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Original research article



Houses of pain: Paying the energy poverty premium for energy inefficiency and inequity in Hungary

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ABSTRACT

This article utilizes the energy affordability ratio and the energy equity threshold to quantify the energy poverty premium in the Hungarian household sector. The focus on equity meets a call to tailor policy solutions to individual needs, in a similar manner to other sectors, such as health, education, and the environment. The novel arrangement of these quantitative methods enables the identification of households that do and do not pay an equitable amount for energy services. The calculations are based on required energy expenditures according to the energy rating of the buildings, instead of the actual energy expenditures. It can be stated that despite regulated and highly subsidized energy prices in Hungary, which are applied uniformly across all households, they generate unequal financial burdens due to the poor energy efficiency of the building stock and low disposable income. There is persistent and onerous energy inequity for almost all Hungarian households. While the median energy affordability ratio is 4.33%, the ratio varies widely across households, with a maximum of 107.27%. The energy equity threshold is 270 kWh/m^{2}a, above which energy poverty is significantly present. Five particularly vulnerable social groups were identified in our study: 1) single person households with at least one dependent child, 2) other single person, 3) pensioner, 4) unemployed, and 5) other economically inactive households. We can conclude that assessing differences in energy affordability across population groups in Hungary requires a new set of indicators. The Hungarian utility cost reduction program needs immediate reforms including more bands for the block pricing system, introduction of a social energy tariff, time of use pilot projects, and greater investment into energy efficiency.

1. Introduction

Since the 1970s, scholars have been unpacking the idea that "*equity and energy can grow concurrently only to a point*" [1]. And even from the early 1900s, with the rollout of the electrical system, efficiency in the name of equity, was viewed as key to alleviating poverty [2]. More recently, equity is used as a justification for rebalancing energy demand to address climate change and energy poverty between the Global North and the Global South [3,4]. Previous research has worked to identify an energy threshold to meet basic needs and understand the point of decoupling the Human Development Index (HDI) from Gross Domestic Product (GDP) [5–8]. Lower-income households are at pains to heat or cool their homes, cook, or generally consume an equal level of energy services as more well-off households [6,9–11]. This article examines energy equity between households in Hungary. More broadly, it considers an energy equity threshold between high and low-income households where each meets its energy needs irrespective of their income. Energy equity is an enduring and timely concept that requires greater attention with diverse methods of inquiry [3,4,10,12–15].

The difficulty of affording energy services means many people are paying a disproportionate share of their income for energy wasted through inefficient homes. For low-income residents, these houses of pain capture them due to their upfront affordability, usually because they are old and of poor construction [9,11,16]. Because of their low energy efficiency, they extract a disproportionate amount of money for basic energy services for equivalent services compared to newer or renovated properties. "*Equity recognizes that each person has different needs*" [4], but with the understanding that they receive similar services [13]. This article uses "*energy equity [to unlock] access to energy for everyone to realize the goals of energy justice*" [13]. The starting point here is: governments can deliver a just and equitable energy system by removing inefficiency and inequity, which can be measured and

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assessed in policy delivery through an energy equity approach [3,4,13,15,17].

Hungary is a particularly revealing example in this regard, as between 2013 and 2026, Prime Minister Viktor Orban's government's signature policy was ensuring all households receive discounted energy, which, on the surface, resembled an equitable energy policy. Numerous studies [18–22] have confirmed that, in most cases, energy subsidies are distributed unevenly among different social groups, and in many cases, the energy expenditure of poorer households exceeds that of wealthier households in both absolute and relative terms. According to Rasanga et al. [21], this overreach is, for example, between 10% and 20% in Great Britain. As Arze del Granado et al. [22] argue that transportation fuel subsidies are an expensive and inefficient way to protect the welfare of poor households, because a large share of the benefits leaks to higher-income groups, with the richest fifth of households receiving about six times as much support as the poorest fifth (on average in the studied developing countries). This is likely to apply to the politically popular universal subsidy Hungarian households receive for their electricity and gas.

Energy equity as a conceptual framework, combined with quantitative methods, can deliver policy suggestions tailored to the circumstances of individuals and households [4,13]. Thereby complementing, but also moving beyond, the governance and institutionalist-based approach of energy justice [23], which seeks to deliver on broader core tenets of justice and contribute towards greater equity in the energy system [13]. Energy justice uses a moral framing to persuade audiences to take particular action based on ethically rooted injustices [24] within the energy governance system of legislative, judicial, and regulatory institutions. Energy equity also draws from a moral framing but seeks to assess, usually through comparative quantitative indicators, how well state institutions or society take action to provide a just outcome. The contribution of energy equity is to highlight inequality among households by measuring inequity and then proposing corrective action. This article meets the recent call in this journal to produce a clearer definition and conceptualization of energy equity, similar to how equity is addressed in fields such as health, education, and the environment [4].

This study is built on three key terms: the energy affordability ratio, the energy equity threshold, and the energy poverty premium. The *energy affordability ratio* is based on the required energy consumption derived from dwellings' energy performance rating (kWh), multiplied by the costs of gas and electricity, and is calculated as the share of these required energy expenditures in net household income. The *energy equity threshold* partially relies on this first indicator, which enables the identification of energy-poor households by calculating the energy affordability ratio in addition to the quality of the dwelling in terms of energy efficiency. Thereby capturing the *energy poverty premium* paid by households and the extent to which the poor incur additional costs due to low-quality buildings [18]. These three ways to quantify various dimensions of energy poverty expose the inequity of the energy system. To identify inequity in the Hungarian household energy sector, we answer the following research questions:

1. What is the energy equity threshold beyond which the energy burden becomes unequal and results in households paying an energy poverty premium?
2. How much of an energy poverty premium does a household pay for a home with poorer energy efficiency?
3. Is there a regressive impact of lower energy efficiency on the poorest households, and do lower quintiles pay a higher energy poverty premium?

This study aims to demonstrate that although regulated energy prices are the same for all households for more than a decade in Hungary, they still represent unequal burdens, highlighting energy inequity. The study contributes to existing literature in three ways. First, it is widely accepted that the poorer households pay more for food in keeping with Engel's law [25,26], but *"evidence on systematic changes in other expenditure categories is hardly available"* [26]. Furthermore, there is a *"lack of systematic attention to the specific mechanisms via which energy inefficiency becomes a poverty premium for financially marginalised households"* [18]. Research examining the magnitude of the energy poverty premium is also limited [21]. Second, the analysis and findings contribute to expanding the definition and concept of energy equity. The term is re-emerging as an important policy framing tool to address individual needs [3,4,13], global and national inequity in energy consumption [27] and connecting it to the energy poverty premium [18]. And third, it updates the assessment of the Hungarian utility cost reduction program, which created a uniform price for all households, regardless of income or social status [28]. This also answers the question previously raised by Galvin, namely, "*it is worth asking what the effects might be if one of these chief causes of energy poverty were substantially reduced on a country-wide basis*" [29]. As we will see, eliminating a single driver of energy poverty is insufficient to address the problem; a comprehensive, multifaceted approach is required. Table 1 provides the definition of the terms relevant in this article to assess energy equity in Hungary.

The paper is organized as follows. Section 2 summarises the utility cost reduction program to provide the policy background and provides some data about the energy poverty and the characteristics of the Hungarian building stock. Section 3 introduces the concept of energy equity and presents the conceptual framework. Section 4 provides an overview of applied data and methodology. Section 5 presents the results of the regressive impact of low energy efficiency homes on households and measures the energy poverty premium. Section 6 delivers answers to our three research questions and translates the application of the results into policies, including the limitations of the study. Section 7 provides the conclusion and brings together the conceptual framing of the energy poverty premium and energy equity threshold to demonstrate the importance of society working to improve efficiency and reduce energy inequity for almost all sections of society.

2. Policy background

The Hungarian government gives substantial financial support to households for nearly all energy sources. These are a combination of subsidies, regulated pricing, and social benefits [28]. Standing out in terms of scale are natural gas, electricity, and district heating, with all prices regulated since 2013. This system is collectively referred to as the 'utility cost reduction program', which effectively operates as a price cap

Table 1
Definitions of Energy Equity Terms.

Terms	Definitions
Energy Equity	Ensuring all individuals have access to affordable, safe, sustainable energy, regardless of life circumstances, and sufficient to support a decent lifestyle and align with goals to eliminate energy poverty [4] while also utilizing energy-efficient technologies.
Energy Efficiency Gap	The difference between the most energy-efficient technologies available and those in actual use [30].
Energy Affordability Ratio	The required energy consumption derived from dwellings' energy performance rating (kWh), multiplied by the costs of gas and electricity, and calculated as the share of these required energy expenditures in net household income.
Energy Equity Threshold	The identified point between energy-poor and energy-affluent households by determining the energy efficiency of the building and the share of required energy expenditures to net household income (energy affordability ratio).
Energy Poverty Premium	Additional costs paid by lower-income households for energy services due to inhabiting low-quality buildings [18] and using suboptimal technologies.
Houses of Pain	The lower a household's income and the poorer the energy efficiency of the dwelling, the higher the proportion of expenditure spent on energy. Low incomes and low building efficiency can force people to spend much of their income on energy services and live in physical and mental discomfort.

Table 2
Residential energy prices and thresholds.

Energy Product	Consumption level	Unit price (including all taxes and levies)	
		HUF	EUR
Electricity	<2523 kWh/year (discount band)	36 HUF/kWh	0.09 EUR/kWh
	>2523 kWh/year	70.104 HUF/kWh	0.18 EUR/kWh
Natural gas	<1729 m^3/year* (discount band)	102 HUF/m^3	0.26 EUR/m^3
	>1729 m^3/year	747 HUF/m^3	1.87 EUR/m^3

Note: *1729 m^3/year = 63,645 MJ/year = 18,088 kWh/year.
Source: own compilation based on [31].

on these three energy sources for residential consumers. The prices are uniform across all households (with no differentiation based on income level or social status), and they have remained fixed between 2013 and 2022, with no adjustment for inflation.

In response to the 2021–2022 energy crisis and Russia's 2022 military invasion of Ukraine, the Hungarian government restructured the utility cost reduction program in 2022. The modification, enacted through Government Decree 259/2022 (VII.21.), introduced a block pricing system (so-called tiered rate): all residential consumers now benefit from regulated tariffs (hereafter, we refer to this tariff as the discounted price) up to the national average household consumption level, 1729 m^3 of gas and 2523 kWh of electricity per year [31] (notably, district heating prices remained fully regulated and unaffected). Consumption above this discount band is charged at a higher, so-called 'market price'. At the same time, there are several contradictions regarding both the determination of the average and the market price. This is explained in more detail below.

First, the upper limit of this discount band is significantly higher than actual national average consumption, thus ensuring lower prices for a much larger proportion of households, although we do not take a position here on whether this is desirable from a social or ethical perspective. According to our calculations, the climate-adjusted average consumption for the period 2015–2021 (i.e., examining the years after the introduction of the utility cost reduction program but before the adjustment) is 1151.31 m^3 for gas and 2198.1 kWh for electricity. Second, the 'market prices' applied to above-average consumption are themselves determined by regulation and do not reflect actual market dynamics. Since 2022, gross electricity prices have been set at 36 HUF/kWh for consumption below the national average, and 70.1 HUF/kWh for usage above this threshold. For natural gas, the corresponding prices are 102 HUF/m^3 and 747 HUF/m^3, respectively (Table 2 contains the amounts in EUR as well). In the meantime, in 2025-S1 for non-household consumer the gas market prices were 300.53 HUF/m^3 (~0.75 EUR/m^3) in band I3,[1] while electricity market prices (for non-household consumers) were 106.96 HUF/kWh (~0.27 EUR/kWh) (consumption from 500 MWh to 1999 MWh - band IC) [32].

The new system, through the high prices above the discount band, penalizes not only excessive consumption due to wasteful use, but also households living in energy-inefficient buildings. However, since the enactment of the new system, the use of natural gas in the household sector decreased by 13.76% from 2022 to 2024 [33].

In early 2025, Hungary introduced an additional layer of complexity to this system through the implementation of Time-of-Use pricing. Energy usage is now categorized into three specific billing periods: mid-peak (6 a.m. to 5 p.m.), on-peak (5 p.m. to 10 p.m.), and off-peak hours (10 p.m. to 6 a.m.). However, for the time being, the same rates apply across all periods and are expected to remain unchanged until at least January 1, 2027 [34].

Rather than evolving into a comprehensive energy poverty reduction strategy, the price cap has increasingly served as a politically expedient policy with high electoral appeal. It aligns with a deeply embedded preference within Hungarian society for predictability over cost-efficiency [35,36]. While politically popular, the program is extremely expensive to maintain. Under this scheme, the state budget reimburses energy suppliers for the difference between the regulated consumer price and the actual market price. Between 2022 and 2024, it cost approximately HUF 5000 billion (around EUR 12.5 billion) [37], and HUF 954 billion (~EUR 2.4 billion)[2] in 2025 [38–40], a fiscal burden that has diverted public resources away from much-needed deep renovation and energy efficiency programs. As a result, the program has created a growing imbalance between residential and industrial energy users. With no relief from market prices, industrial consumers now pay approximately 20–25% more for energy than in neighboring countries, resulting in significantly higher operational costs and undermining industrial competitiveness.

According to the original version of National Energy Climate Plan and the National Energy Strategy from 2020 [41,42] the primary objectives of the utility cost reduction program were: 1) reduce household energy expenditures, 2) shield residents from volatile energy markets, and 3) alleviate energy poverty. These objectives have been partially achieved. First, the program has made household energy increasingly affordable in purchasing power terms over time and has led to some of the lowest residential energy prices in the EU [32,43]. Second, the regulated prices were partly phased out in 2022, just when prices rose dramatically, and consumers needed protection the most. Third, despite improvements in energy affordability, energy poverty has remained a serious problem.

Hungary has no separate statutory definition of energy poverty. Instead, the issue is addressed in policy and legislation through the concept of vulnerable households. The Hungarian Energy Efficiency Act defines a 'household to be supported' as a vulnerable household whose annual energy expenditure, covering the heating of the dwelling to 20 °C and the provision of hot water, exceeds 25% (!) of the household's annual income (Act 2015/57 on Energy Efficiency, 2015 / para. 1/28.b). The National Energy and Climate Plan (Section 4.4, Dimension of the Internal Energy Market – Energy Poverty Chapter) also refers to vulnerable households, defined as those who have difficulties in meeting their household energy needs. However, this 25% threshold cannot be directly derived from either the international or the Hungarian energy poverty literature (e.g. [44–46]); rather, it is the result of a straightforward legislative decision. It can be interpreted as an administrative instrument aimed at targeting the most severe cases of energy poverty, while at the same time significantly narrowing the scope of households eligible for support.

In Hungary, 9.1% of the total population, and 23.7% of persons at risk of poverty or social exclusion, live in underheated dwellings (this metric is entirely based on household self-reporting and perceived adequacy [47]) which places the country in the middle of the EU ranking (the EU average is 17.9% and 31.2%, respectively) [32]. However, other studies show less favorable data. According to Antunes et al., the proportion of households with an energy burden above 10% (i.e., the percentage of household income spent on home energy services) exceeds 43% in Hungary, which is one of the highest figures in the EU [48]. OPENEXP's study also places Hungary among the worst-performing countries in the EU in this regard [49].

According to government policy, the result of the utility cost reduction program is that the number of energy-vulnerable consumers is around 300,000 [50]. However, poverty statistics in Hungary are generally systematically underestimated [51,52], and other sources [53]

[1] 28.73 HUF/kWh (0.07 EUR/kWh); band I3 means consumption from 10,000 GJ to 99,999 GJ

[2] EURHUF = 400

suggest that the number of people living in energy poverty is around 0.8 to 1 million (total number of households is 4 million [54]). The latter is much more consistent with the international research mentioned earlier.

2.1. Household energy consumption and main characteristics of the building stock

Low electricity and gas prices have only partially mitigated energy poverty in Hungary. The program covers only natural gas, electricity, and district heating, excluding the most typical fuels used by the energy poor, such as firewood and lignite. Nationally, the share of dwellings heated with traditional fuels (in addition to these, household waste also falls within this category) is about 33.9% in 2022, but there are counties where this figure exceeds 50% [54]. The price of standard sawn firewood more than tripled between 2010 and 2024.

Beyond energy prices, two additional factors significantly contribute to energy poverty in Hungary: 1) the outdated building stock and 2) the low level of disposable income. Although Hungary has made some progress on both fronts, these efforts have not been sufficient to produce a meaningful improvement in the situation of those affected by energy poverty. We will explain this below.

In Hungary, the average energy consumption of the national housing stock is around FF (201–250 kWh/m^{2}a) [50], but most buildings fall into the HH (311–400 kWh/m^{2}a) rating [55]. The latest report by Habitat for Humanity Magyarország highlights the uncertainty of the available figures, presenting an even more alarming picture: 80% of the buildings consume above 237 kWh/m^{2}a [56] and the consumption of only 280,000 residential buildings is less than 130 kWh/m^{2}a [55]. Generally, the worst performing building stock refers to buildings with GG (251–310 kWh/m^{2}a) or worse energy ratings [57]. It can be stated that 2.6–3 million residential properties (out of 4.6 million) require some form of energy modernization [50,58].

According to the current legislation [59] the preparation of energy performance certificates is mandatory in cases of property transactions, occupancy permits, and rental agreements. The certifications are stored in a central e-energy certification database [60]. Fig. 1 presents the distribution of energy performance certificates uploaded in 2022–2023. While the dataset is not representative - new buildings with high energy ratings (AA++ – AA) are likely to be overrepresented - it nevertheless provides an indicative picture of the housing stock.

As Csoknyai notes, the greatest savings potential lies in the worst-performing building types - namely, single-family houses constructed before 1990 [61]. Households relying on traditional fuels for heating are overrepresented in the lower-income deciles and typically live in this type of building [45]. Here, 60–70% of heating energy could be saved through insulation and upgrading the heating system. Comprehensive energy efficiency programs could reduce Hungary's primary energy demand by 25–30% by 2030 compared to 2010 levels [62].

The annual renovation rate of the housing stock has remained extremely low. To renew the building stock within 30 years - a timeframe generally considered feasible - a renovation rate of at least 3% per year is required (a rate of 1% would extend the process to 100 years). The average renovation rate in the EU stands around 1% in the 2010s [63,64], while the rate of deep renovation (defined as achieving at least a 60% improvement in energy efficiency) is just 0.2%[3] [65]. In Hungary, these figures are even lower: the average renovation rate ranges between 0.5% and 1%, and the deep renovation rate is only 0.1%, meaning that only 4000–5000 dwellings are upgraded each year. These figures highlight that, despite some initiatives, energy efficiency improvements have not been prioritized over the past decade. This situation was further aggravated by the government's decision in October 2015 to redirect EU energy efficiency funds from residential to public building renovation, in contradiction to earlier plans. This effectively led to the dismantling of all residential energy efficiency programs [66]. These issues are partly addressed by a home renovation program (calls of KEHOP Plusz-4.1.7–24 and KEHOP Plusz-4.1.8–24) available from July 1, 2024, which requires a minimum energy savings of 30% [67].

In 2023, ten EU Member States recorded actual individual consumption per capita (household material welfare) above the EU average, while seventeen remained below it. Hungary had the lowest level, at 30% below the EU average, followed by Bulgaria (27%), and Slovakia and Latvia (both 25%) [32]. Hungary's adjusted gross disposable income of households per capita, measured in purchasing power standards (PPS), was somewhat better at EUR 21,219 in 2023, compared to the EU average of EUR 28,046.

3. The energy equity threshold concept

"*Energy equity should ensure that all individuals have access to affordable, safe, sustainable energy, which should be enough to support a decent lifestyle and align with goals of energy poverty elimination and social welfare improvement*" [4].

The underlying philosophy of energy equity rests on a post-growth framing of wellbeing economics [8]. With concern for planetary boundaries and the long-term wellbeing sustained with minimal resource use [8]. In this article, we use Ivan Illich's framing of an energy equity threshold as a foil to test whether households can adhere to a set consumption level to live in energy equity, irrespective of income or abilities. By developing a household threshold approach, linked to the poverty premium, it extends previous threshold research [7] while highlighting the role of efficient energy production and efficiency technologies to deliver a higher quality of life for all by potentially adhering closer to an environmentally sustainable level [6].

The research in this article falls within the small set of 'energy equity' literature [4,13], which quantifies the amount of income and inflection points that move households out of fuel poverty [4]. Here, we aim to meet the call to develop metrics that are important for creating a "*shared understanding of energy equity indicators*" and common evaluation standards for inequities [4]. Literature sitting within this realm deals with the HDI [68], with the Capabilities Approach serving as an effective conceptual lens to study the metrics of energy poverty and equity [7,69]. Sen and Nussbaum represent this approach well by seeking to evaluate human wellbeing and the freedom to achieve [70,71] and producing a list of 'central human capabilities' connected to energy consumption [68]. Within this measurement approach of wellbeing is to demonstrate not just the minimal feasible amount of energy required for a quality life, but also demonstrate how energy efficiency improvements go "*beyond the satisfaction of basic needs*" without significantly increasing per capita energy use [6]. Ensuring households are not paying a poverty premium in this equity gap relies on measuring differences between households and the cost of a minimum level of wellbeing.

The assumption here is there is an energy efficiency gap, "the existing gap between the most energy- efficient technologies available at some point in time and those that are actually in use" [33,see 77,78]. Conceptually, it is important to show how convergence can happen in homes. Table 3, demonstrates the conceptual framing of improving efficiencies and improving energy services regardless of the household status [16]. While an 'optimal house' may exist, it also needs to reflect the 'energy efficiency gap,' which is the difference between the deployed technology and the optimum energy efficiency measures [72,73]. With households and businesses underinvesting because of the inability to accurately predict future energy prices [73]. This can be because of the 'socially optimal' price for energy, which differs from an optimally economically efficient price, or the 'true cost' of energy obscured by subsidies or other market-distorting measures [74]. Therefore, building the optimal home is stymied because of the unknown future energy price, coupled with the payback period for the most efficient technology. Leading to homeowners or businesses investing in sub-optimal

[3] The deep renovation rate should be increased to 3% (i.e. fifteen times) by 2030 and maintained in the EU until 2050, according to the commitments.

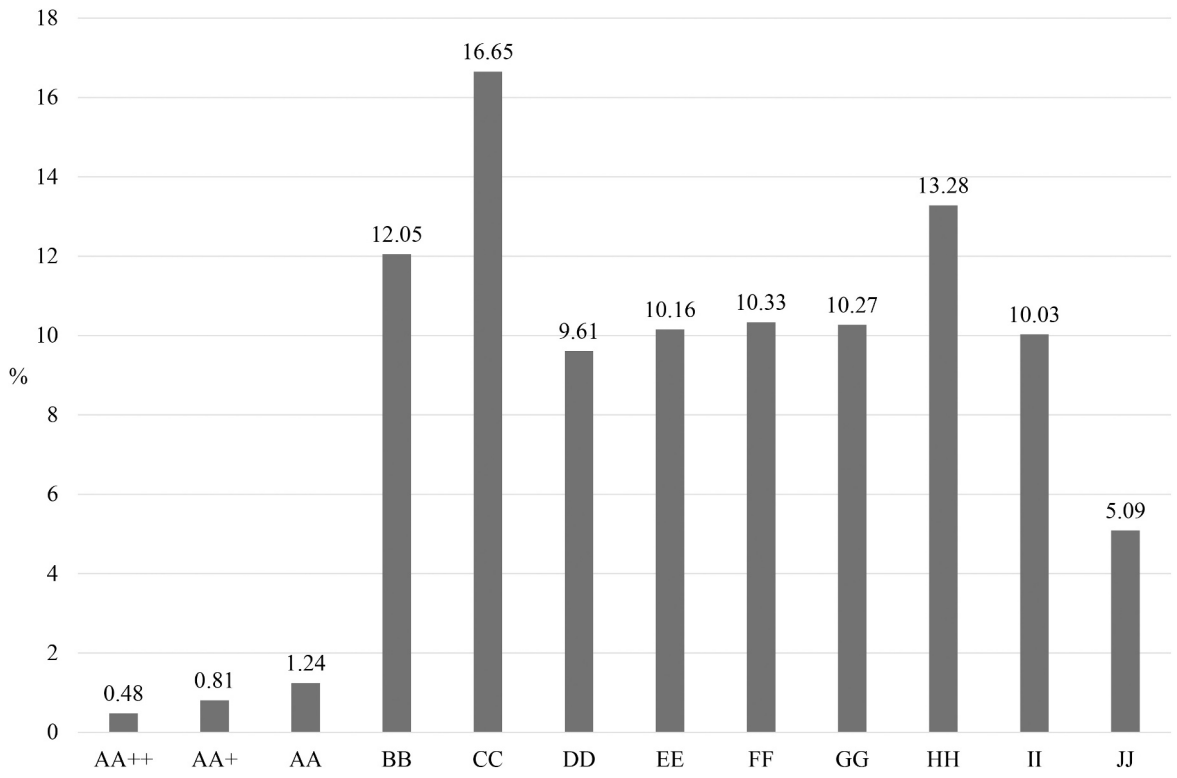


Fig. 1. Share of energy performance certificates by energy ratings in Hungary, issued in 2022–2023 (%).
Source: own compilation based on e-energy certification database [60].

Table 3
Energy efficiency and services in households.



	Energy poor households	Energy affluent household	Optimal household
Energy Use	Low	High	Low
Technology Efficiencies	Low	Medium	High
Energy Services	Low	High	High

Source: altered from Boardman 1999, 32 [16].

technologies or other solutions [73].

Boardman outlines how investment into energy efficiency can lift energy-poor households out of energy poverty, while also reducing energy bills for those not in poverty. The proposal is to ensure both types of households have high efficiency and high levels of energy services while consuming a low amount of energy [16]. Similar to the projection of equalization energy consumption and increase in production to increase GDP and wellbeing, adherence to an energy equity threshold forces the prioritization of efficiency over production.

The diffusion of energy-efficiency technologies in homes contributes to equity among households. Equity and minimal power use are framed through this threshold approach that:

"*Equity and energy can grow concurrently only to a point. Below a threshold of per capita wattage, motors improve the conditions for social progress. Above this threshold, energy grows at the expense of equity. Further energy affluence then means decreased distribution of control over that energy*" [1].

The energy equity threshold serves as an equilibrium point between production and consumption thereby establishing system boundaries. Other scholars consider minimal power usage in the home, or the decoupling of GDP from energy consumption [5–7]. Illich provides a follow-up to the dangers of energy affluence. It is a "*political fallacy*" to assume there is no social or environmental cost with clean and abundant energy, which is often correlated as a "*panacea for social ills*" [1]. Energy affluence supports higher levels of economic growth and human well-being, but there are indications that this 'social limits' hypothesis is based on "*diminishing returns*" [8]. With low and middle-income countries, or households, holding a strong connection between increased energy consumption to economic growth, while high-income countries hold a weaker connection after a threshold [14,27]. Hickel and others consider a 'green growth' approach that decouples GDP from resource use on a global scale, which appears impossible to quantify and implement within planetary limits, therefore policymakers need to consider alternative approaches [5]. However, a global threshold approach does indicate a significant leveling off of benefits about a certain threshold, indicating, "*highly developed countries could use a fraction of their current energy without any measurable loss in human development*" [7].

Equalizing GDP and wellbeing by increasing energy production demonstrates the necessity to expand the energy system, irrespective of the bounds of system resources. Framing the present case study research on households in Hungary and other countries in the European Union, demonstrates the catch 22 of catching up to Western European energy consumption levels. Previous research by these authors demonstrates that the coupling of energy production and GDP means an increase in the HDI is also tied to economic growth [14,75]. Decoupling of GDP and HDI occurred largely in Western Europe because they reached a relatively high energy consumption level. For former Communist countries in Eastern Europe to match the same level of wellbeing, their energy consumption would need to increase. Inversely, a reduction in energy consumption (e.g. because of high prices) would lower wellbeing (HDI) in both sets of countries [14]. More broadly, forecasts estimate that the electricity demand growth in emerging markets and developing economies will be over 60% by 2060, even with energy efficiency measures,

which is akin to adding another China in terms of energy demand; with half of this global energy production done by fossil fuels [76]. From a household or national level, understanding where the energy equity threshold lies provides the ability to assess demand, social needs and technologies to foster a greater efficient use of resources.

From the energy efficiency gap to the energy poverty premium, there is a strong case for investigating the role of energy equity in household energy consumption. Inequality in energy consumption places households and countries with lower HDI at a disadvantage relative to higher-income households and countries. The ability to measure households' energy consumption, along with understanding the best and worst technology in homes, means equity can be measured between households and new policies can be created to lift households out of energy poverty. In addition, finding ways to lower energy consumption by higher-income households that may be inefficiently using energy. Measuring energy poverty and energy equity requires a different toolset. As the next sections demonstrate, quantifying the difference between households begins this process of identifying household inequity.

3.1. Energy poverty measurements – 2 M and the LILEE-index

Differences in the share of household income spent on energy services reveal inequalities in energy affordability across social groups. A significant portion of the literature on energy poverty [44,46,53,77] uses an expenditure-based approach to measure the extent of the problem, which is defined as the lack of energy affordability. According to Tang et al. this latter is *"the ability of households to access and afford energy services relative to their income levels"* [78]. In most cases, if the households' actual energy expenditure exceeds a given threshold, it refers to energy poverty. Several threshold values are currently in use: 10%, 6% and 4%, representing a normative approach and applying objective indicators [29]. However, there may be many cases where the use of such an absolute threshold is misleading. It does not take into account the overconsumption associated with a high standard of living, or if there are simply no costs associated with fuel consumption. The 2 M indicator and the LILEE index were developed to overcome this problem. In the following, we present these in detail.

The 2 M indicator "presents the percentage of households whose share of energy expenditure in income is more than twice the national median share, thereby capturing households that allocate a remarkably high share of income to energy" [48]. The biggest drawback of this indicator is that it obscures the cause of overspending: it is unclear whether this is the result of a very high standard of living (e.g. heated swimming pool, sauna, carport) or low energy efficiency [18]. Nonetheless, it applies national data to determine the equity threshold, thereby capturing a distinctive snapshot of how households in a country commonly balance their needs.

A new fuel poverty metric, the so-called Low Income Low Energy Efficiency (LILEE) has been used in England (UK) since 2021 and has been planned to overcome the disadvantages of the indicators presented earlier. The index is based on the assumption that energy poverty is determined by three main factors: household income, household energy requirements (called Fuel Poverty Energy Efficiency Rating) and fuel prices [79,80]. Based on it, a household is considered to be fuel poor if it meets two thresholds:

1. The property has an energy efficiency rating of band D or below [79]. This band D means 151–230 kWh/m^2/year primary energy demand.
2. *And* spending the required amount to heat their home, they get below the official poverty line [79].

The latter is very important because it means that energy poverty is not approached through actual energy expenditures, but the calculation is based on required fuel costs according to the energy efficiency of the home. This way, it is possible to avoid underestimating energy poverty by excluding groups that already limit their energy consumption by applying different coping strategies [81].

3.2. Determining the energy equity threshold

The energy poverty literature describes the energy poverty premium as the double burden that poor households both pay and experience: those on low incomes pay more for equivalent energy services than those on higher incomes [21]. In this study, the energy poverty premium refers to the additional required energy-cost burden associated with poor building energy performance, expressed relative to household income. Its magnitude captures both the depth of energy poverty, often termed the energy poverty gap, and the regressive effect of low energy efficiency on households with limited financial resources [48].

This study combines the LILEE approach with the 2 M indicator to develop an energy equity threshold and measure the energy poverty premium. To overcome the limitations of the 2 M indicator, we incorporate building energy efficiency—an element of the LILEE index—thereby developing a two-dimensional energy equity threshold. A household is considered to face an inequitable energy burden, and thus to pay an energy poverty premium, when two conditions are met simultaneously: first, its required energy expenditure exceeds the applicable 2 M; and second, it occupies a dwelling with an energy performance worse than the specified efficiency category. The first condition identifies a disproportionately high energy burden relative to income, whereas the second links this burden to structural inefficiency rather than to discretionary or luxury energy use.

Fig. 2 illustrates this relationship. The thick, horizontal black line represents the energy equity threshold, while the upward-sloping line indicates worsening building energy performance. The shaded area above the energy equity threshold line denotes situations in which required energy costs exceed an equitable share of household income. Within this area, poorer building performance increases both the likelihood and magnitude of the energy poverty premium, illustrating its regressive nature, as lower-income households bear a disproportionate burden.

Conversely, households below the energy equity threshold are assumed to pay an equitable share of their income for the required energy services of their energy-efficient dwelling. This does not mean that their energy expenditure is necessarily low in absolute terms, nor does it imply that all energy consumption below the threshold is socially or environmentally desirable. Rather, it indicates that the required energy burden is not disproportionate in relation to household income and dwelling efficiency.

The energy equity threshold is an analytical tool for identifying the intersection of inadequate affordability and poor housing energy performance, and for distinguishing the regressive energy burden faced by low-income households from high consumption that is primarily linked to affluence. This distinction is especially relevant in Hungary, where uniform subsidized energy prices may reduce nominal prices while leaving the underlying inequalities of income and housing quality unresolved.

4. Data and methodology

Our study is based on three main data sets: 1) household net income, 2) average size and energy efficiency of dwellings, 3) electricity and gas prices in the household sector. Only electricity and natural gas are considered in this analysis. On the one hand, they represent the prevailing energy sources among Hungarian households, together accounting for 66.51% of the residential energy mix. On the other hand it is a desirable societal goal to move up the energy ladder and leave behind the low-quality fuels which accounted for 31.4% of space-heating energy consumption in Hungary in 2022 [54,82,83].

The data used is presented in detail in Table 4. During the selection, we followed the indicators used in the LILEE index. All data refer to the year 2023.

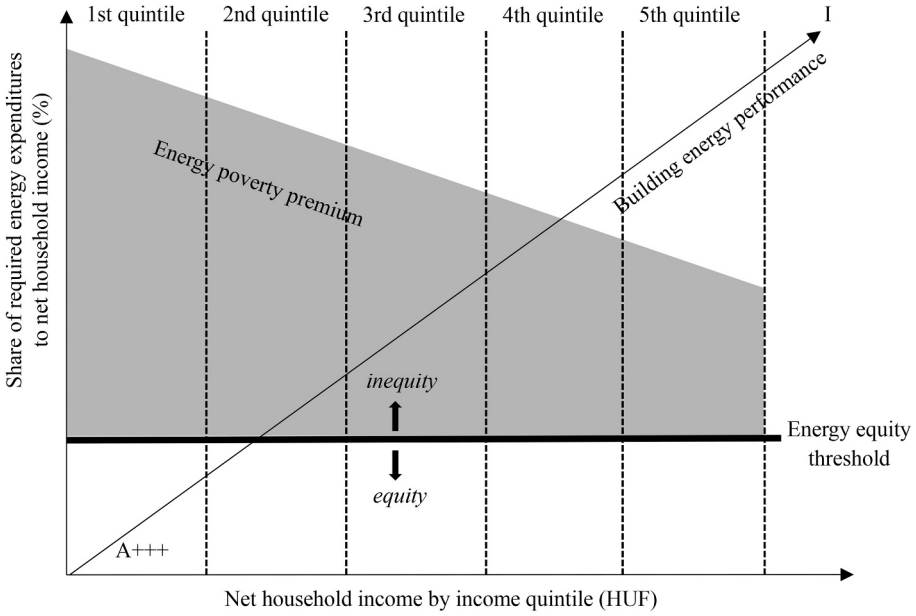


Fig. 2. Conceptual approach of the energy poverty premium and energy equity threshold.

Table 4
Applied data.

Data group	Indicator	Source
Net income of households	Net income per capita by income quintiles [HUF/person/year]	[84]
	Net income of households with or without children or single person [HUF/person/year]	
	Net income per capita of active, retired, unemployed and other inactive households [HUF/person/year]	
Average size and energy efficiency of dwellings	Number of households and persons by income quintiles	
	- Number of households, grossed up - Number of persons, grossed up - Average size of households [number of persons]	
	Number of households and persons with or without children as well as one-person households	
	- Number of households, grossed up - Number of persons, grossed up - Average size of households [number of persons]	
	Number of active, retired, unemployed and other inactive households and persons	
	- Number of households, grossed up - Number of persons, grossed up - Average size of households [number of persons]	
	Average size of dwelling by income quintile and tenure status [m^2]	[32]
	Number of new energy performance certificates in 2022–2023 by county level	[60]
Electricity and gas prices	Gas and electricity prices in the household sector [HUF/m^3 and HUF/kWh]	[31]
	Gas and electricity consumption limits for households [m^3 and kWh]	

Table 5
The examined type of consumers.

Type of households with or without children or single person	Type of households by economic activities
Households with dependent children: single person, at least one dependent child (Gr.1.)	Active households, total
Households with dependent children: two adults, one dependent child (Gr.2.)	Pensioner households, total
Households with dependent children: two adults, two dependent children (Gr.3.)	Unemployed households, total
Households with dependent children: two adults, three or more dependent children (Gr.4.)	Other inactive households, total
Other household with dependent children (Gr.5.)	
Total of households with dependent children (Gr.6.)	
Households without child: single person households (Gr.7.)	
Households without child: two adults without children, both adults younger than 65 years (Gr.8.)	
Households without child: two adults without children, at least one of them aged 65 years or older (Gr.9.)	
Other households without child (Gr.10.)	
Total of households without child (Gr.11.)	
Total of single person households (Gr.12.)	
Single person households, male (Gr.13.)	
Single person households, female (Gr.14.)	
Single person households, persons younger than 65 years (Gr.15.)	
Single person households, 65 year-old or older persons (Gr.16.)	

Households are classified as follows (Table 5), based on the classification used by the Hungarian Central Statistical Office: regions, income quintiles, economic activities (active, retired, unemployed and other inactive households) and type of households (households with or without children or single person) in order to examine in detail the situation of vulnerable consumers [85].

Since our data refer to the year 2023, we use the energy performance certificates valid at that time (Table 6). This decision is further justified by the fact that the new classification system (valid from 2024) has become much stricter without being accompanied by a significant renovation wave, meaning that the energy efficiency of existing buildings has not kept pace with regulatory changes. There is also less differentiation for the worst energy-performing buildings, merging the HH-II-JJ categories into one. However, taking this change into account, we provide our policy recommendations for these new energy performance standards.

A minimum and maximum primary energy consumption is assigned

Table 6
Energy performance certificate classifications (comparison of old and new energy ratings).

Old classifications (valid between 2016 and 2023)		New classifications (valid from 2024)	
Energy ratings	Overall energy performance	Energy ratings	Overall energy performance
AA++	0–40 kWh/m^{2}a	A+++	0 kWh/m^{2}a
AA+	40–60 kWh/m^{2}a	A++	0–38 kWh/m^{2}a
AA	61–80 kWh/m^{2}a	A+	39–68 kWh/m^{2}a
BB	81–100 kWh/m^{2}a	A	69–76 kWh/m^{2}a
CC	101–130 kWh/m^{2}a	B	77–99 kWh/m^{2}a
DD	131–160 kWh/m^{2}a	C	100–122 kWh/m^{2}a
EE	161–200 kWh/m^{2}a	D	123–152 kWh/m^{2}a
FF	201–250 kWh/m^{2}a	E	153–190 kWh/m^{2}a
GG	251–310 kWh/m^{2}a	F	191–236 kWh/m^{2}a
HH	311–400 kWh/m^{2}a	G	237–296 kWh/m^{2}a
II	401–500 kWh/m^{2}a	H	297–380 kWh/m^{2}a
JJ	501- kWh/m^{2}a	I	381- kWh/m^{2}a

Source: own compilation based on [86].

to each energy rating (we use the minimum values in our calculations). Overall energy performance means the primary energy consumption per unit of floor area per year that is used for space heating, space cooling, water heating, and lighting, excluding cooking and other electric appliances [87]. The measurement unit for this is kWh/m^{2}a (kilowatt-hours per square meter per year). This indicator provides a good approximation of a household's energy use, as it covers those household activities that account for around 85% of total household energy consumption (see Appendix, Table 11). When determining the overall energy performance and thus the energy rating, the condition of the heating system, the domestic hot water system, the ventilation system, the cooling system and the lighting system are also taken into account [87]. We note here that the LILEE index in England is structured in exactly the same way methodologically.

The calculations are performed using the following formulas:

$$NIH_i = SIZE_i{*}INC_i$$

where: NIH_i is the net income per household i, $SIZE_i$ is the average size of household i, and INC_i is the net income per capita in household i.

In this study, data relating to natural gas are typically given in m^3. While the utility cost reduction program calculates with an exceptionally high calorific value for natural gas (1 m^3 = 36.81 MJ = 11.33 kWh) [31]. Until then, we considered a lower value to be desirable, following other benchmark studies [88]. The average annual combustion rate used for the conversion: 1 m^3 = 34 MJ = 10.46 kWh [89]. Each household (i.e., consumer point) is entitled to a total of 20,611 kWh of discounted energy (of which 2523 kWh is electricity and 18,088 kWh is natural gas). The total cost of it ($EE_{max,cap}$) is HUF 267,186 (~668 EUR).

$$EE_{max,cap} = 36\ HUF{*}2523\ kWh + 102\ HUF{*}1729\ m^3 = 267,186\ HUF$$

M_i is the ratio of electricity and gas expenditure at the upper limit of the discounted residential tariff band to household i's net income:

$$M_i = \frac{EE_{max,cap}}{NIH_i}{*}100$$

Here we note that detailed data on household electricity and gas consumption are available at various regional levels, but we do not know how much is sold at discounted prices, what proportion of households fall within the discount band, and what percentage must pay market prices for electricity and natural gas. However, we know from our previous analysis [82] that the majority of households can remain within the discount band, its upper limit may be interpreted as the national median, hereinafter referred to as M.

Detailed (actual) household energy expenditure data have been also unavailable since 2020, following the discontinuation of consumption diaries in the Household Budget Survey [84]. To fill up this data gap, our methodology is based on the required energy expenditure according to the energy rating of the buildings. From this, the Energy Affordability Ratio ($EAR_{i,k,l}$) can be calculated using the following equation:

$$EAR_{i,k,l} = \frac{EE_{max,cap} + (SIZE_i{*}CATEFF_k - 20,611){*}ENPRICE_l}{NIH_i}{*}100$$

where: $SIZE_i$ is the average size of household i (m^2), $CATEFF$ is the minimum energy consumption (kWh/m^{2}a) by energy rating k (AA++, AA+, AA, BB, CC, DD, EE, FF, GG, HH, II, JJ), $ENPRICE$ is the market-based price by l fuel (i.e. electricity, gas).

$PP^{rel}_{i,k,l}$ is the energy poverty premium paid by household i, living in a dwelling with k energy rating using fuel l:

$$PP^{rel}_{i,k,l} = \frac{\left[EE_{max,cap} + (SIZE_i{*}CATEFF_k - 20,611){*}ENPRICE_l\right]}{NIH_i}{*}100 - 2M$$
$$= EAR_{i,k,l} - 2M$$

The energy poverty premium indicates how much more a household in a less energy-efficient dwelling pays compared to others whose consumption remains below twice the national median. It can be measured in percentage (%) and derived from this, in national currency (HUF) too ($PP^{abs}_{i,k,l}$).

$$PP^{abs}_{i,k,l} = \frac{PP^{rel}_{i,k,l}}{100}{*}NIH_i$$

The following assumptions were used in the calculations:

- households optimize their use of electricity and natural gas available at discounted prices to remain within the discount band;
- households use the maximum amount of energy available at a discounted price and meet any demand above this with electricity or gas purchased at market prices.

5. Results

5.1. Energy affordability and energy poverty premium in different income quintiles

The ratio of electricity and gas expenditure at the upper limit of the discounted residential tariff band to net household income (M) is low (4.67%) without significant regional differences (Appendix, Fig. 5). We hereafter consider this 4.67% as the national median of the energy affordability ratio in 2023 and 2 M is twice this amount ($2\,M = 4.666\%{*}2 = 9.33\%$). At current residential energy prices, 2 M is equal to 2*267,186 HUF = 534,372 HUF. In the following section we focus on income quintiles and the vulnerable social groups.

To determine the energy affordability ratio and the energy poverty premium calculated for income quintiles, we use data on average dwelling size [32]. While the national average in 2023 is 90.5 m^2, the 4th and 5th income quintiles live in larger properties (see Appendix, Table 12).

We continue our calculations by examining income quintiles (Table 7). Note that even for households living in EE-rated buildings, the amount of energy available at discounted prices is sufficient. If they consume the maximum of this amount, the energy affordability ratio will be 9.53% in the poorest income quintile and 3.16% in the wealthiest. 1st quintile already signals affordability problems: the value (9.53%) exceeds the $2\,M$. Although, owing to their smaller dwelling size, households in the 1st quintile can meet their energy needs within the discount band even in GG-rated buildings, this is true only up to EE-rated dwellings for the 5th quintile. From the FF category onwards, the 5th quintile exceeds the discount band because of their larger floor area.

In case of those living in HH, II, and JJ-rated buildings, the EAR exceeds twice the median for the given quintile, and is highest (61.52%)

Table 7
Energy affordability ratio by energy rating of buildings and income quintiles (*EAR*, 2023, %).

	1st income quintile	2nd income quintile	3rd income quintile	4th income quintile	5th income quintile	Total
Share of the maximum discounted energy costs in net household income	9.53	5.75	5.02	4.60	3.16	4.67*
	*Electricity***					
FF	9.53	5.75	5.02	4.60	3.22	4.67
GG	9.53	7.10	6.94	8.08	7.48	7.24
HH	21.68	14.86	13.89	14.85	12.60	13.89
II	40.10	26.49	24.32	25.01	20.27	23.86
JJ	60.57	39.41	35.91	36.31	28.79	34.94
	*Gas***					
FF	9.53	5.75	5.02	4.60	3.22	4.67
GG	9.53	7.13	6.97	8.14	7.56	7.29
HH	21.90	15.02	14.05	15.04	12.77	14.06
II	40.67	26.87	24.68	25.39	20.59	24.22
JJ	61.52	40.03	36.48	36.89	29.27	35.50

Note: grey colored cells indicate values where it is above 2 M.
* National median of the energy affordability ratio (*M*).
** The demand above the discount band is met fully with electricity or gas purchased at market price.

for households in the 1st quintile in buildings with JJ energy ratings (Table 8). It raises serious affordability issues, making it likely that those living here face numerous problems. They are stuck at the bottom of the energy ladder, using low-quality energy sources, and are likely to face the 'eat or heat' dilemma [90]. Residents are often under-educated and lack stable income sources [44,45,83,91]. For these households, breaking out of this situation can only be achieved with complex assistance.

The analysis then turns to reverse the reasoning and examine the level of building energy performance that could be covered by energy expenditure equivalent to 2 M for each income quintile. Specifically, we estimate the maximum building energy performance level that a household could afford if it spent an amount equal to 2 M of its income on electricity and natural gas (Table 8). The result depends on whether the demand above the discount band is met fully with electricity or gas purchased at market price. Our calculations show that the 2 M is sufficient for an average energy performance of 269.07 kWh/m^{2}a (when excess demand above the discount band is met fully with gas at market price), and 269.84 kWh/m^{2}a when met with electricity (Its average, rounded to the nearest whole number, is 270 kWh/m^{2}a). The estimated values range from a minimum of 246.46 kWh/m^{2}a to a maximum of 272.7 kWh/m^{2}a. It should also be noted that households in the first quintile cannot fully benefit from the total amount of energy available at the subsidized price (without cost crossing the energy equity threshold). The energy expenditure associated with 2 M would be sufficient to cover an energy performance level of 246.46 kWh/m^{2}a.

Table 8
The maximum level of affordable energy performance (kWh/m^{2}a) taking into account the 2 M (%) and the average dwelling size (m^2) per income quintile.

	Gas (kWh/m^{2}a)*	Electricity (kWh/m^{2}a)*
1st income quintile	246.46	246.46
2nd income quintile	267.73	268.23
3rd income quintile	270.97	271.64
4th income quintile	261.34	262.11
5th income quintile	271.38	272.70
Total	269.07	269.84

Note: *The demand above the discount band is met fully with electricity or gas purchased at market price.

In the next step the energy poverty premium is estimated. We show how much more a household living in a property with poor energy efficiency (GG energy rating or worse) has to spend on energy than a household living in a property with better energy efficiency and staying under 2 M. The results for the 1st quintile are highlighted here (Fig. 3), more data is available in Appendix (Tables 13 and 14). The energy poverty premium is paid by households living in GG, HH, II or JJ-rated buildings. In relative terms the 1st quintile pays the highest energy poverty premium, in JJ-rated buildings it exceeds 50%. It can be concluded that there is no significant difference in terms of whether households use electricity or gas to meet consumption above the quantity available at the discounted price. In addition, it is important to note that the energy poverty premium increases at an accelerating rate (disproportionately) by energy ratings, which is a double burden.

Fig. 4 provides a summary of Tables 7, 8, and Fig. 3 (plus Tables 13 and 14 in Appendix) and assigns empirical results to the conceptual framework presented in Fig. 2. The black circle and the grey triangle indicate the EAR, that is, the share of required energy expenditures paid by a household in a given income quintile, depending on the energy rating of its dwelling (assuming that the household fully uses the amount of energy available at the subsidized price and meets any additional demand with natural gas or electricity at market price). The 2 M line indicate the energy equity threshold is set at a minimum of 246.46 kWh/m^{2}a and a maximum energy consumption of 272.7 kWh/m^{2}a, and furthermore 2 M equals 9.33%.

The figure also points to further imbalances. In Hungary, there is a large gap in net income per household between the 1st and 2nd quintiles on the one hand and the 4th and 5th quintiles on the other, while the net household income of the 2nd, 3rd, and 4th quintiles almost overlaps. This highlights deep social inequalities, with a very poor group at the bottom facing limited opportunities to move up. The figure also highlights the regressive impact: almost all households living in less energy-efficient dwellings pay a disproportionate amount for energy services.

5.2. Energy affordability and energy poverty premium in the most vulnerable household types

If we look at households raising children and single-person households (Table 9), we see exceptionally high EAR values (>60%) in the latter (Gr. 7, 12–16) and moderately high values (almost 50%) among those raising children alone (single parents – Gr.1). In their case, the same can be said for households with JJ energy rating, belonging to the 1st quintile: the EAR value is so high that it makes the use of higher quality fuels (gas and electricity) almost impossible. Residents need to adopt some kind of coping strategies, especially if they want to avoid the previously mentioned 'eat or heat' dilemma.

Breaking down households further by economic activity status (active, retired, unemployed, and other inactive households and persons), we find EAR values exceeding the 2 M for all unemployed and other inactive households (Table 10). While the active households pay more than double of the national median (2 M) in only under GG energy rating, in case of pensioner households this already happens under FF. Extreme cases (where EAR is close to 100%) can be found again in JJ energy ratings (for unemployed and other inactive households).

In Table 9, we identified a particularly high EAR in single-person households (Gr. 7, 12–16) and single parents (Gr. 1). In their case, we can speak of a remarkably high energy poverty premium as well. While in Gr. 1 the value is 39.54% (gas) and 38.76% (electricity) in the JJ category, in Gr. 7, 12–16 it exceeds 48% (Tables 15 and 16). In other words, households in these categories pay a very high surcharge because they live in buildings with extremely poor energy efficiency.

Excluding active households with minimum HH energy rating and pensioner households with minimum GG energy rating and properties of unemployed and other inactive households with better energy (minimum FF) performance, the energy poverty premium exceeds 10 percentage points in all other cases, and its value increases at a growing rate

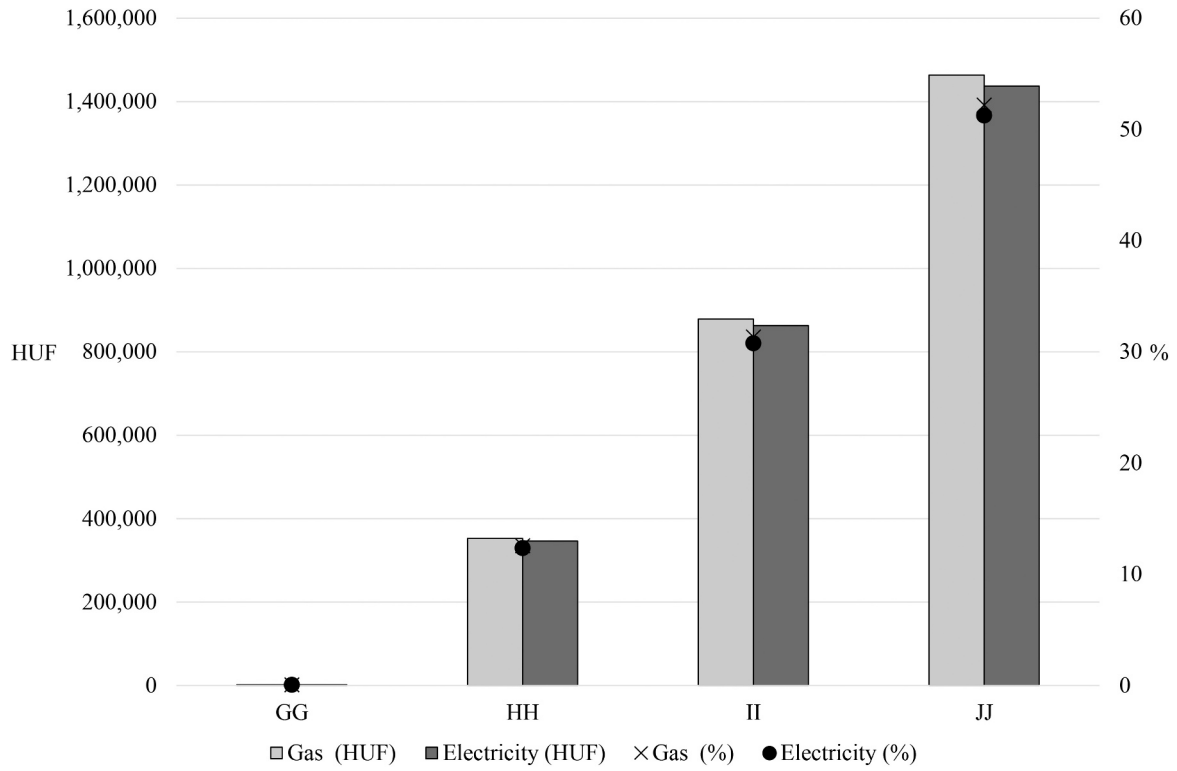


Fig. 3. Energy poverty premium in 1st quintile by fuel both in absolute and relative terms (PP, 2023, HUF, %).

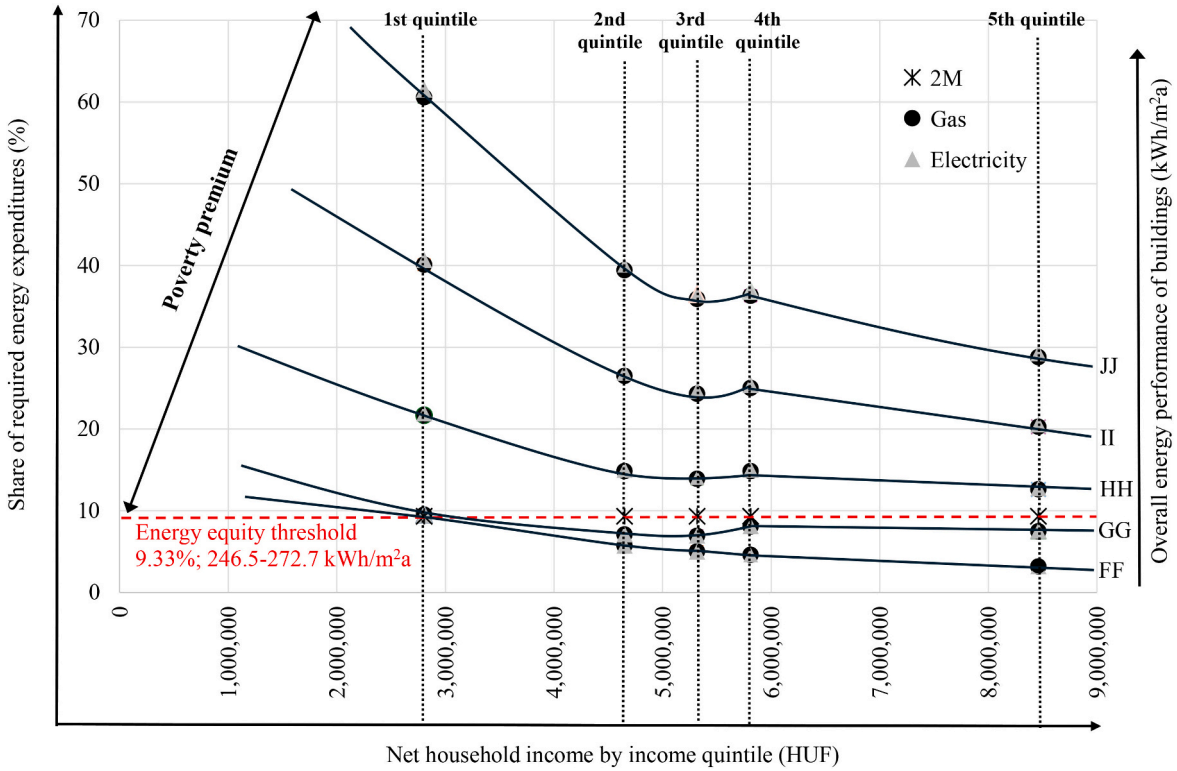


Fig. 4. Empirical illustration of the energy equity threshold and energy poverty premium.

by energy ratings (Tables 17 and 18). The unemployed and other inactive households are in the most difficult situation. This is related to the fact that strengthening the social safety net in Hungary is not a policy objective, as the 2022 amendment to the Social Act places the state last in the hierarchy of responsibility for social security - after the family, local governments, and churches - thereby primarily shifting the duty of care onto individuals [92]. According to Eurostat data, while expenditure on social protection as a percentage of GDP stood at 21.19% in 2012

Table 9
Energy affordability ratio in households with or without children as well as one-person households by energy rating of buildings (*EAR*, 2023, %).

	AA++, AA+, AA, BB, CC, DD, EE, FF	GG		HH		II		JJ	
	Mi	Gas*	Elec.*	Gas *	Elec.*	Gas*	Elec.*	Gas*	Elec.*
Gr.1 (single person, at least one dependent child)	6.42	10.03	9.97	19.35	19.12	33.33	32.84	48.86	48.09
Gr.2 (two adults, one dependent child)	3.89	6.07	6.04	11.72	11.57	20.18	19.88	29.58	29.12
Gr.3 (two adults, two dependent children)	3.3	5.15	5.12	9.94	9.82	17.12	16.87	25.1	24.7
Gr.4 (two adults, three or more dependent children)	3.27	5.11	5.07	9.85	9.73	16.97	16.72	24.87	24.48
Gr.5 (other household with dependent children)	2.91	4.54	4.51	8.76	8.65	15.09	14.86	22.12	21.77
Gr.6 (total of households with dependent children)	3.63	5.67	5.64	10.94	10.81	18.85	18.57	27.63	27.19
Gr.7 (single person households)	8.55	13.36	13.27	25.76	25.45	44.36	43.71	65.04	64.01
Gr.8 (two adults<65 without children)	4.06	6.35	6.31	12.25	12.1	21.09	20.78	30.92	30.43
Gr.9 (two adults without children, at least one of them aged 65 years or older)	4.85	7.58	7.53	14.62	14.44	25.18	24.81	36.92	36.33
Gr.10 (other households without child)	3.04	4.75	4.72	9.16	9.05	15.78	15.55	23.13	22.77
Gr.11 (total of households without child)	5.33	8.33	8.27	16.06	15.87	27.66	27.26	40.55	39.91
Gr.12 (total of single person households)	8.55	13.36	13.27	25.76	25.45	44.36	43.71	65.04	64.01
Gr.13 (single person households, male)	7.77	12.14	12.06	23.42	23.13	40.33	39.74	59.13	58.19
Gr.14 (single person households, female)	9.17	14.32	14.23	27.63	27.29	47.58	46.88	69.76	68.65
Gr.15 (single person<65 households)	7.97	12.46	12.37	24.02	23.73	41.38	40.77	60.66	59.7
Gr.16 (single person>65 households)	9.2	14.37	14.28	27.72	27.38	47.73	47.03	69.98	68.87

Note: grey colored cells indicate values where the value is above 2 M (>9.33%); average size of dwelling is 90.5 m^2.
* The demand above the discount band is met fully with electricity or gas purchased at market price.

Table 10
Energy affordability ratio in active, retired, unemployed and other inactive households by energy rating of buildings (*EAR*, 2023, %).

	AA++, AA+, AA, BB, CC, DD, EE, FF	GG		HH		II		JJ	
	M_i	*Gas**	*Elec.**	*Gas**	*Elec.**	*Gas**	*Elec.**	*Gas**	*Elec.**
Active households	3.92	6.12	6.08	11.80	11.66	20.33	20.03	29.80	29.33
Pensioner households	7.43	11.61	11.53	22.39	22.12	38.57	38.00	56.54	55.65
Unemployed households	13.19	20.60	20.47	39.74	39.25	68.44	67.43	100.33	98.74
Other inactive households	14.10	22.03	21.88	42.49	41.97	73.18	72.10	107.27	105.58

Note: grey colored cells indicate values where the value is above 2 M (>9.33%); average size of dwelling is 90.5 m^2.
* The demand above the discount band is met fully with electricity or gas purchased at market price.

(compared to a significantly higher European Union average of 28.43%), this figure had declined to 16.79% by 2023 (with the EU average at 27.83%) [32].

6. Discussion and policy recommendations

Combining the energy poverty premium with the energy equity threshold provides a metric to understand when required energy costs exceed an equitable share of household income. Poorer building performance, as established by building standards, determines the likelihood of energy poverty and the disproportionate burden low-income households bear compared to energy-affluent households with higher income. The energy equity threshold is not an arbitrary line but takes into account the best available technology for buildings, as reflected in their energy rating, along with household income, and share of energy expenditure. The results from Hungary indicate the energy burden on households is disproportionate to income which means universally low energy prices benefit the energy affluent by dissuading the adoption of energy efficient technologies while keeping lower income households in energy poverty. These 'houses of pain,' where, for the worst-off households, energy requirements exceed income, highlight the inequity present among Hungarian households. A more thorough analysis is provided by answering the three research questions.

The first research question asks, 'What is the energy equity threshold beyond which the energy burden becomes unequal and results in households paying an energy poverty premium?' The energy equity threshold is determined by two dimensions: 1) the energy efficiency of the building and 2) the share of required energy expenditures to net household income (energy affordability ratio). So, considering paying the energy poverty premium, a household's overall energy performance must be worse than 270 kWh/m^2a and energy affordability rate must be above 2 M (under the current pricing and regulatory framework, it is 9.33%).

The energy performance of buildings is key to keeping the energy affordability ratio under 2 M for all social groups. This ratio is critical to deliver both an equitable energy system that accounts for Hungary's building types and salary levels. Households living in buildings with poor energy efficiency - defined as energy performance exceeding 270 kWh/m^2a, a category in which most Hungarians reside regardless of income - pay a significantly higher energy poverty premium. This reflects an energy equity approach by reducing inequalities in access to adequate energy services while also improving the overall efficiency of the energy system. Parsing the data using the energy equity threshold addresses the need to account for differences in people's starting points, which have not been properly addressed in energy equity metrics [4]. We do this by accounting for income and the energy performance of buildings, thereby producing an energy equity threshold, which identifies who is paying a poverty premium for energy services.

The second research question can also be answered: 'How much of an energy poverty premium does a household pay for a home with poorer energy efficiency?' According to our calculations, the ratio of electricity and gas expenditure at the upper limit of the discounted residential tariff band to net household income is 4.67% with low regional differences. However, this initially positive picture is significantly shaded when we differentiate the calculations according to income quintiles and the energy efficiency of buildings. Discounted prices ensure affordable energy services up to overall energy performance level of 270 kWh/m^2a (considering the average size of Hungarian dwellings), but above that the consumers increasingly have to pay unrealistically high, regulated, and artificially set market prices.

For the 1st income quintile the ratio of electricity and gas expenditure at the upper limit of the discounted residential tariff band to net household income is 9.53%, which exceeds twice the national median (2 M = 9.33%) indicating affordability problems. This also explains the problem presented in the authors' earlier studies [82], namely, why poorer households use low-quality fuels at a significantly higher rate, including their continued reliance on firewood. For them, the use of higher-quality energy sources is not a matter of choice, but rather a necessity due to their unaffordability. In buildings with the worst energy rating, households in the 1st income quintile would have to spend 60.57%–61.52% of their income on electricity and gas to meet the energy needs of their homes. However, our results are slightly more favorable than Antunes et al.'s [48] findings. According to their calculations, the average energy affordability ratio was 10.6% in 2015 in Hungary, with a maximum value of 87.8% and a minimum value of 0.2%. These results also indicate the lack of the *"fair distribution of benefits and burdens"*[13] .

The high energy affordability ratio is associated with a high energy poverty premium for households living in the worst-performing buildings. The energy poverty premium offers a measurement of equity in the energy system. It could even rise to 50% for many in the lowest quintile, while around 25–30% for the 2nd to the 4th quintiles. The latter means that instead of a 4.6–5.75% energy affordability ratio, they face a 36.89–40.03% ratio, and they have to spend 25–30 percentage points more on energy services. This estimated magnitude of energy poverty premium exceeds values reported in the literature; for instance, Rasanga et al. estimate it at between 10% and 20% in the UK [21].

The analysis clearly confirms the third research question, 'Is there a regressive impact of lower energy efficiency on the poorest households, and do lower quintiles pay a higher energy poverty premium?' Our results highlight that Hungarian households living in the worst-performing buildings pay a disproportionate share of their income for energy services. This amount is regressive and indicates the double burden poorer households carry: the lower a household's income and the poorer the energy efficiency of the property where they live, the higher the proportion of expenditure spent on energy. Their low incomes force them to spend much of their budget on energy, or to live in physical (and mental) discomfort due to the energy inefficiency of their homes [46]. A disproportionate, and even a high amount of income, is necessary to meet household energy needs. Even affluent households face high electricity and gas costs when they in energy-inefficient homes. It follows from this finding that Engel's law applies not only to food-related consumer expenditures, but also to energy costs: the poorer households pay more not only for food, but for energy services as well.

Beyond income quintiles, we identified five types of households which are more affected by the unequal energy burdens: 1) single person households with at least one dependent child, 2) other single person, 3) pensioner, 4) unemployed and 5) other inactive households. These result in such extreme cases that even the total income of households would not be sufficient to meet the energy needs of the property, with the energy affordability ratio exceeding 100%. This is consistent with the results of international research, with Haffner and Boumeester also identifying older singles and single-parent households as particularly vulnerable [77].

6.1. Policy recommendations

This study confirms that the energy poverty premium resulting from the combination of low energy efficiency and low income (i.e. the additional costs paid by households), is significant and represents a double burden, which is unlikely to change without targeted measures and comprehensive energy efficiency programs. While, as a flagship propaganda tool, the utility cost reduction program remains politically popular and largely untouchable (even if it seems in Hungary's new Tisza party government, which has so far approached it cautiously), it poses a significant obstacle to systemic reform. Its fiscal burden, combined with its distortion of energy pricing signals, continues to impede progress towards a more sustainable and equitable energy system. At the same time, its transformation appears unavoidable; accordingly, we propose the following recommendations:

1) The immediate reform of the utility cost reduction program, whose long-term sustainability has already become questionable, is necessary. The main question is: how should the utility cost reduction program be restructured to be more equitable? The program should not merely treat the symptoms but reduce the real cost of consumption, increase the energy resilience of households and reduce energy poverty. Keeping in mind the principle of 'different social groups need different incentives,' the household energy prices have to be differentiated. It means that subsidies should be made more progressive, and that additional consumption above the energy equity threshold should be more progressively expensive. Implementation of an increasing 'block tariff regime', where higher consumption blocks subsidize lower ones [93] redistributes the social costs of energy inequity. To implement this, additional consumption bands should be set, and household consumption volumes should be reviewed regularly.
2) Policymakers should establish a statutory definition of energy poverty and revise the category of vulnerable households on the basis of the two conditions defining the energy poverty premium: 1) a dwelling's energy performance must be worse than 270 kWh/m^{2}a, and 2) the share of required fuel costs to net household income, calculated according to the dwelling's energy rating, exceeds the 2 M. A social energy tariff – following the UK example – could then be targeted at households meeting both criteria. Implementing this approach would require comprehensive energy assessments of residential buildings, the wider issuance of energy performance certificates, and completion of the e-energy certification database.
3) We recommend launching Time of Use pilot projects for electricity, in which, for example, existing energy communities and municipalities with Sustainable Energy and Climate Action Plans in force (i.e., those already committed to green goals) would divide the day into specific billing periods. It generally means that peak prices are highest and off-peak prices are the lowest, between them we find a 'standard flat rate' (mid-peak) [94]. Increasing use of smart meters and other devices would enable consumers to play a more active role in electricity systems would strengthen the energy citizenship [94].
4) As demonstrated by our calculations, keeping residential energy prices low and reforming the programme are not sufficient to alleviate energy poverty, whose main drivers in Hungary are currently low energy efficiency and low disposable income. Consequently, in the medium and long term, energy policy efforts should focus on improving the energy efficiency of buildings and promoting deep renovations. Dwellings that have undergone deep renovation can more easily switch to alternative heating fuels, phasing out low-quality fuels through upgrades to the electricity network and heating system. A wide range of strategies (e.g. updated version of National Energy and Climate Plan, National long-term renovation strategy 2020) [50,95] and policy proposal packages [61,62] are already available in this area; therefore, we do not elaborate on the details here.

6.2. Contribution of energy equity and limitations

This paper started off with an axiom that "*equity and energy can grow concurrently only to a point*" [1]. The results above demonstrate that the point of departure of equity is 270 kWh/m^{2}a in a Hungarian dwelling. "*Equity recognizes that each person has different needs*" [4]. Therefore, this study has taken into account the different compositions of households, such as single, with or without children, or retired, in addition to income, dwelling size, and efficiency. Building on previous threshold research [6,7], the energy performance of dwellings delivers a metric to

measure consumption against these other variables thus assessing the different needs against the set energy costs of a home. Using the energy equity threshold identifies the real energy efficiency gap between technologies in use, the best available, and the circumstances of inhabitants [33,see 77,78].

Drawing on Illich's philosophical approach, which holds that energy affluence means less control over energy [1], we can simplify this to argue that energy consumption above a threshold is wasted because production or consumption avoids the best available technologies. "*Below a threshold of per capita wattage*" the condition for social progress exists [1]. However, living below the threshold means people live in their houses of pain marked by their payment of a poverty premium, while energy affluence is unnecessary for households with high income and inefficient energy technology [7]. Moral claims for greater energy equity can be linked to the redistribution of energy resources and assessed using HDI, GDP, and social frameworks, such as the Capabilities Approach [7,68,69]. This moral framing requires further investigation and expansion outside of this paper, particularly in connecting energy equity to energy justice [4,13,24]. In addition, other authors provide a good starting point for further refinement of the relationship between energy equity and energy poverty. [96–99]. The strength of energy equity is the quantification and evaluation methods that dig deeper, exposing, for example, why there is an energy efficiency gap and what inhibits wider deployment of more efficient technologies [73,74,100]. This meets the call for the development of an energy equity framing, similar to those in public health, the environment, and education [4]. Determining where energy affluence lies, based on both technical and moral claims, helps build a more efficient and equitable energy system.

This article contributes to the literature on energy thresholds and HDI-GDP decoupling, along with post-growth studies [5–8,11,101]. It does so at the scale of the home to demonstrate how to deliver energy equity within concrete, measurable system boundaries. We demonstrate that a minimal feasible amount of power suffices to meet basic needs for all households. Further research could explore the secondary impacts or policy choices of ensuring a basic energy consumption threshold for all households. This paper contributes to the role that energy equity [4,13] plays in an 'optimal house', highlighting the energy efficiency gap, which is normally obscured by government subsidies and other market-distorting measures [16,74]. While also acknowledging convergence of equity and energy services for all households, irrespective of background or income. Further research needs to capture the equity dynamics between households and the factors preventing building or renovating towards an optimal house, where energy use is low but technological efficiencies and energy services are high (See Table 3). This article has identified the threshold where income, energy demand, and quality of a building is optimal for social equity in Hungary. Replicating this exercise in other countries or regions could contribute to improving energy equity for many more households.

There are further limitations to this study. Empirically, our calculations are based on secondary, cross-sectional data. Due to limited data availability on actual household energy expenditure and electricity and gas consumption within the discounted tariff band, the analysis relies on required fuel costs by building energy ratings. Furthermore, only electricity and natural gas are considered among household energy sources, assuming that households fully utilize the discounted amounts of electricity and natural gas and cover any consumption above this threshold with either electricity or natural gas. Finally, the study does not account for differences in expenditure structures and energy consumption between urban and rural areas, nor for variations in heating systems. The detailed development and impact assessment of the policy recommendations (listed in Section 6.1) lie beyond the scope of this study; however, we consider such an analysis indispensable before any decisions are taken.

7. Conclusion

The starting point of this article was a century-old policy and technical struggle with energy and equity [1–4,13]. In the context of low energy prices and energy-inefficient buildings, increasing energy consumption does not equal an equitable energy system. The renewed interest due to climate change and the energy crises of the 2020s requires both conceptual and methodological developments [4]. In this paper, we introduce three new indicators: the energy affordability ratio, the energy equity threshold, and the energy poverty premium. We determine the national energy affordability ratio (4.67%). Twice this value (2 M), combined with an overall energy performance of 270 kWh/m^{2}a, defines the energy equity threshold. It shows the extent of poor energy efficiency at which meeting buildings' energy needs becomes an affordability problem, and it enables quantification of the energy poverty premium. It confirms that lower energy efficiency has a regressive impact on the poorest households and that lower quintiles pay a higher energy poverty premium.

The houses of pain are marked by high poverty premiums paid by low-income households for energy wasted due to inefficient homes. Although household gas and electricity prices in Hungary were among the lowest in the EU in 2025, energy affordability remains a serious challenge. This underscores that low-regulated prices alone do not prevent energy poverty in the absence of an energy-efficient housing stock, nor an equitable energy system. Uniform regulated prices and related subsidies produce inequitable outcomes, disproportionately benefiting higher-income households, while lower-income households - typically living in less energy-efficient dwellings – bear a higher energy burden and pay a larger energy poverty premium.

From a policy perspective, further work should be carried out to reform the utility cost-reduction program. We consider it particularly important (along the lines outlined in Subsection 6.1) to develop a model of consumption patterns associated with different price levels. The introduction of a social energy tariff also requires careful preparation; in designing such a scheme, the involvement of affected stakeholders and the establishment of a simplified application and assessment system are of particular importance. The application of this research to other countries should be conducted to guide policy-making in identifying the energy equity threshold for effective policy intervention. This focus on energy equity builds on the premise that people have different starting points and energy consumption needs, and therefore require differentiated opportunities and support schemes [4]. Bringing relief to people living in these 'houses of pain' highlights how a focus on energy equity can reduce energy consumption for all while improving or maintaining energy services in the home.

CRediT authorship contribution statement

Tekla LaBelle-Szép: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Michael Carnegie LaBelle:** Writing – review & editing, Writing – original draft, Validation, Supervision, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Tekla LaBelle-Szep reports a relationship with Hungarian Academy of Sciences that includes: funding grants. The other authors have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

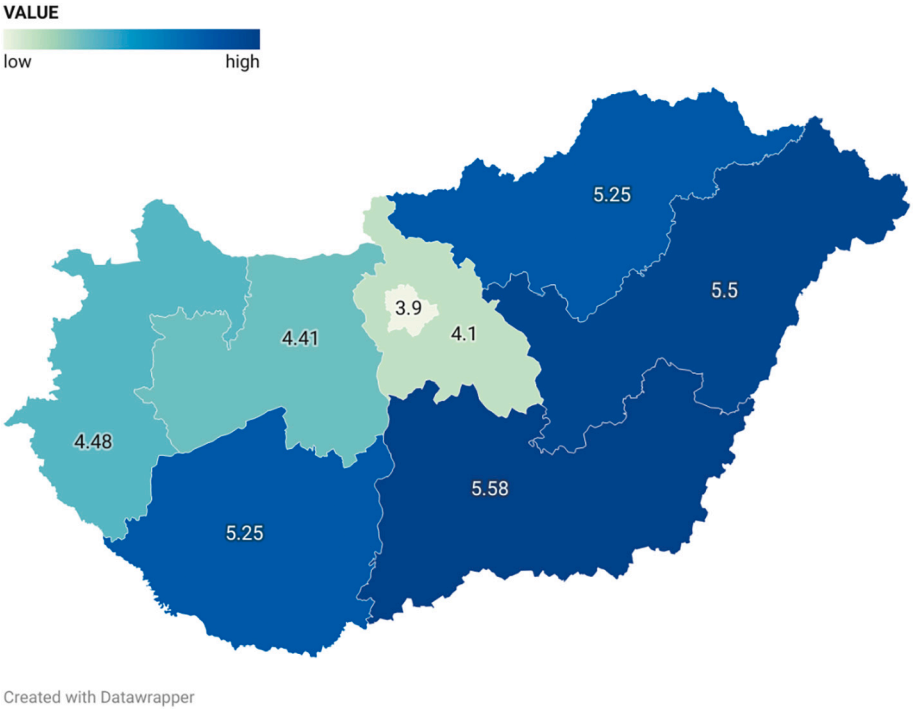


Fig. 5. The ratio of electricity and gas expenditure at the upper limit of the discounted residential tariff band to net household income by NUTS-2 regions (M_{total}, 2023, %).

Table 11
Final energy consumption of households in Hungary, by energy source and type of use (2023, %).

	Space heating and cooling	Water heating	Cooking	Lighting and appliances	Total
Electricity	4.19	38.67	18.24	100.00	20.08
Derived heat	8.54	15.03	0.00	0	8.04
Natural gas	53.26	41.55	62.89	0	46.43
Coal and coal products	0.86	0.00	0.00	0	0.60
Oil and petroleum products	0.05	0.80	18.76	0	1.19
Renewables	33.10	3.95	0.12	0	23.66
Share of final energy consumption by type of use	69.79	13.87	5.56	10.78*	100.00

Source: [33].
Note: *of which 1–2 percentage points are used for lighting.

Table 12
Average size of dwelling (m^2) in 2023.

	Total	1st quintile	2nd quintile	3rd quintile	4th quintile	5th quintile
Size	90.5	81.9	85.7	87.9	93.6	102.9

Source: [32].

Table 13
Energy poverty premium in absolute terms (by income quintile, *PP*, 2023, HUF)*

	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity
GG	1662	1733								
HH	352,595	346,224	264,853	256,933	251,339	242,521	331,970	320,830	291,228	276,295

(*continued on next page*)

Table 13 (*continued*)

	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity
II	878,994	862,960	815,676	797,645	816,302	797,114	933,570	911,386	952,601	925,528
JJ	1,463,882	1,437,112	1,427,702	1,398,436	1,444,039	1,413,328	1,602,013	1,567,559	1,687,461	1,646,898

* The demand above the discount band is met fully with gas or electricity purchased at market price.

Table 14
Energy poverty premium in relative terms (by income quintile, *PP*, 2023, %)*

	1st quintile		2nd quintile		3rd quintile		4th quintile		5th quintile	
	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity	Gas	Electricity
GG	0.06	0.06								
HH	12.57	12.35	5.70	5.53	4.73	4.56	5.71	5.52	3.44	3.27
II	31.34	30.77	17.54	17.16	15.35	14.99	16.07	15.68	11.26	10.94
JJ	52.20	51.24	30.71	30.08	27.15	26.58	27.57	26.98	19.94	19.46

* The demand above the discount band is met fully with gas or electricity purchased at market price.

Table 15
Energy poverty premium in households with or without children as well as one-person households (Gas*, *PP*, 2023, %).

	Gr.1	Gr.2	Gr.3	Gr.4	Gr.5	Gr.6	Gr.7	Gr.8	Gr.9	Gr.10	Gr.11	Gr.12	Gr.13	Gr.14	Gr.15	Gr.16
GG	0.70						4.03					4.03	2.81	4.99	3.13	5.04
HH	10.02	2.39	0.61	0.52		1.61	16.43	2.92	5.29		6.73	16.43	14.09	18.30	14.70	18.39
II	24.00	10.85	7.79	7.64	5.76	9.52	35.04	11.76	15.86	6.45	18.34	35.04	31.01	38.26	32.05	38.41
JJ	39.54	20.25	15.77	15.55	12.79	18.30	55.72	21.59	27.59	13.80	31.23	55.72	49.80	60.44	51.34	60.66

* The demand above the discount band is met fully with gas purchased at market price.

Table 16
Energy poverty premium in households with or without children as well as one-person households (Electricity*, *PP*, 2023, %).

	Gr.1	Gr.2	Gr.3	Gr.4	Gr.5	Gr.6	Gr.7	Gr.8	Gr.9	Gr.10	Gr.11	Gr.12	Gr.13	Gr.14	Gr.15	Gr.16
GG	0.64						3.94					3.94	2.73	4.90	3.04	4.95
HH	9.79	2.24	0.49	0.40		1.48	16.12	2.77	5.11		6.54	16.12	13.80	17.96	14.40	18.05
II	23.51	10.55	7.54	7.39	5.53	9.24	34.38	11.45	15.48	6.22	17.93	34.38	30.41	37.55	31.44	37.70
JJ	38.76	19.79	15.37	15.15	12.44	17.86	54.68	21.10	27.00	13.44	30.58	54.68	48.86	59.32	50.37	59.54

* The demand above the discount band is met fully with electricity purchased at market price.

Table 17
Energy poverty premium in active, retired, unemployed and other inactive households (Gas*, *PP*, 2023, %).

	Active households, total	Pensioner households, total	Unemployed households, total	Other inactive households, total
GG		2.28	11.27	12.70
HH	2.48	13.07	30.41	33.16
II	11.00	29.25	59.12	63.86
JJ	20.48	47.22	91.01	97.96

* The demand above the discount band is met fully with gas purchased at market price.

Table 18
Energy poverty premium in active, retired, unemployed and other inactive households (Electricity*, *PP*, 2023, %).

	Active households, total	Pensioner households, total	Unemployed households, total	Other inactive households, total
GG		2.20	11.14	12.55
HH	2.33	12.79	29.92	32.64
II	10.70	28.67	58.10	62.77
JJ	20.00	46.32	89.41	96.25

* The demand above the discount band is met fully with electricity purchased at market price.

Data availability

Data will be made available on request.

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