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ENERGY POVERTY AND ITS SOCIAL, INCOME AND HOUSING DIMENSIONS: INSIGHTS FROM EUROSTAT DATA

Tibor László Csegődi
Hungarian University of Agricultural and Life Sciences, Szent István Campus, Gödöllő, Hungary

Abstract
Energy poverty is characterized by a household's inability to afford adequate energy services for a decent standard of living, extends beyond mere income deprivation, encompassing factors such as poor housing conditions, high energy prices, and inefficient energy consumption. Consequently, understanding and addressing energy poverty requires a holistic approach. energy poverty is also shaped by factors such as the energy efficiency of dwellings, the cost of energy, and individual energy consumption behaviors. Early scholarly contributions, notably Brenda Boardman's seminal work, established the foundational understanding of energy poverty as a condition where households are unable to afford adequate energy services to maintain a healthy and comfortable living environment. Building on Boardman's work, subsequent research has further refined these factors, integrating aspects like energy efficiency, housing quality, and the broader socio-economic context to provide a more nuanced understanding of energy poverty dynamics. The complexity behind the concept of energy poverty has led to varied measurement approaches globally, with no single, universally accepted standard for assessing energy poverty, leading to challenges in international comparability and policy implementation. Recognizing these complexities, the European Union has moved towards a more comprehensive understanding, seeking to integrate various dimensions into a cohesive Framework. The European Union's approach often incorporates metrics such as the inability to keep homes adequately warm, the presence of leaking roofs or damp walls, and high housing cost overburden rates to capture the lived experiences of energy-poor households. This research employs a methodology centered on four basic indicators extracted from Eurostat data, enabling a comprehensive examination of energy poverty's social, income, and housing quality components. Specifically, the selected indicators – percentage of total population living in a dwelling with structural defects, percentage of households unable to keep home adequately warm, and housing cost overburden rate – offer a framework for assessing the multifaceted nature of energy poverty across EU member states. The general trend indicates a slight improvement in the level of energy poverty across EU countries, albeit with persistent variations between the best and worst performers. While some policy measures may be effective broadly, others require refinement to address specific national or regional challenges. Furthermore, an increased focus on energy efficiency policies and renewable energy sources has been identified as a key driver for alleviating energy poverty, particularly in the long-term. This underscores the critical need for agile and adaptable policy responses that can swiftly address emergent challenges while fostering long-term resilience in energy systems.
Keywords: energy poverty, poor housing conditions, household income, home maintenance costs, energy efficiency.
JEL classification: Q48, Q58, I32

Introduction

Energy poverty, a multifaceted socioeconomic issue, has garnered increasing attention within the European Union due to its profound implications for household well-being, public health, and environmental sustainability (Oesterreich & Barej-Kaczmarek, 2024). This phenomenon, characterized by a household's inability to afford adequate energy services for a decent standard of living, extends beyond mere income deprivation, encompassing factors such as poor housing conditions, high energy prices, and inefficient energy consumption (Foster & Poston, 2023). The prevalence of energy poverty significantly impacts various facets of life, potentially leading to adverse health outcomes, social exclusion, and economic strain for affected households (Champagne et al., 2023). Consequently, understanding and addressing energy poverty requires a holistic approach that considers its complex interplay of social, economic, and structural determinants (Oesterreich & Barej-Kaczmarek, 2024). This paper aims to dissect the intricate components of energy poverty within the European context, focusing on social, income, and housing quality dimensions, utilizing comprehensive Eurostat data to provide an empirical analysis. Specifically, this study will investigate how indicators such as the percentage of the population living in dwellings with structural defects, the inability to keep homes adequately warm, and the housing cost overburden rate contribute to the overall burden of energy poverty across EU member states. This analysis will also explore the underlying mechanisms through which these factors exacerbate energy vulnerability, considering both demand-side and supply-side perspectives (Leipziger et al., 2023). Furthermore, the research will identify potential policy levers and interventions that could mitigate the impacts of energy poverty, emphasizing the importance of integrated strategies that span energy efficiency, social welfare, and housing policy. Such multifaceted approaches are crucial for fostering a just energy transition and ensuring that all citizens have access to affordable, clean, and reliable energy services, thereby contributing to the broader objectives of the European Green Deal. This examination acknowledges the absence of a universally agreed-upon EU-level definition for energy poverty, which complicates consistent measurement and policy formulation across member states, thereby necessitating the use of a dashboard of indicators rather than a single metric for comprehensive understanding (Bardazzi et al., 2023;

Leipziger et al., 2023). This analytical approach enables a nuanced assessment of the phenomenon, moving beyond simplistic income-based definitions to encompass structural and social vulnerabilities (Mochida et al., 2025) (Bardazzi et al., 2023). The complex interplay of these factors necessitates a multidimensional approach to assessment, moving beyond singular indicators to capture the true breadth and depth of energy deprivation across diverse socio-economic landscapes (Fabbri et al., 2023) (Spandagos et al., 2023). Recent academic discourse increasingly emphasizes the need for comprehensive frameworks that integrate socioeconomic data with environmental factors to accurately predict and address energy poverty (Kez et al., 2023). This study therefore provides an in-depth analysis of these components, drawing on Eurostat data from 2010, 2015, and 2022 to reveal temporal dynamics and spatial disparities in energy poverty across EU countries (Oesterreich & Barej-Kaczmarek, 2024). This research will also assess how various national policies, and socio-economic contexts influence these disparities, contributing to a more granular understanding of energy poverty's manifestations across the Union. This comprehensive approach aims to inform targeted policy interventions by identifying the most vulnerable populations and the specific drivers of their energy deprivation within different member states. The study states three hypotheses:

H1: Based on the available data, it is hypothesized that countries with a higher proportion of people living in dwellings with leaking roofs, damp walls, floors or foundations, or rot in window frames or floors will also exhibit a higher share of households unable to keep their homes adequately warm.

H2: It is further hypothesized that countries with higher housing cost overburden rates in urban areas are associated with a higher percentage of households unable to keep their homes adequately warm.

H3: In line with existing theoretical expectations, it is hypothesized that countries with higher levels of households' gross disposable income (log-transformed) will demonstrate lower rates of households unable to keep their homes adequately warm.

Literature review

The following literature review traces the evolution of the energy poverty concept within the European context, beginning with foundational work in the 1990s and progressing to contemporary understandings, while also delineating the pertinent European Union legal framework. It further explores the definitional challenges inherent in this complex phenomenon and elaborates on the composite indicators proposed by the European Union to measure its various dimensions (Oesterreich & Barej-Kaczmarek, 2024). Initially conceptualized primarily through an income-centric lens, the understanding of energy poverty has significantly broadened to incorporate multidimensional aspects, recognizing that financial hardship alone does not fully encapsulate the issue (Spandagos et al., 2023). This expanded perspective acknowledges that energy poverty is also shaped by factors such as the energy efficiency of dwellings, the cost of energy, and individual energy consumption behaviors (Castaño-Rosa et al., 2019). Furthermore, recent scholarships emphasize the importance of integrating technological and governance innovations to effectively address energy poverty, moving beyond traditional income and cost factors (Varo et al., 2022). Early scholarly contributions, notably Brenda Boardman's seminal work, established the foundational understanding of energy poverty as a condition where households are unable to afford adequate energy services to maintain a healthy and comfortable living environment (Yip et al., 2020). This initial conceptualization highlighted the interplay between low-income, high-energy costs, and inefficient housing structures as primary drivers of this multifaceted problem (Oesterreich & Barej-Kaczmarek, 2024). This framework was subsequently expanded to include six energy vulnerability factors, such as access and affordability (González-Pijuan et al., 2023). Building on Boardman's work, subsequent research has further refined these factors, integrating aspects like energy efficiency, housing quality, and the broader socio-economic context to provide a more nuanced understanding of energy poverty dynamics (Urquiza et al., 2019). For instance, the European Fuel Poverty and Energy Efficiency project further refined the definition, emphasizing the difficulty in maintaining an adequate standard of heat at a reasonable price, aligning with the citizen's right to appropriate temperature enshrined in the United Nations' Sustainable Development Goals (Oesterreich & Barej-Kaczmarek, 2024). This evolution underscores a shift from a purely economic definition to one that encompasses social and environmental dimensions, acknowledging energy poverty as a systemic issue with wide-ranging implications for public health, social equity, and climate action. This expanded perspective recognizes that energy poverty is not merely a matter of financial deficit but is deeply intertwined with broader infrastructural and environmental inequalities, necessitating a distinct analytical approach separate from general poverty studies (Simcock & Bouzarovski, 2023). The discourse has evolved to consider energy poverty as a distinct form of deprivation, emphasizing the need for targeted policies that address energy-specific vulnerabilities rather than solely relying on general anti-poverty measures (Jiang et al., 2019). This nuanced understanding highlights that vulnerability to energy poverty can stem from diverse factors, including inadequate household energy systems, specific needs due to illness or disability, and broader demographic characteristics, signifying a fluid state rather than a static condition (Bardazzi et al., 2023). Indeed, while the income-to-energy cost ratio often serves as a primary indicator, energy poverty is a complex issue extending beyond mere financial hardship, encompassing situations where energy bills consume a disproportionately high percentage of income or necessitate a reduction in household energy consumption to levels detrimental to health and well-being (Fabbri et al., 2023). This complex interplay of factors necessitates a multidimensional definition that incorporates social, economic, and housing quality components to accurately identify and address the various manifestations of energy poverty (Fabbri et al., 2023). This complexity has led to varied measurement approaches globally, with no single, universally accepted standard for assessing energy poverty, leading to challenges in international comparability and policy implementation (Jiang et al., 2024). For instance, different indicators can identify varying numbers of households at risk and households with distinct characteristics, thus providing an ambiguous basis for academic studies and policy design (Deller et al., 2021). The ongoing debate surrounding appropriate metrics underscores the need for contextually sensitive indicators that can nonetheless be harmonized for broader comparative analyses (Tait, 2017). Recognizing these complexities, the European Union has moved towards a more comprehensive understanding, seeking to integrate various dimensions into a cohesive framework (Bardazzi et al., 2023). This proactive stance aims to bridge the definitional gaps and provide a methodological basis for monitoring and mitigating energy poverty across its member states (Pérez-Fargallo et al., 2020). This integrated approach acknowledges the multifaceted nature of energy deprivation, moving beyond a sole reliance on income metrics to encompass housing quality, energy efficiency, and broader socio-economic determinants (Castaño-Rosa et al., 2019). This evolution has led to the adoption of composite indicators, reflecting the multifaceted nature of energy poverty, driven by factors such as low-income, high-energy costs, poor energy efficiency of dwellings, and inadequate energy infrastructure (Josa & Aguado, 2019). Specifically, the European Union's approach often incorporates metrics such as the inability to keep homes adequately warm, the presence of leaking roofs or damp walls, and high housing cost overburden rates to capture the lived experiences of energy-poor households (Pérez-Fargallo et al., 2022).

The legal foundations of energy poverty within the European Union can be traced back to Directive 2009/72/EC, which first introduced the concept in a regulatory context. This directive highlighted essential elements such as the protection of vulnerable customers, the prevention or limitation of electricity disconnection for affected households, and the promotion of energy efficiency improvements in residential buildings. The regulatory framework evolved further in line with broader climate governance commitments. In alignment with the obligations adopted under the 2015 Paris Agreement, the European Council formally endorsed in December 2020 an enhanced climate ambition, requiring the European Union to reduce greenhouse gas emissions by at least 55% by 2030 compared with 1990 levels. This revision constitutes a substantial increase from the previous 40% target and is regarded as a prerequisite for achieving full climate neutrality by 2050. Meeting the revised 2030 target necessitates significant sectoral transformations, including a 60% reduction in emissions from buildings, a 14% decrease in their overall energy demand, and an 18% reduction in heating and cooling-related energy consumption across the Union. In response, the European Commission introduced the Fit for 55 legislative package, comprising amendments to existing directives and regulations, as well as newly established legal instruments, with the objective of ensuring that Member States implement the structural and policy measures required to attain the envisaged decarbonization trajectory. Identifying the geographical distribution and sociodemographic characteristics of the population groups most vulnerable to the EU Green Deal and its climate objectives for 2030 and 2050 is essential for ensuring a socially inclusive transition. This requirement has been formally acknowledged by the European Commission for the 2020–2025 policy agenda as a fundamental precondition for successful implementation. Within this evolving policy context, the intersection of distributive fairness challenges associated with the green transition and the impacts of the recent global energy crisis (2022–2023) has placed energy poverty at the center of contemporary economic policy discussions (Maier, 2025). Energy poverty therefore constitutes a recurring concern within the Fit for 55 package, given that several proposed measures are projected to place significant financial pressure on low-income households residing in inefficient buildings. Consequently, multiple provisions – formally embedded in binding EU directives – require Member States to implement safeguards and targeted interventions to prevent energy-poor households from being disproportionately affected by the progressing energy transition (Sáfián-Farkas, 2023). This framework was subsequently refined and expanded under Directive (EU) 2023/1791, which offers a comprehensive and explicit definition of energy poverty as a household's lack of access to essential energy services necessary to ensure adequate living standards and health. These services include, but are not limited to, sufficient heating, hot water, cooling, lighting, and electricity required for the operation of household appliances, while acknowledging that national socioeconomic conditions, existing social policies, and broader policy environments shape how the concept is operationalized across Member States. While several Member States have begun institutionalizing targeted responses, significant variation remains. In the Hungarian policy context, dedicated measures addressing energy poverty have not yet emerged, and the conceptualization of the phenomenon remains at an early stage. A nationally agreed definition is still absent, and no operational indicators have been established to systematically identify affected population groups. These gaps are further reinforced by the insufficient availability of relevant datasets, which poses a significant barrier not only to accurately assessing the scope and characteristics of energy poverty, but also to the effective design, implementation, and evaluation of policy interventions intended to mitigate its impacts (Sáfián-Farkas, 2023).

Methodology

These indicators are crucial for quantitative analyses that aim to pinpoint the precise drivers and manifestations of energy poverty across diverse European regions. The selection of appropriate indicators is paramount, as different measures can yield varying results regarding the prevalence and characteristics of energy poverty, necessitating careful consideration of their strengths and limitations in an analytical context. Furthermore, the choice of indicators significantly influences the design and effectiveness of policy interventions aimed at alleviating energy poverty, underscoring the need for validation and sensitivity analysis in their application. This research employs a methodology centered on four basic indicators extracted from Eurostat data, enabling a comprehensive examination of energy poverty's social, income, and housing quality components. This quantitative approach facilitates the identification of patterns and correlations among these indicators, providing insights into the interdependencies between different dimensions of energy poverty. Specifically, the selected indicators – percentage of total population living in a dwelling with structural defects, percentage of households unable to keep home adequately warm, and housing cost overburden rate – offer a framework for assessing the multifaceted nature of energy poverty across EU member states. These specific indicators were chosen for their reliability and widespread use in social studies, reflecting established practices in assessing living conditions and deprivation within the European statistical system. Additionally, the use of Eurostat data ensures comparability across countries, which is essential for understanding regional disparities and for formulating pan-European policy recommendations. This approach allows for a granular analysis of how specific housing conditions and financial burdens contribute to the overall energy poverty landscape, moving beyond generalized assumptions to empirically grounded conclusions. The integrated nature of these indicators facilitates a comprehensive diagnostic assessment, allowing for the identification of specific vulnerabilities within different household typologies and geographic regions. Such detailed analysis is crucial for developing targeted interventions, as the effectiveness of energy poverty policies is contingent upon a precise understanding of its manifestations among various demographic groups. This research also considers the potential for hidden energy poverty, where households limit their energy consumption due to vulnerability, a nuanced aspect often overlooked by more conventional measures. Furthermore, the availability of static data and its comparability across time and space present important methodological considerations, especially when conducting analyses spanning multiple periods.

Study design and sample

This is an ecological, country-level, cross-sectional study using EU-27 Member States as observational units (N = 27). The analysis focuses on calendar year 2023 and relies only on four indicators extracted from Eurostat.

Data and variables

Four variables were used exactly as provided (percentages are in percentage points, 0–100):

1. Winter energy poverty (DV) – Percentage of households unable to keep the home adequately warm (Winter).
2. Urban cost burden – Housing cost overburden rate by degree of urbanization (cities) (Cost).
3. Income – Households' gross disposable income (million euro) (Income), transformed as logInc = log (Income) to reduce right skew and interpret effects as semi-elasticities.

Hypotheses 1–3 were tested based on the pairwise Pearson correlations. Analyses were conducted with SPSS.

Results

The analysis reveals significant disparities in energy poverty prevalence across EU member states, reflecting varied socio-economic conditions and energy market structures. For instance, countries with historically lower GDPs and less developed social protection systems often exhibit higher rates of energy poverty. This disparity underscores the complex interplay between macroeconomic factors and household-level energy vulnerability. Moreover, the highest synthetic measure of energy poverty in 2022 was observed in Luxembourg, influenced by real expenditure per capita, net social protection benefits for housing costs, final energy consumption per household, and electricity prices, alongside Malta, Croatia, and Slovenia. Conversely, Latvia, Romania, and Bulgaria demonstrated some of the lowest values in the same period, primarily due to their performance on indicators such as housing cost overburden and the inability to adequately warm homes. These findings highlight the heterogeneous nature of energy poverty across the EU, emphasizing the necessity of country-specific policy interventions tailored to local contexts rather than a one-size-fits-all approach. For example, some nations, such as Greece, have seen substantial increases in fuel poverty, particularly between 2010 and 2013, with significant public health implications, while Belgium, Denmark, Italy, and Greece recorded the highest risk of energy poverty in 2022. This spatial and temporal variation underscores the dynamic nature of energy poverty, influenced by a confluence of economic, social, and policy factors at both national and regional levels. Notably, significant reductions in energy poverty levels have been observed in countries like Latvia and Italy, while Nordic nations such as Sweden and the Netherlands consistently report the lowest incidences, reflecting social welfare systems and efficient energy markets. Such regional disparities further demonstrate that comprehensive policies addressing energy affordability, housing quality, and energy efficiency are crucial for mitigating energy poverty across the European Union. This is particularly evident when considering the varying definitions of energy poverty across member states, which can significantly influence reported prevalence rates and the targeting of intervention strategies.

Table 1. Pairwise Correlation Matrix of Study Variables

	Winter energy poverty (%)	**Bad living conditions (%)**	**Hosting cost overburden (%)**	**LOG (Income)**
Winter energy poverty (%)	1,00	0,378 (p=0,052)	0,046 (p=0,819)	0,064 (p=0,751)
Bad living conditions (%)		1,00	-0,051 (p=0,801)	0,106 (p=0,600)
Hosting cost overburden (%)			1,00	0,255 (p=0,200)
LOG (Income)				1,00

Sources: Pearson, Two-Tailed; EU-27 (2023)

Percentage of households unable to keep home adequately warm (%), Percentage of total population living in a dwelling with leaking roof/damp/rot, Housing cost overburden rate by degree of urbanization (cities) (%), LOG (Income) = LOG [Households gross disposable income (million euro)]
Source: own calculation based on the Eurostat (2025) data

In the 2023 EU-27 cross-section (N=27; Table 1.), **bad housing conditions** show a **moderate, positive** association with winter energy poverty (**r = 0.378, p = 0.052**), indicating only **marginal** evidence (at the 10% significance level) for H1. **Household income (log)** is essentially unrelated to winter energy poverty (**r = 0.069, p = 0.731**), so H2 is **not supported**. **Urban housing cost overburden** is also unrelated to winter energy poverty (**r = 0.046, p = 0.819**), so H3 is **not supported**. Together, the results point to **housing quality/energy efficiency** as the most plausible driver among the tested factors in 2023, while income and urban cost burden do **not** explain cross-country variation.

These variations highlight the crucial role of social safety nets and efficient energy markets in mitigating energy poverty. Understanding the nuanced interplay between household income and housing costs is therefore critical for developing effective energy poverty mitigation strategies. Furthermore, considering the multifaceted nature of energy poverty, which also encompasses housing quality and the ability to maintain adequate warmth, a comprehensive approach integrating housing policy with energy policy is imperative for sustainable improvement. This holistic perspective enables the development of targeted interventions that address the root causes of energy poverty, rather than merely treating its symptoms.

These indicators collectively underscore the multidimensional nature of energy poverty, extending beyond mere income constraints to encompass structural deficiencies in housing and the resultant inability to maintain thermal comfort. Such complexities necessitate a nuanced analytical framework that accounts for the interplay between socioeconomic factors, housing characteristics, and energy policy. Consequently, a deeper dive into the specific determinants of these indicators across different European Union member states is warranted to identify best practices and areas requiring urgent intervention.

According to winter energy poverty, the most fundamental thing is to examine the proportion of households that are unable to heat their homes to an adequate temperature, based on EUROSTAT data (see ilc_mdes01 online data code). The rate of this phenomenon, also known as winter energy poverty, in households – based on the average of the 27 member states of the European Union – has hardly changed between 2015 and 2023. Between 2015 and 2019, there was a slight decrease (from 9.6% to 6.9%), while between 2020 and 2023, there was an increase (from 7.5% to 10.6%). Looking at the data for a few countries, this trend can be observed in Belgium, the Czech Republic, Germany, Romania, and Austria. It is important to emphasize that only the trend has been highlighted, as individual Member States started from different values and arrived at different values over the years. However, it is a fact that winter energy poverty has decreased significantly in Bulgaria, Greece, and Lithuania. A recent study in Greece (Halkos-Kostakis, 2023) attributes these positive developments to targeted subsidies and energy efficiency investments (and access to better heating technologies). Building renovation programs play a prominent role in Lithuania (Streimikiene et al., 2021), but in Bulgaria (Wojewódzka-Wiewiórska et al., 2024), for example, positive change is significant in "only" a few objective indicators (energy efficiency investments). Without going into the underlying details, based solely on the raw data, Finland and Luxembourg were the least affected by winter energy poverty in 2023.

The presented Eurostat data on the inability to keep homes adequately warm reveal significant disparities across EU member states, reflecting diverse energy mixes, housing stock efficiencies, and socio-economic conditions. Specifically, countries in Southern and Eastern Europe consistently report higher percentages of households experiencing this form of energy poverty, underscoring the influence of prevailing building standards, climate variations, and income inequality on thermal comfort. Such persistent regional variations highlight the critical need for targeted policies that address both the structural deficiencies in housing infrastructure and the economic vulnerabilities of households, thereby fostering a more equitable distribution of energy security across the Union. Furthermore, the dynamic shifts observed in several countries, such as the notable increase in Germany and Ireland from 2020 to 2023, suggest the impact of external factors like energy market volatility and geopolitical events on household energy affordability. This necessitates a deeper quantitative analysis to pinpoint the precise drivers behind these fluctuations and to develop evidence-based interventions.

Let us examine the data in more detail based on the hypotheses outlined above:

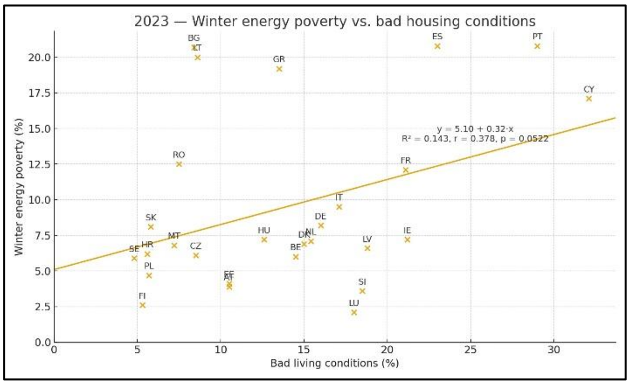

Fig. 1. Linear regression model between winter energy poverty and bad housing conditions
Source: own calculation based on the Eurostat (2025) data

Figure 1 shows the relationship between winter energy poverty (%) and poor housing conditions (%) in EU Member States (2023). Linear regression indicates a weak positive correlation ($r = 0.378$; $R^2 = 0.143$; $p \approx 0.05$). This means that although an increase in poor housing conditions is associated with a higher risk of energy poverty, the explanatory power of the relationship is low: the model explains only 14% of the variance. The weak correlation with climatic factors (although energy poverty is paradoxically high in southern European countries, this is not due to the climate but to the poor condition of buildings and lower incomes), the application of regulated energy prices (as in Hungary), and the very different income situations of households can explain this.

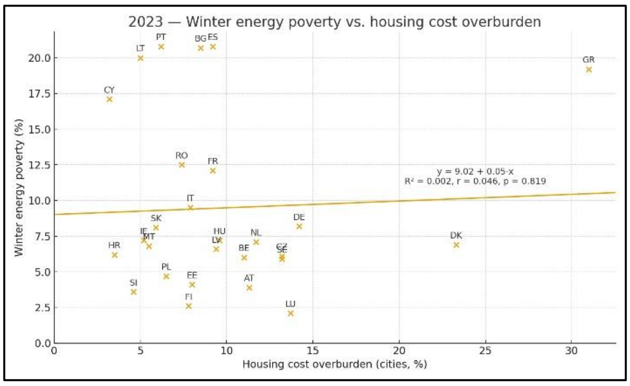

Fig. 2. Linear regression model between winter energy poverty and housing cost overburden

Source: own calculation based on the Eurostat (2025) data

The Figure 2 shows the relationship between winter energy poverty (%) and housing cost burdens. The results show that linear regression reveals virtually no correlation ($r = 0.046$; $R^2 = 0.002$; $p = 0.819$). This means that the extent to which urban households are burdened by excessive housing costs does not explain the development of energy poverty at all. One possible reason for this is that winter energy poverty specifically measures deprivation resulting from a lack of heating, which is not necessarily associated with high housing costs, as rent and maintenance costs also play a role. At the same time, it is important to emphasize the phenomenon of hidden energy poverty or forced energy deprivation. Low housing costs can be a misleading indicator, as some households deliberately deprive themselves of heating. This is why complex indicators (incorporating income, health, and subjective thermal comfort data) are needed to reveal hidden energy poverty. If, in addition to the above indicators, we also examine the gross disposable income of households in relation to winter energy poverty, we can categorize the individual EU member states into four groups. High energy poverty combined with low income, but not necessarily high housing costs, in Bulgaria, Portugal, Lithuania, Spain, Greece. Low energy poverty combined with high income levels and moderate housing costs in Luxembourg, Finland, Sweden, Denmark, Austria, and the Netherlands. The third group consists of "medium" countries, i.e. countries with medium energy poverty, medium income levels and medium housing costs, typically in Central Europe. In addition to Hungary, this group includes Slovakia, Poland, Romania, Croatia, and Latvia. Finally, the fourth group consists of outliers such as Greece (high income but relatively high energy poverty), Denmark (high income but low energy poverty), and Cyprus, where energy poverty is extreme despite relatively low-income levels.

However, the general trend indicates a slight improvement in the level of energy poverty across EU countries, albeit with persistent variations between the best and worst performers. This improvement, however, is often marginal and unevenly distributed, necessitating a deeper exploration of the underlying factors contributing to these disparities. For instance, countries like Ireland and Estonia have shown significant progress in reducing energy poverty indicators, while others, despite overall improvements, still exhibit areas of concern. This suggests that while some policy measures may be effective broadly, others require refinement to address specific national or regional challenges. Furthermore, an increased focus on energy efficiency policies and renewable energy sources has been identified as a key driver for alleviating energy poverty, particularly in the long-term. The production of green energy, for example, is becoming increasingly crucial due to its lower costs, which can directly reduce energy expenses and facilitate access for vulnerable households. However, challenges remain in ensuring equitable access to these renewable energy sources, particularly for low-income households which may face prohibitive upfront costs or limited access to financing mechanisms for energy efficiency upgrades. Moreover, the effectiveness of energy efficiency improvements in mitigating energy poverty is contingent upon their integration with broader social policies that address income inequality and housing quality. Many energy-poor households face exacerbated economic barriers, including higher risk and greater financial hurdles to implementing energy efficiency interventions. This reinforces the need for comprehensive policy frameworks that not only promote energy-efficient technologies but also provide financial assistance and targeted support to ensure that the benefits of such advancements reach all segments of the population, especially those most affected by energy poverty. The dynamic international situation, characterized by fluctuating energy carrier prices and internal socio-economic issues, further complicates the prediction of energy poverty trends, making even short-term forecasts prone to substantial error.

Conclusions

Taken together, the presented results underscore the critical need for agile and adaptable policy responses capable of addressing emergent challenges while supporting long-term resilience in energy systems. Such resilience necessitates a multi-faceted approach, integrating energy infrastructure with social support mechanisms and innovative technological solutions to safeguard against future energy shocks and ensure equitable access for all citizens. Moreover, the recent geopolitical shifts and their resultant impact on energy markets highlight the urgent need for strategies that enhance energy security and reduce reliance on volatile external sources (Oesterreich & Barej-Kaczmarek, 2024). This includes accelerating the transition to diversified and domestically sourced renewable energy, as well as implementing demand-side management strategies to optimize energy consumption (Oesterreich & Barej-Kaczmarek, 2024). These strategic shifts are paramount for fostering energy independence and insulating vulnerable populations from the unpredictable fluctuations of global energy markets (Oesterreich & Barej-Kaczmarek, 2024). Furthermore, continued governmental efforts in assisting households through both financial interventions and energy efficiency improvements are essential for addressing energy poverty, alongside exploring additional measures to counteract the adverse effects of recent price and inflation increases (Spandagos et al., 2023). This includes not only direct financial aid but also investment in educational programs that empower consumers with knowledge about energy conservation and the benefits of adopting sustainable energy practices. Such initiatives, coupled with advancements in machine learning for predicting energy poverty, could provide more precise and less self-report-dependent interventions, allowing for better targeting of support measures and the integration of supplementary factors influencing energy consumption (Spandagos et al., 2023). This is crucial for overcoming targeting challenges and improving the efficacy of energy poverty alleviation schemes, particularly by enhancing transparency and evaluating the fairness potential of hypothetical interventions (Spandagos et al., 2023). Given the complex interplay of socio-economic and environmental factors, a comprehensive policy framework must therefore integrate energy justice principles with economic realities, ensuring equitable access to sustainable energy solutions for all households (Volodzkienė & Štreimikienė, 2024). Moreover, the emphasis on renewable energy sources within the European Green Deal underscores the strategic imperative to achieve climate neutrality by 2050, directly impacting energy policy and accelerating the shift away from fossil fuels (Hahn et al., 2025). This transition, however, must be managed carefully to prevent exacerbating energy poverty, particularly for vulnerable populations, necessitating inclusive strategies and equitable funding mechanisms (Lee et al., 2024). The Just Transition Fund and similar programs represent key financial instruments for assisting countries in achieving these goals, especially those struggling with social protection payments, energy efficiency, and supplier switching rates (Spandagos et al., 2023). This highlights the necessity of a coordinated policy response that balances ambitious climate targets with the imperative of social equity, ensuring that the benefits of the energy transition are broadly distributed. Achieving this balance requires continuous monitoring and evaluation of policy effectiveness, adapting strategies to address emerging challenges and ensuring that the transition genuinely leaves no one behind (Newell & Mulvaney, 2013; Kime et al., 2023). Specifically, policymakers must consider the distributive, procedural, and recognition justice dimensions of energy policy to foster equitable outcomes during decarbonization (Sovacool et al., 2019). This approach necessitates a paradigm shift from solely focusing on technological solutions to one that deeply embeds social equity and participatory governance in energy policy formulation (Healy & Barry, 2017).

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Dr. Tibor László Csegődi, lawyer-economist (master's degree in regional and environmental economics), assistant lecturer, Department of International Regulation and Economic Law, Szent István Campus Agricultural and Food Economy Institute of the Hungarian University of Agrarian and Life Sciences. He has an absolutorium in Business and Organizational Sciences, and his doctoral thesis is in progress. His research area: rural development, environmental law, climate protection, energy efficiency, building local climate- and energy-conscious communities. H-2100 Gödöllő, Páter Károly u. 1, Hungary, Tel.: +36-30-981-6424, +36-28-522-000/3286, e-mail: csegodi.tibor.laszlo@uni-mate.hu, ORCID ID: 0009-0005-9538-6827.