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Energy poverty and socioeconomic profiles: A case study of NUTS 2 regions in Italy, Lithuania and Poland using cluster analysis and mapping

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Abstract. This article analyses energy poverty from a regional perspective, focusing on NUTS 2 regions of Italy, Lithuania and Poland. It proposes a joint taxonomy of territorial profiles that combines a direct indicator of energy deprivation with macro-level socio-economic variables capturing affordability, social vulnerability, human capital, labour-market conditions and the dynamics of the productive structure. Using hierarchical cluster analysis and cartographic representation, the study identifies four regional profiles of energy deprivation and socio-economic context and assesses whether they primarily reflect within-country territorial

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gradients or cross-border similarities. The resulting taxonomy is largely country-structured, with limited cross-border overlap. High deprivation emerges in two distinct configurations: one associated with broader income and labour-market fragilities and one persisting despite comparatively favourable socio-economic fundamentals, pointing to the potential relevance of needs and system factors. The proposed taxonomy provides a concise tool to jointly interpret energy deprivation and socio-economic conditions at the NUTS 2 level and to inform place-sensitive policy interventions.

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JEL Classification: Q41, I32, R12

1. INTRODUCTION

The 2020 pandemic crisis and the effects of the war in Ukraine had a profound impact on the economies of European Member States and their effects are still visible in the European macroeconomic framework (Nagaj & Korpysa, 2020; Streimikiene, 2022; Tagliapietra et al., 2023; Sipiczki, Z., et al., 2024). Despite a scenario that points to moderate and sustained growth in 2026, uncertainty remains elevated, particularly regarding energy market prices (European Commission, 2025). This uncertainty is further amplified by geopolitical tensions involving the Strait of Hormuz, one of the world's most critical oil transit chokepoints that can quickly transmit new shocks to international energy markets (IEA, 2026). Energy is a persistent problem in the European Union, both because of its implications for climate transition and because of its redistributive and welfare effects, given the direct impact of energy costs on households' material conditions and their ability to access essential energy services (European Energy Network, 2019; International Energy Agency, 2019; Bakó, F., et al., 2021; Pécsinger, J., et al., 2025). Tackling energy poverty becomes crucial to achieving a fair and inclusive energy transition for all European countries (European Commission, 2025). This is mainly motivated by the fact that energy poverty hurts individuals' physical and mental health, with further repercussions on social relations and educational opportunities (Middlemiss et al., 2019; Pacudan & Hamdan, 2019; Thomson et al., 2017; Tvaronavičienė et al., 2021; Khalid et al., 2025). From an international point of view, the United Nations has recognised its importance by including it in the 2030 Agenda for Sustainable Development with Goal 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all, placing the affordability and adequacy of domestic energy services at the centre of development policies (United Nations, 2015). Recent international literature has also stressed the socio-economic impacts of energy poverty across different world regions and the importance of scalable responses to the problem (Filho et al., 2025).

In Europe, energy poverty has progressively moved from a marginal social concern to an explicit objective of energy and climate policy. Since its formal recognition in EU legislation in 2009, the issue has been gradually incorporated into the European policy framework through the European Pillar of Social Rights, the Clean Energy for All Europeans package and more recent regulatory and policy developments. In this process, energy poverty has increasingly been framed as a structural dimension of the green transition rather than as a residual social issue (Vasa et al., 2024; Sahoo et al, 2025). In particular, the Energy Efficiency Directive (EU/2023/1791) explicitly aims to alleviate energy poverty, empower consumers and provide the current definition of the phenomenon (European Commission, 2024). At the same time, energy poverty has also become increasingly relevant at the local level, as shown by initiatives such as the Covenant of Mayors for Climate and Energy, which has mobilised thousands of local governments around climate and social transition goals (Energy Poverty Advisory Hub, 2024).

In this scenario, energy poverty is interpreted as a multidimensional phenomenon and several indicators are used. The shared definition refers to energy poverty as a lack of access to essential energy services and specifies that it is fuelled by the interaction between affordability issues, high energy costs and low energy efficiency in homes (Energy Poverty Advisory Hub, 2024; European Commission, 2023b; European Commission, 2023a). To address the phenomenon in the European context, this study uses the share of people unable to keep their homes adequately warm, a direct and subjective indicator of energy deprivation that involves households in its measurement. The subjective nature of the indicator is a limitation of the study, since responses may be influenced by households' social and cultural characteristics (Energy Poverty Advisory Hub, 2023). In addition, energy deprivation may reflect infrastructural and geographical constraints operating at different territorial scales and may be affected by climatic characteristics typical of the territories linked to the satisfaction of energy needs (European Commission, 2023a; Min et al., 2024). Considering these limitations, this study takes various socio-economic dimensions to examine the characteristics of regions in Italy, Lithuania and Poland within the broader framework of energy poverty. This three-country design enables a comparative assessment of regional profiles across different national contexts within the EU, highlighting both within-country heterogeneity and cross-country differences in the socioeconomic configurations associated with energy deprivation. In 2024, the share of the European population unable to keep their homes adequately warm was 10.6%, with marked differences across Member States. Lithuania recorded one of the highest values (20.0%), Italy remained below the EU average (8.6%), while Poland, at 3.4%, was among the lowest-incidence cases (Eurostat, 2024). This cross-country heterogeneity is consistent with comparative evidence showing that EU countries remain differentiated in terms of energy poverty levels (Oesterreich & Barej-Kaczmarek, 2024).

In line with the objective of the paper, the proposed cluster analysis is developed on a NUTS 2 territorial scale and uses regional variables that describe the socio-economic context in order to consider the phenomenon also from a spatial point of view. This approach allows regional typologies to be constructed and highlights spatial patterns that are comparable across countries, in line with recent regional assessments showing that meaningful territorial comparisons can also be developed without household-level microdata (Xenakis et al., 2025). Consequently, the results are interpreted as territorial profiles associated with energy deprivation, which are useful for descriptive and policy purposes and preparatory to a subsequent identification of causal relationships. Building on this motivation, the paper pursues three objectives. First, it derives a replicable taxonomy of NUTS 2 regional profiles from the joint distribution of thermal discomfort and socio-economic conditions. Second, it assesses whether the resulting profiles primarily reflect within-country territorial gradients or cut across national borders. Lastly, it interprets high-deprivation profiles by distinguishing configurations consistent with affordability constraints from those plausibly related to needs and broader system factors. The rest of the paper is organised as follows. Section 2 outlines the conceptual background on energy poverty, with a focus on definitions and measurement approaches. Section 3 describes the data and methodology, detailing the variables and the process that leads to the results. Section 4 presents the discussion of results, illustrating the spatial distribution of clusters and their socioeconomic characterisation, while section 5 summarises the main findings and highlights policy-relevant implications.

2. LITERATURE REVIEW

2.1. Definitions and measurement of energy poverty

Energy poverty was introduced into scientific debate several decades ago and despite extensive discussion on the subject there is no common definition of the phenomenon. In the European debate, the terms fuel poverty and energy poverty coexist and its measurements stem from these concepts. The former is historically rooted in the United Kingdom and typically refers to households' inability to afford adequate domestic energy services often operationalised through expenditure-based thresholds and driven by the interaction of low-income, high-energy costs and poor housing efficiency (Bouzarovski & Petrova, 2015; Bouzarovski, 2014). It is now widely accepted that energy poverty can be measured using objective approaches that link disposable income spent on energy costs to subjective approaches that focus on perceived deprivation in living conditions (Del Río et al., 2025; Szczygieł et al., 2024; Kot et al., 2024). As early as 1979, an attempt was made to diagnose households with difficulties in paying fuel and energy bills, also taking into account energy costs, identifying a threshold of 12% of income as the condition of deprivation (Isherwood & Hancock, 1979). A subsequent study conducted by Bradshaw and Hutton defined energy poverty as a social phenomenon that was related to the shortage of financial resources suffered by an individual or a group of people to provide them with adequate heating and lighting for their homes (Bradshaw & Hutton, 1983). This line of work culminated in Boardman's first formal definition, under which energy poverty affects households that need to spend more than 10% of their income to secure a minimum level of domestic energy provision (Boardman, 2010). Another policy-oriented refinements shifted from a simple expenditure share to a relative framework, most notably Hills' Low Income High Costs (LIHC) approach, which classifies households as energy-poor when they combine low income, defined as below 60% of the median equivalised disposable income, with high required energy costs (Hills, 2012).

More recent contributions have further broadened the concept of energy poverty. Another approch linked it to underheating and to the adverse health consequences associated with inadequate indoor thermal conditions (Liddell & Morris, 2010). Also, the issue is framed more broadly in terms of households' lack of access to energy services provided through external systems and infrastructures (Bouzarovski et al., 2012). Next was emphasised the affordability dimension, describing energy poverty as a condition in which household energy expenditure exceeds residual income after essential living costs have been met (Moore, 2012). Building on these strands, the European Union currently defines energy poverty as a household's lack of access to essential energy services, including adequate heating, hot water, cooling, lighting and electricity for appliances, resulting from a combination of factors such as unaffordability, high energy expenditure and poor housing energy efficiency (Energy Poverty Advisory Hub, 2025). Although this EU framework provides a common reference point, national interpretations still reflect country-specific priorities and institutional settings.

2.2. Territorial approaches to energy poverty

Since this study aims to enrich the discussion on energy poverty by incorporating a territorial perspective, it is useful to recall the growing body of regional and spatial research on the topic. Recent contributions show that energy poverty should not be understood only as a household-level condition, but also as a territorial phenomenon shaped by climatic conditions, socioeconomic structures, housing characteristics and institutional arrangements (Widyanti and Włodarczyk, 2023; Lieth et al., 2025; Korkmaz & Senyel Kurkcuoglu, 2025; Zeman et al., 2025). At the European scale, regional analyses have highlighted marked spatial disparities in energy vulnerability across NUTS areas and have shown that similar technical conditions may produce different levels of deprivation depending on local adaptive capacity and broader contextual factors (Andreoni, 2024; Della Valle et al., 2025). Further, it has been demonstrated that energy vulnerability tends to cluster geographically and that its drivers vary substantially across territories, reflecting different combinations of income constraints, settlement patterns, housing quality and access to services (Lehtonen et al., 2024; Zardo et al., 2024). In addition, recently it has pointed to the regional level as a crucial scale for future research and policy design, as it makes it possible to capture subnational heterogeneity that remains hidden in national averages (Guarascio et al., 2025). Taken together, these considerations support the need to study the phenomenon considering also the spatial element into the analysis.

3. DATA AND METHODOLOGY

3.1. Variables and territorial units

Given data availability and coverage at the interested territorial scale, 2022 was selected as the reference year for the analysis (Eurostat, 2022). NUTS 2 regions, which typically comprise between 800000 and 3 million inhabitants, are designed for planning and monitoring EU cohesion policies and are selected as the reference territorial unit of this study, being an appropriate territorial level for highlighting differences even within countries and allowing for comparable comparisons between sub-national units (Eurostat, 2025). Our analysis takes the share of people unable to keep their home adequately warm (EnPo) to represent energy poverty. To provide a first descriptive picture, Figure 1 depicts its geographical distribution on Italian, Lithuanian and Polish NUTS 2 showing a heterogeneous scheme, although some spatial patterns can be identified. In Italy, there is a clear territorial polarisation, with the highest values concentrated in the South and the Islands (in particular, Campania with 16.20%), while the Central-Northern regions show predominantly lower levels (for instance, Provincia Autonoma di Bolzano with 1.30%), confirming consistency with the North-South divide pattern, which suggests that energy deprivation is closely linked to socio-economic vulnerability and household spending power, as well as structural differences in building stock and heating and cooling requirements. In Poland, the distribution reveals a prevalence of intermediate values and, compared to Italy, there is less widespread heterogeneity. Finally, Lithuania stands out for its more homogeneous values in the highest class of the indicator with Vidurio ir vakarų Lietuvos regionas (17.80%) and Sostinės regionas (16.90%). This descriptive pattern is broadly consistent with recent EU-level evidence locating the highest energy poverty levels in Eastern and Southern Europe and the lowest levels in Northern and Central Europe (Sompolska-Rzechuła et al., 2025).

As a limitation of the study, we note that thermal discomfort may reflect both affordability constraints (limited resources relative to energy costs) and needs and system factors (climate, housing efficiency, market conditions and institutional settings). In this sense, the selected indicator captures an outcome of energy deprivation, while physical and market determinants are not explicitly modelled. The resulting clusters should therefore be interpreted as descriptive territorial profiles rather than as a causal decomposition of drivers. Before outlining the methodological procedure, the variables included in the analysis are presented and their selection is justified based on their documented relationship with energy poverty.

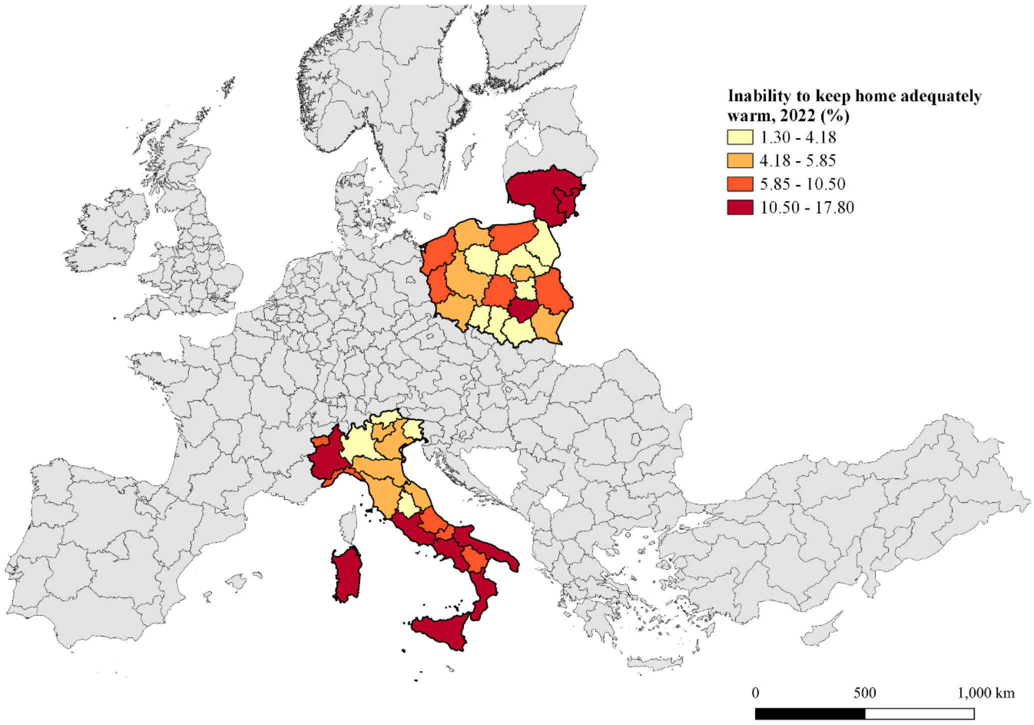

Figure 1. Share of population unable to keep their homes adequately warm across Italian, Lithuanian and Polish NUTS 2 regions

Source: Own elaboration on Eurostat 2022 regional data

Descriptive statistics and the Pearson correlation matrix are reported in Table 1 and Table 2. To represent the educational dimension, the proportion of the population aged 25-64 with tertiary qualifications (ISCED 5-8) is used as a proxy for regional human capital, which is relevant for access to employment and income resilience. Higher human capital is generally associated with better employment opportunities, higher average wages and lower exposure to precarious conditions, all of which affect households' ability to meet unavoidable expenses such as energy costs (Del Río et al., 2025; Koukoufikis et al., 2024; Thomson & Bouzarovski, 2019; Teixeira et al., 2024). The at-risk-of-poverty rate (AROP) is included as a summary measure of economic vulnerability and risk of social exclusion, dimensions that are frequently associated with energy poverty. This indicator helps identify the segment of the population exposed to tighter budget constraints and a lower capacity to absorb price shocks or unexpected changes in household expenditure, which often result in cuts to essential consumption. From this perspective, X2 is useful in distinguishing regional contexts where energy deprivation is more directly attributable to widespread social vulnerability and economic fragility (Koukoufikis et al., 2024; Nagaj & Korpysa, 2020; Teixeira et al., 2024). Household disposable income in Purchasing Power Standard (PPS) captures the affordability channel, that is, the ability to sustain energy costs without falling into deprivation. Since energy is a relatively fixed expense in the short term, lower levels of disposable income reduce the scope for adjustment and increase the likelihood that energy costs will compete with other essential consumption items. In this sense, X3 allows regions to be positioned along a spending-capacity dimension that is central to interpreting the economic component of energy poverty (Nagaj & Korpysa, 2020; Lyra et al., 2022; Chaton & Lacroix, 2018). The employment rate reflects the strength of the labour market, since greater employment fragility may translate into higher exposure to energy poverty through a reduction in available resources and a lower capacity to plan expenditure and investment (Del Río et al., 2025; Drescher & Janzen, 2021). Finally, to capture the degree of regional economic vitality, the enterprise death rate, defined as the ratio of dead enterprises to active enterprises, is included as an indicator of the productive context. Although not directly measuring energy poverty, it helps differentiate regional profiles in which energy vulnerability emerges in contexts characterised by greater fragility or ongoing transformation of the business structure. This dimension is relevant for comparative analysis because business dynamics may be reflected, directly or indirectly, in employment stability and local economic prospects, thereby influencing households' ability to meet energy costs in the medium term.

Table 1

Descriptive statistics

Variable	Unit of measure	Mean	Min	Max	CV	Eurostat code
EnPo	%	7.32	1.30	17.80	60.55	ilc_mdes01_r
X1	%	27.17	15.20	62.10	37.21	edat_lfse_04
X2	%	17.40	5.60	37.10	49.43	ilc_li41
X3	PPS per inhab.	18010	13200	27400	19.37	nama_10r_2hhinc
X4	%	73.51	48.80	87.80	13.05	lfst_r_lfe2emprt
X5	%	9.80	5.66	14.78	35.12	bd_size_r

Source: Own elaboration on Eurostat 2022 regional data

The descriptive statistics reveal marked heterogeneity among the considered regions. Inability to keep home adequately warm shows an average of 7.32 and a high coefficient of variation of 60.55%, highlighting a elevate differentiated territorial distribution of the phenomenon. A similar degree of dispersion is observed for AROP, which shows a coefficient of variation of 49.43%, consistent with a high degree of heterogeneity in the levels of socio-economic vulnerability in the sample. Disposable income of households is relatively more stable, while the employment indicator has an average of 73.51 and overall limited variability with CV 13.05%, suggesting less pronounced differences along this dimension. The share of highly educated population has an average of 27.17, but with a particularly high maximum value (62.10), indicating the presence of regional contexts with human capital endowments well above the sample average. Last, the business system variable shows medium-high variability (CV 35.1%), indicating significant differences in the dynamics of the regional productive demography.

Table 2

Pearson correlation matrix.

	EnPo	X1	X2	X3	X4	X5
EnPo	1.00	0.01	0.62	-0.22	-0.50	-0.11
X1	0.01	1.00	-0.34	-0.15	0.65	0.68
X2	0.62	-0.34	1.00	-0.47	-0.82	-0.18
X3	-0.22	-0.15	-0.47	1.00	0.27	-0.63
X4	-0.50	0.65	-0.82	0.27	1.00	0.52
X5	-0.11	0.68	-0.18	-0.63	0.52	1.00

Source: Own elaboration on Eurostat 2022 regional data

The correlation matrix can provide a first indication of how energy deprivation is related to the selected socioeconomic dimensions. The indicator of energy poverty is strongly and positively correlated with the AROP (0.62) and strongly and negatively with the employment rate (-0.50), while it is only weakly related to household disposable income (-0.22) and essentially uncorrelated with the share of population with tertiary education (0.01). The block formed by AROP, employment rate, population share with advanced education and disposable household income reveals a clear socioeconomic gradient: regions with higher employment and a larger share of tertiary-educated population tend to display lower poverty risk. Overall, these patterns indicate the presence of a common socioeconomic axis, while EnPo and X5 contribute additional, non-redundant information, which justifies the use of cluster analysis to identify regional profiles combining energy deprivation, social vulnerability and business dynamics.

3.2. Cluster analysis procedure

After examining the descriptive statistics and observing the distribution of the energy deprivation indicator using quintile classes through QGIS tools, cluster analysis is performed to identify territorial types and to build regional profiles based on a combination of the measure of energy poverty and a set of socio-economic variables using Statistica software. Cluster analysis is primarily concerned with identifying patterns of similarity and dissimilarity among a set of observations and, more broadly, with providing an empirically grounded way to classify objects into meaningful groups (Punj & Stewart, 1983). Cluster analysis techniques explore multivariate datasets to assess whether observations can be summarised into a relatively small number of clusters, such that units within the same cluster resemble each other while differing, in relevant respects, from units assigned to other clusters (Everitt et al., 2011). The next step, cluster mapping, is an essential component of this strategy as it allows us to verify whether the profiles identified show a specific territorial distribution and to assess the extent to which segmentation is driven by intra-country differences rather than systemic effects between countries.

The most common approaches in cluster analysis are centroid-based clustering and hierarchical clustering. The latter is taken for our analysis. Hierarchical clustering does not require the number of clusters to be established a priori but generates a nested structure of partitions represented by a dendrogram, which describes how observations are progressively grouped at different levels of similarity (Di Franco, 2017). By cutting the dendrogram at different heights, it is possible to obtain solutions with a variable number of clusters, from 1 to the total number of observations.

Since the variables have different measurement scales, the data are standardised before estimating the distances between regions using the following expression:

$$x_{stand} = \frac{x - \mu_x}{\sigma_x}$$

where μ_x and σ_x represent the sample mean and standard deviation, respectively. This transformation produces variables with a mean of zero and a standard deviation of one, allowing for a more balanced measure of similarity between regions. As mentioned above, classification is obtained by means of agglomerative hierarchical clustering (joining tree) applied to cases, using Euclidean distance and Ward's aggregation criterion, which minimises the total within-cluster variance (Ward, 1963). The following expression refers to Euclidean distance:

$$d^E(U_i, U_j) = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2}$$

where x_{ik} and x_{jk} indicate the values assumed by the two units on the k-th variable considered and represents the total number of variables. The measure quantifies the overall dissimilarity between U_i and U_j as the square root of the sum of the squared deviations over the p dimensions, resulting in zero only when the two units coincide on all variables and increasing as the differences grow.

The choice of the number of clusters is made by inspecting the dendrogram and the aggregation sequence and is the result of the authors' choice in the search for the best compromise between parsimony and comprehensibility of the solution (Di Franco, 2017). The scree plot presented in Figure 2 is also helpful in selecting the number of clusters.

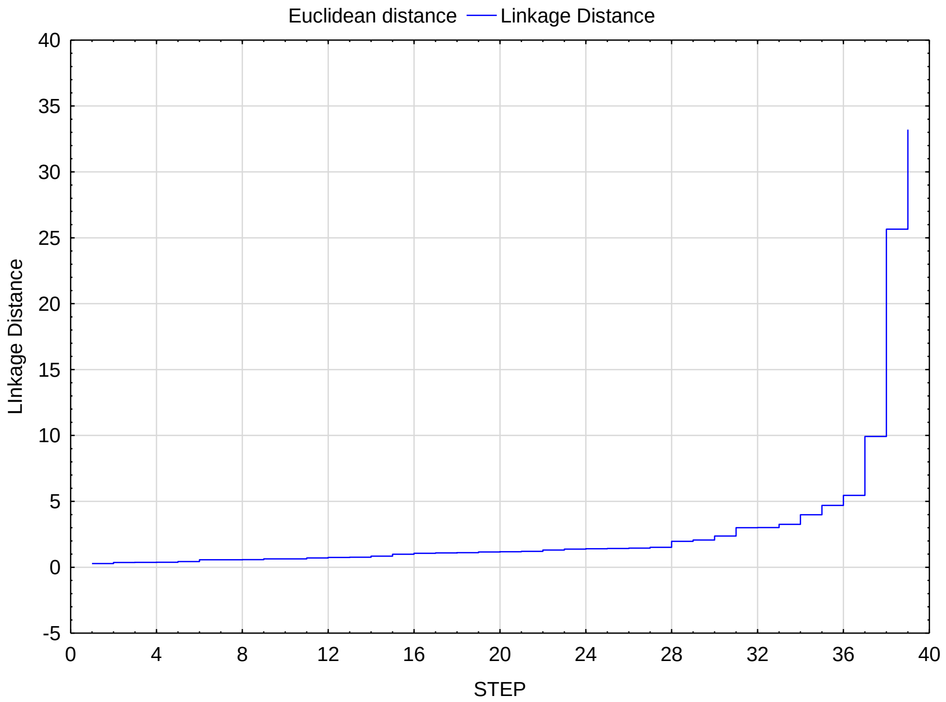

Figure 2. Scree plot

Source: Own elaboration on Eurostat 2022 regional data

The scree plot suggests that a four-cluster solution is the most appropriate, as it shows a rapid increase in the bound size between 5 and 10 linkage distance. Looking at the dendrogram, this indicates the formation of 4 clusters. Solutions with 3 and 5 clusters were considered too: with 3 clusters, the partition combines different socio-economic profiles, reducing the ability to distinguish potentially different mechanisms of energy deprivation, while with 5 clusters, small subgroups emerge from internal divisions of clusters that are already interpretable, adding detail without changing the overall geography. After substantive analysis, nonparametric analysis of variance was used to verify the acceptability of the selected partition and to determine the distribution of differences in the remaining partitions. After conducting a Kruskal-Wallis ANOVA test to test the differences in the studied indicators between the resulting clusters, it was found that in the case of division into four clusters, all indicators showed differences between groups. The test results are presented in Table 3.

Table 3

Kruskal-Wallis test results by cluster

Variable	**H Kruskal - Wallis Test**	**df**	**N**	***p-value***
EnPo	14.15	3	40	0.003**
X1	33.35	3	40	0.000***
X2	22.47	3	40	0.001**
X3	27.65	3	40	0.000***
X4	26.52	3	40	0.000***
X5	30.71	3	40	0.000***

Source: Own elaboration on Eurostat 2022 regional data

Notes: * $p < .05$; ** $p < .01$; *** $p < .001$.

The results show that all indicators differ between the resulting clusters. In each case, p<α. Accordingly, the four-cluster solution was retained for interpretation.

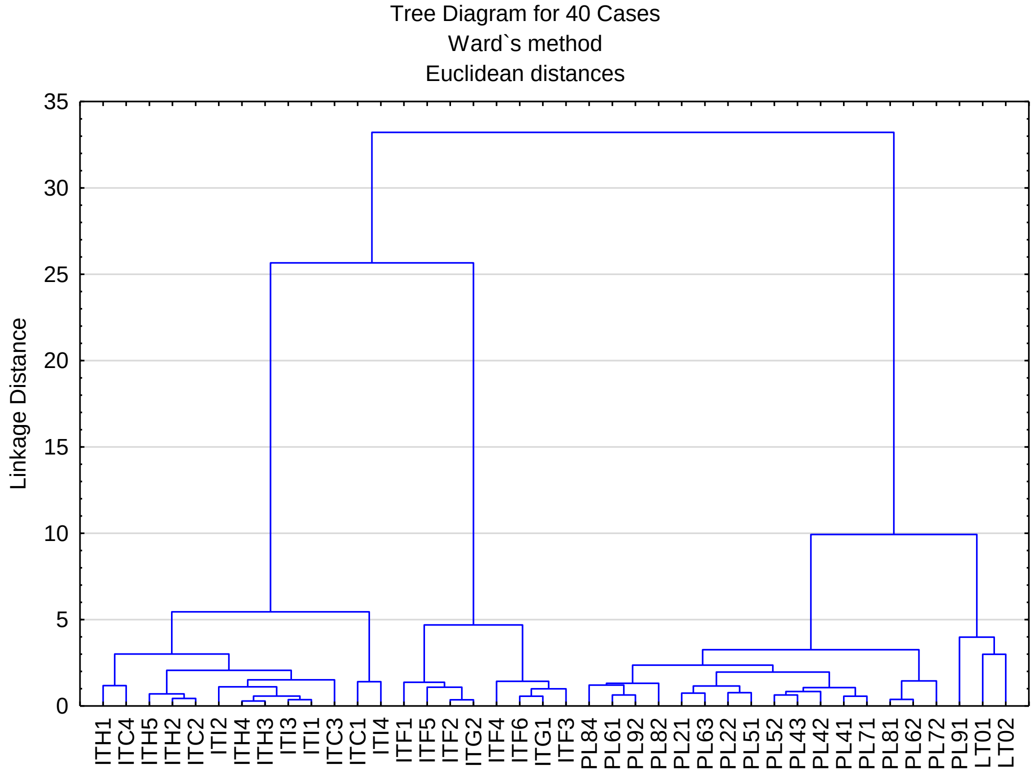

Figure 3. Dendrogram

Source: Own elaboration on Eurostat 2022 regional data

For interpretation, summary statistics are used for each cluster. Specifically, for each indicator j and k cluster the ratio r_{kj} is computed between the cluster average and the overall sample average, $\bar{x}_{k,j}/\bar{x}_{\cdot,j}$, to obtain an immediate reading of the profiles. This reading is used descriptively to define territorial types:

$$r_{kj} = \frac{\bar{x}_{k,j}}{\bar{x}_{\cdot,j}}$$

Finally, the clusters obtained are represented cartographically, assigning each region a cluster label and displaying its spatial distribution, revealing the presence of territorial patterns in order to build a taxonomy of regional profiles and compare their geography.

4. EMPIRICAL RESULTS AND DISCUSSION

4.1. Cluster profiles

The results identify four regional profiles that explain how energy deprivation is intertwined with socio-economic conditions and with an indicator of the dynamics of the production system, allowing for the creation of a comparable taxonomy of territorial contexts across the three national settings considered. The following interpretation is descriptive and should be read as a pattern consistent with the cluster composition rather than as causal evidence. Figure 4 reports the average values used to interpret the clusters, while Figure 5 maps the groups.

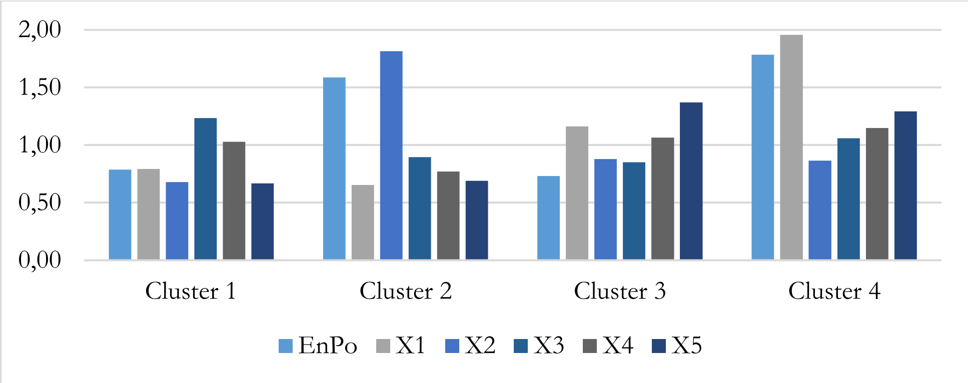

Figure 4. Cluster profiles based on relative average values
Source: Own elaboration on Eurostat 2022 regional data

The analysis identifies four regional profiles. In Cluster 1, energy deprivation is relatively limited and occurs in a context of higher incomes and lower poverty risk. In this case, the affordability channel appears to operate more effectively, as households seem to have sufficient economic capacity to sustain energy costs without widely forgoing heating. When read together with the map, this profile characterises a large part of central and northern Italy and is consistent with the existence of an internal territorial gradient in which more favourable socio-economic conditions and stronger social protection mitigate the effects of price shocks and seasonal climate fluctuations. Cluster 2 represents the profile in which energy deprivation most clearly appears as part of broader economic and social fragility. Here, energy poverty is not an isolated phenomenon, but one dimension of a wider vulnerability structure in which household budget constraints are tighter and essential consumption is more easily reduced when energy becomes a fixed expense. Its concentration in southern Italy and in the islands makes the territorial dualism particularly evident, as energy deprivation is embedded in an already disadvantaged socio-economic context. Cluster 3 describes a situation in which energy deprivation remains relatively low despite lower average incomes, but alongside favourable employment rates and good levels of tertiary education. In economic terms, this suggests that regional average income alone is not sufficient to anticipate the intensity of the phenomenon and that employment stability, together with institutional and system conditions, may also play an important role. High business mortality in this cluster may reflect ongoing changes in the productive structure and does not appear to translate automatically into greater energy deprivation. The map shows that this profile characterises almost all Polish regions, pointing to a certain degree of country-level homogeneity in the combination of energy vulnerability and socio-economic fundamentals. Finally, Cluster 4 is characterised by very high energy deprivation despite high levels of tertiary education. In this case, the socio-economic dimension does not fully explain the observed deprivation, making it plausible that unobserved drivers such as climate and heating needs, the quality and efficiency of the building stock and energy prices also play an important role. On the map, this profile largely overlaps with Lithuania, while also including the Polish region of Warszawski stołeczny, which appears to deserve additional attention.

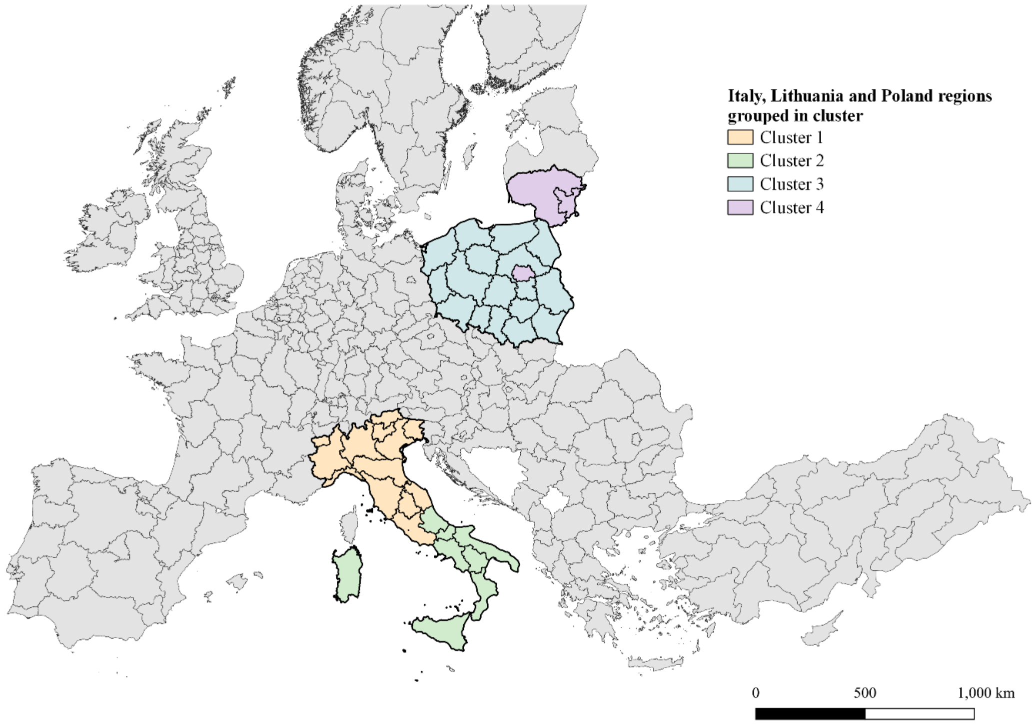

Figure 5. Spatial distribution of clusters on Italian, Lithuanian and Polish NUTS 2 regions

Source: Own elaboration on Eurostat 2022 regional data

5. CONCLUSION

Overall, the paper contributes a replicable and policy-oriented taxonomy of NUTS 2 energy-deprivation profiles obtained by jointly considering thermal discomfort and socio-economic conditions. Beyond ranking regions, the taxonomy shows that similar levels of energy deprivation can be embedded in distinct socio-economic configurations, implying that place-sensitive policy mixes should differentiate between affordability-oriented measures and interventions addressing housing efficiency and broader system conditions. When discussing the profiles that have emerged, it is useful to distinguish between determinants attributable to available economic resources and determinants attributable to energy needs. The indicator inability to keep home adequately warm captures an outcome of deprivation that depends both on household budget constraints and on the intensity of heating needs, which in turn is influenced by geographical and climatic factors and, more generally, by systemic conditions such as the quality and efficiency of the building stock, the structure of energy prices and the architecture of support measures. In this context, empirical evidence suggests that the socio-economic component, although crucial, does not fully explain the phenomenon: Cluster 4, characterised by high energy deprivation despite relatively favourable socio-economic indicators, is consistent with a more significant role of the needs channel and structural determinants not observed in the information set adopted.

In a first set of contexts, energy deprivation appears to be closely aligned with broader socio-economic fragilities: when poverty risk, employment weakness and lower human capital endowments combine with less favourable income conditions, energy tends to take on the nature of a rigid expenditure, squeezing other essential consumption and reinforcing vulnerability. In a second set of contexts, however, high deprivation also occurs in the presence of relatively solid socio-economic fundamentals, suggesting that socio-economic drivers alone are not sufficient to explain the observed outcome and that determinants related to energy needs and systemic factors are more relevant.

Cluster mapping further supports this interpretation. In Italy, there is a clear internal segmentation between areas of greater solidity and areas of vulnerability, with a territorial gradient consistent with the distribution of energy deprivation. On the contrary, Poland and Lithuania tend to have more homogeneous profiles at country level, suggesting that the classification captures not only intra-national differences, but also structural system components that characterise national contexts. It follows that, within the scope analysed, the clusters are at least partly country-driven: this aspect does not reduce the usefulness of the approach, but clarifies its interpretation, indicating that the comparison between the three countries reflects both internal territorial differences and broader institutional and structural differences.

In terms of application, the usefulness of the taxonomy lies in the possibility of linking different profiles to differentiated policy strategies. In contexts where the affordability channel dominates, social protection and income support instruments or measures targeting payment capacity are more relevant, while in contexts where deprivation is less aligned with monetary poverty, a package of structural interventions aimed at reducing energy needs and price exposure through improvements in building efficiency and interventions in the supply and regulation system appears to be central. In this sense, cartographic evidence does not merely locate vulnerability but also helps to suggest where the combination of instruments should change.

The results must be read taking into account certain limitations. First, the indicator "unable to keep home adequately warm" is a self-reported outcome measure and, although widely used for comparative purposes, does not fully capture the multidimensional nature of the phenomenon. Second, the set of variables is intentionally focused on the socio-economic dimension and does not explicitly include physical or market determinants, which may help explain situations where deprivation remains high despite favourable socio-economic fundamentals. Third, as in any clustering procedure, the solution is sensitive to technical choices and should therefore be interpreted as a descriptive segmentation tool, not as inferential evidence. Given this, the directions for future research are clear and should integrate physical and system variables to distinguish more clearly between affordability and needs channels and to develop an econometric (possibly spatial) strategy on drivers of energy poverty to better understand the phenomenon in the European context.

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REFERENCES

Andreoni, V. (2024). Energy poverty in EU: Using regional climatic conditions and incidence of electricity prices to map vulnerability areas across 214 NUTS 2 European regions. *World Development Sustainability, 4*, 100146. https://doi.org/10.1016/j.wds.2024.100146

Bakó, F., Berkes, J., & Szigeti, C. (2021). Households' electricity consumption in Hungarian urban areas. *Energies*, *14*(10), 2899, 1–23. https://doi.org/10.3390/en14102899

Boardman, B. (2010). *Fixing Fuel Poverty: Challenges and Solutions* (1st ed.). Routledge. https://doi.org/10.4324/9781849774482

Bouzarovski, S. (2014). Energy poverty in the European Union: Landscapes of vulnerability. *WIREs Energy and Environment, 3*(3), 276–289. https://doi.org/10.1002/wene.89

Bouzarovski, S., & Petrova, S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. *Energy Research & Social Science, 10,* 31–40. https://doi.org/10.1016/j.erss.2015.06.007

Bouzarovski, S., Petrova, S., & Sarlamanov, R. (2012). Energy poverty policies in the EU: A critical perspective. *Energy Policy, 49*, 76–82. https://doi.org/10.1016/j.enpol.2012.01.033

Bradshaw, J., & Hutton, S. (1983). Social policy options and fuel poverty. *Journal of Economic Psychology*, *3*(3–4), 249–266. https://doi.org/10.1016/0167-4870(83)90005-3

Chaton, C., & Lacroix, E. (2018). Does France have a fuel poverty trap? *Energy Policy, 113*, 258–268. https://doi.org/10.1016/j.enpol.2017.10.052

Del Río, P., Burguillo, M., & Kiefer, C. P. (2025). Which are the main determinants of energy poverty? A systematic review of the literature. *Energy Efficiency, 18*(6), 58. https://doi.org/10.1007/s12053-025-10345-x

Della Valle, N., Maduta, C., D'Agostino, D., & Koukoufikis, G. (2025). Unpacking energy vulnerability in the European Union: Linking thermal discomfort with adaptive capacity. *Energy Research & Social Science, 129*, 104376. https://doi.org/10.1016/j.erss.2025.104376

Di Franco, G. (2017). *Tecniche e modelli di analisi multivariata* (2a ed.). FrancoAngeli

Drescher, K., & Janzen, B. (2021). Determinants, persistence and dynamics of energy poverty: An empirical assessment using German household survey data. *Energy Economics, 102*, 105433. https://doi.org/10.1016/j.eneco.2021.105433

Energy Poverty Advisory Hub. (2023). *The "Inability to keep home adequately warm" indicator: Is it enough to measure energy poverty?* European Commission, Directorate-General for Energy

Energy Poverty Advisory Hub. (2024). *Taxonomy of Social Energy Plans, Strategies and Policies*. https://energy-poverty.ec.europa.eu/observatory/publications/taxonomy-social-energy-plans-strategies-and-policies

Energy Poverty Advisory Hub. (2025). About. European Commission, Directorate-General for Energy. Retrieved December 4, 2025, from https://energy-poverty.ec.europa.eu/about

European Commission. (2023a). *Commission Recommendation (EU) 2023/2407 on energy poverty*. Official Journal of the European Union, L. https://data.europa.eu/eli/reco/2023/2407/oj

European Commission. (2023b). Commission staff working document: EU guidance on energy poverty (SWD(2023) 647 final). https://data.consilium.europa.eu/doc/document/ST-14519-2023-ADD-1/en/pdf

European Commission. (2024). Energy poverty. Retrieved December 3, 2025, from https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-poverty_en

European Commission. (2025). *European Economic Forecast: Autumn 2025* (European Economy Institutional Paper No. 327). Publications Office of the European Union. https://doi.org/10.2765/2173364

European Energy Network. (2019). *EnR position paper on energy poverty in the European Union*. Italian Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Energy Efficiency Department

Eurostat. (2022). Regions. Database. https://ec.europa.eu/eurostat/web/regions/database

Eurostat. (2024). Database. Inability to keep home adequately warm by NUTS 2 region. (ilc_mdes01_r). https://doi.org/10.2908/ILC_MDES01_R

Eurostat. (2025). History – NUTS – Nomenclature of territorial units for statistics. European Commission. Retrieved December 4, 2025, from https://ec.europa.eu/eurostat/web/nuts/history

Everitt, B. S., Landau, S., Leese, M., & Stahl, D. (2011). *Cluster analysis*. Chichester: John Wiley & Sons.

Filho, W. L., Rebelatto, B. G., Salvia, A. L., Rampasso, I. S., Gatto, A., Barrioz, V., Aina, Y. A., Hunt, J. D., Anholon, R., Ribeiro, P. C. C., & Brandli, L. L. (2025). Addressing energy poverty: Regional trends and examples of best practice. *Energy for Sustainable Development, 85*, 101647. https://doi.org/10.1016/j.esd.2024.101647

Guarascio, D., Reljic, J., & Zezza, F. (2025). Energy vulnerability and resilience in the EU: Concepts, empirics and policy. *Journal of Industrial and Business Economics, 52*(3), 683–726. https://doi.org/10.1007/s40812-025-00340-9

Hills, J. (2012). *Getting the measure of fuel poverty: Final report of the fuel poverty review*. London School of Economics and Political Science

International Energy Agency. (2026). *Strait of Hormuz – Oil security and emergency response*. https://www.iea.org/about/oil-security-and-emergency-response/strait-of-hormuz

International Energy Agency. (2019). *World Energy Outlook 2019*. International Energy Agency.

Isherwood, B. C., & Hancock, R. M. (1979). *Household expenditure on fuel: Distributional aspects*. Economic Adviser's Office, Department of Health and Social Security

Khalid, B., Chaveesuk, S., & Chaiyasoonthorn, W. (2025). Generation Y entrepreneurial competitiveness: An empirical analysis of determining factors. *Entrepreneurial Business and Economics Review*, 13(4), 147-163. https://doi.org/10.15678/EBER.2025.130408

Kot, S., Piontek, B., & Khalid, B. (2024). The economic shockwaves of the Russia-Ukraine conflict and energy sources prices–The impact on international energy markets. *Acta Montanistica; Slovaca*, 29(2), 353-366, https://doi.org/10.46544/AMS.v29i2.10

Korkmaz, E., & Senyel Kurkcuoglu, M. A. (2025). Analysis of the socio-spatial vulnerabilities to energy poverty factors of Türkiye. *Energy and Buildings, 330*, 115343. https://doi.org/10.1016/j.enbuild.2025.115343

Koukoufikis, G., Ozdemir, E., & Uihlein, A. (2024). *Shedding light: Unveiling the dynamics of energy poverty in the EU*. Publications Office of the European Union. https://doi.org/10.2760/7432189

Lehtonen, O., Hiltunen, A. P., Okkonen, L., & Blomqvist, K. (2024). Emerging spatial clusters of energy poverty vulnerability in rural Finland—Byproducts of accumulated regional development. *Energy Research & Social Science, 109*, 103418. https://doi.org/10.1016/j.erss.2024.103418

Liddell, C., & Morris, C. (2010). Fuel poverty and human health: A review of recent evidence. *Energy Policy*, *38*(6), 2987–2997. https://doi.org/10.1016/j.enpol.2010.01.037

Lieth, J., Abel, D., & Jünger, S. (2025). Between national trends and local realities: Spatializing energy vulnerability in 16 EU countries. *Energy Policy, 206*, 114695. https://doi.org/10.1016/j.enpol.2025.114695

Lyra, K., Mirasgedis, S., & Tourkolias, C. (2022). From measuring fuel poverty to identification of fuel poor households: A case study in Greece. *Energy Efficiency, 15*(1), 6. https://doi.org/10.1007/s12053-021-10017-6

Middlemiss, L., Ambrosio-Albalá, P., Emmel, N., Gillard, R., Gilbertson, J., Hargreaves, T., Mullen, C., Ryan, T., Snell, C., & Tod, A. (2019). Energy poverty and social relations: A capabilities approach. *Energy Research & Social Science, 55*, 227–235. https://doi.org/10.1016/j.erss.2019.05.002

Min, B., O'Keeffe, Z. P., Abidoye, B., Gaba, K. M., Monroe, T., Stewart, B. P., Baugh, K., & Sánchez-Andrade Nuño, B. (2024). Lost in the dark: A survey of energy poverty from space. *Joule, 8*(7), 1982–1998. https://doi.org/10.1016/j.joule.2024.05.001

Moore, R. (2012). Definitions of fuel poverty: Implications for policy. *Energy Policy*, *49*, 19–26. https://doi.org/10.1016/j.enpol.2012.01.057

Nagaj, R., & Korpysa, J. (2020). Impact of COVID-19 on the Level of Energy Poverty in Poland. *Energies*, *13*(18), 4977. https://doi.org/10.3390/en13184977

Oesterreich, M., & Barej-Kaczmarek, E. (2024). Assessment of energy poverty in EU countries in 2010-2022. *Journal of International Studies, 17*(2), 75–99. https://doi.org/10.14254/2071-8330.2024/17-2/4

Pacudan, R., & Hamdan, M. (2019). Electricity tariff reforms, welfare impacts and energy poverty implications. *Energy Policy*, 132, 332–343. https://doi.org/10.1016/j.enpol.2019.05.033

Pécsinger, J., Sipos, D., Macher, G. Z., & Rácz, É. V. P. (2025). A Multidimensional Analysis of Energy Poverty in the EU: Exploring Complex Drivers and Cross-Dimensional Impacts. *Chemical Engineering Transactions*, *121*, 1–6. https://doi.org/10.3303/CET25121001

Punj, G., & Stewart, D. W. (1983). Cluster Analysis in Marketing Research: Review and Suggestions for Application. *Journal of Marketing Research, 20*(2), 134–148. https://doi.org/10.1177/002224378302000204

Sahoo, S. K., Goswami, S. S., Božanić, D., & Mitra, S. (2025). Evaluating Green Economy Strategies Through Multi-Criteria Decision Analysis: A Systematic Review. *International Journal of Economic Sciences*, 14(1), 385-407. https://doi.org/10.31181/ijes1412025245

Sipiczki, Z., Imre, G., & Varga, J. (2024). How "Hungaricum" is inflation in Hungary? The classical and specific factors of outstanding inflation in Hungary. *Journal of Infrastructure, Policy and Development*, *8*(15), 8981, 1–14. https://doi.org/10.24294/jipd8981

Sompolska-Rzechuła, A., Becker, A., & Oleńczuk-Paszel, A. (2025). Territorial Variation of Energy Poverty and Good Health and Well-Being in European Union Countries—A Spatial Analysis. *Energies, 18*(20), 5491. https://doi.org/10.3390/en18205491

Streimikiene, D. (2022). Energy poverty and impact of Covid-19 pandemics in Visegrad (V4) countries. *Journal of International Studies, 15*(1), 9–25. https://doi.org/10.14254/2071-8330.2022/15-1/1

Szczygieł, O., Harbiankova, A., & Manso, M. (2024). Where Does Energy Poverty End and Where Does It Begin? A Review of Dimensions, Determinants and Impacts on Households. *Energies, 17*(24), 6429. https://doi.org/10.3390/en17246429

Tagliapietra, S., Veugelers, R., & Zettelmeyer, J. (2023). Rebooting the European Union's Net Zero Industry Act (Bruegel Policy Brief No. 15/2023). Bruegel. https://www.bruegel.org/sites/default/files/2023-07/PB%2015%202023.pdf

Teixeira, I., Ferreira, A. C., Rodrigues, N., & Teixeira, S. (2024). Energy Poverty and Its Indicators: A Multidimensional Framework from Literature. *Energies, 17*(14), 3445. https://doi.org/10.3390/en17143445

Thomson, H., & Bouzarovski, S. (2019). Addressing energy poverty in the European Union: State of play and action. EU Energy Poverty Observatory (EPOV)

Thomson, H., Snell, C., & Bouzarovski, S. (2017). Health, Well-Being and Energy Poverty in Europe: A Comparative Study of 32 European Countries. *International Journal of Environmental Research and Public Health, 14*(6), 584. https://doi.org/10.3390/ijerph14060584

Tvaronavičienė, M., Mazur, N., Mishchuk, H., & Bilan, Y. (2021). Quality of life of the youth: assessment methodology development and empirical study in human capital management. *Economic Research-Ekonomska Istraživanja*, *1-18*. https://doi.org/10.1080/1331677X.2021.1956361

United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development (A/RES/70/1). United Nations. https://undocs.org/A/RES/70/1

Ward, J. H., Jr. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association, 58*(301), 236–244. https://doi.org/10.1080/01621459.1963.10500845

Widyanti, R., & Włodarczyk, A. (2023). Environmental strategies of energy companies during the Covid-19 pandemic. *Polish Journal of Management Studies*, *28*(1), 380-396, https://doi.org/10.17512/pjms.2023.28.1.22

Xenakis, A., Mexis, F. D., Kanellou, E., & Doukas, H. (2025). Assessing Energy Poverty in Greece Using Open-Access Data: A National and Regional Analysis Based on the 10% Indicator. *Energies, 18*(21), 5787. https://doi.org/10.3390/en18215787

Vasa, L., Kubatko, O., Sotnyk, I., Piven, V. Trypolska, G. & Pysmenna, U. (2024). Economic and environmental drivers of renewable energy transition in the EU. *Environmental Economics*, *15*(2), 232-245. https://doi.org/10.21511/ee.15(2).2024.16

Zardo, L., Cortinovis, C., & Lucertini, G. (2024). Prejudices May Be Wrong: Exploring Spatial Patterns of Vulnerability to Energy Poverty in Italian Metropolitan Areas. *Sustainability, 16*(20), 8975. https://doi.org/10.3390/su16208975

Zéman, Z., Kálmán, B. G., & Vasa, L. (2025). The impact of domestic material consumption and energy mix on socioeconomic indicators – A global analysis from 1990 to 2022, *Resources Policy*, 107. https://doi.org/10.1016/j.resourpol.2025.105658