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Faces of Poverty: Who Are the Energy Poor in Poland?

Abstract

Objective: The author's goal is to portray energy poor households in Poland based on several well-recognised and original indicators and some clustering techniques. In this study, I check whether the target population is identified correctly and I show possible directions in which the state energy poverty policy might evolve in this regard.

Research Design & Methods: The ten-percent energy poverty measure, the ability-to-keep-home-warm, and the hidden-energy-poverty measures are used to examine the profiles of the energy poor. My source of data is the energy consumption module of the Household Budget Survey collected by the Polish statistical office in 2018. The statistical techniques include multiple linear regression, lasso regression, partitioning around medoids procedure, and hierarchical clustering, among other things.

Findings: All indicators produce different rates of energy poverty, but they are consistent in describing the energy poor groups. Two similar clusters are obtained. The first group is composed mostly of retired single women occupying blocks of flats. The second group is represented mainly by working men living in families with children in stand-alone houses in remote areas.

Implications / Recommendations: Although politicians might choose an energy poverty measure which gives the convenient level of energy poverty incidence, the profile of the target population does not change much. The above implies that regardless of the approach to estimating energy poverty, the profiles obtained in this study should be considered as a target population for policy actions.

Contribution / Value Added: Energy poverty in Poland is often linked to low-stack emissions coming from the residential sector. The owners of single-family houses are the main target of many state programmes aimed at improving the air quality in the country as well as fighting energy poverty. In this study, I show that there are at least two target groups. The results are robust with regard to energy-poverty measuring.

Keywords: energy poverty, profiles, hidden energy poverty, energy poverty ratio, subjective indicator, Poland

Article classification: research article

JEL classification: C1, D1, D6, I3, Q4

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Introduction

The discussion on the energy poverty metrics comes to the point at which a choice of a single energy poverty measure becomes needless (Deller, 2018). First of all, this is because countries differ in terms of socio-economic grounds and consequences of energy poverty. Secondly, energy poverty data collection is limited. Thirdly, the phenomenon of energy poverty is too complex to be captured through one measure. Researchers agree that all measures are equally important, as they reflect various aspects of energy poverty (Sareen et al., 2020).

Energy poverty can be defined as a condition in which households or individuals suffer from an insufficient level of essential energy services (EPOV, 2021a). The EU Commission recommends that member-states develop their approach to tackle energy poverty (EU Commission Recommendation 2020/1563). The existing energy poverty indicators are quite numerous. There are supporting indicators, such as demographic factors, energy prices, supply choice, heating system, etc. (Rademaekers et al., 2016). Another category is subjective indicators, such as the ability-to-keep-home-warm or the leaking-roofs-damp-rot. There are also expenditure-based indicators, such as the Low Income High Cost (UK Government, 2021), etc. According to some, classification indicators are primary, e.g. the share of energy expenditures, or secondary, e.g. the number of rooms per person (EPOV, 2021b). The above-mentioned list of indicators is non-exhaustive.

In this study, I shift the focus away from the energy poverty metrics towards considering the profiles of the energy poor instead. The goal is to describe the portrait of the energy poor and examine sources of energy that each group uses for heating their homes. I would like to prove that regardless of the metrics, similar groups of the energy poor can be identified. In order to test this hypothesis, I select three measures of energy poverty.

The first measure is the hidden energy poverty indicator. This indicator builds on the premise that people save on energy costs when facing budget constraints and having cheap energy sources, such as coal, firewood, biomass, and others (Karpinska & Śmiech, 2020a). Here I estimate the energy costs required to meet the energy needs of a household. If the required energy costs are too high to push a household into income poverty, then this household experiences hidden energy poverty. Energy poverty is invisible, because the share of energy costs in the total budget is low (Karpinska & Śmiech, 2020b). This phenomenon received the attention of authors from different countries (Meyer et al., 2018; Papada & Kaliampakos, 2020; Betto et al., 2020). The problem is acute among the poor population (Brunner et al., 2012).

The second measure is the self-reported energy poverty indicator. These measures have become very popular in comparative studies due to their simplicity and suitability for replication (Karpinska & Śmiech, 2020c; Thomson & Snell, 2013; Bouzarovski & Tirado-Herrero, 2017). At least three self-reported energy poverty indicators are worth mentioning here. The first one is the answer to the question on the ability to keep homes warm, also frequently used in dynamic assessments of energy poverty (Karpinska & Śmiech, 2021a; Chaton & Lacroix, 2018). The second one is the question on the arrears on utility bills. The third one is the assessment of buildings' technical condition; the question is about problems with a dwelling such as a leaking roof, damp walls/floors/foundation, rot in window frames, or floor. The questions come from the 2021 EU Survey on Income and Living Conditions (EU-SILC), which is the primary source of micro-level data for the energy poverty research in Europe.

The third measure is the ten-percent energy poverty ratio. This ratio was introduced by Boardman (1991). According to this indicator, energy poverty occurs when more than 10% of households' income is spent on energy needs. In the UK, 10% represented the double median threshold at that time, and as such it is proved to be improper to measure energy poverty (Schuessler, 2014). After years of discussions, the ten-percent energy poverty ratio has been replaced by the Low Income High Cost indicator (Hills, 2012), which is the official measure of energy poverty in the UK and as such is contested by some researchers (Middlemiss, 2017; Moore, 2011). Yet, the ten-percent energy poverty ratio attracts a lot of attention and is often computed (Miazga & Owczarek, 2015). This measure of energy poverty is considered in the Polish social policy planning and is claimed by the governmental representative Piotr Naimski (2021) to be a good indicator of energy poverty in Europe.

The comparative analysis of energy poverty profiles has been rarely considered in the literature (Belaïd, 2018; Primc et al., 2019; Sanchez-Guevara et al., 2020). I contribute to the limited literature on energy poverty groups in Poland (Lis et al., 2016) and argue that – contrary to the results provided by Fizaine and Kahouli (2018) – the selection of an indicator in this case does not impact the profile of the energy poor groups.

The study is divided into several sections. In the introduction, I explain the concept of energy poverty, set the hypothesis, state my contribution, and review the literature. The next section is dedicated to data and methods. In the section on the results, I discuss the outcomes of the study. In the last section, I summarise the main points.

Data and methods

I obtain cross-sectional data for this analysis from the Polish statistical office. My database consists of the Household Budget Survey (HBS) and the recent energy consumption module (EGD[1]) of the HBS. The module is collected once in three years and is available for the year 2018 at the latest. My sample contains information on 4081 households, which represents 11.3% of all observations from the HBS. The sample is considered as a representative minimum.

In order to count energy poor households, I use three indicators. The first one is the original approach to reveal hidden energy poverty developed by Karpinska and Śmiech (2020a). The second one is a subjective assessment of a household's ability to keep the home warm. The third one is a ten-percent energy poverty ratio that points at high – i.e. more than 10% – energy expenditures in households' income.

The hidden energy poverty indicator requires the estimation of energy costs[2]. The energy costs are regressed against household type, building characteristics, living conditions, income level, etc. In total, 12 variables are utilised; the variables' description is provided in Table 1. In order to account for the composition of a household, I modify the disposable income according to the OECD equivalisation scale, where coefficients 1, 0.5, and 0.3 are applied to the first adult, the next adult, and a child under 14 years old respectively.

For the subjective energy poverty indicator, the respondents need to answer the question: "In your opinion, does your house/flat provide thermal comfort (is it warm enough in winter, adequately cool in summer)?" Figure 1 shows the distribution of income and energy costs.

I perform the analysis in two stages. First, I calculate the energy poverty rate in three cases, such as hidden energy poverty, subjective energy poverty, and energy poverty ratio. The study relies on hidden energy poverty estimations published in a recent report (Karpinska & Śmiech, 2021b). The multiple linear regression is calculated using the ordinary least squares method. The formula is as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_{\underline{n}} \underline{\mathrm{x}}_{\underline{n}} + \varepsilon, \qquad (1)$$

where y is a response variable, β_0 is a constant term, $\beta_{\underline{n}}$ are coefficients for variables x, ε is an error

[1] The survey on energy consumption in households [Pol. *Ankieta o zużyciu paliw i energii w gospodarstwach domowych*].

[2] In the ten-percent energy poverty indicator, I use actual and not modelled energy costs.

Table 1. The description of variables

Variable	Category
Type of building	Blocks of flats Single-family Other
Year of construction	before 1946 in 1946–1960 in 1961–1980 in 1981–1995 in 1996–2011 after 2011
The total usable floor area of the apartment	up to 50 m^2 50–100 m^2 100–200 m^2 above 200 m^2
Number of rooms	1 room 2 rooms 3 rooms 4 rooms more than 4 rooms
Subjective evaluation of the building (whether it has appropriate technical and sanitary conditions, namely efficient wastewater, water, electricity, gas, and heating installations; good condition of the roof, walls, floors, windows)	yes no
Thermal comfort of the building	yes no
Subjective perception of a household's financial condition	good rather good neither good nor bad rather bad bad
Urban and rural areas	densely populated intermediate thinly populated
Household type	with dependent children without dependent children one-person household other
Voivodeship	
Insulation in buildings	yes, entirely yes, partially no don't know

Source: own elaboration.

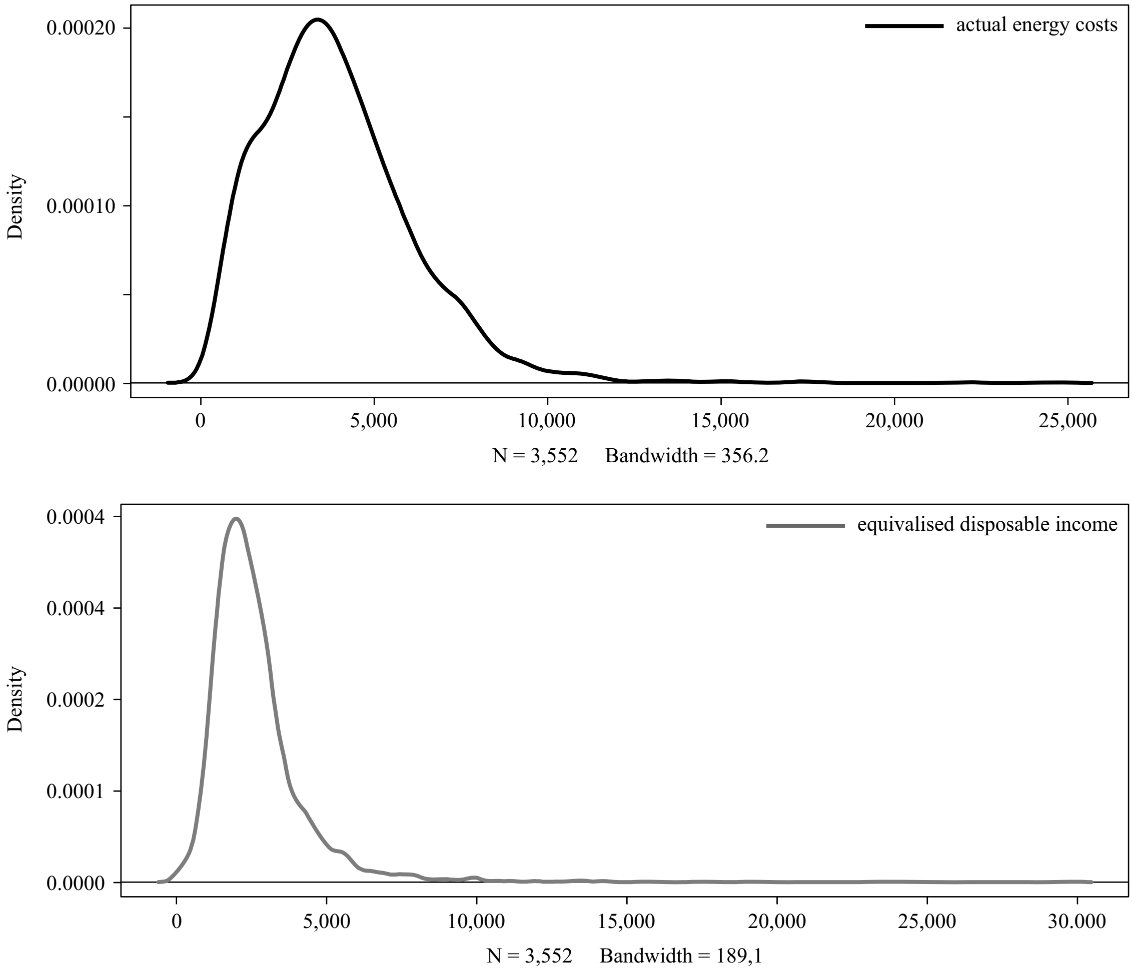


Figure 1. The distribution of annual energy costs and monthly equivalised household disposable income
Source: own elaboration.

term, and *n* is the number of variables. Following the lasso procedure, I check the robustness of the results. The shrinkage makes it possible to retain only the most informative variables as well as it solves the problem of possible correlations between them (Tibshirani, 1996). I apply the most regularised version to ensure the accuracy and predictability of the model.

Second, I group the energy poor population into clusters. The groups are obtained in partitioning around medoids procedure and hierarchical clustering. Both methods belong to unsupervised machine learning algorithms that are widely explored in energy poverty studies (Belaid, 2018). The first one creates an algorithm for finding the most representative object, i.e. a medoid, and for assigning each observation to the closest medoid. In the second method, the similarity between observations is measured in terms of distance, which in my case is Ward's minimum variance distance.

All computations are done in R.

Results

According to my estimations, the rate of energy poverty oscillates between 13.17% and 33.3%, and depends on the metrics I use. Figure 2 presents the results. The lowest rate is reported by households themselves. When answering the question on the thermal comfort of buildings, 13.17% of the households recognise that houses are not comfortable in terms of the temperature inside. Quite similar results are obtained for hidden energy poverty; 17.2% of households are classified as energy poor by the original measure[3]. The ten-percent ratio yields the highest rate of energy poverty (33.3%). It is worth noting that the ten-percent ratio captures only high-energy expenditures and ignores the energy-saving aspect of energy poverty.

Tables 2 and 3 illustrate the coverage of different energy poverty measures. The similarity of classifications measured by the adjusted Rand index shows a very high level of disagreement. It is worth noting that households classified by all three measures as energy poor constitute only 10.58% of all households, whereas the non-energy-poor account for 7.31% of observations. This finding confirms that the measures I choose capture different aspects of energy poverty. Politicians might be tempted to opt for the measure that shows low numbers in the case of pro-governmental forces, and *vice versa* (Karpinska, 2018). The hidden-energy-poverty overlaps with the ten-percent measures to a much greater extent (54.92%) than the subjective-energy-poverty indicator with either of the measures considered in the study.

The profiles of the energy poor are presented in Figures 3, 4, and 5. I identify two groups, the respective PAM and hierarchical results are shown in Figures A1, A2, and A3. Despite striking differences in classifications between different measures of energy poverty, the profiles of energy poor households are almost the same. It can be easily noticed that one group consists of mostly elderly people inhabiting thinly populated areas. The retired or inactive people in the group occupy small two-room flats of about 50–100 square meters in old blocks constructed before 1961 or single-family houses of the same size and age in almost equal proportions. Buildings are, for

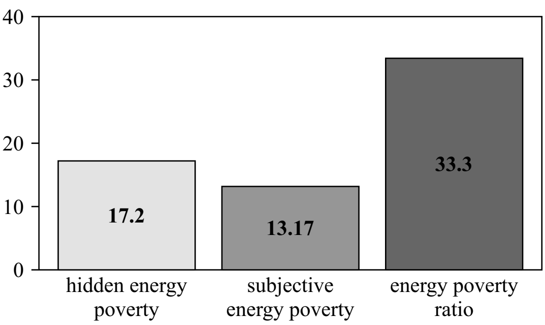


Figure 2. Energy poverty prevalence in Poland, 2018 (in %)

Source: own elaboration.

Table 2. The adjusted Rand index estimates

	Ten-percent measure	Subjective energy poverty
Hidden energy poverty	0.21	0.05
Subjective energy poverty	0.008	

Note: The closer the adjusted Rand index is to 1, the greater similarity between classifications is found.

Source: own elaboration.

Table 3. The overlap between different energy poverty measures (in %)

	Ten-percent measure – yes		Ten-percent measure – no	
Hidden energy poverty	yes	no	yes	no
Subjective energy poverty – yes	10.58	17.93	3.37	54.92
Subjective energy poverty – no	2.16	2.61	1.06	7.31

Source: own elaboration.

[3] The regression results are available upon request.

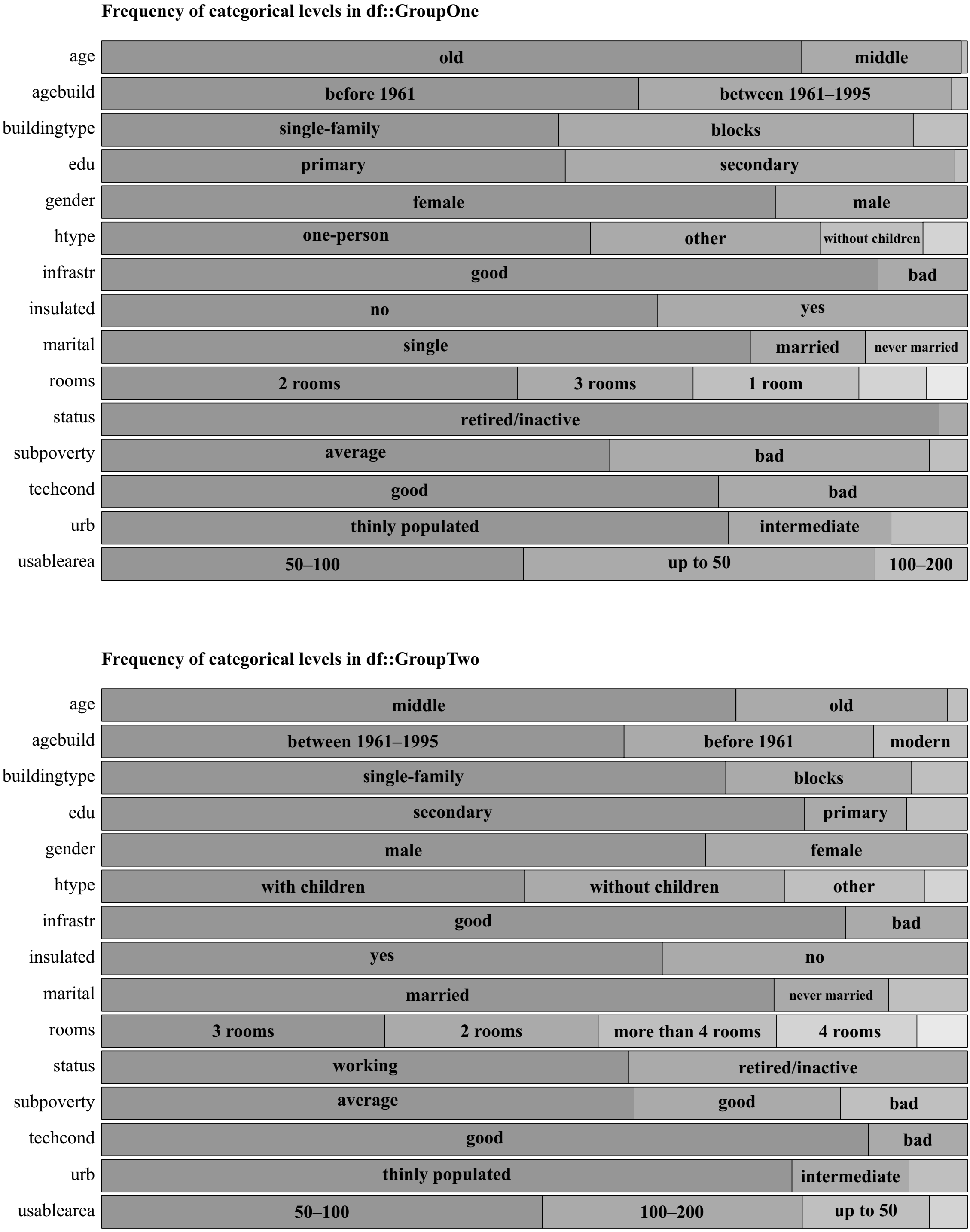


Figure 3. Profiles of the energy poor – hidden energy poverty

Source: own elaboration.

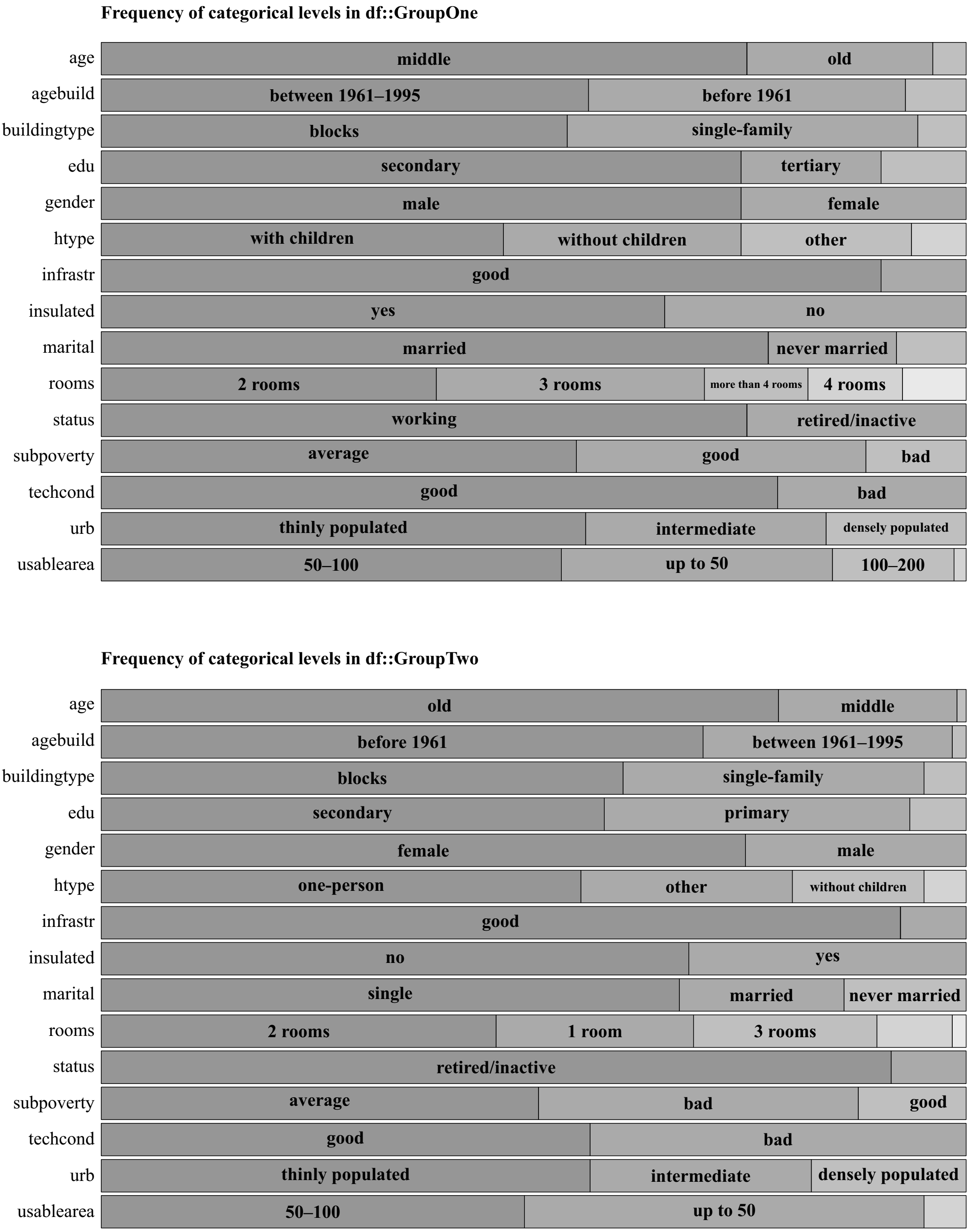
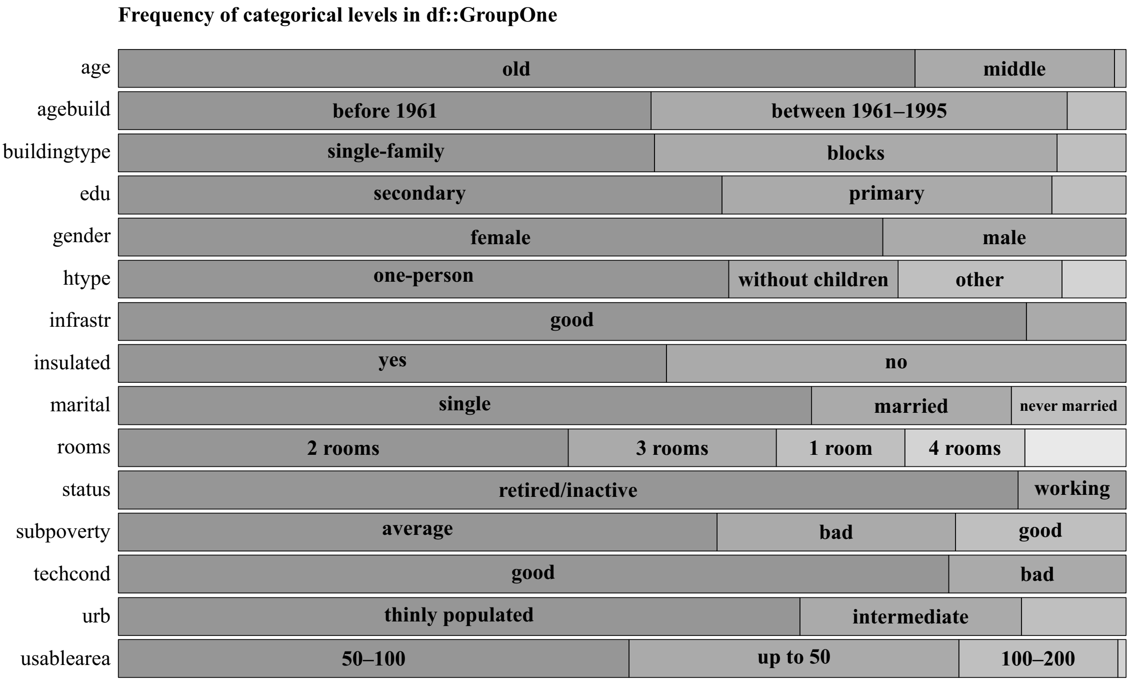


Figure 4. Profiles of the energy poor – subjective energy poverty

Source: own elaboration.



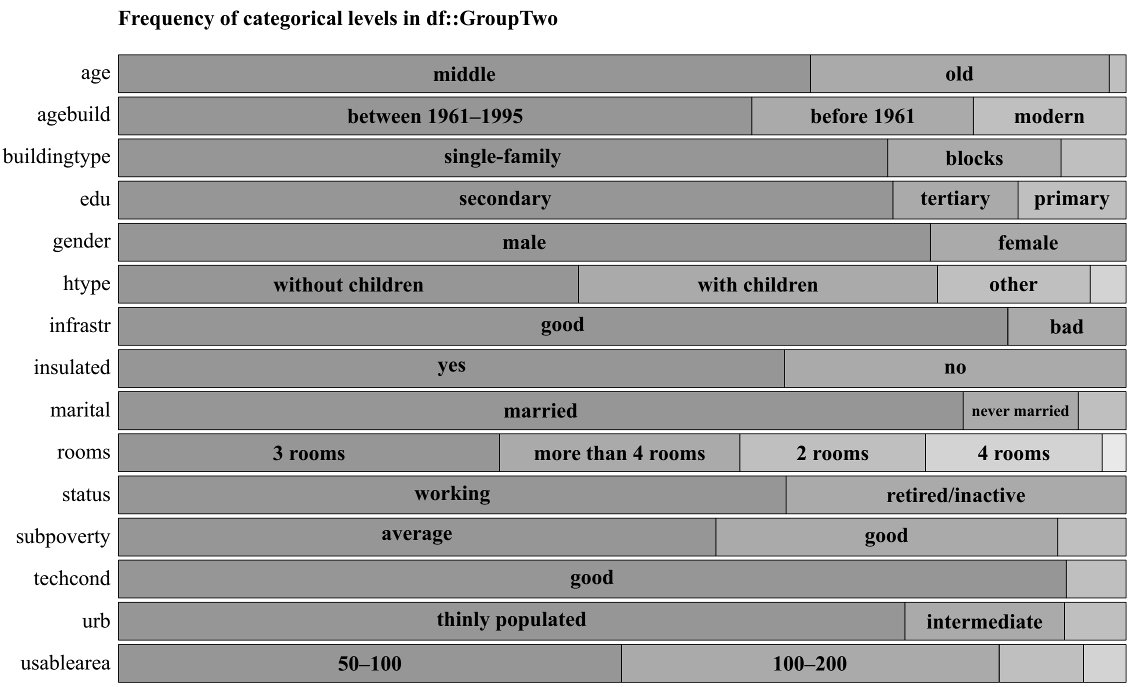


Figure 5. Profiles of the energy poor – ten-percent energy poverty ratio

Source: own elaboration.

the most part, not insulated. This group is mostly represented by single women reporting average ability to make ends meet, i.e. subjective poverty. The highest level of education in the group is primary or secondary. The level of urbanisation is predominantly low. The infrastructure, such as shops and access roads, is good in both groups.

The other group consists of households with or without children, living in single-family buildings and sometimes blocks of flats in case of subjective energy poverty. According to the subjective energy poverty indicator, blocks of flats dominate in this group. The buildings are built between 1961 and 1995, and the respondents state that they are in good technical condition, i.e. they have appropriate technical and sanitary conditions (efficient wastewater, water, electricity, gas, and heating installations) as well as their roofs, walls, floors, windows, etc. are in a good shape. Heads of households consist of married middle-aged men who are active on the labour market. The heads of households indicate average ability to cope with financial difficulties in this group. The level of education achieved by the heads of households is a bit higher than in the first group, i.e. the obtained education is predominantly secondary. The usable area is around 50–100, sometimes 100–200 square meters, which might be difficult to heat. The buildings are mostly insulated. It is interesting to mention that subjective indicators – such as poverty, technical conditions of houses, etc. – reported by households are not bad in both groups. A subjective assessment most probably indicates a relative position of a household compared to other households in the neighbourhood.

Both groups have common traits. One characteristic feature which is worth mentioning is that the usable area of buildings or flats is too big for these households, particularly in the case of single-family households or households without children. Primary sources of energy used for heating purposes in both groups per different indicators are represented in Figures 6, 7, and 8. Unsurprisingly, in all groups – regardless of the type of buildings – coal is the major source of heating. The next preferred source of heating is district heating, which is especially relevant to blocks of flats and firewood. The other sources play a marginal role in households' energy consumption. Solid fuels used by the energy poor for heating their premises inevitably deteriorate the air quality in the country. Yet, the low price of coal and firewood determines the choice of energy for people experiencing budget constraints.

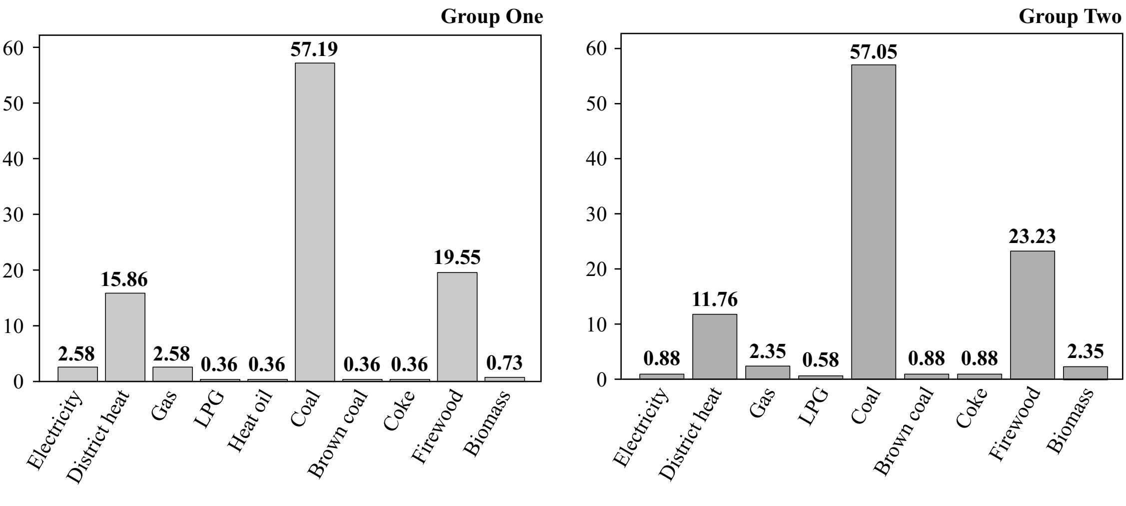


Figure 6. Primary source of heating homes – hidden energy poverty (in %)

Source: own elaboration.

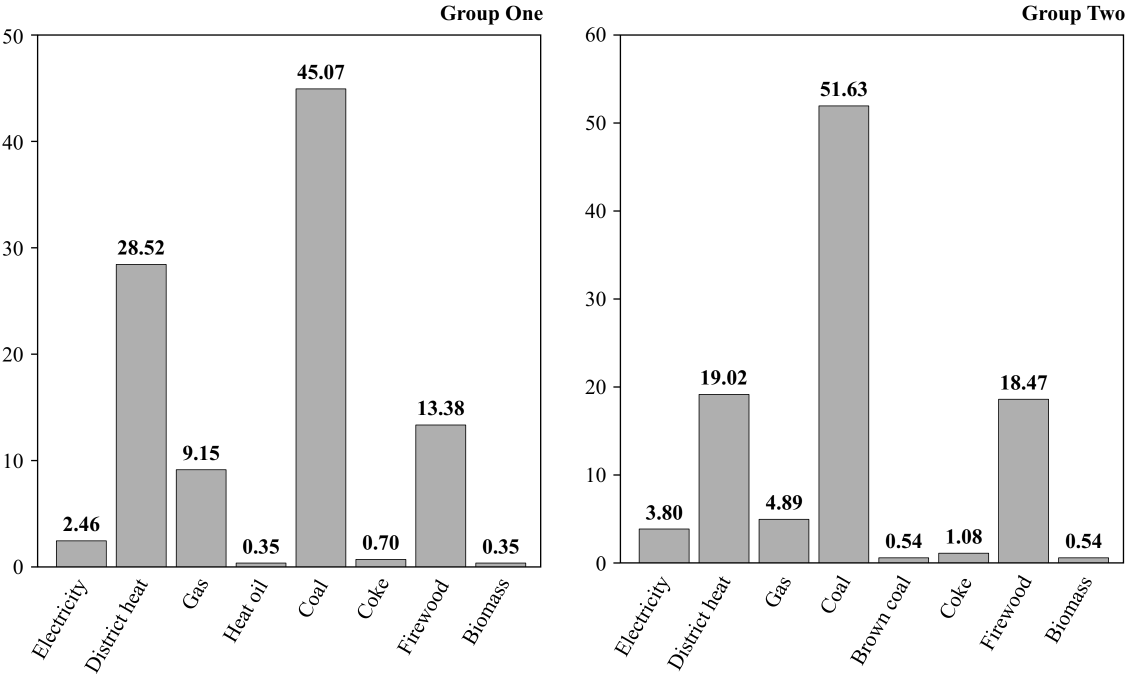


Figure 7. Primary source of heating homes – subjective energy poverty (in %)

Source: own elaboration.

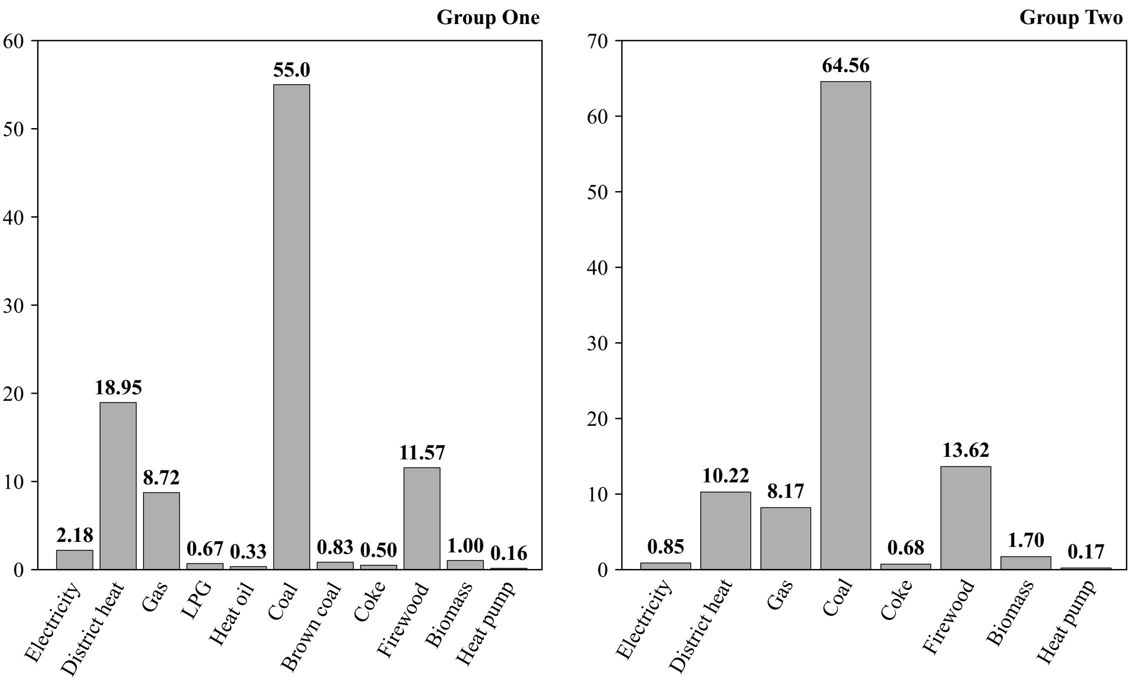


Figure 8. Primary source of heating homes – ten-percent energy poverty ratio

Source: own elaboration.

Concluding remarks

In this study, I describe the portrait of the energy poor households in Poland based on the EGD and the HBS statistics from 2018. Three measures of energy poverty that capture different aspects of this phenomenon are utilised, i.e. hidden energy poverty, subjective energy poverty, and ten-percent energy poverty ratio. I claim that despite the low overlap between these measures, the profile of the energy poor remains the same. The latter fact provides grounds for a clear policy targeting. I believe that the problem of energy poverty metrics yielding inconsistent rates can be overcome by focusing on the beneficiaries of the energy poverty policies.

According to my estimations, energy poverty in Poland affects up to 33.3% of people per ten-percent energy poverty ratio, up to 17.2% per the previously described original hidden energy poverty indicators, and up to 13.17% per subjective energy poverty indicator. Only 10.58% of Poles are classified as energy poor by all three measures. Actual energy expenditures are used to compute the ten-percent energy poverty ratio. To obtain the hidden energy poverty rate, I model energy expenditures accounting for households' needs and buildings' parameters. The prevalence of energy poverty provides little understanding of the target group. Moreover, different political reasons might stand behind the choice of the energy poverty indicator. Tuning the results provides a better or worse picture of energy poverty in Poland. In this study, I draw attention to the energy poor themselves, as well as to the mix of energy sources they use to heat their homes.

I discover two groups of the energy poor. The first one consists of retired single women occupying old buildings, mostly blocks of flats. The second group comprises households with and without children, led by men active on the labour market and living in stand-alone houses. In both cases, the occupied property might be difficult to heat. The homes of the energy poor could be found in less urbanised regions usually characterised by a low level of people's general well-being. The images I draw provide clear guidance for policymakers on who the energy poor are and where to find them. The results are robust to different energy poverty metrics, including the original one proposed by Karpinska and Śmiech (2020a), as well as the most popular one, frequently reviewed in the literature.

One of the most important conclusions is that the energy poor rely on dirty solid fuels as a primary source of heating their homes, i.e. coal and firewood. District heating is not that common even in blocks of flats, where the energy poor live. The low price of coal and firewood and a low level of urbanisation of the affected areas make it difficult and unreasonable to conduct a thermal modernisation of these buildings and to offer the energy poor modern energy sources that require significant investments. Given the age and the social status of some groups of the energy poor, the only reasonable solution might be social assistance and subsidies. When discussing energy poverty in Poland, one should bear in mind the link between the air quality and pollutions coming from the residential sector. For the time being, the vast majority of the energy poor rely on dirty fuels.

The study is limited by the data availability, i.e. the EGD module is collected only once in three years. The comparative analysis of the energy poor profiles obtained for all known at the moment measures of energy poverty seems an interesting topic for future research.

Appendix

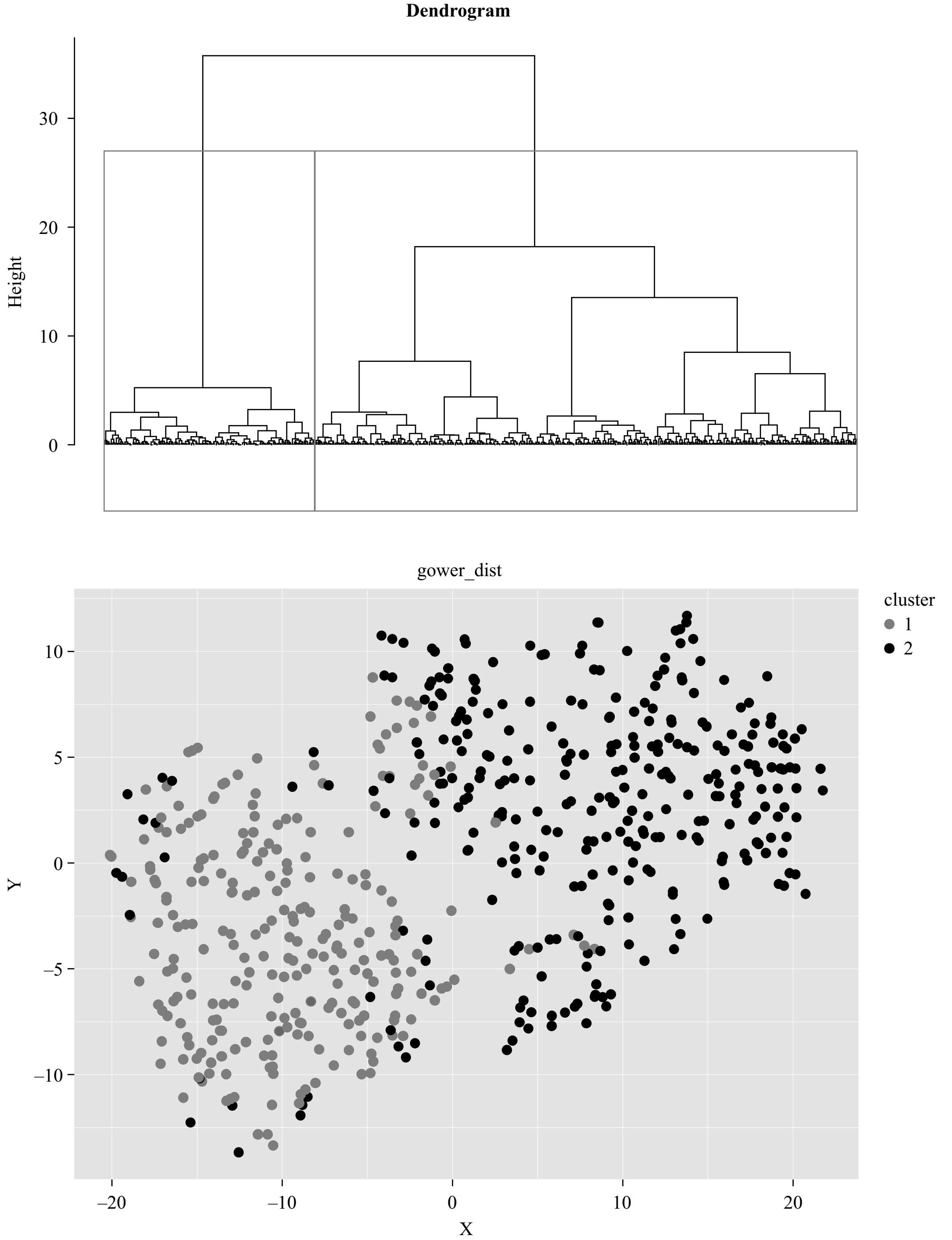


Figure A1. Hierarchical clustering and PAM results – hidden energy poverty

Source: own elaboration.

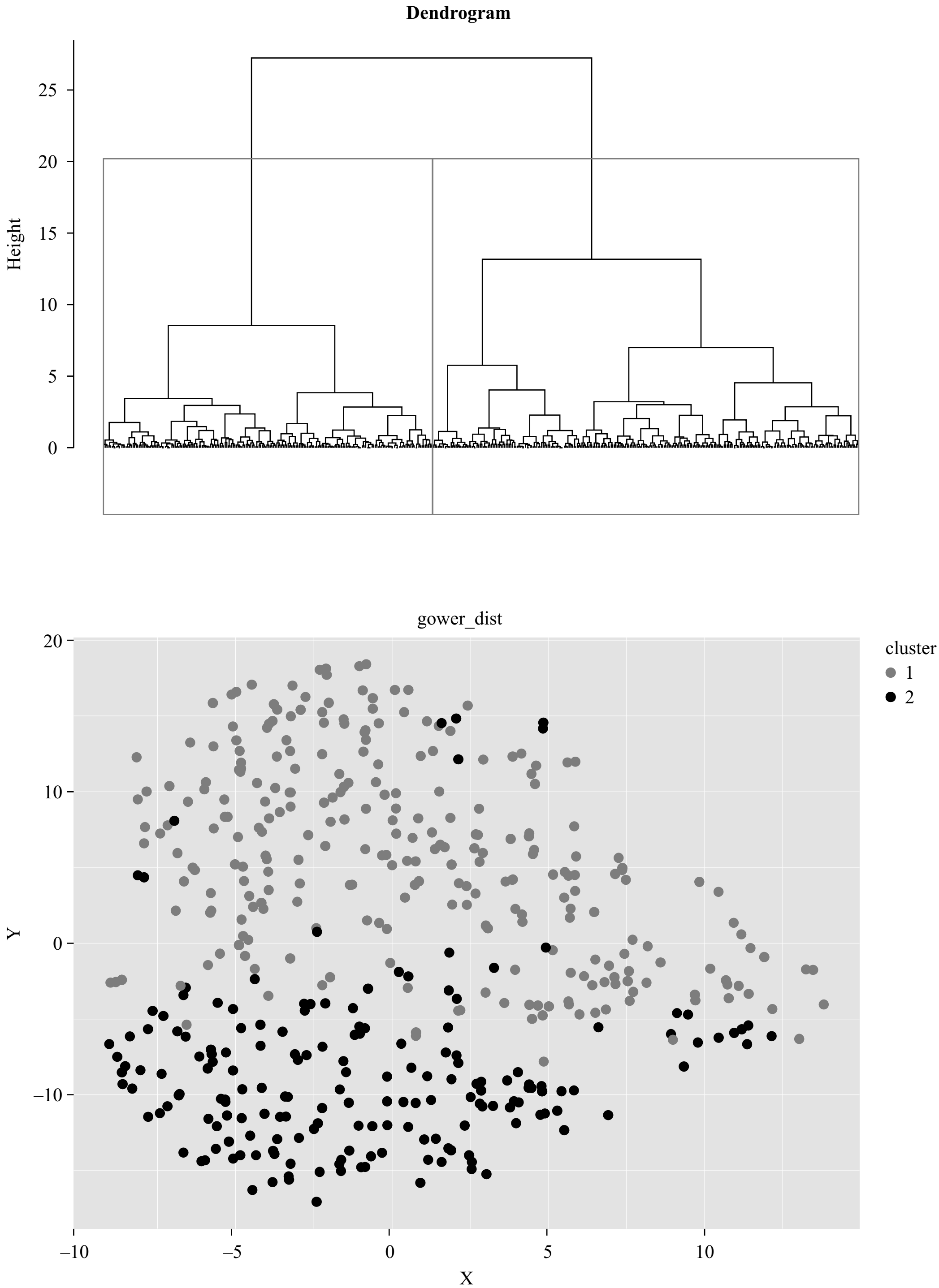


Figure A2. Hierarchical clustering and PAM results – subjective energy poverty

Source: own elaboration.

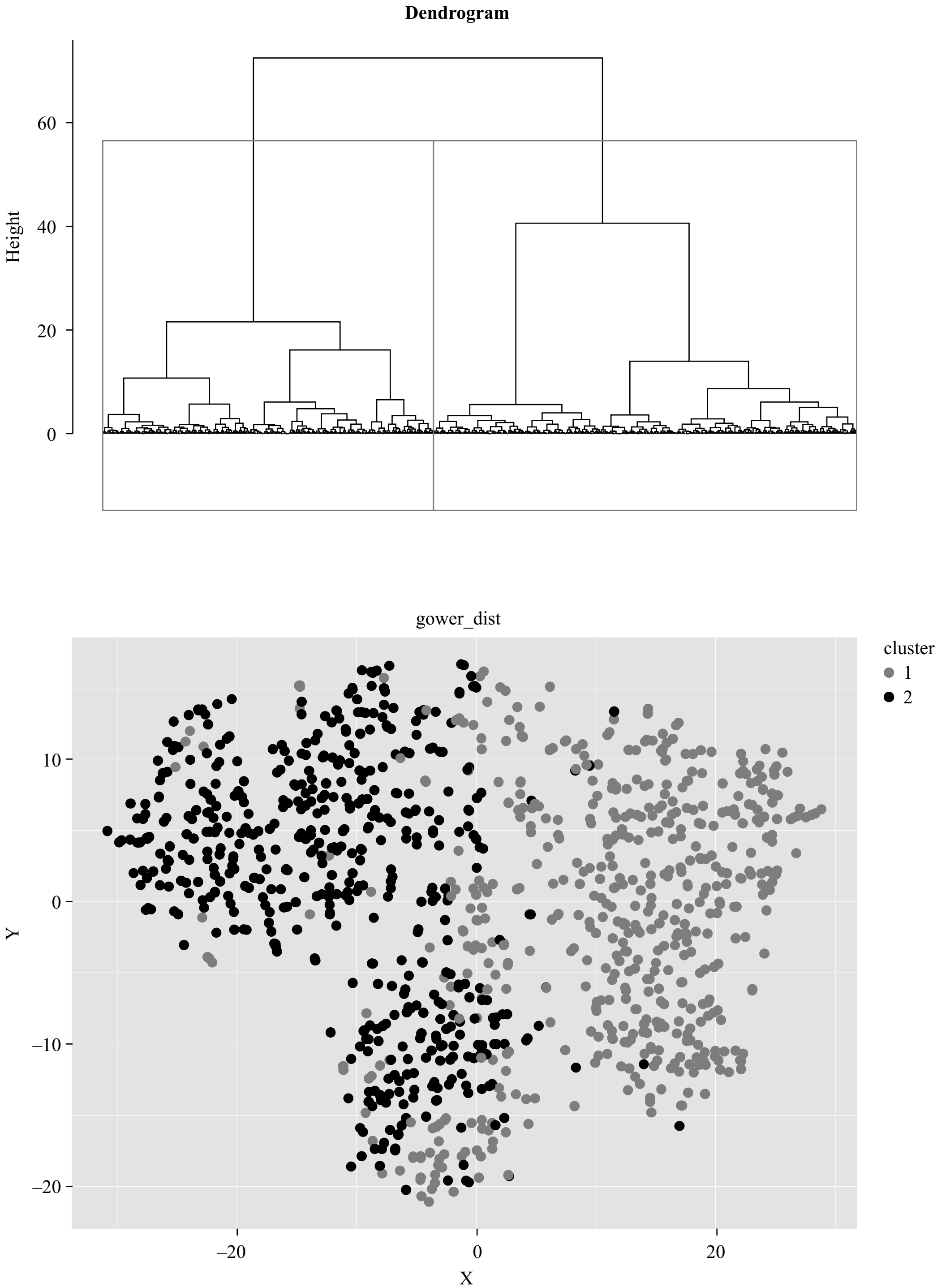


Figure A3. Hierarchical clustering and PAM results – ten-percent energy poverty ratio

Source: own elaboration.

References

Belaïd, F. (2018). Exposure and risk to fuel poverty in France: Examining the extent of the fuel precariousness and its salient determinants. *Energy Policy*, *114*, 189–200. https://doi.org/10.1016/j.enpol.2017.12.005

Betto, F., Garengo, P., & Lorenzoni, A. (2020). A new measure of Italian hidden energy poverty. *Energy Policy*, *138*, 111237. https://doi.org/10.1016/j.enpol.2019.111237

Boardman, B. (1991). *Fuel Poverty: From Cold Homes to Affordable Warmth*. Belhaven Press.

Bouzarovski, S., & Tirado-Herrero, S. (2017). The energy divide: Integrating energy transitions, regional inequalities and poverty trends in the European Union. *European Urban and Regional Studies*, *24*(1), 69–86. https://doi.org/10.1177/0969776415596449

Brunner, K.-M., Spitzer, M., & Christanell, A. (2012). Experiencing fuel poverty. Coping strategies of low-income households in Vienna/Austria. *Energy Policy*, *49*, 53–59. https://doi.org/10.1016/j.enpol.2011.11.076

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

Deller, D. (2018). Energy affordability in the EU: The risks of metric driven policies. *Energy Policy*, *119*, 168–182. https://doi.org/10.1016/j.enpol.2018.03.033

EU Commission Recommendation 2020/1563 on energy poverty. C/2020/9600. OJ L 357: 35–41.

EU Energy Poverty Observatory (EPOV) (2021a). *What is energy poverty?* https://www.energypoverty.eu/about/what-energy-poverty

EU Energy Poverty Observatory (EPOV) (2021b). *Indicators & Data*. https://www.energypoverty.eu/indicators-data

EU Survey on Income and Living Conditions (2021). Available at: https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions (accessed: 10.10.2021).

Fizaine, F., & Kahouli, S. (2018). On the power of indicators: How the choice of the fuel poverty measure affects the identification of the target population. *FAERE Policy Papers*, 2018–01. https://doi.org/10.1080/00036846.2018.1524975

Hills, J. (2012). *Getting the Measure of Fuel Poverty: Final Report of the Fuel Poverty Review*. Centre for the Analysis of Social Exclusion.

Karpinska, L. (2018). Direct energy poverty metrics: What are the rates for Poland? *Folia Oeconomica Cracoviensia*, *59*, 3–22.

Karpinska, L., & Śmiech, S. (2020a). Conceptualising housing costs: The hidden face of energy poverty in Poland. *Energy Policy*, 111819. https://doi.org/10.1016/j.enpol.2020.111819

Karpinska, L., & Śmiech, S. (2020b). Invisible energy poverty? Analysing housing costs in Central and Eastern Europe. *Energy Research & Social Science*, *70*, 101670. https://doi.org/10.1016/j.erss.2020.101670

Karpinska, L., & Śmiech, S. (2020c). On the persistence of energy poverty in Europe: How hard is it for the poor to escape? *Energy RESEARCH LETTERS*, *1*(3), 14158. https://doi.org/10.46557/001c.14158

Karpinska, L., & Śmiech, S. (2021a). Breaking the cycle of energy poverty. Will Poland make it? *Energy Economics*, *94*, 105063. https://doi.org/10.1016/j.eneco.2020.105063

Karpinska, L., & Śmiech, S. (2021b). Raport: Energetyczna bieda. Raport o gospodarstwach domowych ubogich energetycznie. Available at: https://politykipubliczne.pl/raport-energetyczna-bieda-raport-o-gospodarstwach-domowych-ubogich-energetycznie/ (accessed: 05.10.2021).

Lis, M., Sałach, K., & Święcicka, K. (2016). Heterogeneity of the fuel poor in Poland – quantification and policy implications. *IBS Working Paper*, 08/2016.

Meyer, S., Laurence, H., Bart, D., Lucie, M., & Kevin, M. (2018). Capturing the multifaceted nature of energy poverty: Lessons from Belgium. *Energy Research & Social Science*, *40*, 273–283. https://doi.org/10.1016/j.erss.2018.01.017

Miazga, A., & Owczarek, D. (2015). It's cold inside – energy poverty in Poland. *IBS Working Paper*, 16/2015.

Middlemiss, L. (2017). A critical analysis of the new politics of fuel poverty in England. *Critical Social Policy*, *37*(3), 425–443. https://doi.org/10.1177/0261018316674851

Moore, R. (2011). *The Hills Fuel Poverty Review Proposal for a New Definition of Fuel Poverty: An Analysis*. Consumer Focus.

Naimski, P. (2021). Ubóstwo energetyczne: PiS pracuje nad rozwiązaniami dla gospodarstw domowych. *Gazeta Prawna*, https://serwisy.gazetaprawna.pl/energetyka/artykuly/8117103,naimski-projekt-pomocy-ubostwo-energetyczne.html (accessed: 15.11.2021).

Papada, L., & Kaliampakos, D. (2020). Being forced to skimp on energy needs: A new look at energy poverty in Greece. *Energy Research & Social Science*, *64*, 101450. https://doi.org/10.1016/j.erss.2020.101450
Primc, K., Slabe-Erker, R., & Majcen, B. (2019). Constructing energy poverty profiles for an effective energy policy. *Energy Policy*, *128*, 727–734. https://doi.org/10.1016/j.enpol.2019.01.059
Rademaekers, K., Yearwood, J., Ferreira, A., Pye, S., Hamilton, I., Agnolucci, P., Grover, D., Karasek, J., & Anisimova, N. (2016). *Selecting indicators to measure energy poverty. Final Report*. European Commission.
Sanchez-Guevara, C., Sanz Fernandez, A., Núñez Peiró, M., Gomez Munoz, G. (2020). Energy poverty in Madrid: Data exploitation at the city and district level. *Energy Policy*, *144*, 111653. https://doi.org/10.1016/j.enpol.2020.111653
Sareen, S., Thomson, H., Herrero, S. T., Gouveia, J. P., Lippert, I., & Lis, A. (2020). European energy poverty metrics: Scales, prospects and limits. *Global Transitions*, *2*, 26–36. https://doi.org/10.1016/j.glt.2020.01.003
Schuessler, R. (2014). Energy poverty indicators: Conceptual issues. Part I: The ten-percent-rule and double median/ mean indicators. *Discussion Paper*, 14–037. http://dx.doi.org/10.2139/ssrn.2459404
Thomson, H. & Snell, C. (2013). Quantifying the prevalence of fuel poverty across the European Union. *Energy Policy*, *52*, 563–572. https://doi.org/10.1016/j.enpol.2012.10.009
Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B (Methodological)*, *58*(1), 267–288.
UK Government (2021). *Fuel Poverty Methodology Handbook*. Available at: https://www.gov.uk/government/publications/fuel-poverty-statistics-methodology-handbook (accessed: 13.11.2021).