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Energy poverty - New insights and analysis for improved measurement and policy

Evidence from unique joint HBS-SILC microdata from Hungary

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Abstract

The analysis of unique joint SILC-HBS microdata from Hungary allows for the joint assessment of different forms of energy poverty at the micro level, and yields a series of novel and policy-relevant insights. This Report finds that existing measures of energy poverty based on subjective valuations and expenditure ratios identify wholly different population segments as energy poor, with less than one in three such households suffering from multiple forms of energy-related deprivation. Different measures also diverge greatly in terms of incidence level, seasonal fluctuations, cross-country comparability, persistence over time, as well as the socio-demographic background, living conditions and AROPE status of those identified as energy poor. These novel findings suggest that energy poverty is very hard to delineate accurately with existing measures. The Report calls for simultaneous improvements in the existing measurement framework and the exploration of new alternative methods, techniques and data for effective social monitoring and sound evidence-based energy policies.

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Executive summary

The empirical analysis presented in this report exploits the distinctive features of joint SILC-HBS national microdata files from Hungary, in order to study important and previously unexplored patterns of energy poverty in the context of EU measurement and policy.

Policy context

There is broad consensus that energy poverty in the European Union is predicated upon a multitude of different vulnerability factors (such as high energy prices, insufficient household incomes, inefficient buildings and appliances, climate, specific household needs), and represents a complex, multi-faceted social policy challenge. Its measurement involves a series of primary and secondary indicators that are very heterogeneous, capture different aspects of energy deprivation, and are derived from different European household surveys. As a result, no comprehensive analysis of energy poverty patterns has been possible so far at the level of individual households. This JRC Technical Report uses a unique joint SILC-HBS micro-level dataset from Hungary to analyse, for the first time, all primary indicators of energy poverty in combination.

Key conclusions

The main conclusion of the Report is that different energy poverty measures tend to identify vastly different population segments as energy poor. Different measures also diverge greatly in terms of incidence level, seasonal fluctuation, cross-country comparability, persistence over time, as well as the socio-demographic background and living conditions of those identified as energy poor. This implies that single measures of energy poverty capture only particular aspects of energy deprivation, and the degree of hidden energy poverty that remain unaccounted for may be high.

The exposed limitations surrounding existing indicators of energy poverty call for improvements to the current measurement framework and survey data architecture. Much of the related efforts should involve European statistical authorities and aim at further harmonisation, integration and refinement of existing European household surveys. The presented findings also call for exploring new avenues, methodologies and data for the measurement of energy poverty, especially as far as the direct assessment of households' energy consumption and energy efficiency are concerned. Improvements along these lines would require collecting and analysing data from energy suppliers or other administrative sources, as well as the detailed survey of households' energy needs, practices and coping strategies. This could contribute to a sound definition of vulnerable consumers, and the development of new policy-relevant and actionable measures of energy poverty based on minimum consumption thresholds and customised energy reference budgets.

Main findings

The main finding of this report is that different forms of energy poverty and deprivation concern largely different population segments. Most dimensions of energy poverty appear in isolation, as households tend to be affected by a very limited number of energy poverty dimensions simultaneously. In particular, those households that struggle to keep their homes warm or pay their utility bills are typically not the ones that spend uncharacteristically little or much on energy in either relative or absolute terms.

The presented empirical analysis also yields a series of additional new insights about existing measures of energy poverty. The most important of these is that

- different measurement approaches can result in markedly different levels of energy poverty;
- consensual measures of energy poverty may be subject to considerable seasonality and lack cross-country comparability as a result;
- the relationship of energy poverty with respect to household income is highly variable across measures, but all forms of energy poverty are present among non-financially distressed households, as well;
- the socio-demographic profiles associated with specific measure of energy poverty may be markedly different: settlement type and household size appear to be the main drivers of household vulnerability, while the role of age and gender is rather limited;
- housing conditions play an important role in explaining horizontal differences in energy poverty: expenditure-based measures indicate large differences across dwelling types, while consensual measures tend to be more sensitive to housing quality;

- energy poverty displays limited persistence at the level of individual households over time;
- the relationship between energy poverty and headline poverty and social exclusion is highly variable across measures: consensual energy poverty displays strong overlaps with AROPE background, while expenditure-based energy poverty concerns mostly non-AROPE households.

Related and future JRC work

Scientific and analytical work on energy poverty at the JRC goes back several years. Since the inception of the Commission's Energy Poverty Advisory Hub, the JRC has provided data assistance and methodological contributions. More recently, the JRC published a report (JRC128084) that engages with ongoing work on situational awareness and indicators setting by summarising data deriving from EU surveys related to energy poverty, transport poverty, and living conditions. The JRC has also reviewed recent policy developments in the EU aimed at addressing energy poverty and the social implications of the climate neutrality transition (JRC130057). In addition, JRC has been actively looking into the distributional aspects of energy poverty and its possibly heterogeneous consequences by gender (JRC132612).

Given the centrality of the topic and measurement of energy poverty to various policy initiatives and policy debates in the EU, the involvement of JRC in the analysis and measurement of energy poverty will continue in the near future. In particular, the JRC research portfolio #20 supports ongoing and forthcoming policy initiatives in the social domain and is linked specifically to fair transitions and energy poverty.[1]

[1] See the relevant JRC Science Hub website for further details: https://joint-research-centre.ec.europa.eu/jrc-science-and-knowledge-activities/inclusive-and-resilient-society_en.

1 Introduction

Energy poverty occurs when a household experiences inadequate levels of essential energy services at home or in daily life. There is broad consensus that energy poverty in the European Union is predicated upon a multitude of different vulnerability factors (such as high energy prices, insufficient household incomes, inefficient buildings and appliances, climate, specific household needs), and represents a complex, multi-faceted social policy challenge (European Commission, 2022c; Thomson et al., 2017).

The effects of energy poverty are multiple. There are clear consequences for health and well-being, as extreme indoor temperatures or pollution are linked with a large number of respiratory and cardiovascular diseases, or even premature deaths (Cong et al., 2022; Liddell et al., 2016; Ormandy and Ezratty, 2012). Children, women and the elderly may be at a particular risk (Palmer et al., 2008; Romero et al., 2018). Energy poverty is also believed to limit one's mobility and transport options, engender sub-standard labour market or economic outcomes, and hold up sustainability, climate action and the green transition (Adom et al., 2021; Mikkonen et al, 2020). For these reason, the EU considers energy poverty a key priority, and has launched several initiatives to eradicate it (see Box 1 for details).

Measuring energy poverty is not straightforward: it is a private condition that tends to vary in both time and space, and is assessed from a culturally sensitive multi-dimensional perspective (Thomson et al., 2017). In theory, a variety of indicators could be used to measure the most salient aspects of energy poverty – such as access, affordability, flexibility, efficiency, needs or behaviour (Della Valle, 2019). In practice, existing measures aim at capturing one of its three most commonly identified causes: insufficient income, lack of energy efficiency in buildings, and high energy prices (Mikkonen et al., 2020). Particular measurement approaches vary along several dimensions, and differentiate between subjective vs. objective, qualitative vs. quantitative, primary vs. secondary, absolute vs relative indicators (Cong et al., 2022; Heindl, 2015; Thomson et al., 2017; Romero et al., 2018). Given the partial nature of available metrics, researchers and practitioners often recommend using a broad portfolio of indicators for an in-depth understanding of energy poverty in both its manifest and hidden forms (Cong et al., 2022; Eisfeld and Seebauer, 2022).

At the EU level and in most Member States, measurement has centred around two types of primary indicators (European Commission, 2022c; Koukoufikis and Uihlein, 2022). These are (1) subjective or consensual indicators based on households' self-reported energy-related deprivation, and (2) objective expenditure-based indicators of the indirect affordability of energy services. While a number of complementary indicators (on electricity and gas prices, dwelling characteristics, excess mortality, among others) are also monitored by national governments and the EU's Energy Poverty Observatory (EPOV), these have received less policy attention due to their incomplete coverage, lack of disaggregation, or indirect relationship with energy outcomes (European Commission, 2022b; Koukoufikis and Uihlein, 2022). The focus on consensual and expenditure-based indicators is also reflected in the Commission's Recommendation on energy poverty (EU 2020/1563) that provides guidance on definitions and measurement. The Recommendation lists only households' inability to keep home warm, arrears on utility bills, and metrics based on households' energy expenditures as the primary indicators.

Since the proposed indicators are derived from different European household surveys, no comprehensive analysis of energy poverty patterns is generally possible at the level of individual households. This JRC Technical Report uses a unique joint SILC-HBS micro-level dataset from Hungary to jointly analyse the main EU indicators of energy poverty for the first time, and produces a series of novel and policy-relevant insights for measurement. Its main conclusion is that different energy poverty measures tend to identify vastly different population segments, and that households struggling to keep their homes warm or avoid arrears on their utility bills are typically not the ones that spend too little or too much on energy in either relative or absolute terms. Different measures also diverge greatly in terms of incidence level, seasonal fluctuations, cross-country comparability, persistence over time, as well as the socio-demographic background and living conditions of those identified as energy poor.

Existing empirical evidence and cross-country comparisons suggest that these findings have strong external validity and likely apply to most EU Member States simultaneously (Devalière and Teissier, 2014; Menyhért, 2022; Palmer et al., 2008). The main policy conclusions are that no single measure of energy poverty can capture all forms and instances of energy-related deprivations, and that a substantial share of such outcomes may remain hidden using only a subset of existing indicators. This calls for improvements in measurement, in particular as far as the ongoing harmonisation and integration of European data collection, and a precise definition of vulnerable households are concerned. The presented findings also call for the exploration of additional new direct measures of energy poverty based on households' energy use, consumption behaviour, dwelling characteristics and minimum energy budgets. Improvements along these lines could greatly enhance both effective social monitoring and targeted policy action.

Box 1. EU policies on energy poverty

Over the past few years, there has been an increased effort from the EU to address energy poverty (Vandyck et al., 2023). Defined as a situation in which households are unable to access essential energy services, it has been a key priority in the Clean energy for all Europeans package (adopted in 2019) and the Just Transition Mechanism (adopted in 2020) in support of a socially inclusive energy transition. In their National Energy and Climate Plans (NECPs), EU Member States have the obligation to tackle energy poverty and many have already integrated targeted measures in their national strategies. To streamline these efforts, the Commission published its Recommendation on energy poverty (EU 2020/1563) that provides guidance on definitions and appropriate indicators for measurement across four dimensions. In line with this, the Fit for 55 package (adopted in 2021), proposed specific measures to identify key drivers of energy poverty risks for consumers (such as high energy prices, low income, or poor energy efficiency buildings and appliances). Energy is also listed as one of the essential services (under principle 20) in the European Pillar of Social Rights, and the Indicators' Sub-Group of the Social Protection Committee has been actively seeking to energy poverty as part of the EU monitoring framework.

Besides legislation, the Commission also engages in extensive consultations, direct support, policy coordination and research in the domain of energy poverty. In 2021, it launched the Energy Poverty Advisory Hub (EPAH) that builds on the work of the EU Energy Poverty Observatory (EPOV) and is the leading EU initiative with the aim of eradicating energy poverty and accelerating the just energy transition of European local governments. In 2022, the Commission established the Inter-Service Steering Group on energy poverty and vulnerable consumers. Among the 33 project portfolios of the JRC Work Programme for 2023-2024, at least seven are directly concerned with various aspects of energy poverty.

The remainder of the Report is structured as follows. Section 2 introduces the unique Hungarian survey data used for the analysis and presents the relevant indicators and measurement aspects. Section 3 compares the incidence of energy poverty associated with each metric and assesses the robustness and stability of the poverty rate within the calendar year. Section 4 focuses on the overlap between the relevant energy poor populations by dimension, and demonstrates the considerable disconnect between the different measurable aspects of energy poverty. Section 5 assesses the role of income and socio-demographic background for energy poverty, and presents the relevant poverty profiles associated with each different metric. Section 6 focuses on living conditions and housing quality as principal drivers of horizontal differences in energy poverty. Section 7 concentrates on the longitudinal dimension and shows how stability in energy poverty at the aggregate level may obscure rather significant volatility at the individual and household levels. As a final exercise, Section 8 presents the differential relationship between energy poverty and generic poverty according to the indicator considered. Section 9 concludes and highlights the relevant policy implications and challenges.

2 Data and measurement

Existing measurement and analysis of energy poverty in the EU are based on two different household surveys. The EU statistics on income and living conditions (EU-SILC) collects comparable cross-sectional and longitudinal data on households' income, social situation and living conditions at annual frequencies, and is used to derive consensual measures of energy poverty based on households self-reported deprivations (European Commission, 2020). The EU Household budget survey (EU-HBS), on the other hand, is a harmonised collection of national budget surveys focusing on households' consumption structure, and is the main source for deriving expenditure-based measures of energy poverty (European Commission, 2022a). Besides the generic statistical issues of data access, timeliness and cross-country comparability, the main limitation of the existing survey infrastructure for energy poverty measurement is that the national HBS and SILC data files are typically collected using different population samples, survey methods and even definitions (Menyhért et al., 2021).

The data used for the current analysis come from the joint HBS-SILC national files from Hungary, originally acquired from the Hungarian Central Statistical Office for the purposes of previous JRC research on absolute poverty measurement (Menyhért et al., 2021). The Hungarian microdata are unique in that the HBS and SILC data components are collected using the same population samples, allowing for the joint analysis of households' living conditions and expenditure patterns at the individual level.[2] This represents a significant advantage over alternative merged household survey data used by Eurostat and selected NSIs that are based on statistical matching and conditionally random imputations across different sources (Balestra and Oehler, 2023; Donatiello et al., 2014). In addition, the joint Hungarian dataset also features a longitudinal component based on rotating population samples, and contains more comprehensive and granular information than the respective European HBS and SILC data files in a number of survey domains (e.g. technical details of the survey interview, quantity information on purchases).

Importantly, the Hungarian data allow for the joint analysis of all primary indicators of energy poverty used in the EU. These include consensual or perception-based measures of households' self-assessed energy situation, as well as expenditure-based measures targeting insufficient or excessive energy spending. The Commission Recommendation (EU 2020/1563) on energy poverty lists the specific metrics in question and defines the particular survey variables and techniques required for their calculation. It also lists a series of complementary indicators, but these refer either to aggregate information (such as electricity or gas prices) or to pre-existing social conditions (such as housing deprivation).

In line with the Commission Recommendation, the empirical analysis in this Report concentrates on the following five primary indicators of energy poverty:

- the share of population having arrears on utility bills (SILC [variable HS021], henceforth ***Arrears***);
- the share of population not able to keep home adequately warm (SILC [HH050], ***HomeWarm***);
- the share of population living in households where the energy expenditure-to-income ratio is more than twice the national median (HBS [HE045, HE0722, HH099], ***HighShare***);[3]
- the share of population living in households where the absolute level of energy expenditures is less than half the national median (HBS [HE045, HE0722], ***LowExpense***);[4]
- the share of population living in households where the energy expenditure share exceeds 30% relative to total expenditures (HBS [HE045, HE0722, HE00], ***FixThreshold***).[5]

[2] See the dedicated website of the Hungarian Statistical Office (HCSO) for more technical and methodological details. Note that the Czech Statistical Office (CZSO) also collects the SILC and HBS surveys using overlapping samples (see its website for details), but the joint microdata are not yet available for analytical purposes.
[3] This indicator is sometimes referred to as 2M in the relevant literature.
[4] This indicator is sometimes referred to as M/2 in the relevant literature.
[5] The *FixThreshold* metrics is not explicitly listed in the relevant Commission recommendation. It is a revised version of the of the first formal definition of energy poverty based on an absolute 10% threshold for the energy expenditure share (Romero et al., 2018). The 30% threshold applied for the current analysis is chosen to be in line with Hungarian households' typical energy expenditure patterns and the implied energy poverty rate based on existing indicators (Heindl, 2015; Thomson et al., 2017).

At least three aspects are worth noting in relation to these metrics. First, each of them are derived separately on either the SILC or the HBS data component and therefore do not lend themselves to joint micro-level analysis in most EU countries.[6] Second, they have limited comparability due to differences in scope: while the SILC-based indicators refer exclusively to energy outcomes at home, the HBS-based indicators consider both housing-related and transportation-related energy expenditures.[7] Third, none of these measures target or capture households' energy behaviour, energy consumption or energy efficiency in a direct manner (Romero et al., 2018; Cong et al., 2022; Thomson et al., 2017). In addition, one may also consider that none of the proposed indicators are able to measure the depth of households' energy poverty (i.e. the shortfall in energy consumption or outcomes relative to the threshold), or are directly responsive to changes in households' financial conditions or purchasing power.[8]

The main advantage of existing measures lies in their simplicity, straightforward interpretation and uncomplicated measurement using the existing European survey data architecture. Alternative approaches aimed at monitoring households' energy consumption, energy efficiency and energy behaviour in a reliable, representative and cross-country comparable manner would be more difficult to implement, and would likely require considerable changes to existing information protocols, reporting practices and survey collections. The more detailed analysis of existing energy poverty measures is therefore of crucial importance not only to deepen our understanding of energy poverty, but also to better understand the current limitations and propose future improvements in relation to existing measures and measurement practices.

[6] In the joint Hungarian dataset used for the current analysis, only the SILC-based income variables were present and used for the calculation of the (HBS-based) *HighShare* indicator.

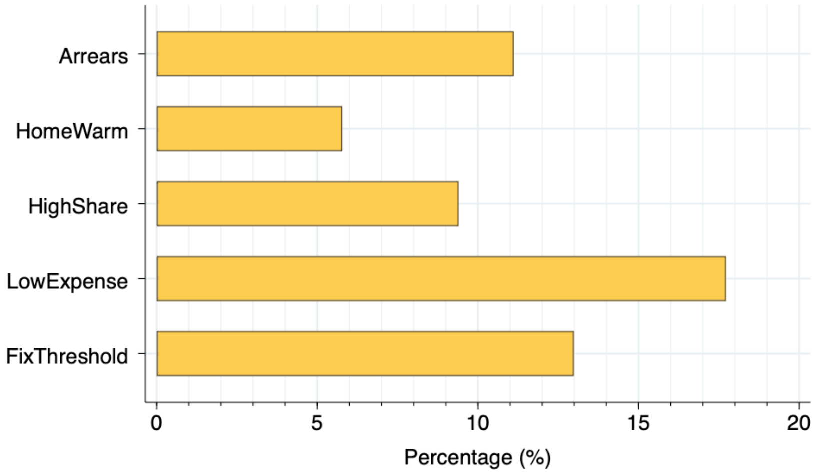
[7] According to the HICP methodological manual that defines special consumption aggregates used by Eurostat, energy expenditures are defined as household spending on both (1) electricity, gas, solid fuels and heat energy [CP045] and (2) fuels and lubricants for personal transport equipment [CP0722]. See European Commission (2018) for further details on the methodology. Available empirical analyses suggest that expenditure patterns for housing-related and transportation-related energy use can be rather different (Menyhért, 2022; Vandyck et al., 2023).

[8] As the analysis by Menyhért (2022) shows, the real income elasticity of energy-related deprivation indicators is rather small. The response of expenditure-based metrics of the distributional type (*HighShare* and *LowExpense*) to changes in households' financial and economic conditions is even more muted, and – depending on the differential exposure and adjustment across various population segments - may even be counter-intuitive.

3 Comparison of different measures

Using the different measures of energy poverty listed above, one may start by comparing the associated poverty rates. This exercise already exploits the merged dimension of the Hungarian data in terms of eliminating common sampling-related differences that tend to characterise income and expenditure surveys in the EU (European Commission, 2020; European Commission, 2022a, Menyhért et al., 2021).

Figure 1. Energy poverty rate by measure



Notes: The figures refer to 2018, and are based on own analysis of joint SILC-HBS microdata from Hungary. See the detailed explanation of the measures in Section 2 of this Report.

Figure 1 shows the level of energy poverty by measure using the full sample (n = 15540) of the 2018 survey wave. The corresponding values range between 5.8% for the ***HomeWarm*** and 17.7% for the ***LowExpense*** metric. Such variations in energy poverty rates across the different metrics are not unique to Hungary and are comparable to the what may be observed in other EU Member States.[9] This highlights that each individual metric applies a unique perspective, and demonstrates the importance of clearly specifying the underlying measure when discussing energy poverty. It also calls for investigating the stability and robustness of the resulting energy poverty rates over time and across indicators.

An oft-overlooked dimension of energy poverty concerns seasonality. Ample empirical evidence shows that European households' energy use fluctuates considerably over the calendar year, and consumption during the winter period is substantially higher than over the summer (Liddell et al., 2016).[10] One can therefore reasonably expect that energy poverty is also subject to seasonal fluctuations, which may be further aggravated by perception bias, recall errors and potential ambiguity surrounding certain survey questions.[11] Own analysis of EU-SILC microdata from 2019 shows that data collection spans multiple quarters of the year in most EU Member States, and that the energy poverty rates based on the ***Arrears*** and ***HomeWarm*** metrics are, respectively, 1.2 p.p. and 1.8 p.p. lower in the summer than in winter on average.[12] Moreover, seasonal differences may reach up to 5 percentage points in selected Member States, which raises serious doubts about the cross-country comparability of certain energy poverty measures in the EU. Similar issues are likely to be

[9] Using EU-wide SILC and HBS microdata from 2015, the largest and smallest within-country differences are observed in Greece (32.9 p.p.) and Slovakia (5.5 p.p.), respectively. Besides the absolute differences, the relative ranking of energy poverty indicators in a country also display large variations across the EU. See some relevant statistics in the Eurostat Data Browser (data codes: ILC_MDES01, ILC_MDES07) for details.

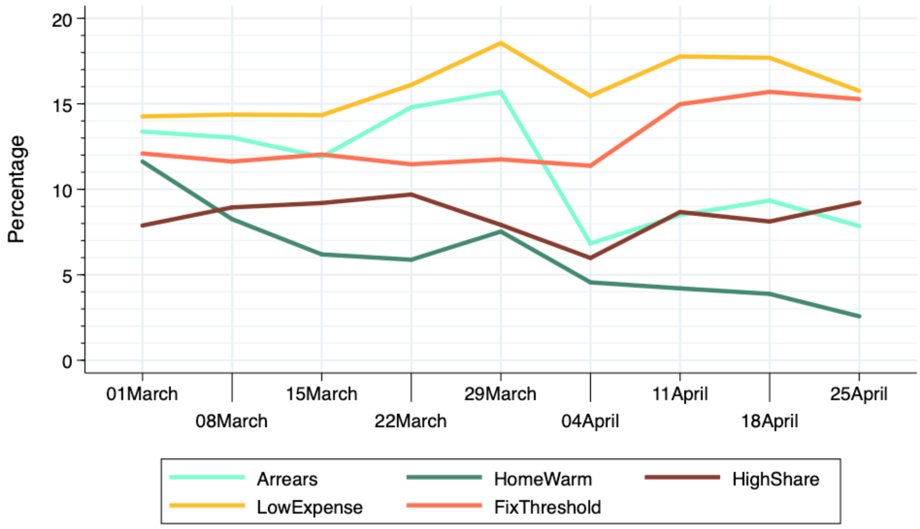
[10] Recent Eurostat data shows that Europe's gas consumption is 2.5-times higher in winter than in the summer. Seasonal fluctuations in electricity and oil are smaller, amounting to 30% and 20%, respectively. For more details, see the relevant monthly energy statistics by Eurostat (NRG_CB data series).

[11] Note that the SILC question 'Can your household afford to keep its home adequately warm?' (variable HH050, used for the *HomeWarm* metric) qualifies neither the meaning of 'adequately warm' nor the time period under consideration. The other survey questions related to arrears on utility bills (form the SILC) and energy expenditures (from the HBS) are less ambiguous and clearly specify the reference period in question (i.e. typically the last 12 month).

[12] Qualitatively similar results are obtained on the basis of other EU-SILC waves, as well.

present in relation to expenditure-based measures of energy poverty from the EU-HBS, where national files often refer to different survey periods.

Figure 2. Seasonality of energy poverty by measure



Notes: The figures refer to weekly aggregates from March and April of 2018, and are based on own analysis of joint SILC-HBS microdata from Hungary. See Section 2 of this Report for more explanations.

Detailed information on interview dates in the Hungarian microdata makes it possible to effectively monitor trends in energy poverty during the year. Figure 2 presents the week-by-week evolution of the energy poverty rate associated with each metric during the relevant data collection period of March and April of 2018. It reveals that SILC-based consensual measures of energy poverty are highly volatile, and decrease substantially with the arrival of the warmer season: ***Arrears*** decreased by 5.1 p.p. between early March and late April (12.9% vs. 7.8%), while ***HomeWarm*** decreased by 8.4 p.p. during the same period (11.0% vs. 2.6%).[13] Figure 2 also shows that expenditure-based metrics display relative stability over time.[14] This tends to suggest that, until further improvements in the cross-country harmonisation of data collection periods, expenditure-based measures of energy poverty may yield more dependable and comparable outcomes.

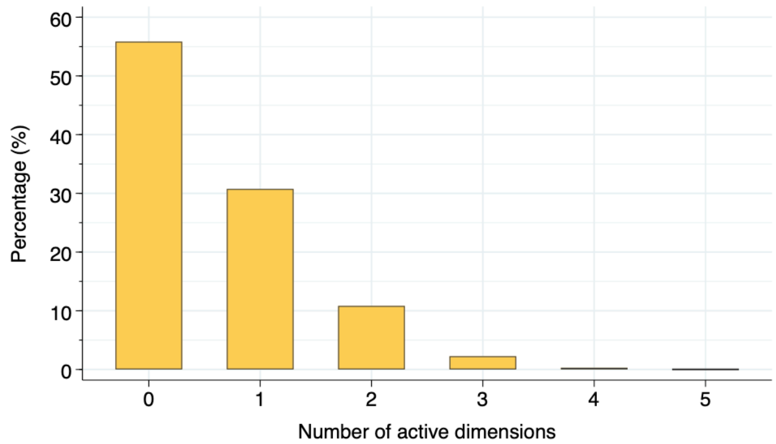
[13] The close correlation of consensual measures with climatic factors gets even more conspicuous when one compares the presented energy poverty trends with the observed historical temperature data collected during the same period. These latter show, for example, that a marked decline in temperatures over the second half of March 2018 were likely responsible for the kinks in the relevant *Arrears* and *HomeWarm* series. For further details, see for example https://www.wunderground.com/history/monthly/hu/budapest/LHBP/date/2018-3.

[14] Note that expenditure-based measures of energy poverty also concern the same reference period as consensual measures in the Hungarian data, and refer to the contemporaneous interview date (and/or diary recording period) rather than some pre-determined prior reference period. The stability of expenditure-based energy poverty measures over time may therefore be the result of (1) combined billing, bill smoothing or flat rate payments on energy services among large parts of the population, and/or (2) some structural features of selected (distributional) metrics (such as *HighShare* or *LowExpense*).

4 Overlap between different measures

Besides additional granularity, the real advantage of the merged Hungarian SILC-HBS microdata lies in allowing to explore the statistical relationship between the different energy poverty measures at the individual and household level. Specifically, by measuring the overlap and joint concentration of different energy poverty dimensions at the micro level, one can better understand the nature, extent and depth of energy-related deprivations.

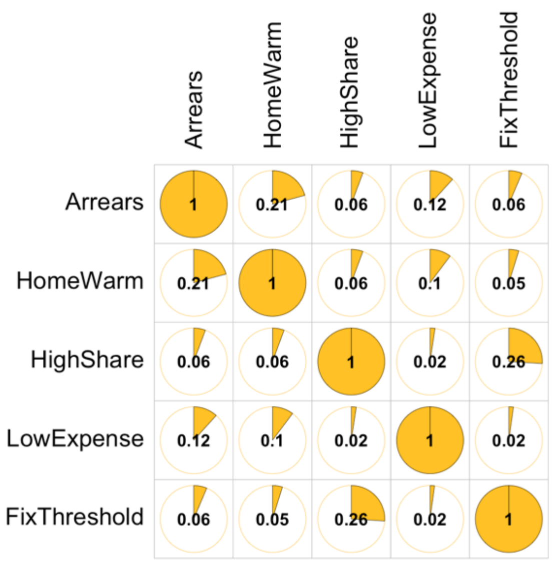
Figure 3. Incidence of energy poverty across households



Notes: The figures refer to 2018, and plot the distribution of households according to the number of active energy poverty dimensions, based on joint SILC-HBS microdata from Hungary.

The histogram in Figure 3 plots the distribution of the national population in 2018 based on their exposure to energy poverty (i.e. by the number of metrics according to which households are considered energy poor). It shows that (1) 55.9% of the population is not energy poor based on either measure, (2) among the remaining 44.1%, an overwhelming majority (30.8%) is energy poor in a single dimension only, and (3) the share of population suffering from energy poverty in three or more dimensions simultaneously is very low (2.6%). This suggests that energy poverty tends to manifest itself in a single dimension at a time, and that consensual and expenditure-based measures likely capture different forms of energy-related deprivations.

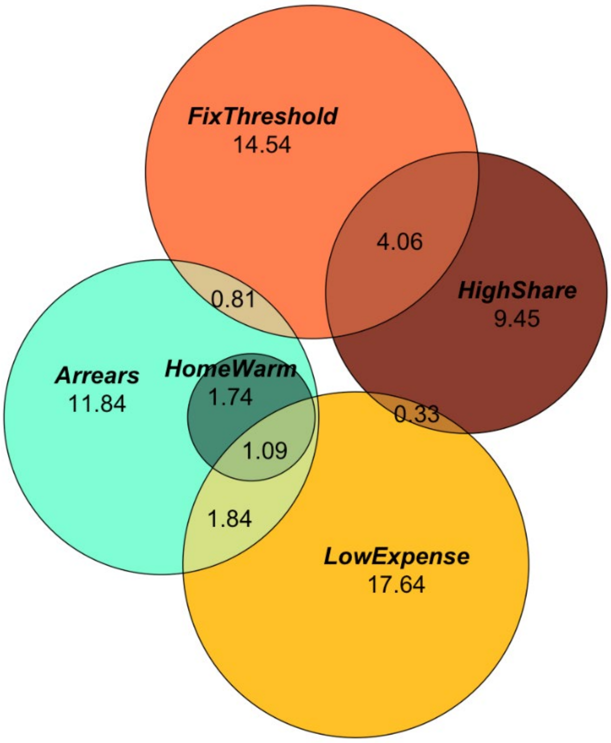
Figure 4. The degree of overlap between pairwise combinations of energy poverty indicators



Notes: The figures refer to 2018, and plot the share of overlapping households based on energy poverty classification in relation to each pairwise combinations, based on joint SILC-HBS microdata from Hungary.

To better understand the inter-relations between different energy poverty dimensions, Figure 4 shows the degree of overlap in relation to each pairwise metric combination. Specifically, it displays the Jaccard index - a statistic used for measuring the similarity between sample sets, defined as the size of the intersection relative to the union – for each pair of measures, and reveals a very high degree of misclassification. The intersection of energy poverty dimensions remains well below 10% for most pairwise combinations, at a level consistent with statistical independence and fully random assignment. Not surprisingly, the largest overlaps are observed between the (HBS-based) ***HighShare*** and ***FixThreshold*** metrics driven by high relative energy spending, as well as the (SILC-based) ***Arrears*** and ***HomeWarm*** measures of self-perceived energy deprivation. The relevant indices, however, remain very low even for these relations (26% and 21%, respectively), which suggests that even similar measurement approaches tend to identify largely different population segments as energy poor.

Figure 5. The spatial relationship between energy poverty dimensions

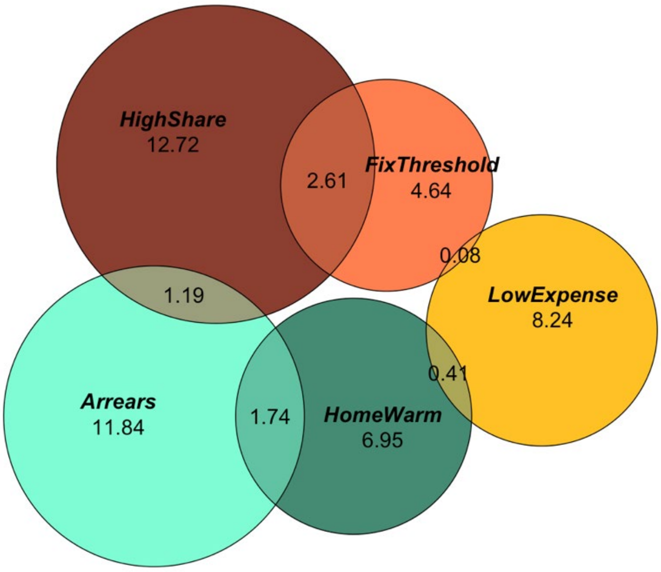


Notes: Own illustration based on joint Hungarian HBS-SILC microdata from 2018, produced with the R package 'eulerr'. The figures represent the percentage point share of the energy poor by dimension and pairwise combination. Note that, due to visualisation constraints, the position of the respective sets is the result of an optimisation procedure and may not represent all set relationship accurately.

Figure 5 offers a graphical illustration of the joint relationship between the various energy poverty measures under consideration. The relevant Venn diagram features area-proportional circles to display the set relationships in question, and confirms the large separation between the respective energy poor populations.[15] Specifically, it highlights that struggling to avoid payment arrears or keep home adequately warm is largely unrelated to households' energy expenditure patterns. This is consistent with the conclusions of previous studies from other European countries (Curtis and Pennecost, 2015; Ormandy and Ezratty, 2012), and calls for a critical re-assessment of existing energy poverty measures and available survey information. It appears to suggest that large variations may exist in households' energy needs, energy consumption and energy efficiency, and that direct measurement of these would likely help identify those that are most vulnerable to energy-related deprivations.

[15] Note that, due to visualisation constraints, the position of the respective sets in Figure 5 is the result of an optimisation procedure and may not accurately reflect all set relationship accurately.

Figure 6. The spatial relationship between housing-related energy poverty dimensions



Notes: Own illustration based on joint Hungarian HBS-SILC microdata from 2018, produced with the R package 'eulerr'. The figures represent the percentage point share of the energy poor based on housing-related energy use only, by dimension and pairwise combination. Note that, due to visualisation constraints, the position of the respective sets is the result of an optimisation procedure and may not represent all set relationship accurately.

One may think that the large disparities between the respective energy poor populations are driven by differences in the scope of the underlying metrics: while the SILC-based indicators refer explicitly to energy use at home, the HBS-based variants target both housing-related and transportation-related energy spending. Empirical evidence suggests otherwise: the misclassification rate across energy poverty measures remains unchanged even if one focuses exclusively on housing-related energy use.[16] The mean of the Jaccard index across all pairwise combinations is actually lower than in case of the headline measures presented before.[17] Figure 6 shows the corresponding Venn diagrams, and reveals that, despite marked changes in the size of the energy poor based on expenditure-based metrics (***HighShare***, ***LowExpense***, ***FixThreshold***), the overlap between the different sets has not qualitatively changed.[18] This is consistent with the previous assertion that disparities in the energy poor populations are due primarily to largely unobserved heterogeneity in dwelling characteristics, living conditions and energy practices that transform energy spending into energy outcomes.

[16] This means considering only the expenditure category CP045 ('Electricity, gas and other fuels') and disregarding category CP0722 ('Fuels and lubricants for personal transport equipment') when calculating the relevant expenditure-based metrics using HBS-microdata.

[17] Disregarding the relationship of sets with themselves, the Jaccard index for the housing-related metrics is 0.09 on average, relative to 0.10 in case of the headline metrics.

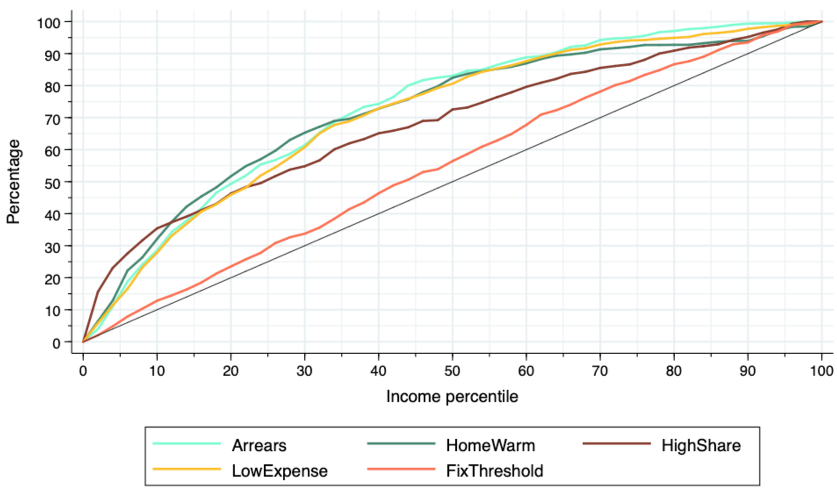
[18] One may note the marked changes in the size of the energy poor population based on housing-related expenditure patterns. Naturally, energy poverty associated with the *FixThreshold* metric is much reduced 4.6% vs. 14.5%), and the same applies to the *LowExpense* metric (8.2% vs. 17.6%) due to the comparatively low level and dispersion of housing-related energy spending (relative to the omitted transportation-related expenditures). However, the share of households whose expenditure-to-income ratio is more than twice the national median (*HighShare*) has increased somewhat (12.7% vs. 9.45%).

5 The role of income and socio-demographic background

In addition to exploring the overlap between the various energy poverty dimensions, it is equally useful to study their relationship with households' income and socio-demographic background. Since these latter often serve as a basis for targeted and/or means-tested social policy interventions (such as income support, child guarantee or housing benefits), a better understanding of their relationship with energy poverty is of crucial policy relevance.

Starting with household income, Figure 7 shows the cumulative accuracy profiles (CAP) associated with each energy poverty measure, using (equivalised disposable) income as the basis for classification. These profiles show, for any given metric and percentile of the income distribution, the cumulative percentage of all the energy poor with equal or lower income. The CAP curve runs parallel to the diagonal if energy poverty is statistically independent from income, and is concave if energy poverty is concentrated among low-income households – with the curvature capturing the general strength of the association between the two (Engelmann et al., 2003). Figure 7 reveals three main types of CAP patterns. First, energy poverty based on the ***FixThreshold*** metric is largely unrelated to household income. Second, energy poverty based on the ***HighShare*** metric is strongly concentrated among very low-income households – more than 35% percent of households with excessive energy expenditure-to-income ratios are found in the lowest income decile. Third, energy poverty based on the consensual metrics and/or low absolute expenditures is predominant among moderately low-income households (across the 2nd–5th income deciles) and particularly rare among households with above-median income.[19] In line with existing evidence from other countries, this suggests that a substantial share of energy poverty is found among non-financially distressed households, and that income support alone is unlikely to eliminate all forms of energy poverty (Thomson et al., 2014; Romero et al., 2018).

Figure 7. The statistical relationship between energy poverty and household income



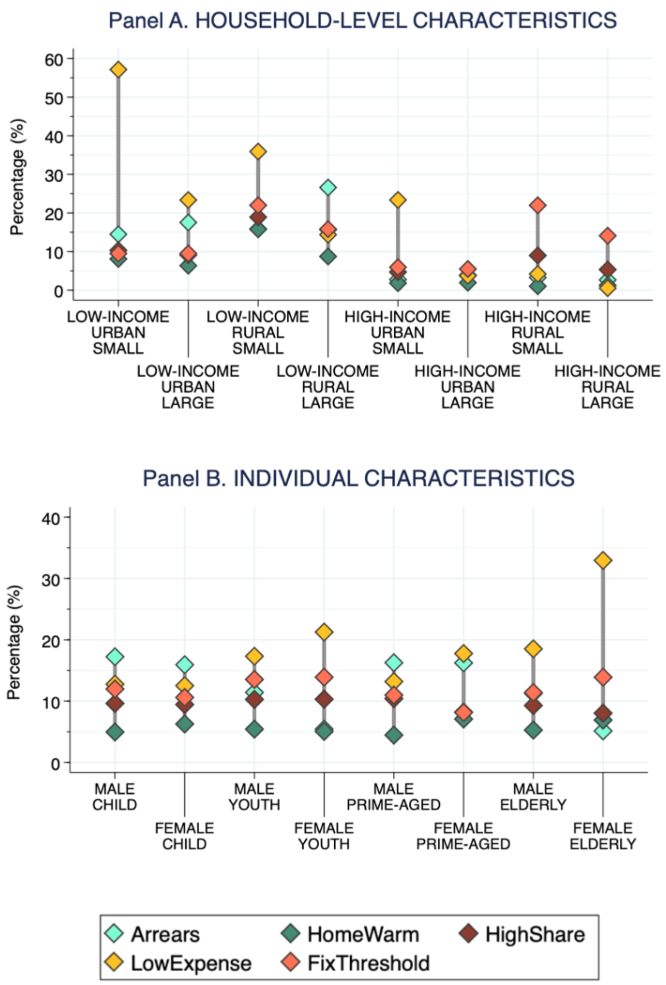
Notes: The figures refer to 2018, and illustrate the relationship (i.e. common accuracy profiles [CAP]) between household income and different forms of energy poverty, based on own analysis of joint SILC-HBS microdata from Hungary. The curves denote the cumulative density of the energy poor based on particular metric associated with each income percentile.

The policy relevance of energy poverty measurement is also evident in relation to households' socio-demographic background. Due to variability in individual preferences, minimum needs, geography and living arrangements, the incidence of different measures of energy poverty may vary considerably between and within social groups. For example, if rural households spend a higher fraction of their budget on heating and transportation, they are more likely to be energy poor based on the ***HighShare*** metric than the ***LowExpense*** metric. Figure 8 plots the energy poverty rate associated with each measure by households' socio-demographic background, and confirms the presence of substantially different poverty profiles. Panel A focuses on

[19] The corresponding accuracy ratios (AR) – the general measure of discriminatory power relative to the case of perfect income-based sorting – range between 11.6% for *FixThreshold* and 52.2% for *Arrears* and *LowExpense*.

household-level characteristics (i.e. income, settlement type, household size), and shows that energy poverty (1) varies within a 25.4 p.p. average range across social groups for a given measure (vs. 56.6 p.p. range for ***LowExpense***); (2) varies within a 20.5 p.p. average range across metrics for a given social group (vs. 49.1 p.p. range for small, urban, low-income households); and (3) displays an average rank correlation of 51% across metrics and 42.5% across social groups. In short, energy poverty patterns are highly heterogeneous across socio-demographic types, and different measures can yield very different energy poverty rates and rankings. Households' vulnerability to energy poverty is most volatile when using the ***LowExpense*** metric, and among small, urban, low-income households.

Figure 8. Energy poverty profiles by households' socio-demographic characteristics



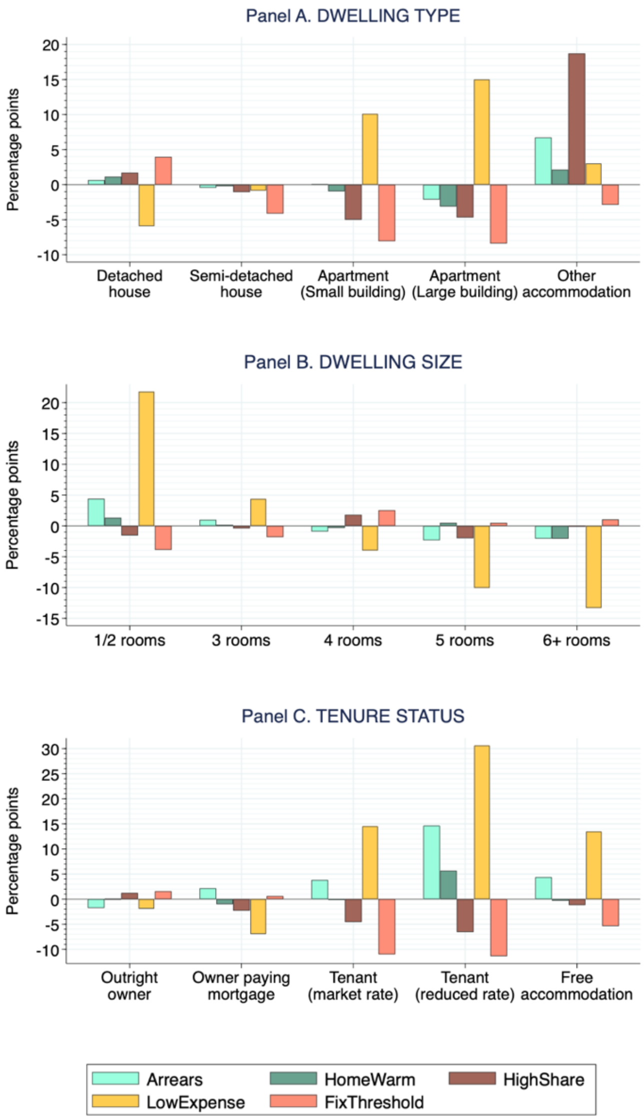
Notes: The figures refer to 2018, and illustrate the relationship between energy poverty and socio-demographic characteristics, based on own analysis of joint SILC-HBS microdata from Hungary. Income groups are created on the basis of the national (equivalised) median, household size is split between 1-2 vs. 3+ members (SMALL vs. LARGE), while CHILD / YOUTH / PRIME-AGED / ELDERLY stand for age groups 0-14 / 15-24 / 25-64 / 65+.

Panel B considers the relationship of energy poverty metrics with respect to individual characteristics such as age and gender. The resulting picture is much more homogeneous, and reveals rather small differences in energy poverty rates between sexes or age cohorts – with the possible exception of elderly women that experience particularly high energy poverty based on low absolute energy spending. Together with the previous findings, this suggests that vulnerability to energy poverty is shaped primarily by socio-economic status and living arrangement rather than individual demography (Papadimitriou, 2023).

6 The role of living and housing conditions

One of the main benefits of the merged Hungarian HBS-SILC microdata is that it allows for the joint analysis of households' living conditions (from the SILC component) and expenditure patterns (from the HBS component). Statistical analysis shows the importance of households' living and housing conditions for energy poverty: in the Hungarian data, dwelling type, dwelling size and tenure status alone explain a larger part of the cross-sectional variation in households' energy expenditure share than income and all standard socio-demographic factors (gender, age, household size, settlement type) taken together.[20]

Figure 9. Energy poverty in relation to households' living conditions



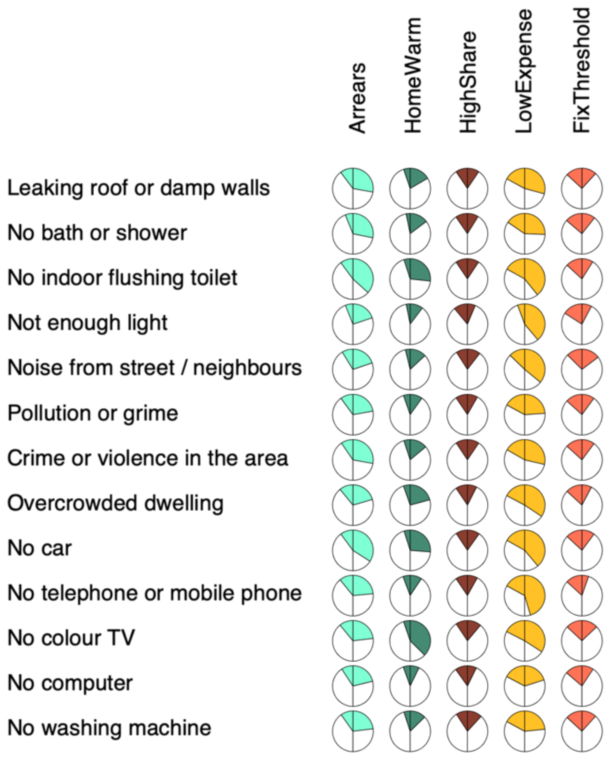
Notes: The figures refer to 2018, and illustrate the relationship between energy poverty and households' living conditions, based on own analysis of joint SILC-HBS microdata from Hungary. The percentage point values indicate differences relative to the national mean. The SILC variables used for the classifications are HH010 (Panel A), HH030 (Panel B) and HH021 (Panel C)

Figure 9 shows the horizontal gaps in energy poverty rates relative to the national average by metric along the aforementioned dimensions of households' living conditions – dwelling type, dwelling size and housing tenure.

[20] Using the 2018 sample, the relevant R-squared statistics for separate regressions of the energy expenditure share on the listed independent variable sets are 12.9% and 6.8%, respectively. The explanatory power of these variables is considerably higher when the absolute level (rather than ratio) of households' energy spending is used as the dependent variable. The corresponding coefficients of variation are 15.5% (for the living condition controls), 18% (for socio-demographic controls without income) and 37.3% (for socio-demographic controls with income), respectively.

The panels reveal that consensual measures of energy poverty (such as ***Arrears*** or ***HomeWarm***) are fairly invariant to differences in living conditions – only reduced-rate tenants report markedly higher inability to keep home warm than others. On the contrary, expenditure-based measures of energy poverty are highly responsive to changes in housing characteristics. Panel A shows that the ***LowExpense*** metric is much higher while the ***FixThreshold*** metric is markedly lower among apartment dwellers relative to the national mean. Panel B shows that the energy poverty based on low absolute energy spending is disproportionately concentrated in small dwellings of 1 or 2 rooms, and is virtually absent among those living in large dwelling with at least 5 rooms. Panel C reveals that, compared to outright owners and mortgage owners, tenants at both market and sub-market rates are facing considerably higher (lower) risk of energy poverty based on the ***LowExpense*** (***FixThreshold***) metric. This confirms that the choice of measurement may crucially determine which housing arrangements are considered particularly vulnerable from the standpoint of energy poverty (Romero et al., 2018; Cong et al., 2022; Eisfeld and Seebauer, 2022).

Figure 10. Energy poverty in relation to housing conditions



Notes: The figures refer to 2018, and illustrate the relationship between energy poverty and households' living conditions, based on own analysis of joint SILC-HBS microdata from Hungary. For each (item-metric) pairwise combination, the pie charts denote the level of energy poverty across households unaffected by the corresponding housing deprivation item (coloured slice in the left crescent) and households affected by it (coloured slice in the right crescent). Larger slices indicate high energy poverty levels, in proportion to the 50% level represented by the full half-circle.

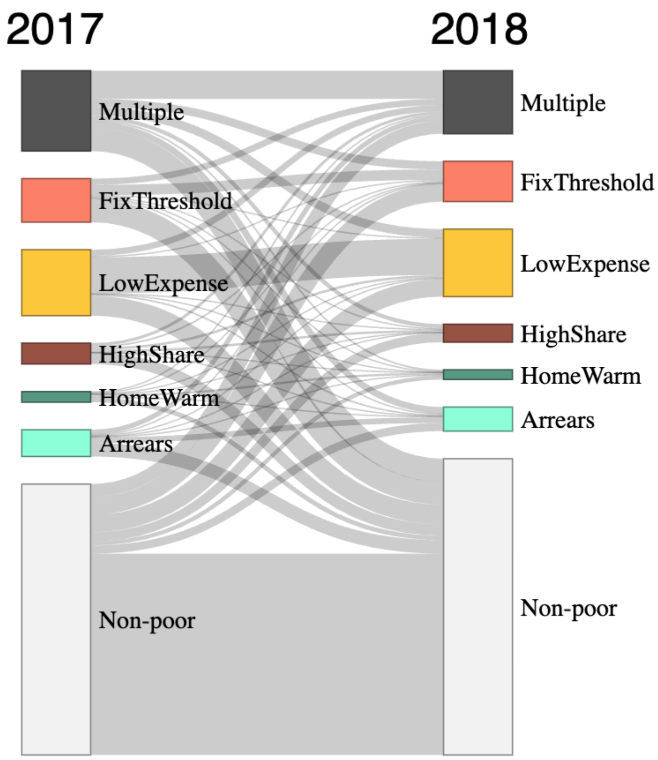
It is also interesting to study how housing quality and dwelling characteristics are statistically related to each of the different energy poverty metrics. Specifically, using the SILC component of the microdata on living conditions in the housing and social exclusion domains, one can compare energy poverty outcomes according to deprivation status. The special pie charts in Figure 10 illustrate, by deprivation item and metric, the mean energy poverty rate for both non-deprived households (left crescent) and deprived households (right crescent). The degree of asymmetry in the coloured slices between the two crescents indicates the gap in energy poverty and the relevance of each particular housing item for adequate energy access. In particular, the figure shows that, for the most part, the ***HomeWarm***, ***HighShare*** and ***FixThreshold*** metrics are rather invariant to differences in housing conditions. Conversely, the measures ***Arrears*** and ***LowExpense*** indicate significantly higher energy poverty among households in sub-par housing conditions. This suggests that improvements in housing conditions and the availability of adequate social housing – potentially combined with some form of income support – may considerably reduce certain forms of energy poverty (Romero et al., 2018; Cong et al., 2022; Cong et al., 2022; Eisfeld and Seebauer, 2022).

7 The longitudinal dimension

An additional distinctive feature of the Hungarian microdata is the reliance on a rotating sample of households and the availability of a longitudinal data component. With around half of all sampled households surveyed repeatedly in 2017 and 2018, it becomes possible to assess the persistence and joint behaviour of energy poverty measures over time.

The analysis of the longitudinal data component (n = 11 135) reveals that the level and distribution of energy poverty is rather stable over time. At the aggregate level, energy poverty in Hungary remained steady between 2017 and 2018 (48.8% vs 45.2%), with its dimensional structure and typical depth also remaining largely similar across households. Surprisingly, this is far from being the case at the micro level: almost half of repeatedly sampled households (47.6%) experienced a change in their energy poverty profiles along the five dimensions considered. Most transitioning households moved from a single-dimension energy poverty status to non-poverty status (13.8%), or the other way around (10.9%). Movements to or from multi-dimensional poverty states were less frequent (10% and 6.7%, respectively). Figure 11 shows the relevant transition patterns, and reveals that many more energy poor households have experienced change in their poverty status than the number of those that reported similar deprivation profiles in both years (71.5% vs. 28.5%). While this suggests that energy poverty is less deep-seated or persistent than other (more generic) forms of poverty, it also tends to make it more difficult to identify vulnerable households and effectively target policies.

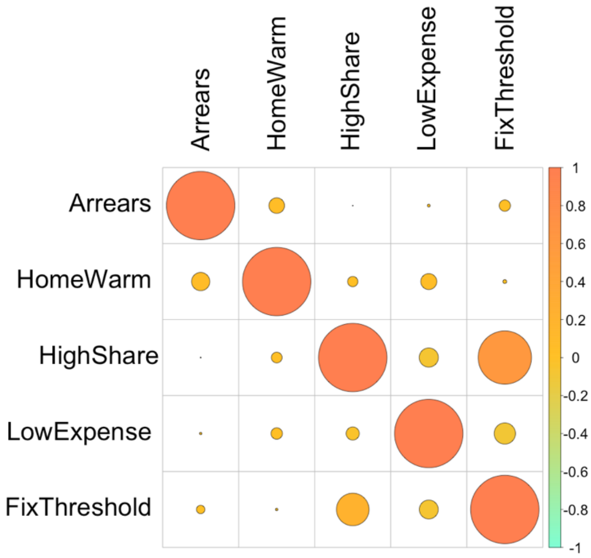
Figure 11. Energy poverty transition patterns between 2017 and 2018



Notes: Own illustration based on joint Hungarian HBS-SILC microdata from 2018, produced with the R packages ‘networkD3’ and ‘tidyverse’. The nodes represent the relative share of population subject to energy poverty in zero (non-poor), singular (*Arrears*, *HomeWarm*, *HighShare*, *LowExpense*, *FixThreshold*) and multiple dimensions, respectively, in a given year. The links across the nodes indicate the observed transition patterns across nodes from 2017 to 2018.

It is therefore instructive to zoom in on the ‘switcher’ population whose energy poverty profile changed from one year to the next. Depending on the particular transition patterns, this may reveal complementary or substitute relationships between different energy poverty dimensions, and could help predict the change in aggregate energy poverty profiles under certain real or hypothetical scenarios. Specifically, using three-way step functions to characterise movements in and out of specific energy poverty dimensions (i.e. +1/0/-1 for in/stay/out), one can calculate the average proximity of movements in relation to each pairwise combination of measures. The polar cases of perfect complements or substitutes are associated with a proximity score of +1 or -1, respectively, while the sign and absolute size of observed scores indicate the directional and associative similarity between transitions. Figure 12 shows the relevant proximity scores for each pairwise combination, and reveals that most transitions in or out of energy poverty status in a given dimension are statistically largely independent of transitions in other dimensions. Real simultaneity is observed only in relation to the ***HighShare*** and ***FixThreshold*** metrics, but most transitions take place in isolation even in such relations.[21] This is consistent with a potentially high incidence of hidden energy poverty, whereby financially-constrained households self-select into different (and sometimes mutually exclusive) forms of energy poverty (e.g. cold home, arrears, high expenditure ratio) that are hard to reliably identify with a limited subset of available energy poverty measures.

Figure 12. Simultaneity of energy poverty transitions between 2017 and 2018



Notes: Own illustration based on joint Hungarian HBS-SILC microdata from 2017 and 2018, produced with the R package 'corrplot'. The coloured circles represent, for each pairwise combination of measures, the proximity between transition movements in and out of poverty status. The size and colour of the circles represent the average strength and direction of the transition patterns between the polar cases of perfect substitutes (-1) and perfect complements (+1).

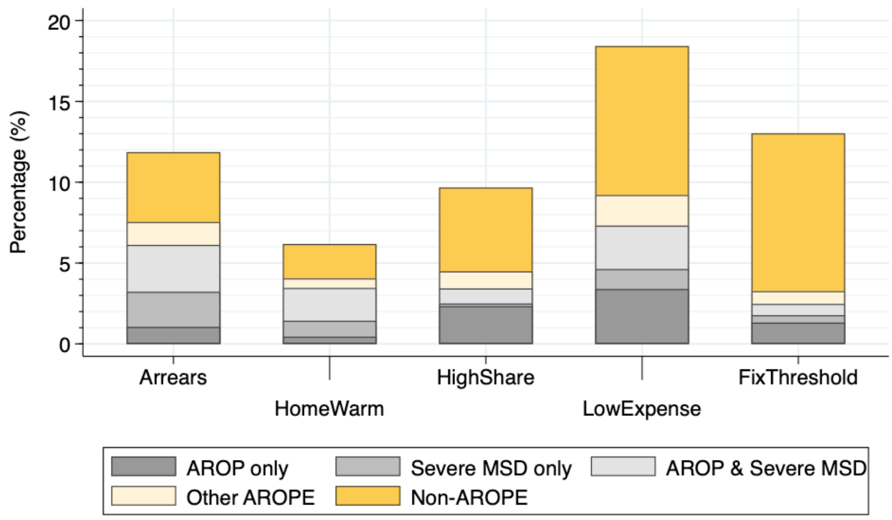
[21] The relevant proximity scores are 0.27 and 0.23, respectively. This means that, on average, among the individuals transitioning into energy poverty based on the *HighShare* (*FixThreshold*) metric, only 27% (23%) transitioned simultaneously into energy poverty based on the *FixThreshold* (*HighShare*) metric.

8 Links to poverty and social exclusion

Finally, it is also important to assess energy poverty metrics in the context of generic measures of poverty and social exclusion, for at least two reasons. Firstly, the Commission recommendation (EU 2020/1563) explicitly considers certain measures of energy poverty (in particular ***Arrears*** and ***HomeWarm***) to be equally calculated for the AROP population segment at risk of monetary poverty.[22] Secondly, the degree of overlap between specific and generic forms of poverty is of crucial importance for policymakers to adequately conceptualise, accurately measure and effectively combat different forms of privation and social exclusion.

The bars in Figure 13 break down the energy poor population according to their AROPE background.[23] It shows that the statistical probability of being at risk of poverty or social exclusion changes considerably from one metric to another. Specifically, while only 25.1% of the energy poor based on the ***FixThreshold*** measure come from an AROPE background, almost two third (65.5%) of households struggling to keep their home warm (***HomeWarm***) are already suffering from generic poverty or social exclusion. The figure also shows that relative monetary poverty is the most common form of social exclusion among those suffering from expenditure-based energy poverty (based on the ***HighShare***, ***LowExpense*** or ***FixThreshold*** metrics), whereas the energy poor based on the ***Arrears*** or ***HomeWarm*** metrics suffer predominantly from (severe) material and social deprivation (MSD).

Figure 13. Break-down of the energy poor population by AROPE background



Notes: The figures refer to 2018, and are based on own analysis of joint SILC-HBS microdata from Hungary. See the explanation and detailed breakdown of AROPE status on the dedicated Eurostat website.

Overall, these findings suggest that, despite their considerable differences, most forms of energy poverty are closely associated with the poverty and social exclusion in the generic sense. Improving the situation for the most vulnerable is therefore expected to simultaneously reduce energy poverty, especially in its consensual forms. Expenditure-based energy poverty tends to concern a larger pool of non-AROPE households and call for more targeted policy interventions.

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[22] For more information on the at-risk-of-poverty (AROP) rate, see the dedicated Eurostat website and official statistics (data code: ILC_LI02).

[23] For more information on the at-risk-of-poverty or social exclusion (AROPE) rate, see the dedicated Eurostat website and official statistics (data code: ILC_PEPS01N).

9 Conclusions and policy recommendations

The empirical analysis presented in this report exploited the distinctive features of joint SILC-HBS national microdata files from Hungary, in order to study important and previously unexplored patterns of energy poverty in the context of EU measurement and policy.

The main conclusion that emerges from the detailed comparison of existing measures of energy poverty is that different forms of energy deprivation concern largely different population segments. Most dimensions of energy poverty appear in isolation, with less than one third of the energy poor suffering from multiple causes. Households tend to self-select into various energy poverty dimensions, and those that struggle to keep their homes warm or pay their utility bills are typically not the ones that spend uncharacteristically little or much on energy in either relative or absolute terms.

The empirical analysis also yields a series of additional novel insights:

- different measurement approaches can result in markedly different levels of energy poverty;
- consensual measures of energy poverty based on households' self-reported valuations are subject to considerable seasonality that may seriously compromise the cross-country comparability of energy poverty outcomes;
- the relationship between energy poverty and household income is highly variable by metric, but all forms of energy poverty are present among non-financially distressed households as well;
- the socio-demographic profiles associated with the respective measures of energy poverty are markedly different; settlement type and household size appear to be the main drivers of household vulnerability, while the role of age and gender is rather limited;
- housing conditions play an equally important role in explaining horizontal differences in energy poverty: expenditure-based measures indicate large differences across dwelling type, dwelling size and tenure status, while housing quality matters most for the incidence of payment arrears and low absolute expenditure on energy;
- while energy poverty appears robust at the aggregate level, longitudinal analysis shows limited persistence at the individual level: almost half of the energy poor change status or transit in or out of poverty from one year to the next;
- the relationship of energy poverty with respect to headline poverty and social exclusion is highly variable across measures: consensual energy poverty displays strong overlaps with AROPE background, while expenditure-based energy poverty concerns mostly non-AROPE households.

These findings are based on the empirical analysis of Hungarian microdata. However, it is reasonable to assume that broadly similar patterns apply equally to most other EU Member States. First, households' energy situation in Hungary is comparable to that of the typical EU country: the analysis of EU-wide microdata from 2015 shows that the mean energy poverty rate in Hungary is almost identical to the typical EU country across the five indicators considered (12.7% vs. 12.9%). Second, some of the presented findings – such as high seasonality or limited overlap between certain indicators – are structural and stem from existing data collection protocols and measurement choices. Third, previous studies from the United Kingdom and selected EU Member States have come to similar conclusions in relation to various aspects of energy poverty discussed in the current analysis (Romero et al., 2018; Curtis and Pennecost, 2015; Heindl, 2015; Palmer et al., 2008).

More fundamentally, the presented analysis reveals serious shortcomings and limitations with respect to all existing measures of energy poverty. Consensual measures of energy poverty are subject to strong seasonality bias and enjoy limited cross-country comparability due to sampling differences, appear to display lower correlations with observable aspects of households' socio-demographic background and living conditions, and strongly overlap with AROPE in terms of the identified population segment. Expenditure-based measures, on the other hand, appear more robust, pertinent and sensitive to changes in households' living conditions, but are not available in a timely and fully harmonised manner across all Member States. A further potential problem with all the indirect measures considered is that they are hardly actionable for policy, as targeting support based on self-reported valuations or expenditure ratios is not feasible, equitable or sustainable.

This calls for immediate improvements to the current measurement framework and survey data architecture. Much of the related efforts should involve European statistical authorities and aim at the further harmonisation and integration of European household surveys. In particular, the synchronisation of data collection periods across EU Member States, the convergence of HBS and SILC surveys towards common definitions and potentially overlapping samples, or the revision and refinement of specific survey questions for improved clarity and consistency could contribute mightily to obtain a more accurate and representative picture of energy poverty across the EU.

This Report also calls for exploring new avenues, methodologies and data for the improved measurement and the effective combating of energy poverty. The cornerstone of such initiatives should be the direct measurement of households' energy consumption and energy efficiency (Thomson et al., 2014). This would require collecting and analysing data from energy suppliers or other administrative sources, as well as the detailed mapping of horizontal differences in households' energy needs, practices and coping strategies. One should also strive to extend the measurement focus of housing-related energy use to incorporate other energy services in the home beyond heating (such as lighting, cooking or cooling).

An ambitious possible solution to providing a policy-actionable measure of energy poverty could be to produce customised energy reference budgets based on minimum consumption thresholds and energy unit costs (Romero et al., 2018, Menyhért et al., 2021). Ideally, the designated minimum consumption thresholds should depend not only on households' socio-demographic background but also their housing condition and resource efficiency, in a manner that incentivises reasonable energy savings, green investment, sustainable renovation and improved resource efficiency. Coupled with a robust underlying definition of vulnerable households, such a novel indicator – when used in conjunction with existing measures – could help better identify and eliminate both the manifest and hidden forms of energy poverty in the EU.

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List of abbreviations and definitions

AROP	At-risk-of-poverty
AROPE	At risk of poverty or social exclusion
CAP	Cumulative Accuracy Profile
EU-HBS	European Household Budget Survey
EU-SILC	European Union Statistics on Income and Living Conditions
HICP	Harmonised Index of Consumer Prices
MSD	Material and social deprivation
NSI	National Statistical Institute

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