in Northern Great Plain (65%), Southern Transdanubia (68%) and Northern Hungary (69%), where the GDP per capita is less than HUF 4,000 thousand.

Results

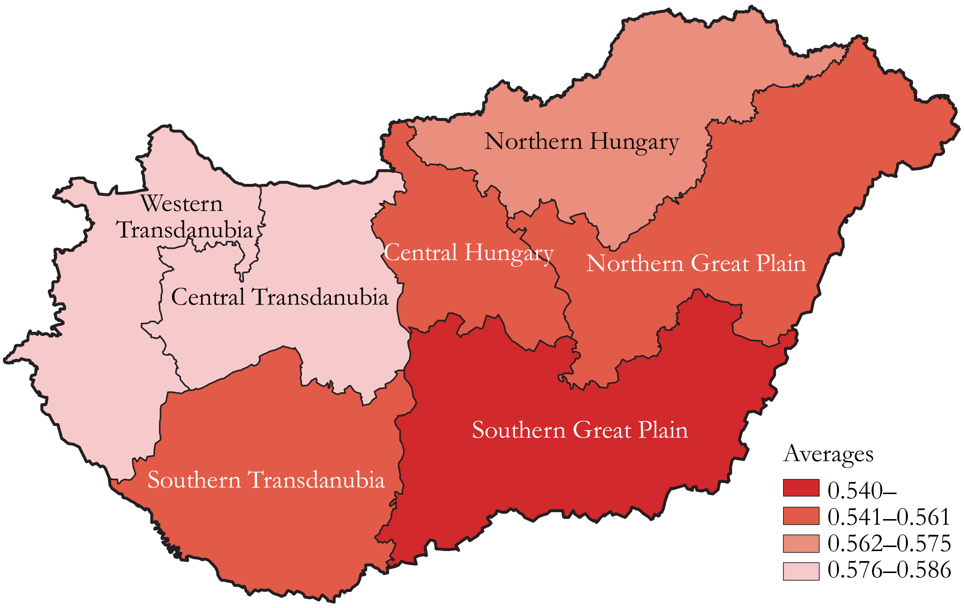
To address the first research question (RQ1), we examined the prevalence of EEM requiring investment across Hungary. We also explored how different regions and types of settlements can be characterised using the EEM index. Before 2022, the most commonly implemented measures included modern lighting and lighting retrofitting, such as selective switching, motion-sensing switches, and energy-saving light sources such as LEDs, adopted by 66.5% of respondents. Insulation and replacement of windows and doors were implemented by 59.4%, while 55.9% opted for energy-saving household appliances. Modern heating upgrades, including replacing radiators, enhancing controllability, and installing condensing boilers, were undertaken by 48.7%. Building insulation, covering walls, slabs, and roofs, was applied by 43.8%. Additionally, 39.8% provided alternative heating modes or fuels, such as mixed fuel boilers or multiple heating modes. Renewable energy sources, including solar panels,

[3] Central Hungary is one of the seven NUTS 2 regions of Hungary. It consists of Pest County and the capital city, Budapest.

solar collectors, and heat pumps, were utilized by 17.9%, and 14.5% employed smart devices, such as remote-controlled heating and smart home systems. Figure 1 presents the regional averages of the EEM index, illustrating the variations and trends in energy efficiency investments in different areas. This analysis highlights regions that excel in implementing EEM and those that may need additional support to improve their energy performance.

Figure 1

Averages of the EEM index by region

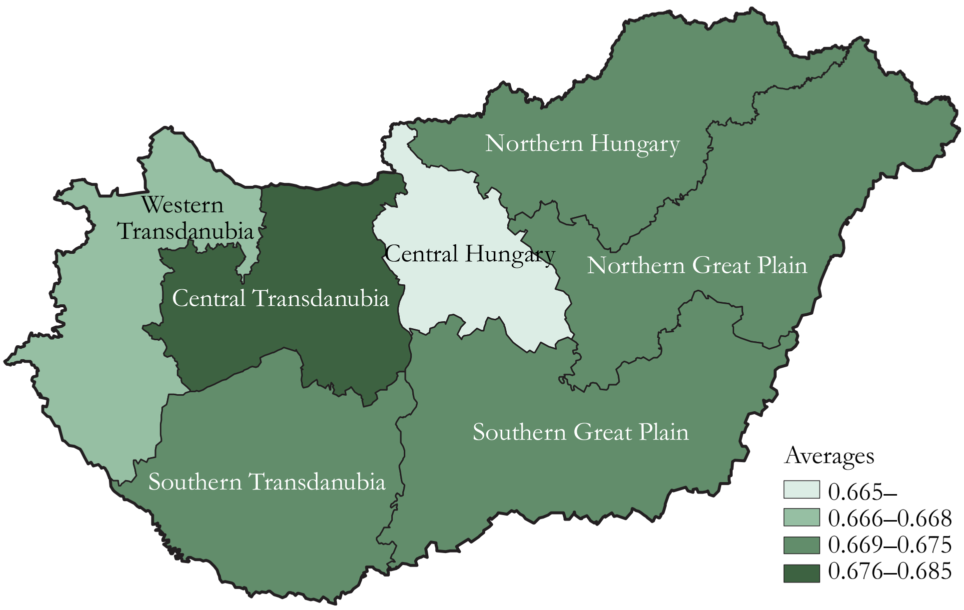


The national average of the EEM index is 0.56, indicating a relatively strong performance in energy efficiency measures. In terms of regional averages, it was observed that Western Transdanubia (0.58) and Central Transdanubia (0.59) exhibit higher values, whereas the Southern Great Plain (0.54) demonstrates a lower value. An ANOVA was conducted to investigate the relationship between the EEM index and regions. The analysis revealed no significant relationship between these variables (Levene F (6, 3644) = 1.497, p = 0.175; F (6, 3643) = 1.831, p = 0.089), suggesting that regional differences do not significantly impact energy efficiency measures across the country. We also assessed the EEM index across different types of settlements (city with county status = 0.60; town = 0.57; village = 0.55; capital = 0.54). The study found that cities with county status have a significantly higher EEM value than the national average, whereas the capital shows a lower value. In this instance, a significant relationship was identified between the type of settlement and the EEM index (Levene F (3, 3647) = 7.081, p < 0.001; W (3, 1808.811) = 10.410, p < 0.001). These results indicate that the inhabitants of cities with county status have led to the implementation of energy efficiency measures.

The second research question (RQ2) examines the prevalence of non-investment energy conservation measures in Hungary and the ECM index across different regions and types of settlements. The most widespread ECM implemented nationwide include turning off lights when there is sufficient natural light or in unoccupied rooms, practiced by 83.2% of respondents, and utilizing natural lighting, adopted by 75.3%. Monitoring the property's energy use is undertaken by 65.7%, while 65.0% switch off appliances, such as televisions, radios, and computers, when not in use. Additionally, 50.3% keep current with energy market news and monitor opportunities. Unplugging electronic equipment when not in use is practiced by 43.5%. Conserving energy at the expense of personal comfort, such as maintaining lower heating temperatures, closing off parts of the home, and minimising lighting, is reported by 32.8%, while 10.7% participate in awareness-raising programmes. The averages of the ECM index by region are illustrated in Figure 2. This figure provides a comparative overview of how different regions perform regarding non-investment energy-saving measures.

Figure 2

Averages of the ECM index by region



The ECM index national average is 0.67, indicating a higher prevalence of non-investment energy conservation measures than the EEM index, which stands at 0.56. Only Central Transdanubia has a notably higher average of 0.69. However, an ANOVA test revealed no significant relationship between the ECM index and regions (Levene F (6, 3644) = 1.813, p = 0.093; F (6, 3643) = 0.613, p = 0.720). In terms of settlement type, cities with county status display a remarkable mean of 0.691, surpassing the national average. In contrast, the capital has the lowest mean (0.657). (The average for the other two types of settlement was as follows: town=0.674; village=0.665) An ANOVA that examine the relationship between the ECM index and settlement type yielded significant results (Levene F (3, 3647) = 6.194, p < 0.001; W (3, 1828.56) = 4.274, p = 0.005), underscoring the influence of settlement type on adopting non-investment ECM.

Our third research question (Q3) explored the primary sources of financing for energy efficiency measures among the population, and whether there are variations by region and type of settlement. One's own resources are the most significant funding source nationwide, accounting for 70.5% of respondents. This is followed by public and other subsidies, utilized by 31.8% of respondents, and bank loans, utilized by 12.5%. Family loans are less prevalent among this group, accounting for only 6.4%. Notably, 22.7% of all respondents indicate no plans for retrofitting energy efficiency. The responses by region and type of settlement are detailed in Table 2.

Table 2

Financial resources for energy efficiency measures by region and type of settlement

(%)

Denomination	Regions							Types of settlement			
	CH	NH	NGP	SGP	CTD	STD	WTD	capital	CwCS	town	village
Own resources	**χ^2 (6) = 15.779 p = 0.015; V = 0.066**							**χ^2 (3) = 10.767 p = 0.013; V = 0.054**			
	70.9	**69.9**	**65.2**	**68.4**	**74.3**	**75.8**	**71.1**	**67.4**	**73.0**	**72.8**	**68.3**
Bank loans	χ^2 (6) = 4.355 p = 0.629; V = 0.035							χ^2 (3) = 0.194 p = 0.979; V = 0.007			
	12.9	11.6	13.3	12.3	10.4	14.7	11.4	12.2	12.3	12.4	12.8
Family loans	χ^2 (6) = 1.544 p = 0.959; V = 0.021							χ^2 (3) = 2.414 p = 0.491; V = 0.026			
	6.3	6.7	6.5	7.3	6.2	5.2	5.9	5.1	6.3	6.9	6.6
Public and other subsidies	χ^2 (6) = 4.879 p = 0.559; V = 0.037							**χ^2 (3) = 12.559 p = 0.006; V = 0.059**			
	32.0	31.1	33.1	33.2	29.4	34.7	28.7	**26.5**	**30.8**	**33.9**	**33.5**
No plans for modernisation	χ^2 (6) = 10.997 p = 0.088; V = 0.055							**χ^2 (3) = 16.345 p < 0.001; V = 0.067**			
	22.6	21.7	24.7	24.6	19.8	17.8	25.8	**27.5**	**21.3**	**19.8**	**24.0**

Notes: CH – Central Hungary, NH – Northern Hungary, NGP – Northern Great Plain, SGP – Southern Great Plain, CTD – Central Transdanubia, STD – Southern Transdanubia, WTD – Western Transdanubia, CwCS – city with county status. Bold highlights are used for chi-square tests where the p value is less than 0.05.

Regarding funding sources, a significant relationship was observed only in utilizing resources across regions. South Transdanubia (75.8%) and Central Transdanubia

(74.3%) exhibit levels above the national average, while North Great Plain (65.2%) falls below. However, no significant relationship with regions was found for other funding sources. Comparisons based on the type of settlement revealed significant differences in three areas. First, utilizing personal resources was higher in cities with county status and other towns and lower in the capital and villages. Second, public and other subsidies were more prevalent in cities and villages; however, less common in the capital. Third, the absence of plans for modernisation was more frequently reported in the capital and villages, in contrast to lower rates observed in cities. These findings underscore the variations in funding preferences and readiness to invest in energy efficiency measures across different types of settlements, providing valuable insights for policymakers and stakeholders involved in energy efficiency initiatives.

Our fourth research question (RQ4) explored the motivations driving consumers to implement energy-saving measures. The analysis revealed that the most significant motivation, with a mean rating of 6.66 on a scale of 10, is the desire to reduce household energy dependency and secure energy supply. Following closely, the commitment to environmental awareness and climate protection emerges as the second most crucial motivation, with a mean rating of 6.06. The fear of financial insecurity and loss of livelihood ranks third, with a mean rating of 5.44. At the same time, utilizing state and self-government subsidies is the fourth most important motivation, with a mean rating of 4.06. The responses by region and type of settlement are provided in Table 3.

Table 3

Motivations for energy saving measures by region and type of settlement

Denomination	Regions							Types of settlement			
	CH	NH	NGP	SGP	CTD	STD	WTD	capital	CwCS	town	village
Fear of loss of financial security/ livelihood	**F (6, 3644) = 5.122 p < 0.001; W (6, 1333.753) = 6.612 p < 0.001**							**F (3, 3647) = 0.558 p = 0.643; F (3, 3647) = 10.237 p < 0.001**			
	5.18	**5.80**	**6.08**	**5.65**	**5.38**	**5.15**	**5.02**	**4.78**	**5.46**	**5.70**	**5.53**
Reducing household energy dependency/ securing security of supply	**F (6, 3644) = 2.597 p = 0.016; W (6, 1330.938) = 2.695 p = 0.013**							**F (3, 3647) = 9.065 p < 0.001; W (3, 1776.199) = 14.423 p < 0.001**			
	6.51	**7.01**	**6.99**	**6.57**	**6.70**	**6.73**	**6.30**	**5.89**	**6.60**	**6.94**	**6.85**
Utilization of state/municipal subsidies	F (6, 3644) = 2.082 p = 0.052; F (6, 3643) = 1.443 p = 0.194							**F (3, 367) = 7.981 p < 0.001; W (3, 1818.038) = 5.303 p = 0.001**			
	3.97	3.92	4.29	4.13	3.76	4.31	4.19	**3.59**	**4.08**	**4.26**	**4.11**
Commitment to environmental/ climate protection	F (6, 3644) = 1.063 p = 0.383; F (6, 3643) = 1.150 p = 0.331							F (3, 3647) = 1.302 p = 0.272; F (3, 3647) = 2.102 p = 0.098			
	6.24	5.94	6.11	5.86	5.92	5.97	6.04	6.10	6.23	6.12	5.86

Notes: CH – Central Hungary, NH – Northern Hungary, NGP – Northern Great Plain, SGP – Southern Great Plain, CTD – Central Transdanubia, STD – Southern Transdanubia, WTD – Western Transdanubia, CwCS – city with county status. Bold highlights are used for ANOVA/Welch tests where the p value is less than 0.05.

Our investigation examined regional disparities and identified significant associations in two instances: first, apprehension about financial stability and livelihood loss were above the national mean in the Northern Great Plain (6.08) and Northern Hungary (5.80), while below the national mean in the Western Transdanubian region (5.02); and second, pertaining to reducing household energy dependency and ensuring supply security, Northern Hungary (7.01) and the Northern Great Plain (6.99) surpassed the national average, whereas Western Transdanubia (6.30) fell below. Regarding distinctions based on types of settlements, we identified significant disparities in three factors: first, fear of financial security/loss of livelihood exceeded the average in urban areas (5.70) and fell below in the capital (4.78); second, in terms of reducing household energy dependency and ensuring supply security, urban areas again exceeded the average (6.94), while the capital lagged behind (5.89); and third, urban areas exceeded the average (4.26) use of state/municipal subsidies, while the capital remained below (3.59).

The fifth and final research question (RQ5) aimed to discern public perceptions about the entities responsible for addressing energy crisis and climate pollution issues. The analysis revealed that the highest average score was attributed to the state (8.52), closely followed by the EU (7.30) and individuals (7.27). In contrast, less responsibility was assigned to local governments (5.90), the workplace (5.19), and local communities (5.01). We also investigated regional and settlement differences in response to this question to explain the variations in perceptions of responsibility across geographic and administrative contexts (Table 4).

Notable regional disparities emerged in two areas in our analysis of perceptions of responsibility for addressing energy crisis issues. First, perceptions of state responsibility were significantly higher than average in Central Transdanubia (8.71) and the Northern Great Plain (8.67), while Southern Transdanubia (8.19) and the Southern Great Plain (8.26) recorded below-average scores. Second, perceptions of individual responsibility were above average in Central Transdanubia (7.53) and Central Hungary (7.50), whereas lower scores were observed in the Southern Great Plain (6.79) and Northern Hungary (6.96). Further analysis of responsibility perceptions based on settlement type also revealed several notable findings. The perceived responsibility of local governments was rated above average in cities with county status (6.60) but received lower ratings in villages (5.51). Responsibility attributed to the workplace was higher among residents of cities with county status (5.63) and the capital (5.40), while residents of villages (4.93) and towns (5.06) assigned lower ratings. The local community's responsibility was similarly rated above average in cities with county status (5.45) and the capital (5.27), with lower scores reported in villages (4.72) and towns (4.87). Finally, individual responsibility was rated higher by respondents from the capital (7.59) and cities with county status (7.42), whereas it was given lower ratings in towns (7.12) and villages (7.14). These findings underscore the nuanced variations in responsibility perceptions across regions and settlement types, providing valuable insights into the diverse perspectives on addressing energy crisis issues among the population.

Table 4

Perception of responsibility for the energy crisis problems by region and type of settlement

Denomination	Regions							Types of settlement			
	CH	NH	NGP	SGP	CTD	STD	WTD	capital	CwCS	town	village
EU	F (6, 3644) = 0.714 p = 0.639; F (6, 3643) = 1.185 p = 0.311							F (3, 3647) = 0.645 p = 0.586; F (3, 3647) = 1.347 p = 0.257			
	7.21	7.51	7.30	7.10	7.36	7.31	7.50	7.18	7.48	7.26	7.29
State	**F (6, 3644) = 4.741 p < 0.001; W (6, 1319.072) = 2.763 p = 0.011**							F (3, 3647) = 1.301 p = 0.272; F (3, 3647) = 0.804 p = 0.492			
	8.54	**8.58**	**8.67**	**8.26**	**8.71**	**8.19**	**8.56**	8.49	8.63	8.50	8.47
Local government	F (6, 3644) = 4.522 p < 0.001; W (6, 1327.632) = 0.699 p = 0.650							**F (3, 3647) = 0.606 p = 0.611 F (3, 3647) = 19.195 p < 0.001**			
	5.88	5.89	5.90	5.78	6.04	5.74	6.11	**6.02**	**6.60**	**5.77**	**5.51**
Workplace	F (6, 3644) = 4.111 p < 0.001; W (6, 1325.651) = 1.284 p = 0.261							**F (3, 3647) = 0.614 p = 0.606 F (3, 3647) = 8.271 p < 0.001**			
	5.21	5.02	5.21	4.92	5.35	5.21	5.44	**5.40**	**5.63**	**5.06**	**4.93**
Local community	F (6, 3644) = 4.144 p < 0.001; W (6, 1326.795) = 1.596 p = 0.145							**F (3, 3647) = 1.751 p = 0.154 F (3, 3647) = 9.512 p < 0.001**			
	5.08	4.81	5.11	4.68	5.07	4.91	5.23	**5.27**	**5.45**	**4.87**	**4.72**
Individuals	**F (6, 3644) = 6.227 p < 0.001; W (6, 1319.842) = 4.327 p < 0.001**							**F (3, 3647) = 9.463 p < 0.001; W (3, 1829.653) = 4.327 p < 0.001**			
	7.50	**6.96**	**7.20**	**6.79**	**7.53**	**7.18**	**7.38**	**7.59**	**7.42**	**7.12**	**7.14**

Notes: CH – Central Hungary, NH – Northern Hungary, NGP – Northern Great Plain, SGP – Southern Great Plain, CTD – Central Transdanubia, STD – Southern Transdanubia, WTD – Western Transdanubia, CwCS – city with county status. Bold highlights are used for ANOVA/Welch tests where the p value is less than 0.05.

Discussion

The regional analyses show that regional differences in household energy efficiency and ECM are minimal and not statistically significant. This is also in line with Nagy et al.'s (2018, 2019) research, who analysed electricity and natural gas consumption indicators per household and per capita and concluded that no significant regional disparities and differences can be detected.

Comparing regions shows a more favourable picture of the energy awareness of households in the West Transdanubian and Central Transdanubian regions, so we will summarise our main findings and try to explain the results focusing on these two regions. For the EEM index (RQ1), the West Transdanubian and Central Transdanubian regions have the highest scores, while other regions are close to the national average. In the ECM index (RQ2), Central Transdanubia stands out, with the other regions close to the national average. Our research has uncovered a significant difference in the use of own resources across regions (RQ3), with a higher proportion in the Transdanubian regions. When analysing motivations (RQ4), our findings reveal that concerns about financial stability and loss of livelihood were below the national average in Western Transdanubia. There were significant regional differences in responsibility perception (RQ5). The state and individual responsibility perception was significantly above the average in Central Transdanubia.

Besides geographical location, climate, and topography, a region's socio-demographic characteristics and economic situation can also determine regional differentiation in energy use and awareness (Borozan 2018). Based on this, we present some characteristics considered relevant by the authors, based on the KSH database for 2022, possibly explaining the more favourable values of the two mentioned regions.

In terms of building characteristics and comfort level, the highest proportion of apartments with all comforts is found in Budapest (80.2%), followed by Central Transdanubia, Central Hungary, and Western Transdanubia (76–77%), which have the lowest proportion of uncomfortable apartments (1.1–1.6%). There are no significant differences in the age distribution of the resident population. The combined proportion of the population aged 0–14 years and over 65 years ranges from 34–36% in all regions. The highest employment rate among the population aged 15–64 is in Budapest (77.1%), followed by Pest County, Central Transdanubia, and Western Transdanubia, with around 75%. Western Transdanubia (2.6%) and Central Transdanubia (3%) have the lowest unemployment rates. The number of jobseekers registered for more than 180 days is lowest in Western and Central Transdanubia, with 4.8% and 6.9% of the total long-term unemployed living in these regions, respectively. The share of graduates in the population aged 25 and over is highest in Budapest (42.5%), followed by Central Hungary (Pest) (27%), Western and Central Transdanubia, where the share of graduates is above 20%. In the rest of the country, this rate is below 20%. The share of people with at most primary education is lowest in these regions (21–23%). The average gross earnings of full-time employees by residence of employees are highest in Budapest, Central Hungary (Pest), Central Transdanubia and Western Transdanubia (the region with the highest value has 1.55 times higher average gross earnings than the region with the lowest value). The gross domestic product per capita is highest in Budapest (11,812 thousand HUF/person, 208% of the national average), followed by Central and Western Transdanubia with values above 5,000 thousand HUF/person, 91–93% of the national average). The data show that the country's most developed regions are Central and Western Transdanubia and Central Hungary (KSH 2023).

Thus, our results are consistent with the literature, showing that education, household income (Brounen et al. 2013, Canepa et al. 2023, Duan et al. 2023, Kasavan et al. 2021) or building characteristics (Santin et al. 2009, Yohanis et al. 2008) and the region's economic development (Duan et al. 2023, Lin et al. 2014) are determinants of household energy use and energy awareness.

The EEM index by type of settlement indicates that cities with county status have significantly higher EEM scores than the national average. The ECM index is also notable for the higher value of cities with county status compared to the national average. A noteworthy result of the responsibility assessment is that the responsibility of local governments in the cities with county status was rated above average. Responsibility for the workplace and the local community was also higher among residents of cities with county status. Finally, individual responsibility was also rated highest (alongside residents of the capital) by respondents from cities with county status. These results indicate that the population of cities with county status can be considered more energy-conscious regarding energy efficiency and ECM. This claim is confirmed by the research of Takácsné Papp (2023a), which found that the municipalities of cities with county status show a higher commitment to energy and climate goals than other types of settlements. A significant percentage of municipal energy use is related to residential buildings. Therefore, at the planning level, municipalities perceive the most significant potential for green transformation in residential buildings (Takácsné Papp 2023b). Our results suggest that the population's attitudes align with this expectation.

The findings for the capital, with lower values of the energy efficiency and energy conservation indices, lower use of own resources for investments, and lower use of public and other subsidies are noteworthy. Respondents in the capital reported the absence of modernisation plans more often than people in the different settlements. This more passive behaviour may be related to the results that the fear of financial security/loss of livelihood, reducing energy dependency and ensuring the security of supply, and taking advantage of state/private subsidies have less (below the country average) motivating power for households in the capital.

Conclusion

There is little research on regional (NUTS 2 level) energy use in the Hungarian household sector. Some studies have analysed the relationship between the socio-economic development of regions and per capita energy use, while others have examined Hungary's renewable energy potential. This paper uses two indices developed by the authors to characterise household energy awareness and presents the results by region and type of settlement. This approach fills a gap in the literature by focusing on household decisions and EEM, considering some factors that influence these decisions. A further added value of the study is that energy awareness is analysed in parallel along the dimensions of region and type of settlement.

Our research did not reveal significant regional differences in EEMs; however, notable differences were observed between various settlement types and in adopting ECMs. Residents of cities with county status scored above the national average on both indices. Nationally, personal savings emerged as the most significant source of funding for EEM, followed by public and other subsidies, and bank loans, while family loans were infrequent. The study further highlights that the key motivators for adopting energy efficiency practices are reducing energy dependency, ensuring energy security, and addressing environmental and climate concerns. Respondents predominantly assigned primary responsibility for mitigating the energy crisis and environmental pollution to the state, followed by the European Union and individuals.

The research has important implications for the public, energy development companies, and policymakers. From a societal perspective, insights into energy awareness and behaviour can inform public outreach efforts, more widely adopting energy-saving practices and reducing energy dependency and environmental impact. For businesses, the findings suggest strategic opportunities for energy efficiency improvements that are most needed by the public and tailoring marketing communications to emphasise the primary motivations behind residential EEM. Policymakers can utilize these results to design more targeted energy-saving programmes and incentives that cater to the specific needs and motivations of Hungary's different regions and settlement types. Given these findings, we recommend fine-tuning ongoing programmes and revising planned initiatives accordingly.

A limitation of this study is its reliance on self-reported data obtained through an online survey, potentially introducing biases and affecting the findings' accuracy. Additionally, the present research examined only regional and settlement type differences, limiting the scope of analysis. Future research aims to expand the analysis by incorporating other factors, such as property characteristics (e.g. type, construction materials, hot water supply, size), household characteristics (e.g. family size, financial situation), and respondent demographics (e.g. gender, age, education, occupation, marital status) to more comprehensively understand the determinants influencing energy awareness and behaviour.

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