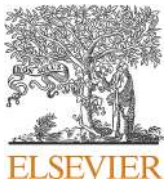
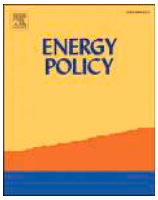
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Measuring energy poverty in rural Albania: A multidimensional and context-sensitive approach

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HIGHLIGHTS

- First multidimensional energy poverty index for rural Albania.
- More than 50 % of rural households face significant energy deprivation.
- Economic hardship is the main driver of energy poverty.
- Subjective discomfort reveals hidden energy poverty cases.
- Policy needs to extend beyond infrastructure to social support.

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ABSTRACT

Energy poverty is a significant issue in the Western Balkans, particularly in rural Albania, where economic vulnerability and infrastructural limitations hinder access to reliable energy. This study provides the first comprehensive assessment of energy poverty in the rural Municipality of Kavaja. The Alkire-Foster methodology developed a multidimensional index from 14 indicators across economic, energy, and subjective well-being dimensions. Data were gathered from 215 individuals through a digital survey conducted under the EU-funded GETA project. The analysis tested various weighting schemes and cut-off thresholds to ensure robustness. Results indicate that energy poverty is widespread, with over 50 % of individuals classified as deprived even under stringent criteria. Economic deprivation, often combined with subjective discomfort, is the dominant factor, emphasising the inadequacy of infrastructure-based assessments alone. The study highlights the need for multidimensional, context-sensitive measurement and targeted policy interventions, offering a replicable framework that can be applied to other rural and transitional regions.

1. Introduction

Reliable and affordable energy is fundamental to economic development, social well-being, and energy independence, which reduces reliance on imports and mitigates price volatility. This is particularly important for the European Union (EU) and Western Balkans, where energy security and affordability remain key challenges in light of recent geopolitical events that have disrupted traditional energy supply chains (World Energy Outlook, 2024).

In response to these challenges, the EU launched the REPowerEU plan, a key component of the EU Green Deal, aiming to diversify energy sources, enhance energy efficiency, accelerate the transition to renewable energy, reduce dependence on external energy suppliers, and stabilise energy prices for consumers and businesses (European Commission: Directorate-General for Communication, 2022). Western Balkans, while not directly part of the EU's REPowerEU plan, have taken similar steps, guided by EU-backed projects aimed at aligning the region with the EU's Green Deal and energy transition goals (Bartlett et al.,

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Nomenclature

$AfCFTA$ African Continental Free Trade Area
$ASEAN$ Association of South East Asian Nations
CEP Clean Energy Package
DS Distribution Sensitivity
EC European Commission
ECS Energy Community Secretariat
EP Energy Poverty
$EPAH$ Energy Poverty Advisory Hub
$EU-SILC$ EU-Statistics on Income and Living Conditions
EU European Union
FD First order Deprivation
$GETA$ Gaming for Energy Transition of Rural Areas
HEP Hidden Energy Poverty
JRC Joint Research Centre
$LIHC$ Low Income High Cost
M Monotonicity
$MEPI$ Multidimensional Energy Poverty Index
PF Poverty Focus
RI Replication Invariance
SD Second order Deprivation
SDG Sustainable Development Goal
SYM Symmetry
$WBIF$ Western Balkans Investment Framework

2022). In such a context, renewable energy sources accounted for 45.3 % of the EU's gross electricity consumption in 2023, up from 41.2 % in 2022, while in the Western Balkans they accounted for approximately 30 % of the total energy mix in the same year (Hochberg, 2024).

Another significant achievement has been the recognition of citizens' and communities' rights to actively participate in the energy sector through the EU's Clean Energy Package (CEP) (Caramizaru and Uihlein, 2020). Along the same lines, Western Balkans Investment Framework (WBIF) financed projects related to community-based energy solutions in the region; for instance, the Energy Community Secretariat (ECS) and the European Commission (EC) have funded capacity-building programs for local stakeholders in the Western Balkans to ensure successful implementation of energy community projects (European Commission, 2024).

Since mid-2021, the sharp escalation in energy prices has placed considerable strain on households and industries throughout the EU and the Western Balkans. This surge has exacerbated existing vulnerabilities and led to a marked increase in individuals experiencing energy poverty. According to the EC's Joint Research Centre (JRC), between 8 % and 16 % of the EU population currently experiences energy poverty, translating to approximately 35 to 72 million people (Koukoufikis et al., 2023). Also, the EU-Statistics on Income and Living Conditions (EU-SILC) survey indicates that in 2023, 10.6 % of the EU population reported being unable to keep their home adequately warm due to financial constraints (Di Meglio, 2024). In contrast, Western Balkan countries reported lower prevalence rates, often below 5 % (Maier and Dreoni, 2024). So far, approximately 18 million people reside in the Western Balkans, encompassing around 5 million households. Albanians make widespread use of outdated wood-burning devices; in rural Albania, 85 % of households rely on wood for heating, primarily using inefficient stoves and fireplaces. Financially, Albanian households allocate a substantial portion of their income to energy expenses; about 20 % of households spend about 12 % of their monthly income on energy, while the national average stands at 9.8 % (RES Foundation, 2018).

Energy poverty, defined as the inability to secure adequate and affordable energy services, is a persistent and multidimensional challenge across the EU and Western Balkans. While substantial progress has been made in identifying and addressing urban energy poverty, rural areas, especially in Southeast Europe, remain under-researched despite facing disproportionate burdens. Rural households are often characterised by lower incomes, poorly insulated dwellings, limited access to modern heating systems, and weaker institutional support. Albania exemplifies this condition, with rural communities experiencing entrenched socioeconomic marginalisation, aging infrastructure, and high energy costs relative to income.

To the best of the authors' knowledge, no previous studies have attempted to estimate energy poverty for this particular area of the Western Balkans, despite the region's unique socioeconomic and geographical characteristics. This research gap is particularly concerning given the well-documented challenges faced by rural communities in accessing affordable and reliable energy services.

This paper aims to fill both empirical and conceptual gaps in the measurement of energy poverty in rural Albania by offering a comprehensive assessment of the issue in this context. The study is guided by two primary research questions:

1. To develop a reliable indicator for measuring energy poverty in Albania's rural regions.
2. To elucidate the complex interconnections between income poverty and energy poverty.

The analysis is based on specific survey data collected in a rural Albanian Municipality in 2023 within the Gaming for Energy Transition of Rural Areas (GETA) project funded by the EU in the framework of the ERASMUS-YOUTH-2022-CB project (ERASMUS-YOUTH-2022-CB, 2022). To address this gap, the authors extend the multidimensional consensual approach originally proposed by Alkire and Foster (Alkire and Foster, 2011) through the development of a comprehensive framework comprising 14 indicators systematically organised into 3 different dimensions. This methodological innovation allows the authors to capture the multifaceted nature of energy poverty beyond conventional income-based measures, providing policymakers with a more nuanced understanding of energy deprivation in Albania's rural areas. Findings have important implications for both academic research and policy development aimed at addressing energy poverty in similar contexts throughout the Western Balkans and beyond.

This paper is structured into six main sections. Section 2 provides a review of the existing literature on energy poverty, with a particular emphasis on multidimensional approaches and studies relevant to rural contexts in the EU and Western Balkans. Section 3 introduces the GETA survey design and implementation, and the conceptual and methodological framework, employing the Alkire-Foster multidimensional approach to construct a composite index using 14 indicators across three dimensions: economic, energy-related, and subjective well-being. Section 4 provides an overview of the rural Municipality of Kavaja, describing its demographic, geographic, and economic features that influence local energy dynamics. Section 5 presents the findings from the multidimensional analysis, including poverty headcount ratios, intensity, and adjusted measures across different weighting Scenarios and cut-offs. Finally, Section 6 summarises need for a multidimensional, context-sensitive approach to addressing energy poverty. It discusses the implications for policy design and outlines future research directions to improve the understanding and targeting of energy-poor populations in rural and transitional settings.

2. Literature review

Despite the critical importance of the Sustainable Development Goals (SDGs) 7, which aim to ensure access to clean, sustainable, and affordable energy for all, nearly 800 million people worldwide still lack access to electricity, predominantly in developing countries (European Commission and Eurostat, 2024). Extensive research worldwide has identified various factors influencing energy poverty, including economic, social, and institutional elements.

In terms of economic factors, Dagher and Janali (2023) conducted a survey of 931 Lebanese households. Results showed that the economic collapse in Lebanon has exacerbated energy poverty, disproportionately affecting vulnerable populations, including those in rural areas where energy infrastructure is often weaker and less reliable. Rural households faced unique challenges due to geographic isolation and limited access to centralised energy grids, leading to prolonged energy shortages and reliance on costly, inefficient energy sources. This situation worsened socio-economic vulnerabilities, limiting access to essential services such as healthcare and education. The Lebanese case highlighted the urgent need for decentralised and context-specific energy solutions in rural areas, such as off-grid renewable energy systems, to improve energy access and resilience. Furthermore, policy responses must account for the structural barriers faced by rural communities to effectively mitigate the multidimensional impacts of energy poverty. Mohsin et al. (2022) investigated the relationship between financial development and energy poverty in Latin American countries. It found that low levels of financial development contribute to increased energy poverty, despite the region generally having higher electricity access than other emerging areas. The study highlighted that a significant portion of Latin American residents still lack adequate energy consumption efficiency and often rely on traditional fuels, proposing that enhanced financial development is a key strategy for alleviating energy poverty and improving energy security across the region.

From a social point of view, Croon et al. (2024) analysed how social housing providers in France, England, and the Netherlands address energy poverty through various targeted interventions. It revealed that social housing providers' strong commitment, spurred by the recent energy crisis, highlighted significant limitations in implementing effective solutions. Key findings indicated that while retrofit prioritisation and behavioural interventions are generally favoured, challenges such as data scarcity, institutional barriers, and balancing long-term investments with immediate tenant needs persisted, emphasising the need for policy reforms that integrate energy costs into housing policies and clarify social housing providers' roles in combating energy poverty. Jacques-Aviñó (2022) qualitatively evaluated the "Energia, la Justa" program in Barcelona, an intervention designed to mitigate energy poverty among vulnerable social services users. The program generally yielded positive outcomes, including economic savings, improved thermal comfort, increased social support, enhanced energy literacy, and greater energy security. However, the perceived effectiveness varied significantly across different vulnerable groups, revealing that the intervention's impact was often constrained by persistent structural barriers like poor housing conditions, complex bureaucracy, and other socio-economic insecurities that the program could not fully address.

On the institutional view side, Zahonogo (2025) highlighted the importance of harmonising tariff policies and regulatory frameworks within the African Continental Free Trade Area (AfCFTA) to improve energy access and mitigate energy poverty as well. The study concluded that lower tariff rates are strongly linked to increased access to clean energy sources, thereby contributing to energy poverty alleviation in the long run. It highlighted that trade liberalisation enhanced the affordability and availability of modern energy technologies, citing successful initiatives in Kenya and South Africa as examples, and also noted the positive influence of renewable energy consumption, remittances, and institutional quality. Gan et al. (2025) investigated how adult children's education impacted their elderly parents' energy poverty in China, using data from the China Family Panel Studies. It robustly demonstrated that higher educational attainment in adult children significantly reduced their parents' energy poverty through increased financial support, improved information access regarding energy-saving practices and policies, and enhanced social capital. The study further revealed that this beneficial effect is more pronounced in rural areas and in families with male children, highlighting key demographic and societal specificities within China.

There are three main approaches to measuring energy poverty, developed since the 1980 s: the expenditure-based approach, the consensus-based approach, and the direct measurements. The expenditure-based approach is based on quantitative data regarding the relationship between energy expenditure levels and income. As they mainly focus on income and expenditure, these expenditure-based indicators are often called 'objective' since they are not influenced by personal opinions. Various methodologies can be used to calculate energy poverty through this approach: three are the most used, and all share a one-dimensional design.

- The percent threshold rule (usually 10 %), which is the first indicator used when the interest in the phenomenon began to be relevant after the oil shocks in the seventies (it was mainly due to its intuitive nature). According to this indicator, there is an energy poverty condition if the percentage of income that goes towards energy expenses exceeds a threshold. Recently, it was the measure selected by Khalid et al. (2024) to study the effects of conflict on energy poverty by using a large country-level dataset comprising 94 economies from 1996 to 2021. Other indicators that analyse EP from the perspective of expenditures are the 2 M indicator and the hidden energy poverty indicator. The first considers households in energy poverty if they spend more than twice the national median share of income on energy (Sánchez-Guevara et al., 2020); the second refers to a household in energy poverty if its heating expenditure is exactly zero (Reaños et al., 2025).
- Low Income High Cost (LIHC), which is a combination of high energy costs and low disposable income, below the official poverty line. When energy costs are high and disposable income is low, the household falls below in an energy poverty condition. It was first introduced by Hills (2011) and subsequently used in different contexts, even with some slight variations. An adaptation of LIHC was proposed by Faiella and Lavecchia (2015), whose indicator includes vulnerability and under-consumption components to consider a household in an energy poverty condition. In detail, this indicator adds two conditions: equivalent expenditure below the median (vulnerable households) value and zero heating expenditure. Focusing on the EU countries, Menyhért (2024) found out with this method that different populations can be segmented as energy poor and that much of energy poverty households may remain hidden. For this reason, the author suggests the need to use new multidimensional approaches, together with the integration of sources coming from surveys, and the exploration of alternative metrics based on the direct measurement of households' energy consumption. From a different point of view, Bardazzi et al. (2024) developed an expenditure-based energy poverty indicator, through a micro simulation model to assess the distributional impact of the 2021–23 price increase on Italian household expenditure on energy poverty.
- Residual energy expenditure, which refers to the comparison between household energy expenditure and the national or regional central tendency (Heindl, 2015). It is possible to determine whether a household is in energy poverty if its expenditures exceed the chosen measure (mainly the median).

Household perceptions of energy poverty are the basis of the second broad category of families, in which data are collected through surveys and (or) questionnaires where households report their experiences and difficulties with adequately heating their homes, managing their energy bills, or meeting their essential energy needs. This deprivation

approach avoids the loss of information that is typical of income/expenditure methods. There are several subjective indicators, including difficulty in maintaining a sufficiently warm home, measured by the percentage of households reporting being unable to maintain an adequate level of heating during the winter; energy bill payment delays, calculated by the percentage of households reporting energy bill payment delays; and perception of energy discomfort, calculated by the percentage of households assessing how uncomfortable they are with energy consumption. This type of indicator captures individuals' difficulties in maintaining adequate heating, managing energy costs, or fulfilling essential energy needs. According to this approach it is possible to reveal energy poverty status by considering at least one indicator (a union or one-dimensional approach, Soto et al., 2025; Śmiech et al., 2025), or by taking a stricter approach in which deprivation must be simultaneous since all types of declared deprivations are considered (intersection or multidimensional approach, Marchand et al., 2019; Simionescu and Cifuentes-Faura, 2024). Thomson and Snell (2013), in their pioneering paper, used a composite indicator by combining three simple indicators derived from the EU-SILC. However, since a key aspect of energy poverty is that it is a multidimensional problem, these composite indicators, taking into account various aspects of the problem, such as technological thresholds or access to modern energy services, are becoming more and more widespread. A comparative critical review of the different multidimensional approaches has been made by Romero et al. (2018). Recently, Reaños et al. (2025) used a multidimensional approach and factor analysis to estimate a composite index that would be used to measure the problem on the extensive and intensive margins, as well as to determine whether the targeting of energy-poor households in Europe was effective. Kashour and Jaber (2024) used EU-SILC consensual indicators to develop a composite index for ranking European Union Member States by their levels of energy poverty and identifying the factors responsible. A composite index of energy poverty, capturing the lack of availability, accessibility, and affordability of energy services in the Association of South East Asian Nations (ASEAN) region and India, has also been developed by Khanna et al. (2019).

Since these first two approaches are the most used in the studies aiming to measure and analyse energy poverty, a significant debate emerges in the literature concerning the selection of the most appropriate approach to quantify and understand the incidence of energy poverty, see, among others, (Villalobos et al., 2021; Betto et al., 2020; Heindl and Schüssler, 2015). This methodological dichotomy raises important reflections on the multidimensional nature of energy poverty, highlighting the complexity of capturing a phenomenon that sits at the intersection of economic, social, and housing well-being dimensions (Campagna et al., 2024). Both approaches have strengths and weaknesses. In general, the first approach is favoured due to its connection with income poverty and alleged neutrality, but it can ignore households that ration energy consumption due to budget constraints. Moreover, since these methods are relative, they can be influenced by average population income and consumption choices (Bardazzi et al., 2021). In contrast, the consensual indicators provide direct indications of multiple deprivation statuses and better reflect cases of inadequate energy use or other forms of deprivation. These are the reasons why Herrero (Herrero, 2017) goes against one-dimensional expenditure-based energy poverty metrics, such as the LIHC measure, and advocates for multi-indicator approaches. However, methods of this approach can be biased by demographic and cultural factors related to the respondents' perceptions (Castaño-Rosa et al., 2019) on adequate temperature (lower expectations by the poor or denial of reality) or other related issues.

Finally, the direct measurement method assesses a home's energy services, such as heating and lighting, against established benchmarks. Internal temperature measurements are used by researchers to assess whether households maintain enough warmth to ensure the well-being and comfort of their residents. This method has been used to develop the first evaluation of energy poverty in Japan using an approach measuring the under-consumption of energy services at regional levels (Okushima, 2019). It yields objective data, but it does not account for contextual differences and varying energy needs (Sy and Mokaddem, 2022).

This paper contributes to this literature by conducting the first comprehensive assessment of energy poverty in rural Albania, employing a multidimensional approach specifically designed to capture the unique characteristics and challenges of rural energy contexts. Our methodological choice is motivated by the growing recognition that traditional uni-dimensional measures may fail to adequately capture the multifaceted complexity of energy deprivation experienced by rural households. As the energy poverty disparity between urban and rural areas has widened over time, research investigating the underlying drivers of this gap has proliferated. Most studies have concentrated on examining the role of socioeconomic variables and exploring the interconnected relationship between energy poverty and rural income inequality (see, among others, (Wang et al., 2024)). Within this expanding research stream, multidimensional energy poverty indices, building upon the foundational work of Nussbaumer et al. (2012), have emerged as the most methodologically sound approach for understanding energy deprivation in rural settings. Recent empirical applications demonstrate the effectiveness of this framework across diverse geographical contexts. Li and Ma (2025), and Koomson et al. (2023) have successfully employed multidimensional approaches to measure energy poverty and energy unaffordability in rural areas of China and India, respectively. These multidimensional indicators are particularly valuable because they integrate both objective measures (such as physical access to modern energy services, reliability of supply, and energy infrastructure quality) and subjective assessments (including household perceptions of energy adequacy and satisfaction with energy services). This comprehensive approach is especially relevant in developing country research, as it better reflects the complex interplay between economic constraints, infrastructure limitations, and cultural practices that characterize rural energy systems. For instance, Shen et al. (2025) demonstrate this approach's analytical power by examining household energy poverty through survey data from $1,485$ rural households across eastern, central, and western China, with particular attention to understanding how gender disparities influence energy poverty levels, access patterns, and expenditure behaviours.

3. Research & methods

This section provides details on the GETA survey design and implementation used for obtaining relevant data on the energy poverty assessment and analysis in the Municipality of Kavaja in Albania. A multidimensional approach is used, and the core method involves adopting a counting poverty approach, which uses two cut-offs: one to identify deprivation within each dimension, and another to determine if an individual is multi-dimensionally poor. To enhance the robustness of its findings, this dual-cut-off procedure is combined with First Order (FO) and Second Order Deprivation (SO) curves. The methodology also incorporates a system of assigning weights to both indicators within each dimension and to the dimensions themselves, aiming to provide a comprehensive measure of energy poverty.

3.1. GETA survey design and implementation

The empirical analysis draws on data collected through field surveys conducted within the Municipality of Kavaja in Albania during April–June 2023. A total of 215 local citizens were surveyed using the GETA survey, designed to capture their perceptions of household energy use, awareness of energy-saving measures, use of heating/cooling systems, energy source usage, household equipment, and difficulties with energy expenses. The selection of the households was done based on the social and economic assistance scheme provided by the Municipality of Kavaja. The Municipality of Kavaja is already aware of the population distribution in regard to social assistance. That being said, such target group is much more exposed to energy poverty, thus is considered to be part of the sampling survey.

The total number of population in the Municipality of Kavaja is 40,556 inhabitants (Territorial strategy of the Kavajë area in Albania, 2025) and, out of this number, approximately 7 % of the population receives social assistance, accounting for 2,838 citizens or 709 households (considering that an average family is composed of 4 members). Taking into consideration the timeline and available resources, the survey was provided to a number (215) representing 30 % of the total families receiving social assistance. Furthermore, the survey was conducted by young energy advisors with relevant expertise in using digital applications to undertake the survey.

Prior to the survey, the energy advisors received extensive assistance with the digital application. Furthermore, based on the obtained data, it was found that the demographic profile of the respondents surveyed revealed an unbalanced gender distribution with a split of 30 % female and 70 % male participants. The age range of the respondents was predominantly between 18 and 55 years old, collectively accounting for 75 % of the sample, while those aged 56 to over 75 constituted the remaining 25 %. In terms of educational background, a significant proportion, 43.3 %, had completed secondary school, followed by those with a university degree at nearly 30 %, indicating a diverse educational landscape among the rural participants. The majority of the respondents, 55.8 %, were married, with single individuals making up over a third of the sample. Household sizes tended towards smaller to medium-sized units, with households of 3 and 4 persons being the most common, totaling over 55 % of the sample. Financially, the largest segment of respondents, 38.5 %, reported a monthly income between $e201-400$, suggesting a prevalence of lower-to-middle income households in the surveyed rural areas. For in-depth information, refer to (GETA Project Consortium, 2023).

As a result, the demographic profile of the respondents surveyed revealed an unbalanced gender distribution, with a split of 30 % female and 70 % male participants. The age range of the respondents was predominantly between 18 and 55 years old, collectively accounting for 75 % of the sample, while those aged 56 to over 75 constituted the remaining 25 %. In terms of educational background, a significant proportion, 43.3 %, had completed secondary school, followed by those with a university degree at nearly 30 %, indicating a diverse educational landscape among the rural participants. The majority of respondents, 55.8 %, were married, with single individuals making up over a third of the sample. Household sizes tended towards smaller to medium-sized units, with households of 3 and 4 persons being the most common, totaling over 55 % of the sample. Financially, the largest segment of respondents, 38.5 %, reported a monthly income between $e201-400$, suggesting a prevalence of lower-to-middle income households in the surveyed rural areas. For in-depth information, refer to (GETA Project Consortium, 2023).

3.2. Conceptual and methodological framework

Let x_i $(i = 1, \dots, n)$ be a vector representing the multidimensional distribution of a population of $n \geq 2$ individuals with $k = 1, \dots, K$ relevant dimensions to measure energy poverty and, for each dimension, we denote by I_k the number of indicators in each dimension D. We also assign weights to both indicators and dimensions, where v_j denotes the weight of each indicator within dimension D, ensuring that $\sum_{j=1}^{I_k} v_j = v_k$. Here, v_k represents the weight of dimension k such that $\sum_{k=1}^{K} v_k = K$.

To identify an individual as multidimensionally poor, we adopt the counting poverty approach proposed by (Alkire and Foster, 2011). This identification step is usually done by using two cut-offs. The first cut-off is a threshold set for each dimension to identify whether the unit is deprived. The second cut-off is the number of dimensions in which an individual must be deprived to be labeled poor. However, the choice of different measures or cut-offs can lead to varying results. Therefore, to enhance the robustness of our findings, we use the above-mentioned dual-cut-off procedure of (Alkire and Foster, 2011) combined with the First order (FD) and Second order Deprivation (SD) curves developed by (Lasso de la Vega, 2010).

According to the procedure as described in (Aristondo, 2018) and (Castellano, 2020) which extends the Foster-Greer-Thorbecke (Foster et al., 1984) class of poverty measures, we calculate the share of individuals deprived in at least m dimensions,[1] the so-called *multidimensional headcount ratio*, as follows:

$$H_m = \frac{q_m}{n}, \tag{1}$$

where q_m is the number of poor households in m dimensions, and the average deprivation among the energy poor individuals, namely the *adjusted headcount ratio*:

$$M_m = \sum_{i=1}^{n} \frac{d_i(m)}{nK}, \tag{2}$$

measured as the ratio of the average number of deprivation that poor people experience to the maximum number of deprivation of the overall population, where $d_i(m) = d_i$ that is the number of the dimensions in which a person is deprived if $d_i \geq m$ and $d_i(m) = 0$ otherwise. M_m can be written as the product of the headcount ratio and the intensity of poverty:

$$A_m = \sum_{i=1}^{n} \frac{d_i(m)}{q_m K}, \tag{3}$$

representing the mean among the poor of the number of deprivations suffered by the poor, that is:

$$M_m = H_m \cdot A_m. \tag{4}$$

The FD curve is the graph obtained by plotting the number of dimensions of deprivation m ranked in decreasing order, against the multidimensional headcount ratio H_m, for $m \leq d$. The FD curve is an increasing step function that is right-continuous, satisfying the following properties: Poverty Focus (PF), Monotonicity (M), Symmetry (SYM), and Replication Invariance (RI).[2] If no individual experiences deprivation, the FD curve remains along the horizontal axis. Conversely, if every individual is deprived in all dimensions, the curve becomes a horizontal line at $H_m = 1$. When the FD curves associated with two vectors of deprivation counts do not intersect, then for any value of m, all counting poverty measures that satisfy PF, MON, SYM, and RI will indicate lower deprivation for the vector associated with the lower curve.

Moreover, we construct the SD curve by plotting the headcount ratio H_m against the adjusted headcount ratio M_m. The SD curve satisfies all the previous properties, plus Distribution Sensitivity (DS), which takes into account the inequality among the poor individuals.[3] When the SD curves associated with two vectors of deprivations do not intersect, then for any value of m, all counting poverty measures that satisfy PF, MON, SYM, RI, plus DS will indicate lower deprivation for the vector associated with the lower curve.[4]

The identification process is based on several assumptions regarding the definition of the normative space, including indicators, dimensions, cut-offs, and weights. To evaluate the impact of varying methodological assumptions, such as adjusting the weights assigned to each dimension of energy poverty, a sensitivity analysis is conducted. Specifically, we consider equal weighting among dimensions, represented as $v = (\mathbf{1}, \mathbf{1}, \mathbf{1})$, as well as different weighting schemes. In the latter case, we examine three specific scenarios: $v = (\mathbf{2}, \mathbf{0.5}, \mathbf{0.5})$, $v = (\mathbf{0.5}, \mathbf{2}, \mathbf{0.5})$, $v = (\mathbf{0.5}, \mathbf{2}, \mathbf{0.5})$.

[1] The two extreme cases are referred to as the union and intersection approaches. Under the union approach, individuals are considered poor if they experience deprivation in at least one dimension. On the contrary, the intersection approach classifies individuals as poor only if they are deprived in all dimensions.

[2] See (Lasso de la Vega, 2010) for the proof.

[3] See (Lasso de la Vega, 2010) for the proof.

[4] When FD and SD curves intersect, it is also possible to obtain a robust conclusion simply by restricting the set of identification cut-offs.

4. Case study

The Municipality of Kavaja, where the energy poverty assessment was carried out, is part of Tirana County. It is located in central Albania and is bordered to the north by the Municipality of Durrës, to the east by the Municipality of Tirana, to the south by the Municipality of Rrogozhinë, and to the west by the Adriatic Sea. The center of this municipality is the city of Kavaja. The new municipality consists of five administrative units: Kavaja, Synej, Luz i Vogël, Golem, and Helmas. All of them are part of the Kavaja District within Tirana County, including one city and 32 villages. The total area of the Kavaja Municipality is 198.81 km^2.

This area, after the 1990s, has experienced a significant population movement toward localities or areas with higher employment opportunities. It holds about 5.8 % of the population of Tirana County. Data indicate that the average population registered in the civil registry of the Municipality of Kavaja for the year 2031 will be 98, 145 inhabitants. The municipality has economic, infrastructural, social, and other forms of interaction with the regions of Tirana, Durrës, Elbasan, and Lushnjë. The city of Kavaja accounts for half of the population of the new administrative unit created by the territorial reform and includes areas with diverse characteristics such as urban, rural, natural, and coastal. These features contribute to a diversified economy. Its strategic location makes it a unit with sustainable development potential, as it is suitable for a wide range of activities. Altogether, these strong territorial elements create a powerful potential for ensuring the sustainable development of the Municipality of Kavaja.

In this study, the authors define a Multidimensional Energy Poverty Index (MEPI) for the rural areas of Albania using 14 indicators grouped into 3 dimensions as listed in Table 1. All the indicators are measured using single data from 2023 within the ERASMUS-YOUTH-2022-CB (2022). In order to classify an individual as deprived in each of the 14 elementary indicators considered, we first identify indicators following the approach proposed in Energy Poverty Advisory Hub (EPAH). The deprivation cut-offs, referring to the individuals, are described in Table 1, according to the works of Sokołowski et al. (2020) and Aristondo (2018), which we have slightly modified due to the data availability at municipal level.

The proportion of income allocated to energy bills is a significant indicator for assessing energy poverty. At the European level, studies show that EU citizens spend approximately 10 % of their monthly income on energy bills. According to national studies in Albania, this share ranges between 15 % and 20 %, although national statistics indicate that it can be as low as 10 %. Therefore, using this indicator as a measure of energy poverty is both appropriate and comprehensive. Another important indicator is the *Number of rooms per person by ownership status*. Although this indicator alone may not provide direct insights into the energy poverty status of the population, it serves as a complementary measure when combined with others, contributing to a deeper understanding of vulnerability levels. Affordability to pay the energy bill is also considered a valuable indicator, offering insights into the population's exposure to energy poverty. In addition, the indicator *Arrears on utility bills / difficulties in paying energy bills on time* has been selected. This indicator reflects one dimension of energy poverty. While not sufficient on its own, it gains relevance when analysed in conjunction with other indicators, enabling a more holistic evaluation of the local context. Another key metric is the *Inability to keep the home adequately warm*, which indicates the share of the population unable to maintain adequate indoor temperatures. When used together with other indicators, it provides a comprehensive picture of both the causes and consequences of energy poverty within the target community. Housing conditions, particularly in relation to a dwelling's energy performance, are also critical. To achieve more detailed insights into the root causes of energy poverty, this should be complemented by indicators such as the *Age of the building* and *Ability to maintain warmth*. Cooking is considered one of the most basic energy needs. In this context, we evaluated energy poverty through the lens of the type of fuel used for cooking. Traditional fuels (e.g., firewood, gas, etc.) involve higher external costs compared to more modern alternatives and can cause significant indoor air pollution, posing health risks. The same reasoning applies to heating practices and the associated indicators. The *Age of the building* is a particularly relevant indicator, as it correlates with other measures such as *Thermal comfort* and *Presence of structural deficiencies* (e.g., leaking roofs, etc.), enabling a deeper evaluation of energy vulnerability. Finally, subjective indicators are also included in the analysis. These help to validate the objective measures and strengthen the robustness of the survey findings.



Fig. 1. Area of interest for the energy poverty assessment in this study (Territorial strategy of the Kavajë area in Albania, 2025).

The main purpose of the project was to assess the level of energy poverty in Western Balkans, specifically in Albania see Fig. 1 where 215 individuals were reached through a digitalised system in the form of web app [5] to provide a survey for collecting all the required data. To determine deprivation cut-offs, we relied on widely used definitions/indicators of energy poverty, explicitly adapted to reflect the context of energy poverty in Albania. Specifically, we referred to well-known approaches to energy poverty, which include objective and subjective variables. The expenditure-based approach defines energy poverty as the inability to afford adequate energy services while keeping expenditures within a reasonable share of income. A commonly used threshold, proposed by Healy et al. (2004), considers a household energy-poor if it spends more than 10 % of its income on energy needs. The consensual approach, on the other hand, is based on subjective indicators

[5] List of the variables is available here https://www.revoltsrl.com/login-energy-survey

Table 1
Index framework; domains, indicators and deprivation cut-off.

Domain	Indicator	Deprivation cut-off
Economic	High share of energy expenditure in income	Individual spends a high share of their income on actual energy costs (more than 10 %).
	Housing deprivation	Deprived if less than one room per person.
	High energy costs	Deprived if he/she declares that the level of energy costs is unaffordable or neutral.
Energy	Inability to pay utility bills	Individual experiences problems paying their utility bills on time (sometimes or always).
	Inability to keep the home adequately warm	Deprived if the dwelling is not warm enough in the winter.
	Inability to keep the home adequately cold	Deprived if the dwelling is not cold enough in the summer.
	Presence of leaks, damp, or rot	He/she lives in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors.
	Cooking energy type	Deprived if the main source of energy used for cooking is wood or biofuel.
	Heating energy type	Deprived if the main source of heating is wood, biofuel, or burning oil.
	Building faults	Deprived if the age of the building he/she lives in is older than 25 years.
Subjective	Opinion about building energy efficiency	Deprived if he/she states very unsatisfied, unsatisfied, or neutral.
	Opinion about devices' energy efficiency	Deprived if he/she states very unsatisfied, unsatisfied or neutral.
	Quality of roof and walls	Deprived if he/she states very unsatisfied, unsatisfied, or neutral.
	Quality of windows and doors	Deprived if he/she states very unsatisfied, unsatisfied, or neutral.

reflecting the inability to afford the necessities of life, as discussed in studies by Thomson and Snell (2013); Aristondo (2018); Healy et al. (2004). We applied the following rules across different dimensions of well-being to classify individuals as deprived. According to the *economic* and *subjective* dimensions, we defined an individual as deprived in that dimension if they are deprived in at least 2 indicators. For the *energy* dimension, we defined as poor an individual who is deprived in at least 4 out of 7 indicators. We refer to Table 1 for a detailed description of deprivation in each indicator. The results are shown in the next section.

5. Results & comments

A consensual approach is used to measure energy poverty in rural areas of Albania. To do that, we selected 14 indicators for different dimensions of poverty, which are thoroughly summarised in Figs. 2 and 3, to obtain a composite measurement of the energy poverty, with the awareness that only a multidimensional indicator represents a reasonable starting point for appropriate research within the rural contexts (Gafa and Egbendewe, 2021). Significant regional disparities exist in energy deprivation between rural and urban areas, with rural areas consistently showing the worst performance (Manasi and Mukhopadhyay, 2024; Ahmed and Gasparatos, 2020). When interpreting these findings, it is important to acknowledge that energy practices are deeply embedded in local cultural contexts and historical traditions. While our analysis identifies certain energy sources and practices as indicators of deprivation based on established frameworks, we recognize that some patterns, such as the use of wood-burning stoves, may reflect cultural preferences, local resource availability, or traditional practices rather than solely representing inadequate access to modern energy services. This distinction is particularly relevant in rural contexts where traditional energy practices may coexist with or even be preferred over grid-based alternatives due to factors including reliability, affordability, cultural significance, or integration with local livelihoods (Bai et al., 2024). Our findings should therefore be interpreted with sensitivity to these cultural nuances, recognizing that energy transitions must respect local contexts while still addressing genuine access and equity concerns.

Note from Figs. 2 and 3 that economic deprivation plays a crucial role in energy poverty - for all the indicators considered, the frequency of deprived individuals is higher than that of non-deprived ones - as affordability issues limit access to adequate energy resources. These results

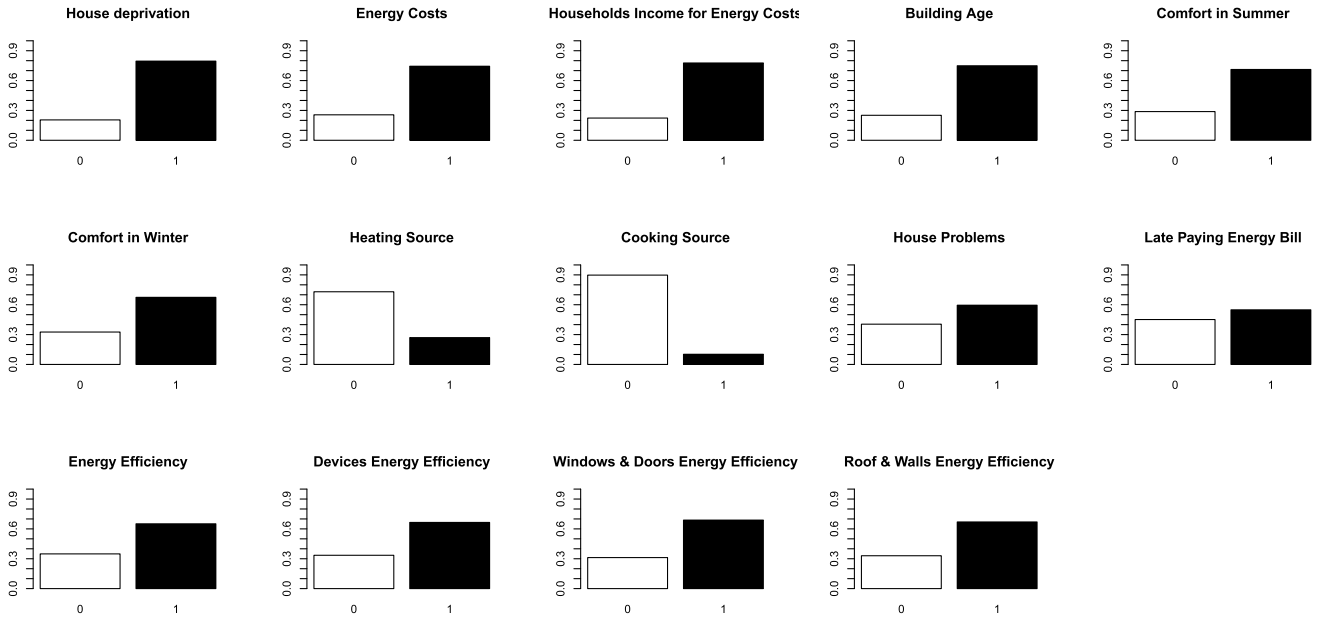


Fig. 2. Distribution of non-deprived (0) and deprived (1) individuals across selected indicators. Indicators 1–3 represent the economic dimension, 4–10 pertain to energy, and 11–14 correspond to subjective well-being.

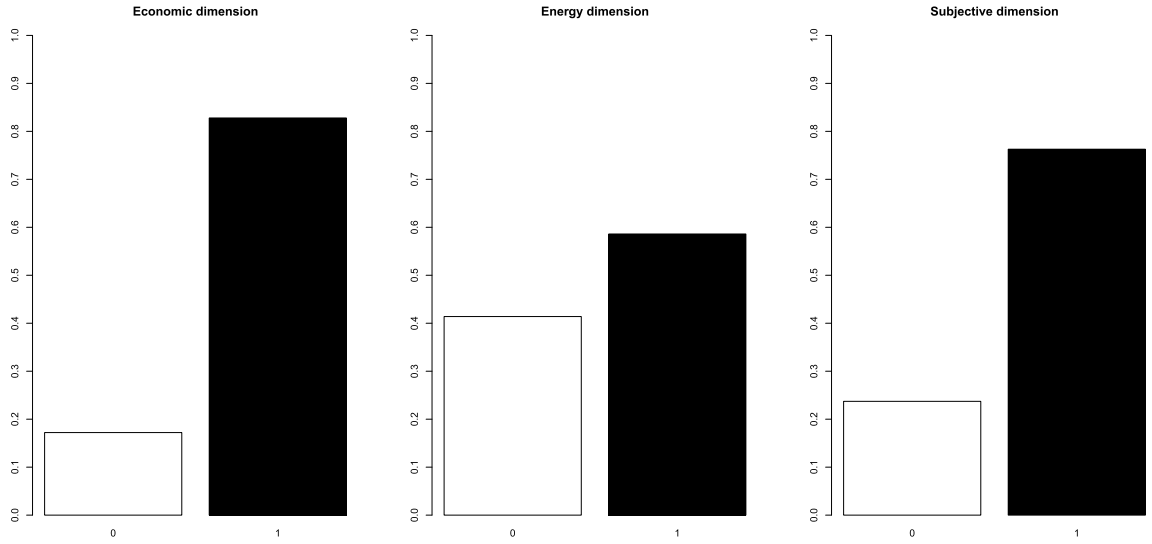


Fig. 3. Distribution of non-deprived (0) and deprived (1) individuals across selected dimensions: economic, energy and subjective.

Table 2
Scenario 1. Measures of poverty: values of headcount ratio (H), intensity of poverty (A),a and adjusted headcount ratio (M). The numbers in the brackets represent 95 % bootstrap confidence interval.

Measure	Cut-off (m)	Scenario 1
H	1	0.935 (0.9 - 0.968)
H	2	0.739 (0.683 - 0.793)
H	3	0.502 (0.433 - 0.568)
A	1	0.776 (0.74 - 0.812)
A	2	0.893 (0.867 - 0.917)
A	3	1 (1 - 1)
M	1	0.726 (0.682 - 0.768)
M	2	0.660 (0.606 - 0.714)
M	3	0.502 (0.433 - 0.568)

Table 3
Scenarios 2–3-4. Measures of poverty: values of headcount ratio (H), intensity of poverty (A), and adjusted headcount ratio (M). The numbers in the brackets represent 95 % bootstrap confidence intervals.

Measure	Cut-off (m)	Scenario 2	Scenario 3	Scenario 4
H	0.5	0.935 (0.902–0.967)	0.935 (0.901–0.969)	0.935 (0.903–0.968)
H	1	0.874 (0.831–0.919)	0.744 (0.683–0.802)	0.795 (0.739–0.849)
H	2	0.828 (0.776–0.879)	0.586 (0.521–0.650)	0.763 (0.704–0.819)
H	2.5	0.693 (0.631–0.754)	0.581 (0.517–0.645)	0.707 (0.644–0.768)
H	3	0.502 (0.432–0.572)	0.502 (0.437–0.569)	0.502 (0.434–0.570)
A	0.5	0.831 (0.797–0.865)	0.702 (0.651–0.756)	0.796 (0.752–0.838)
A	1	0.877 (0.851–0.902)	0.839 (0.798–0.881)	0.906 (0.883–0.930)
A	2	0.907 (0.889–0.926)	0.975 (0.964–0.986)	0.931 (0.916–0.947)
A	2.5	0.954 (0.942–0.966)	0.977 (0.968–0.988)	0.952 (0.940–0.964)
A	3	1 (1-1)	1 (1-1)	1 (1-1)
M	0.5	0.777 (0.734–0.819)	0.656 (0.603–0.711)	0.744 (0.695–0.792)
M	1	0.767 (0.722–0.812)	0.624 (0.566–0.681)	0.721 (0.666–0.774)
M	2	0.751 (0.703–0.799)	0.571 (0.508–0.634)	0.710 (0.653–0.765)
M	2.5	0.661 (0.602–0.720)	0.568 (0.505–0.631)	0.673 (0.612–0.732)
M	3	0.502 (0.435–0.570)	0.502 (0.437–0.569)	0.502 (0.434–0.570)

are in line with several recent studies on the topic (see, among others, Yang et al., 2025 and Yang et al., 2025). According to the heating and cooking system, the majority of individuals are not deprived, suggesting that most have access to reliable cooking and heating sources. However, to consolidate these gains and achieve comprehensive coverage, policymakers should design targeted rural strategies to promote clean cooking technologies, and to expand access to sustainable energy sources in under served communities prioritizing, for example, energy access for diverse socioeconomic backgrounds through subsidies and/or microfinance options (Hosan et al., 2024).

Subjective indicators, based on self-reported comfort and housing conditions, highlight discomfort, emphasising the need for improved efficiency solutions. In this context, a “neutral” response does not signal satisfaction, but rather uncertainty or a lack of positive adequacy - and therefore, functionally, a shortfall. Accordingly, neutrality is treated as a non-affirmative response and aligns with the binary thresholding logic of multidimensional energy poverty index of Nussbaumer et al. (2012).

As previously outlined, the identification process rests on several assumptions regarding the definition of the normative space of each measure (dimensions/indicators, cut-offs and weights). The analysis considers different scenarios in which each dimension is assigned a weight. The weight of each indicator depends on the number of indicators within its dimension. For the first scenario, we assume equal weights among dimensions so that $\upsilon_k = 1$, for $k = 1, \ldots, 3$. In Scenario two, the economic dimension is given strong preference and assigned a weight of 2, whilst the remaining two domains are assigned a weight of 0.5 respectively. In Scenario three, the energy dimension is given strong preference and assigned a weight of 2, whilst the remaining two indicators are assigned a weight of 0.5 respectively. In Scenario four, the subjective dimension is given strong preference and assigned a weight of 2, whilst the remaining two dimensions are assigned a weight of 0.5 respectively. Thus, we have five identification cut-offs: 0.5, 1, 2, 2.5, and 3. For $m = 0.5$ and $m = 3$, individuals are classified as poor if they are deprived in at least one dimension (union approach) or all dimensions, respectively. For $m = 1$, we consider as poor individuals deprived in at

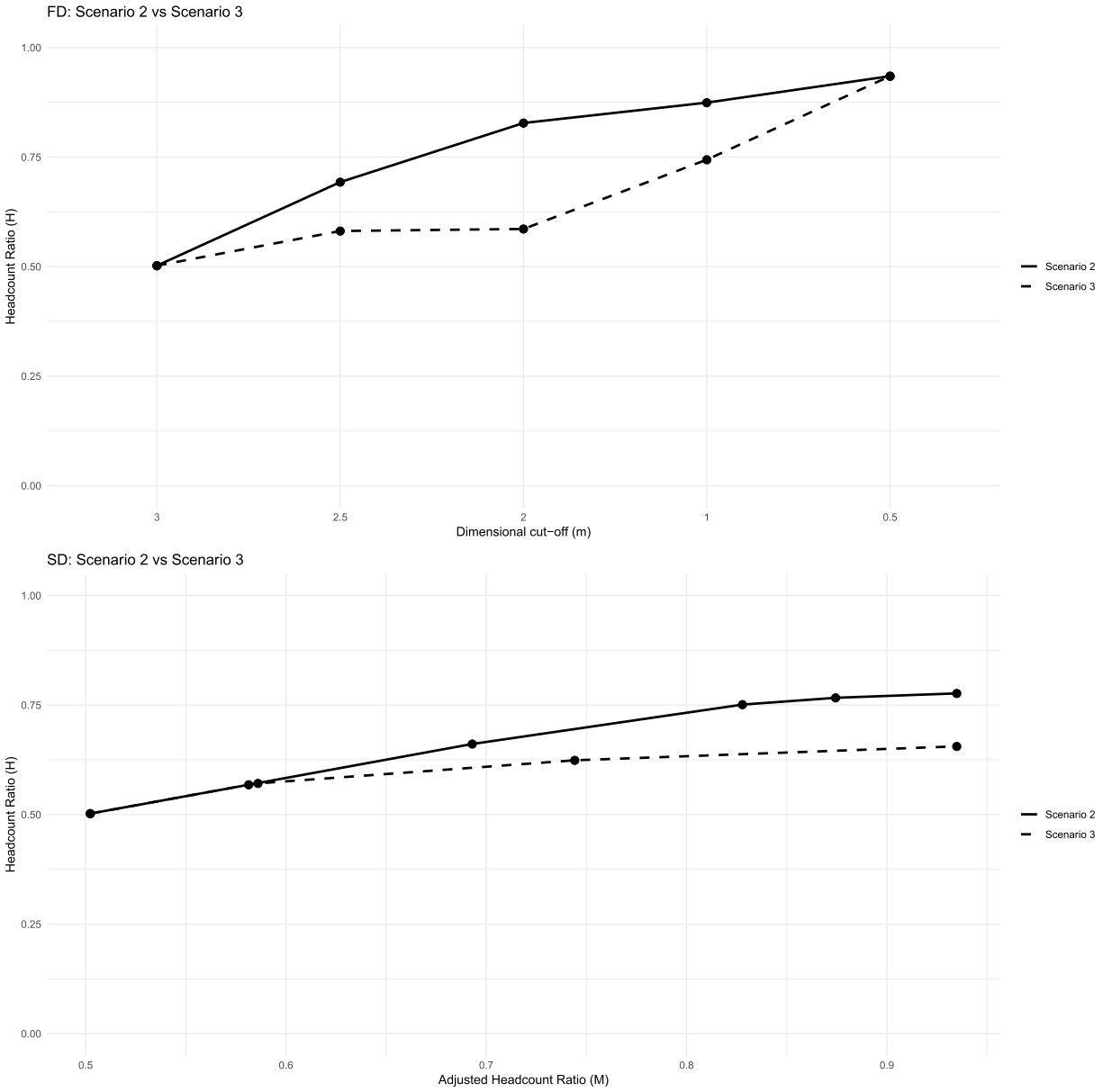


Fig. 4. Scenario 2 vs Scenario 3. FD curve (panel a) and SD curve (panel b).

least the dimensions that jointly weigh the least. For $m = 2$, we consider as poor individuals deprived in at least the dimension that weighs the most, and for $m = 2.5$, individuals deprived in at least the dimension that weighs the most, with any of the other dimensions. Tables 2 and 3 show the counting poverty measures of $H(m)$, $A(m)$, and $M(m)$ for all the feasible cut-offs according to the four Scenarios considered in the analysis.

According to Table 2, which describes measures of energy poverty by considering equally weighted dimensions, in rural areas of Albania, the level of energy poverty can be considered quite high, despite the lack of official data for comparison. Indeed, approximately 50 % of the population (as indicated by the adjusted headcount ratio $M_3 = 0.502$) experiences multidimensional energy poverty, facing simultaneous deprivations across all three dimensions considered in our analysis. The adjusted headcount ratio accounts not only for the incidence of poverty (i.e., how many people are affected) but also for the intensity of deprivation experienced by those individuals. This means that a substantial portion of the rural population lives in conditions that systematically fail to meet basic energy needs - such as ensuring adequate home comfort, energy efficiency, and affordability - highlighting a serious and multifaceted vulnerability that warrants targeted policy intervention. The incidence rate we observed is consistent with figures reported in other rural areas across Central and Eastern Europe (Karpinska and Śmiech, 2020). Our findings align with broader European evidence regarding hidden energy poverty in remote rural areas of Central and Eastern Europe. In these regions, households experiencing hidden energy poverty tend to share common characteristics, highlighting how limited infrastructure and seasonal income fluctuations exacerbate the challenges of energy poverty for these rural communities (Karpinska and Śmiech, 2023).

Furthermore, a sensitivity analysis using different weighting schemes (Scenarios $2-4$ are described in Table 3) for the considered dimensions provides deeper insights into the energy poverty situation. Specifically, when we compare the adjusted headcount ratio for the case where $m = 2$ (as reported in the bottom panel of Table 3), we find that the value is consistently lower in Scenario 3, where the weight assigned to the

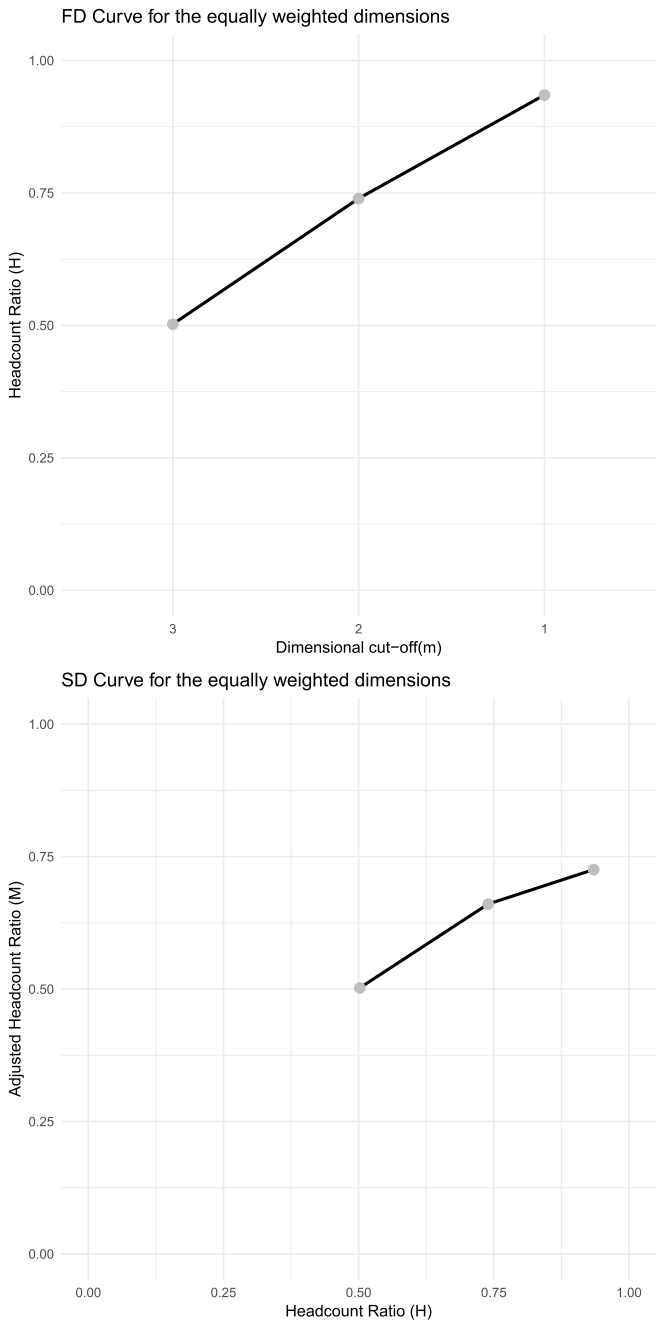


Fig. 5. Scenario 1. FD curve (panel a) and SD curve (panel b).

energy dimension is set to 2, compared to Scenarios 2 and 4, in which the weight of 2 is assigned to the economic and subjective dimensions, respectively. This suggests that the economic dimension (and to a lesser extent, the subjective dimension) plays a crucial role in identifying the poorest individuals, an aspect that might be overlooked if energy poverty is assessed solely in terms of energy inefficiency, without considering its multidimensional nature. This confirms that poverty and social exclusion remain prevalent in rural areas. Notably, rural regions exhibit the highest maximum values for both energy poverty and traditional poverty indicators (Pereira and Marques, 2023). Indeed, 29.3 % of individuals are deprived in the economic dimension, while 21.4 % are deprived in the subjective dimension, yet neither reports deprivation in the energy dimension (see Fig. 3). Consequently, energy policy frameworks require locally differentiated approaches rather than uniform implementation on national scales. Strategic interventions, including renewable energy deployment targets and energy poverty alleviation objectives, should be formulated at appropriately localized scales depending on the degree of urbanization. The energy accessibility challenges faced by rural communities, for instance, differ substantially from those encountered in urbanized contexts (Pereira and Marques, 2023).

Fig. 4, which provides a visual comparison between Scenario 2 (solid line) and Scenario 3 (dashed line), clearly reinforces this finding. Specifically, the FD and SD curves corresponding to Scenario 3 consistently lie below those of Scenario 2, at least for the case where $m = 2$. This graphical evidence confirms that assigning a higher weight to the energy dimension (as in Scenario 3) results in a lower overall level of multidimensional energy poverty compared to assigning the same weight to the economic dimension (as in Scenario 2). The position of the curves illustrates a systematic reduction in both the incidence and intensity of deprivation under Scenario 3, further validating the impact of dimensional weighting on the poverty measure.

For the sake of completeness, we also present the FD and SD curves for the scenario in which all three dimensions are equally weighted, as shown in Fig. 5. This baseline case serves as a useful benchmark for comparison, allowing us to assess how alternative weighting schemes, such as those used in Scenarios 2 and 3, affect the distribution and intensity of multidimensional energy poverty. The inclusion of this equally weighted scenario provides a more comprehensive understanding of the role that dimension-specific weights play in shaping the outcomes of the analysis.

6. Conclusions and policy implications

The systematic measurement of energy poverty represents more than a mere academic exercise; it is a critical lens through which we can examine the most fundamental aspects of human well-being and social equity. This study reveals a complex landscape of energy poverty in Albania, particularly in rural areas, that demands a multifaceted policy approach. While the majority of individuals are not entirely deprived of heating and cooking systems, the high levels of subjective discomfort underscore the critical need for targeted interventions. Our analysis highlights that economic deprivation significantly constrains energy access, creating a cyclical challenge where limited financial resources prevent households from obtaining adequate energy services. From a comparative perspective, the methodological insights of this research offer significant potential for cross-national application, particularly in developing and transitional economies with similar socioeconomic characteristics. The study's innovative approach of combining objective infrastructure assessment with subjective well-being indicators provides a robust framework that could be adapted to other contexts, especially in Eastern European, Balkan, and similar rural-dominated economies. The sensitivity analysis demonstrates the crucial role of economic dimensions in identifying energy-poor populations. Individual states, unions of states, and international organizations—each with different roles, powers, and responsibilities—have made strong commitments to tackling energy poverty and protecting vulnerable households. This dedication is reflected in the adoption of targeted policies, broad measures, and strategic recommendations aimed at significantly reducing energy poverty, which currently affects more than 1.18 billion people worldwide (United Nations, 2024). However, these initiatives do not always reach the households that most need assistance. Our findings highlight several policy implications stemming from the complex and multifaceted nature of energy poverty. Governments should give more consideration to the relationship between income poverty and energy poverty found in this study. Housing costs have a decisive impact on vulnerability, and actions to promote employment and develop economic activities could mitigate the phenomenon. For this reason, policymakers should prioritise a comprehensive strategy that goes beyond merely assessing energy infrastructure and instead adopt a multidimensional approach that integrates economic and subjective indicators. We recommend breaking this cycle

through comprehensive, multi-pronged strategies that address both immediate affordability issues and long-term economic empowerment. In line with our results, the study highlights the need for targeted economic support combined with energy efficiency upgrades and community-specific interventions to significantly reduce energy poverty. While energy policies have traditionally been implemented nationally, a regional approach would better address local residential energy patterns and their specific implications. Governments should implement holistic strategies that simultaneously address income disparities and housing conditions. Energy poverty reduction must be integrated with broader social policy frameworks. National strategies should align interventions with the socio-economic characteristics of vulnerable populations. A one-size-fits-all approach is inadequate as energy poverty varies significantly across household profiles and regional contexts. Policy design should incorporate targeted measures addressing specific needs, enabling more efficient resource allocation and developing integrated responses that combine housing support, income assistance, and energy efficiency measures tailored to rural contexts.

This research has limitations, primarily the lack of comprehensive official data in rural areas, potentially introducing bias. Additionally, self-reported indicators introduce subjectivity that may affect precision. In fact, the current absence of direct questions regarding expenditure amounts represents a methodological limitation that could be addressed in future survey designs. In the continuation of our research agenda on energy poverty, we plan to address this limitation through the acquisition and integration of comprehensive expenditure data. Future extensions of this work will develop more sophisticated analytical frameworks incorporating detailed energy expenditure data with multidimensional socioeconomic variables, enabling the implementation of EU-recommended expenditure indices such as the LIHC, 2 M, and Hidden Energy Poverty (HEP) index. These methodological advancements will facilitate a more comprehensive understanding of energy poverty's systemic challenges and provide enhanced policy-relevant insights for addressing this multifaceted phenomenon. Despite limitations, this analysis presents a transferable methodology for researchers and policymakers in regions with similar rural energy access and economic transition challenges. By emphasizing context-specific metrics, the research offers a scalable model for understanding and addressing energy poverty across national boundaries.

CRediT authorship contribution statement

Meivis Struga: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Gloria Polinesi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Mosè Rossi:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Alfonso Carfora:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gabriele Comodi:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Oltion Marko:** Writing – review & editing, Writing – original draft, Supervision.

Declaration of competing interest

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

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Data availability

Data will be made available upon request.

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