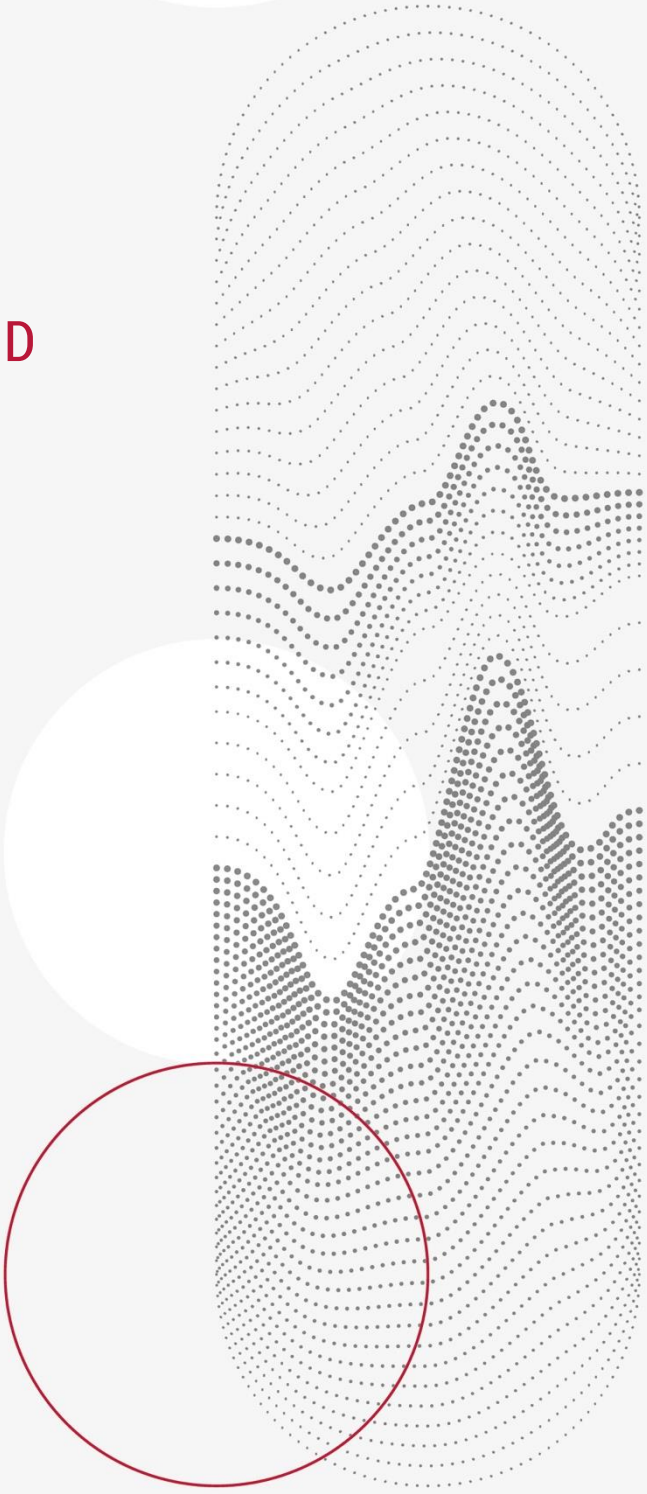
IBS RESEARCH REPORT 01/2019
JANUARY 2019

DEFINING AND MEASURING ENERGY POVERTY IN POLAND

Jakub Sokołowski
Aneta Kiełczewska
Piotr Lewandowski



ibs research report 01/2019

january 2019

DEFINING AND MEASURING ENERGY POVERTY IN POLAND•

Jakub Sokołowski ♦

Aneta Kiełczewska ♣

Piotr Lewandowski ♥

Abstract

The EU Member States are obliged to assess the scale of energy poverty in their respective national contexts. We propose a new definition of energy poverty in Poland, with different levels of specificity corresponding to the needs of different levels of administration. We also propose a set of five indicators for measuring energy poverty based on data from the Polish Household Budget Survey. Two expenditure-based indicators identify energy-poor households: a modified version of the Low Income High Cost indicator and an indicator based on actual energy expenditures. Three self-reported indicators related to financial capability, the physical condition of the dwelling, and the subjective level of thermal comfort are used to measure the severity of energy poverty. We find that all five indicators show that the older the dwelling is, the higher the risk of energy poverty is. Moreover, while the expenditure-based measures show that households living in detached houses have higher energy poverty rates than households living in multifamily buildings, the thermal comfort indicator shows the opposite relationship. Households living in dwellings without central heating are at a higher risk of energy poverty, according to all self-reported indicators.

Keywords: fuel poverty, LIHC, thermal comfort, energy affordability

JEL: I32, R29, Q40

• We thank Stefan Bouzarovski for insightful comments and Adam Pigoń for help with developing the econometric model. This paper is a result of a project delivered in cooperation with EY Poland for the Structural Reform Support Programme of European Commission (service contract number - SRSS/C2018/031). This paper uses Statistics Poland data. Statistics Poland has no responsibility for the results and the conclusions, which are those of the authors. The usual disclaimers apply. All errors are ours.

♦ Institute for Structural Research, University of Warsaw. E-mail: jakub.sokolowski@ibs.org.pl.

♣ Institute for Structural Research. E-mail: aneta.kielczewska@ibs.org.pl.

♥ Institute for Structural Research. E-mail: piotr.lewandowski@ibs.org.pl.

Table of contents

1. Introduction

Energy poverty can result from a combination of factors that cause a household to have above-average energy needs and costs, including living in a building with low energy efficiency, having high energy costs, and having a low household income. Energy-poor households usually have two options (Boardman, 2010): they can either spend an above-average amount of their income on energy (heat, light, cooking, and appliance use), and thereby accept having fewer resources to cover other needs, including the most basic ones; or they can consume less energy, and thereby accept having a cold and uncomfortable home, and a reduced standard of living.

We propose a definition of energy poverty and a set of five indicators for measuring energy poverty in Poland. We have selected indicators that capture the specific context of energy poverty in Poland. Our set of indicators includes two expenditure-based indicators that can be used to identify energy-poor households and target social support, and three self-reported indicators that can be used to measure the severity of energy deprivation. The former group of indicators includes a version of Low Income High Cost (Hills, 2012), and an indicator based on the share of actual energy expenditures in income. The latter group of indicators includes measures of financial capability, the physical condition of the dwelling, and the subjective level of thermal comfort. To calculate these indicators, we use the Polish Household Budget Survey data for 2017, which were collected by Statistics Poland.

The report builds upon IBS' previous work on energy poverty. This earlier research was focused on adapting the expenditure-based measures to the Polish data and context (Miazga and Owczarek, 2015, Lis et al., 2016, Lewandowski and Sałach, 2018), analysing the socio-economic and spatial heterogeneity of households identified as energy poor (Lis et al, 2016, 2017), collecting stylised facts about the energy-poor households who live in detached houses (Lewandowski et al., 2018), and assessing the policy implications of and options for responding to these issues (Lis and Szpor 2016; Rutkowski et al., 2018). In this report, we focus on improving the measurement of energy poverty by identifying the set of indicators that is the most appropriate for Poland, and by proposing a policy-relevant definition. We take stock of the recommendations of the EU Energy Poverty Observatory.

We introduce a set of five indicators and a matching definition that enable us to measure and monitor the incidence of energy poverty in Poland at the national and the regional level, as well as among sub-populations. This approach also allows us to identify the characteristics of the households affected by energy poverty, which in turn allows us to tailor support measures to the circumstances of energy-poor households. These support measures may include improving the energy efficiency of buildings, installing efficient energy sources, or providing financial support (Rutkowski et al., 2018). Last but not least, we have also built a statistical model that will allow policymakers to perform fast and easy calculations of energy poverty indicators at the national, regional, and sub-population levels.[1]

This report is structured as follows. Section 2 contains a definition of energy poverty and a set of five matching energy poverty indicators. In Section 3, we present the results of statistical and econometric analyses of the properties of these indicators. In Section 4, we present recommendations for how the measurement of energy poverty in Poland could be improved, including by developing a specific model of required energy expenditures.

[1] The model is not publicly available. It was delivered to the Structural Reform Support Programme of European Commission and Polish Ministry of Energy.

2. Defining energy poverty

2.1. Energy poverty in the European policy agenda

The first definition of energy poverty is attributable to Boardman (1991, 2010). Energy poverty occurs when households have insufficient funds to pay for the most basic levels of energy needed for heating, lighting, cooking, and appliance use. Energy poverty at the most general level is understood as the inability of a household to afford energy services. This first definition was operationalised in the UK with the "10% threshold"; i.e., the point at which a household needs to spend more than 10 per cent of its income on energy services. Energy poverty in Europe can also be understood as occurring when households are threatened by "cold homes", "non-payment", or "energy precariousness" (Bouzarovski, 2018).

The issue of energy poverty is gaining recognition across the EU Member States, as it has recently been added to the official policy agenda of the European Union. For example, the Clean Energy Package and the Electricity Directive proposals explicitly mention energy poverty (Bouzarovski, 2018). In these proposals, EU officials link energy poverty to the concept of vulnerable consumers, and thus prohibit the disconnection of their electricity supply (European Commission, 2017). The Directive also provides a general definition of energy poverty:

"Energy services are fundamental to safeguard the well-being of the Union citizens. Adequate warmth, cooling, lighting and the energy to power appliances are essential services to guarantee a decent standard of living and citizens' health. Furthermore, access to these energy services empowers European citizens to fulfil their potential and it enhances social inclusion. Energy poor households are unable to afford these energy services due to a combination of low income, high energy expenditure and poor energy efficiency of their homes" (European Commission, 2017).

Frame 1. Comparison of definitions applied in the EU Member States

Almost all of the countries in Europe (with the exception of Sweden) recognise energy poverty as an important problem both in academic and political debate (a detailed analysis is due to INSIGHT_E, 2015). For the purpose of this document we have only reviewed the officially adopted definitions. We present a summary of common elements of the energy poverty definitions applied in the EU member states:

- Broad understanding of energy services, encompassing heating, cooling, lighting and use of appliances;
- Energy services are an elementary need of all citizens;
- Recognition of the relation between energy poverty, health problems and social exclusion;
- Identification of three causes of energy poverty, i.e. low incomes, high energy prices and low energy efficiency of buildings.

Therefore, at the EU level, energy poverty can be understood as the inability of a household to secure socially and materially necessary levels of energy in the home. The acknowledgment of energy poverty in the EU directive draft is expected to lead to greater recognition of this issue. In addition, the Member States are required to estimate the number of households experiencing energy poverty under the agreed upon and forthcoming EU Regulation on the Governance of the Energy Union (based on Commission proposal COM (2016) 759 of 30 November 2016). These estimations should take into account the domestic energy services needed to guarantee basic standards of living in the relevant national context, existing social policies, and other relevant policies.

2.2. Pros and cons of general and specific definitions

In this report, we have assessed the different approaches and concepts used in defining energy poverty in Poland. First, we note that energy poverty can be understood either in general or in specific terms. Second, we observe that the definition can be used in a cross-country or a national setting. Based on a general understanding of the issue as referring to deprivation of energy services, similarities in energy poverty patterns can be found across countries. Differences in the results of cross-country analyses of energy poverty are generally attributable to differences in the socio-economic disparities measured; e.g., income/expenditure levels, the characteristics of the energy sector and market, or subjective assessments of thermal comfort. Therefore, defining energy poverty presents a two-fold problem: i.e., by choosing a general definition that allows for comparability and synergy in the planning and implementation of policies, capturing the specific context of energy poverty in a given country becomes more difficult. Thus, when deciding to whether to use a more general or a more detailed definition of energy poverty, policymakers should be aware that they may be forfeiting the advantages of one of these approaches when applying the other.

The benefits of each approach are described and critically assessed in this report. The evaluation is based on a general assumption that the definition should be related to the purpose it will serve. Thus, the definition that is optimal for national or regional policy planning may differ from the definition that is optimal for academic research.

General definition

Among the advantages of a using a general definition of energy poverty are that it takes into account the internationalisation of energy markets and climate change mitigation policies. Bouzarovski and Petrova (2015) cited the most important arguments in favour of using a common EU definition of energy poverty: namely, recognition and clarification. In the following, we present their main findings, critically evaluate them, and add other elements that are suitable in the Polish context.

Using the common EU-level definition of energy poverty may increase the visibility of the problem at the Member State level.

Although the visibility of the issue of energy poverty has risen with the recent inclusion of energy poverty in national and EU policies, it is still a poorly recognised topic with a fragmented evidence base. The European Energy Poverty Observatory[2] promotes knowledge about energy poverty, and has sponsored several other projects and initiatives that address the issue (e.g., the ENGAGER network). However, in many European countries, energy poverty has yet to enter the wider social debate. Therefore, using a general definition of energy poverty may help to promote a better understanding of the problem. Increasing visibility may result in the prioritisation of support mechanisms for energy-poor households and the mobilisation of additional funding at both the national and the EU level.

[2] The EU Energy Poverty Observatory (EPOV) is an initiative by the European Commission to help Member States in their efforts to combat energy poverty. The web portal: https://www.energypoverty.eu is the main focal point for the Observatory, and includes a wide range of resources.

Highlighting energy poverty as a policy problem might encourage synergies across administration levels.

Highlighting energy poverty may contribute to the emergence of synergies in tackling the problem across national, regional, and local administrations; as well as across different ministries and departments (e.g., the ministry of energy, the ministry of the environment, and the ministry of entrepreneurship and technology).

Establishing a general definition may solve the problem of the use of unclear and often conflicting definitions of energy poverty by different EU institutions and researchers.

The lack of clarity about how energy poverty should be defined has led to the use of inaccurate measures of energy poverty. For example, the 10% energy poverty threshold has been misapplied by researchers who failed to adjust it to the country-specific distribution of energy expenditures (Liddell et al., 2012), or to base it on actual energy expenditure data (Moore, 2012; Bouzarovski and Petrova, 2015).

Detailed definition

Applying a general definition of energy poverty can be problematic, as it may be insufficient to capture the issue of energy poverty in a specific national context. Using a general definition can, for example, be inappropriate when the evidence base is scarce, the comparability of the data is limited, and there is a risk of decreasing relevance or path dependency (Bouzarovski and Petrova, 2015).

General knowledge about energy poverty is limited.

A systematic analysis of energy poverty in each country that takes into account the country-specific context is called for. Conducting such an analysis is predicated upon data availability, especially data on differences in energy consumption and expenditure levels; and, most importantly, data on socio-economic differences between countries (e.g., differences in income/expenditure levels, or different perceptions of thermal comfort). Currently, however, a specific model for estimating hypothetical energy consumption levels exists only in the UK: namely, the BREDEM model, which describes the energy expenditure patterns of households (Henderson and Hart, 2015). The use of a more detailed definition of energy poverty may allow for the implementation of a similar methodology in Poland, thereby improving the measurement and monitoring of energy poverty in that country.

A general definition may be overly broad, which may limit its relevance.

A general definition of energy poverty needs to be relatively broad in order to accommodate the multi-dimensional characteristics of this issue. However, a definition that does not take into account the specific characteristics of energy poverty in a given context may not be useful for policy planning, or for identifying individual energy-poor households. Thus, a general definition could lead to overgeneralisations of the risk of energy poverty.

It is difficult to reverse or modify a general definition and policy planning due to path dependency.

Once a particular energy poverty mitigation strategy is established, it may be very difficult to reverse or modify it. This is evident in the UK, where the 10% indicator and definition has been used from 2001 to 2013 (Bouzarovski and Petrova, 2015). Therefore, developing a more detailed definition that increases in specificity when moving from the national to the regional and local levels of administration could solve the problem of path dependency.

2.3. Recommended definitions for Poland

We recommend using different levels of specificity when defining energy poverty depending on the purpose of a given policy planning effort. For example, an administration could apply a general definition of the term when formulating international or national policies, and a specific definition of the term when formulating regional and local policies. Thus, our definitions could be consulted in drafting a targeted law or decision.

We propose a definition of energy poverty that strengthens the process of policy planning and captures the specific Polish context of energy poverty. Our solution increases the visibility of the problem, allows for the development of synergies across administrations, and adds to the evidence base and general knowledge of energy poverty; but it also provides safeguards against path dependency (Bouzarovski and Petrova, 2015).

General definition – identifying energy-poor households

Energy poverty occurs when a household is unable to afford the energy needed to provide its members with adequate warmth, cooling, lighting, and appliance use due to a combination of factors, which may include having a low income, high energy expenditures, and a home with low levels of energy efficiency. For a household to be classified as energy poor, it has to meet two criteria simultaneously: i.e., it must have high required energy costs (above the national median level) and a low income (residual income[3] below the official poverty line) or, the household's share of actual energy expenditures in income needs to be higher than twice the median of this value in the population.

Two indicators applicable to identify energy-poor households:

- Low Income High Costs, and
- Twice the median share of energy expenditures.

Specific definition – monitoring the severity of deprivation

Energy poverty occurs when a household is unable to afford the energy needed to provide its members with adequate warmth, cooling, lighting, and appliance use due to a combination of factors, which may include having a low income, high energy expenditures, and a home with low levels of energy efficiency. For a household to be classified as energy poor, it has to meet two criteria simultaneously: i.e., it must have high required energy costs (above the national median level) and a low income (residual income below the official poverty line) or, the household's share of actual energy expenditures in income needs to be higher than twice the median of this value in the population. The severity of energy poverty, or the level of the severity of deprivation, is indicated by self-reported measures of the financial capability of the household (measured by the ability to pay utility bills), the physical structure of the dwelling (measured by the presence of rot or damp), as well as the household members' subjective assessments of thermal comfort.

The indicators applicable to identify energy-poor households are:

- Low Income High Costs, and

[3] Residual income is defined as disposable income minus housing cost (DECC, 2016).

- Twice the median share of energy expenditures.

The indicators applicable to measure the severity of energy deprivation are:

- Inability to pay utility bills on time;
- Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors; and
- Inadequate thermal comfort in winter.

3. Measuring and monitoring energy poverty

3.1. Classification of energy poverty indicators

Selecting a set of energy poverty indicators presents a challenge similar to that of defining energy poverty: on the one hand, the indicators should capture the multi-dimensional aspect of energy poverty; but on the other, they should allow for the efficient and relatively straightforward planning and application of energy policies. We select five indicators outlined in Table 1. These indicators capture the different facets of energy poverty and provide complementary information (the correlations between these indicators range from -0.3 to 0.3, cf. Appendix II). We base our selection on a review of the academic literature, a survey of the relevant methodologies, and an assessment of the data that are available in Polish and European datasets. The detailed evaluation criteria we applied, as well as the indicators we considered but did not select for use, are described in Appendix II. A detailed description of the methodologies underlying each of the five chosen indicators is included in Table 2.

Table 1. General characteristic of indicators

Indicator	Approach	Category	Method of application	Experience of application to energy poverty issue	Country-specific or internationally available and comparable
Low Income High Costs	Expenditure-based	Income / expenditure	Constructed metric	Policies and literature	Internationally comparable
Twice the median share of energy expenditure	Expenditure-based	Income / expenditure	Constructed metric	Policies and literature	Internationally comparable
Inability to pay utility bills on time	Self-reported	Financial capability	Single metric	Literature	Internationally comparable
Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	Self-reported	Physical infrastructure	Single metric	Literature	Internationally comparable
Inadequate thermal comfort in winter	Self-reported	Physical infrastructure	Single metric	Literature	Country specific

Source: Own elaboration.

Table 2. Detailed description of energy poverty indicators

<table>
<tr><th colspan="9">Low Income High Cost</th></tr>
<tr><td>Introduction</td><td colspan="8">The LIHC indicator was first proposed by Hills (2012), and forms the basis of the United Kingdom's strategy for decreasing energy poverty. The indicator replaces the "10% income share" indicator as an official measure of energy poverty in the UK.
The option of using the LIHC indicator to calculate both the incidence of energy poverty and the energy poverty gap is one of its most important advantages, and led to its implementation in the UK. The indicator has proven to be stable in its usefulness in identifying energy poverty and assessing the effectiveness of interventions (GOV.UK, 2018).</td></tr>
<tr><td>Method</td><td colspan="8">A household that meets two criteria simultaneously is defined as energy poor: i.e., the household must have high hypothetical energy expenditures and a low income.</td></tr>
<tr><td rowspan="11">Hypothetical energy expenditures</td><td colspan="8">The high hypothetical energy expenditures criterion is met if the hypothetical equivalent household energy expenses are higher than the median of the equivalent energy expenditures in the population.</td></tr>
<tr><td colspan="8">The household energy expenditures are the sum of its expenditures on electricity and heat.</td></tr>
<tr><td colspan="8">The hypothetical household energy expenditures are the household's energy expenditure levels given the characteristics of its members and of the building it inhabits, and the price of the energy (depending on the type of heating) the household needs to consume to maintain an optimal temperature in the dwelling and to make adequate use of lights and appliances.</td></tr>
<tr><td colspan="8">The optimal solution is to implement a model that calculates the required energy expenditure levels for a given household living in a building with specific characteristics and a specific type of heating. No such model exists for Poland. In 2015, IBS has commissioned KAPE, a Polish institute that researches energy-efficient building technologies, to calculate the required energy expenditure levels for various types of buildings based on 2014 data and prices. These calculations were used by Miazga and Owczarek (2015).</td></tr>
<tr><td colspan="8">Due to the lack of a full-fledged, regularly updated model of required energy expenditures, the hypothetical energy expenditures are calculated based on distributions of the actual energy expenditures of households in a given year. The value of the hypothetical energy expenditures is determined for 84 categories that differ according to the type of building (multi-family, detached or semi-detached house, single-family detached house), the type of heating (central heating, fuel stoves, electric stoves, gas stoves), and the period of building construction (seven periods). Here, we follow Lis et al. (2016, 2017), and Lewandowski and Sałach (2018).</td></tr>
<tr><td colspan="8">The hypothetical expenditures on electricity for a given household are the average of expenditures on electricity per person multiplied by the number of people in the household in a particular household category.</td></tr>
<tr><td colspan="8">The hypothetical expenditures on heat for a given household are the average of expenditures on heat per square meter multiplied by the usable floor area of a building in a particular household category.</td></tr>
<tr><td colspan="8">In the context of heat expenditures, the concept of under-occupation is introduced. It is defined by two conditions: the Parker Morris criterion[4] and the Eurostat[5] criterion.</td></tr>
<tr><td colspan="8">According to the Parker Morris criterion, a dwelling is under-occupied if its size exceeds the following parameters in relation to the number of people in the household:</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>9 and more</td></tr>
<tr><td>66 m^2</td><td>97 m^2</td><td>122 m^2</td><td>158 m^2</td><td>179 m^2</td><td>194 m^2</td><td>229 m^2</td><td>256 m^2</td></tr>
</table>

[4] Based on DECC (2016)

[5] Based on https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Under-occupied_dwelling

Table 2. (continued) Detailed description of energy poverty indicators

	According to the Eurostat criterion, a dwelling is under-populated if it has more than an adequate number of rooms given the composition of the household. An adequate number of rooms is defined as one common room, one room for a couple in a relationship, one room for two children of the same sex between the ages of 12-17, one room for two children under age 12 regardless of gender, and one room for every other person.
	We assume that the part of a dwelling that is under-occupied according to the Parker Morris criterion is not used. On this basis, the hypothetical energy expenses of a given household are reduced.
	To equivalise the hypothetical energy expenditures, we use a scale with a two-person household as a reference point. The coefficients for households with a given number of people are obtained by dividing the median hypothetical energy expenses of households with a given number of people by the median hypothetical energy expenses of a two-person household.
Low income	The low income criterion is fulfilled for households that meet two conditions simultaneously. The first condition is met if the equivalent income of the household is in the bottom 30% of the income distribution in the population. The second condition is met if the equivalent income of a household, calculated after the fixed housing costs, is lower than the individual income threshold.
	The equivalent disposable income of a household is set according to the modified OECD equivalence scale: the first adult is assigned a weight of one, each next person aged 14 or older is assigned a weight of 0.5, and each child under age 14 is assigned a weight of 0.3.
	The household's expenditures on rent or mortgage payments and on water supply and other services are deducted from the disposable income of the household in order to calculate the household's income after fixed housing costs.
	The equivalisation of income after fixed housing costs is calculated according to the Fuel Poverty scale: the first adult is assigned a weight of 0.58; each next person aged 14 or older is assigned a weight of 0.42, and each child under age 14 is assigned a weight of 0.2.
	The threshold of equivalent income after fixed costs of housing is determined individually; i.e., separately for each household. The threshold is the sum of two components: 60% of the median equivalent income after fixed housing costs, and the hypothetical equivalent energy expenses of a given household.
Twice the median share of energy expenditures	
Introduction	The indicator identifies households with high energy costs; i.e., those with energy expenditures equal to or more than twice the country-level median. As energy expenditures or the income shares spent on energy services are usually right-skewed, it is preferable to use the median (rather than the mean) as an indicator (Schuessler, 2014).
Method	According to this indicator, a household for which the share of actual energy expenditures in income is higher than twice the median of this value in the population is identified as energy poor.
Actual energy expenditures	Household energy expenditures are the sum of expenditures on electricity and heat.

Table 2. (continued) Detailed description of energy poverty indicators

Inability to pay utility bills on time	
Introduction	The indicator offers insights into the strategies energy-poor households use to maintain their everyday lives in constrained circumstances (Gibbons and Singler, 2008). Low-income households spend a substantial share of their income on utility services such as electricity or heating. This indicator takes a more detailed look at the affordability of electricity and district heating for low-income consumers. Families who struggle to pay their energy bills may face a choice between purchasing food or energy; or "eat-or-heat" (Beatty et al. 2011). Additionally, being unable to pay bills for energy services on time may result in a deprivation spiral; i.e., being in arrears may lead to the disconnection of services, and thus to having insufficient heating and a lack of thermal comfort. This situation may in turn lead to health problems and social isolation.
Method	The indicator is created based on responses to the following question in the survey: "Considering the last 12 months, how do you assess the level of satisfaction of your needs regarding the payment of housing-related bills on time (fixed costs, rent, rental costs, etc.)?" The households answering "low" or "rather low" are identified as energy poor.
Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	
Introduction	The presence of damp indicates that the dwelling is not energy efficient. It may also be a manifestation of a continuously unheated or ineffectively heated home (Healy and Clinch 2002).
Method	The indicator is created based on responses to the following question in the survey: "In your view, does your apartment have a leaking roof; damp walls, floors, or foundations; or rotting window frames or floors?" The households answering "yes" are identified as energy poor.
Inadequate thermal comfort in winter	
Introduction	By taking into account responses to survey questions that ask whether the household is unable to sufficiently heat its dwelling, this measure takes into account energy requirements, and thus allows us to identify energy-poor households who have been passed over by objective measures. The indicator provides information on the experiences of people living on low incomes and their attitudes about thermal comfort and energy use.
Method	The indicator is created based on responses to the following question in the survey: "In your view, is your apartment warm enough in the winter (has technically efficient heating or sufficient insulation)?" The households answering "no" are identified as energy poor.

Source: Own elaboration.

3.2. Data source – Household Budget Survey

We use data from the Household Budget Survey (HBS) carried out by the Statistics Poland (GUS). It is a nationwide survey based on a representative sample of households. The survey is carried out continuously throughout the year. The observation unit in the study is a household (single or multi-person).

The subject of the HBS is primarily the household budget; i.e., the revenues and the expenditures (cash and non-cash) of all members of the surveyed household, and the consumption spending on selected goods and services. The study also collects in-depth information on household equipment (e.g. appliances), their housing conditions, and their subjective assessment of their material situation. Each month, different households are surveyed. Each of the households keeps monthly records of its expenditures, consumption quantities, and revenues in special budget books. At the end of the quarter, an additional interview is conducted with a household member.

The survey is conducted on a random sample of households. The sample is drawn according to a two-stage scheme with different probabilities of selection at a given stage. The statistical regions are randomly selected at

the first stage, and the apartments are randomly selected at the second stage (in each month, two apartments are chosen from each of the randomly selected research areas). The number of surveyed households per year is around 37,000.

As the study is conducted using the representative method, it gives us the opportunity to generalise the results obtained to all households in the country. In the first step, the weight for each household is calculated as the inverse of the probability of choosing a given household. In the second step, the weight adjustment is carried out. Information on the number of households in 12 categories from the National Census is used for this purpose. The categories are based on the number of people in each household (one-person, two-person, three-person, four-person, five-person, and six or more-person households) in cities and in rural areas.

3.3. Descriptive results for the five indicators

The indicators employed to describe energy poverty in Poland provide a detailed picture of the relevant national context of energy poverty. The application of these indicators enables us to identify groups of vulnerable households and to measure the severity of their energy deprivation, which in turn enables us to target social support to these households. In figures 1 to 6 we present the results for all five indicators for both the general population and selected subgroups.

Table 3. Abbreviations used to describe the indicators

Indicator	Abbreviation
Low Income High Costs	LIHC
Twice the median share of energy expenditures	2M
Inability to pay utility bills on time	BILLS
Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	ROOF
Inadequate thermal comfort in winter	COMFORT

Source: Own elaboration.

Based on the analysis of the set of indicators, we draw the following conclusions (figures 2 to 6):

- energy poverty mainly affects households living in detached dwellings built before 1980;
- coal, wood, and oil stoves are the main heating sources in energy-poor households; and
- retirees and people relying on other social benefits are the most vulnerable social groups.

A summary of these results is provided in the table 4.

Table 4. Summary of the volume of households identified as energy-poor in Poland in 2017 [thousands of households]

Category	Indicator				
	LIHC	2M	BILLS	ROOF	COMFORT
All households identified as energy poor	1 276.0	2 400.1	295.2	943.6	1 229.6

Table 4. (continued) Summary of the volume of households identified as energy-poor in Poland in 2017 [thousands of households]

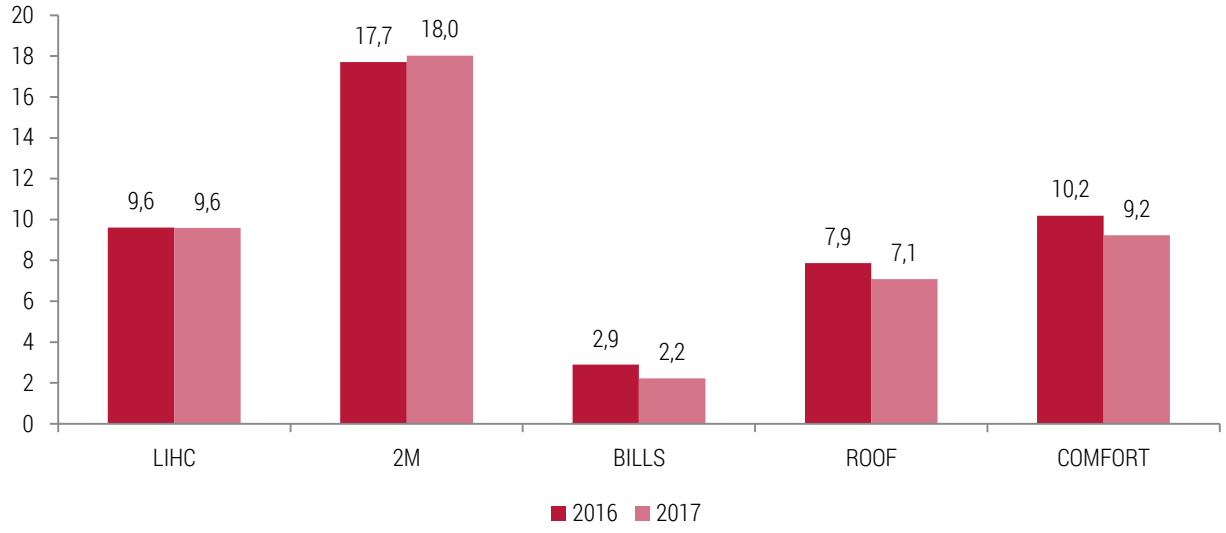
Detached houses by period of building construction	before 1946	154.0	221.6	26.5	183.4	145.0
	1946 - 1960	120.5	192.7	18.6	103.0	103.3
	1961 - 1980	318.0	384.5	29.9	93.7	135.4
Coal, wood or oil stoves		212.9	212.9	336.8	82.3	355.5
Retirees		564.3	564.3	1 219.0	108.9	314.5
Other social benefits		106.9	106.9	178.4	65.1	110.9

Source: Own calculations based on the Household Budget Survey data.

In 2016 and 2017, the share of energy-poor households identified using the LIHC measure remained at the same level, and increased by 0.3 percentage points for the twice the median share of energy expenditures indicator (figure 1).

The 2M measure shows substantially larger shares of energy-poor households than the other indicators in both 2016 and 2017. By contrast, the inability to pay utility bills on time indicator finds a considerably lower share of energy poverty in Poland than the other measures. The differences in the sizes of the shares of energy-poor households found with each indicator are related to their construction. As LIHC is a relative measure, we would expect it to show a rather stable share of energy-poor households through the years, as the income and expenditure thresholds used to determine energy poverty change with the financial situations of households. As twice the median share of energy expenditures is an absolute measure, and is based on actual (and not hypothetical) energy expenditures, it is likely to identify a relatively large share of energy-poor households that are sensitive to energy prices. Finally, as the inability to pay utility bills on time indicator is based on an ambiguous question from the HBS survey (level of satisfaction rather than arrears), it may be expected to generate a smaller and more ambiguous share of energy-poor households.

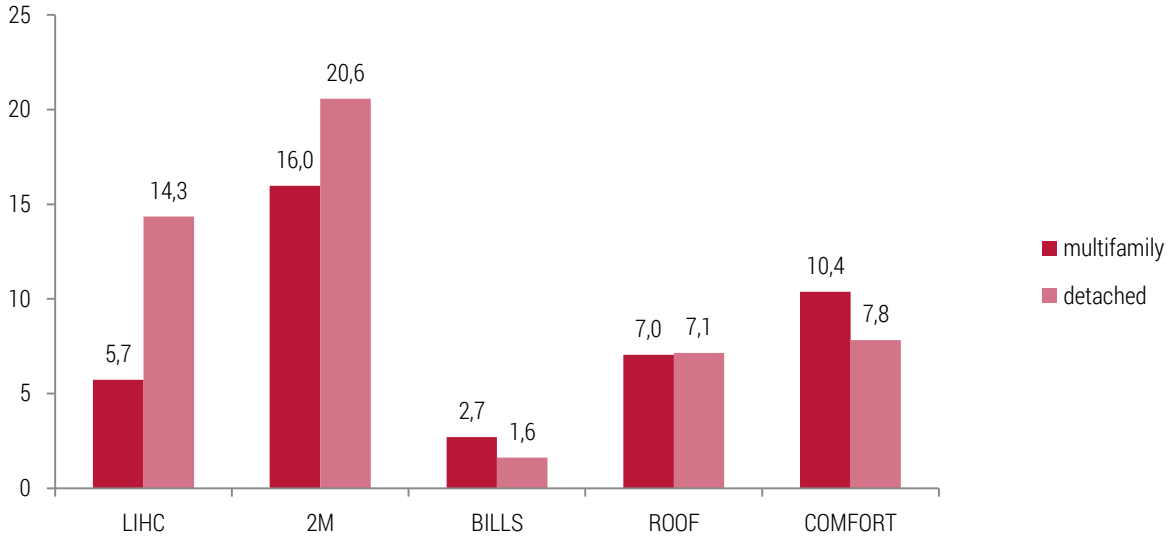
Figure 1. Energy poverty indicators in 2016 and 2017 [% of households]



Source: Own calculations based on the Household Budget Survey data.

The incidence of energy poverty in Poland is found to be higher in households that occupy detached houses (figure 2; for a detailed analysis, see Lewandowski et al., 2018). However, the two self-reported indicators, inability to pay utility bills on time and inadequate thermal comfort, show a higher incidence of energy poverty among households that occupy multifamily buildings.

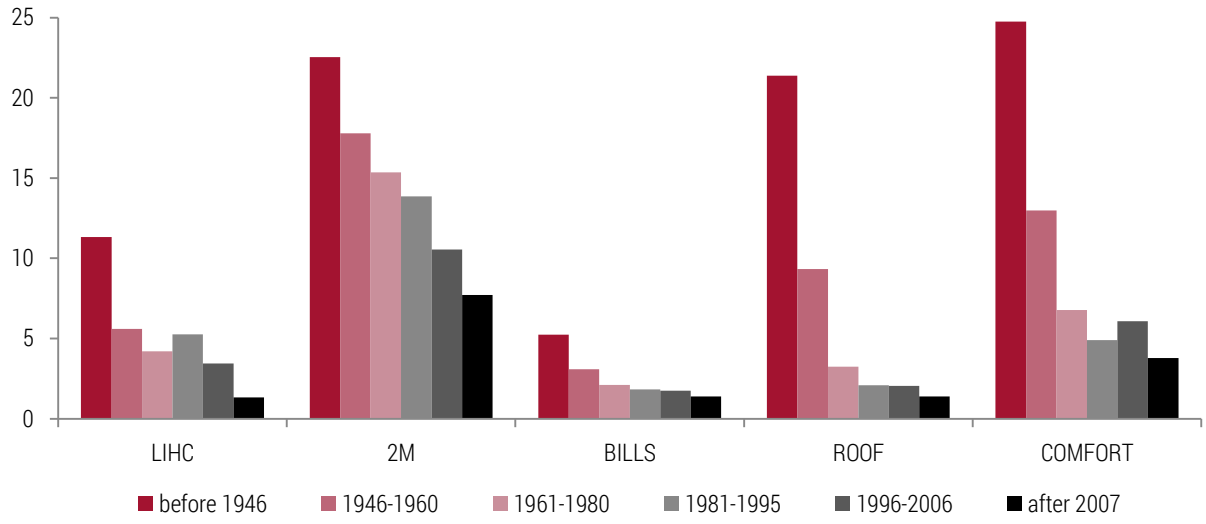
Figure 2. Share of energy-poor households in detached and multifamily buildings, 2017 [% of households]



Source: Own calculations based on Household Budget Survey data.

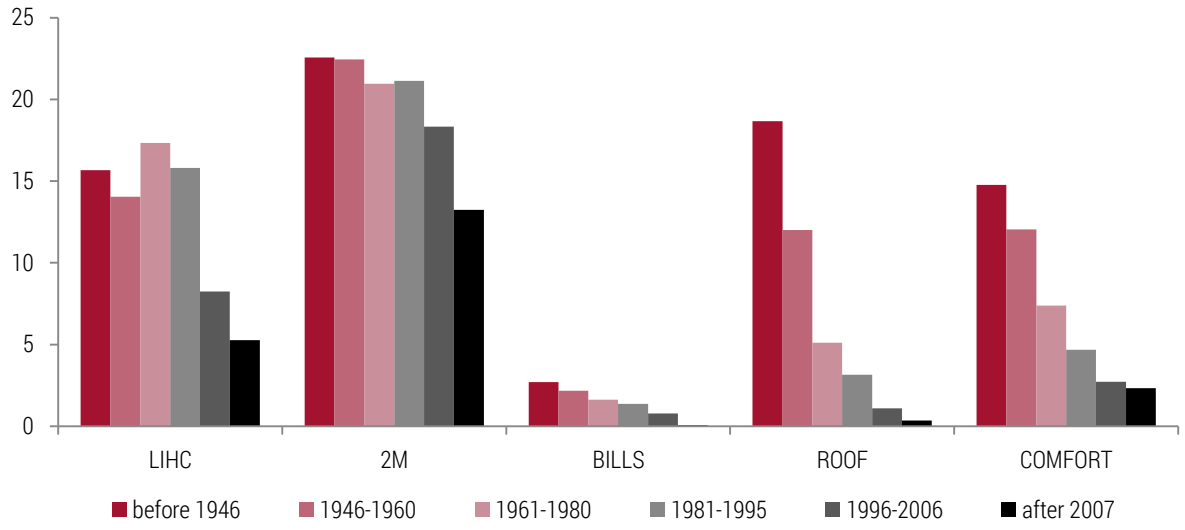
The incidence of energy poverty is found to be especially high among households that occupy older dwellings (figures 3 and 4). This finding is consistent with the definition of energy poverty, which states that energy poverty is predicated upon the energy inefficiency of buildings. Regardless of which measure is applied, the highest risk of energy poverty is observed among households that live in buildings constructed before the 1946-1995 period.

Figure 3. Share of energy-poor households in multifamily buildings by the year of building construction, 2017 [% of households]



Source: Own calculations based on Household Budget Survey data.

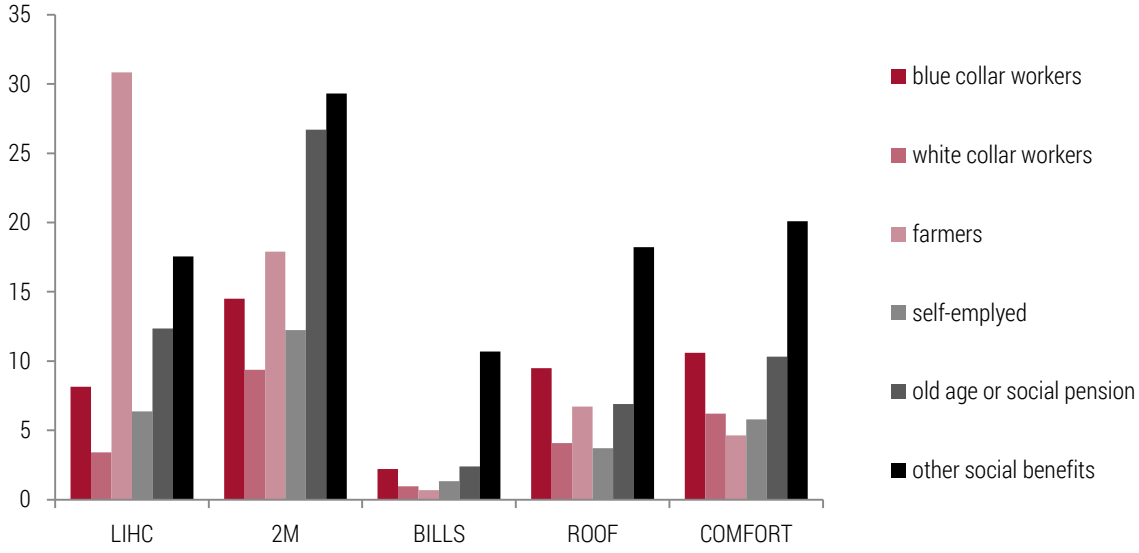
Figure 4. Share of energy-poor households in detached buildings by the year of building construction, 2017 [% of households]



Source: Own calculations based on Household Budget Survey data.

The Low Income High Cost indicator identifies farmers as the most vulnerable group. The four remaining measures show that the highest risk of energy poverty is in households that rely on other social benefits.

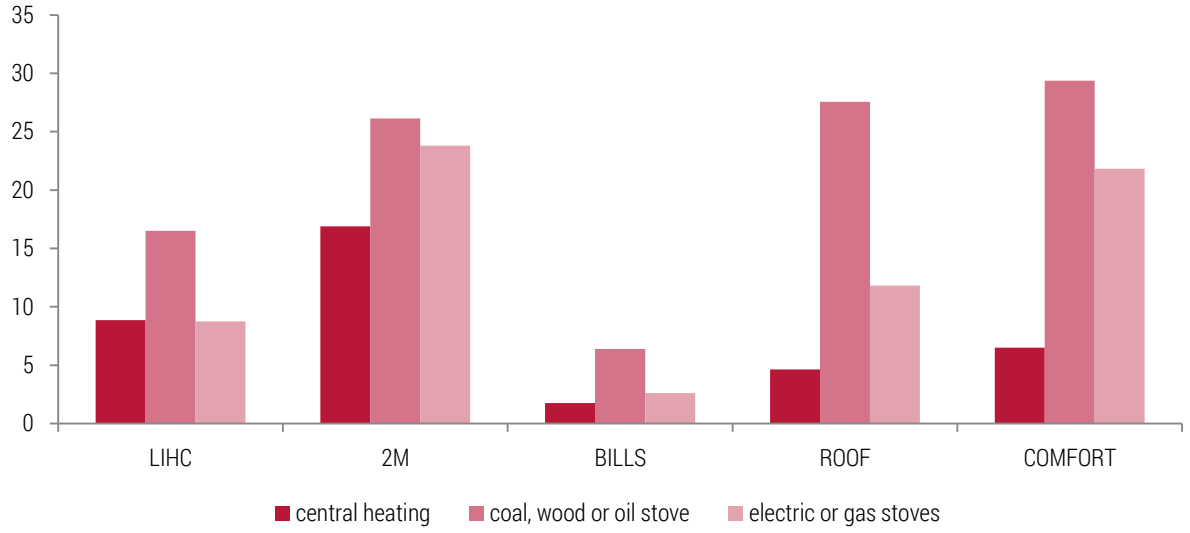
Figure 5. Share of energy-poor households by the main source of income, 2017 [% of households]



Source: Own calculations based on Household Budget Survey data.

In order to relate energy poverty to air pollution, we analyse the results of indicators according to the main heating sources. Fossil fuels are a fundamental element of the Polish energy system. Poland has among the highest greenhouse gas emissions per gross domestic product and carbon intensity levels in Europe. Local air pollution represents a large environmental health risk in Poland, and household heating is a major source of local air pollution (IEA, 2017). The key factors in the production of air pollution through heating are the age and the efficiency of combustion in heating units.

Figure 6. Share of energy-poor households by the main heating source, 2017 [% of households]



Source: Own calculations based on Household Budget Survey data.

According to every indicator, coal and wood stoves are the most common sources of heating in energy-poor households. Thus, local emissions may be related to energy poverty among households. Of the energy-poor households, 72% use coal, 19% use wood, and only 4.5% use gas as their primary heating fuel (Lewandowski et al., 2018). In Poland, the relationship between the high levels of biomass use and the ability to acquire inexpensive (or free) biomass may result in decreased household energy expenditures, which could complicate the process of identifying energy-poor households.

3.4. Regional differences in the incidence of energy poverty in Poland[6]

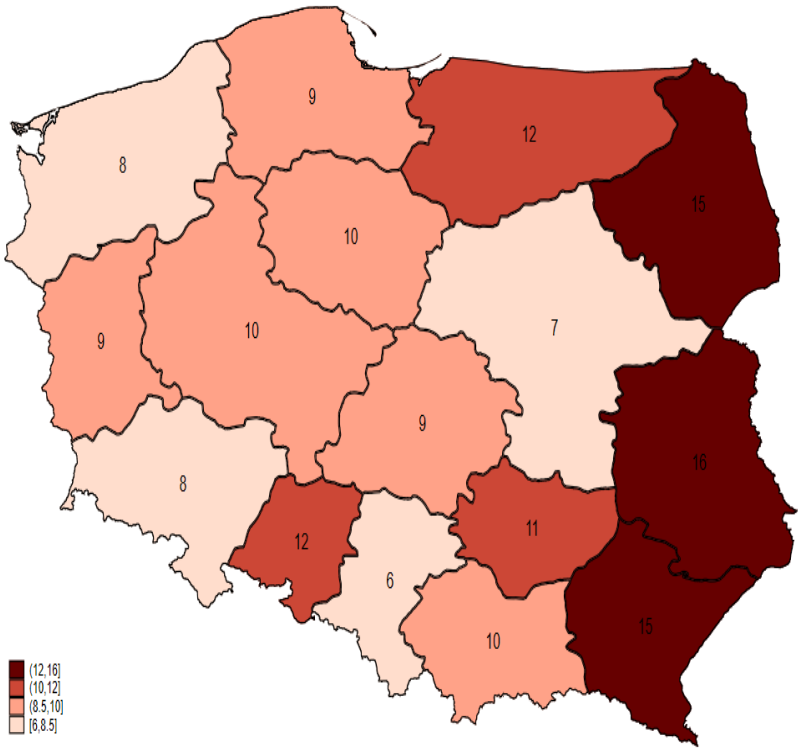
In this subsection, we discuss the regional heterogeneity according to each of five indicators. We focus on the voivodships (NUTS-2 level),[7] and relate the regional energy poverty statistics to the socio-economic characteristics of each region. Figures 7 to 11 present the results for particular indicators.

According to the Low Income High Cost measure (Figure 7), the inhabitants of the eastern voivodships of lubelskie (16%), podkarpackie (15%), and podlaskie (15%) are at highest risk of energy poverty. This finding is likely attributable to a combination of low average income levels, high unemployment levels, and high risks of income poverty in those regions. In addition, this result may be linked to the construction of the model (opolskie[2] per building; Statistics Poland, 2017a).

[6] For a more detailed analysis of the regional heterogeneity of energy poverty in Poland, see Bouzarovski and Tirado-Herrero (2017) and Lis et al. (2017).

[7] The HBS data do not allow for analysis at a finer disaggregation level.

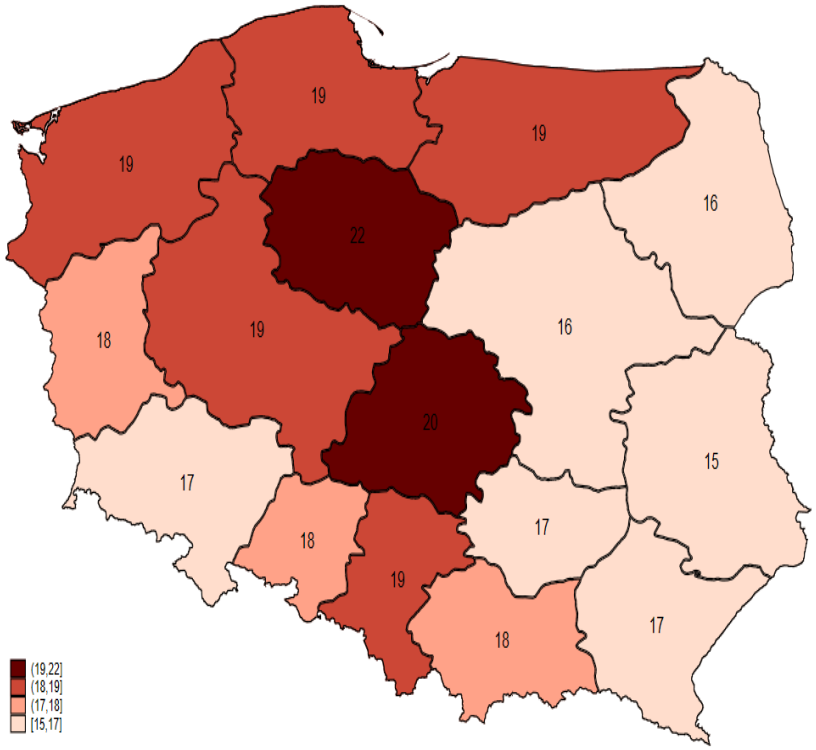
Figure 7. Share of energy-poor households in Polish regions according to the Low Income High Costs indicator [% of households]



Source: Own calculations based on Household Budget Survey data.

Kujawsko-pomorskie (22%) and łódzkie (20%) exhibit the highest risk of energy poverty, according to the twice the median share of energy expenditures indicator (Figure 8). These regions are characterised by relatively high unemployment levels and low average income levels (Statistics Poland, 2017a). Compared to the outcome of the Low Income High Cost indicator, this measure shows a higher risk of energy poverty in the wealthy regions of Poland. This is because the 2M indicator provides information on how energy poverty is distributed across the regions in terms of actual expenditures, and may be influenced by energy prices.

Figure 8. Share of energy-poor households in Polish regions according to the twice the median share of energy expenditures indicator [% of households]



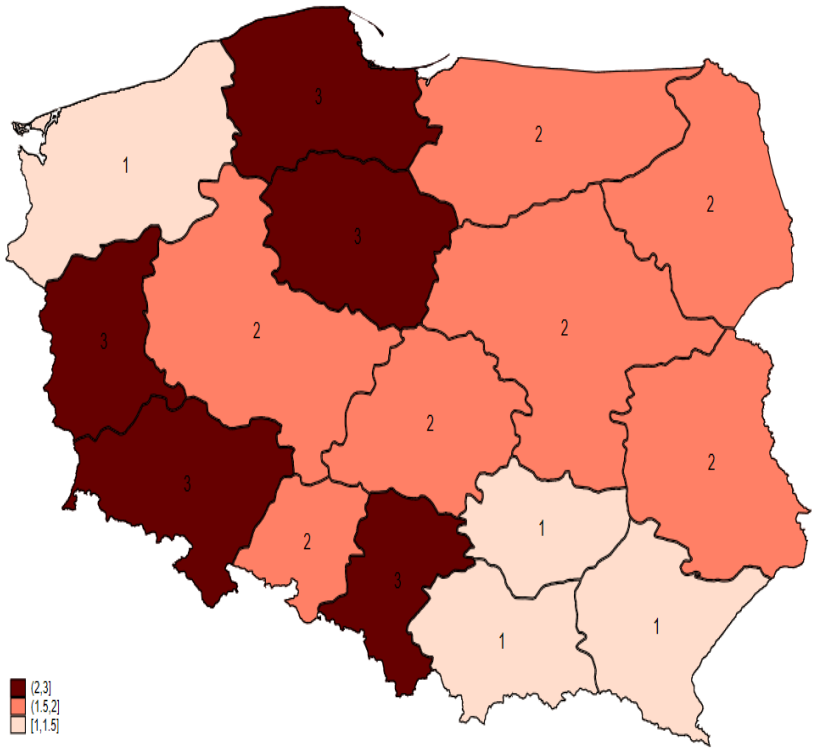
Source: Own calculations based on Household Budget Survey data.

According to all three self-reported measures, dolnośląskie is the region with the highest share of energy-poor households. In dolnośląskie, the share of buildings that are old and have low energy efficiency levels is particularly high.

Pomorskie, kujawsko-pomorskie, lubuskie, and śląskie (3%) are found to be the regions with the highest risk of energy poverty in terms of inability to pay utility bills on time (Figure 9). This measure identifies a smaller share of energy-poor households than the other indicators.

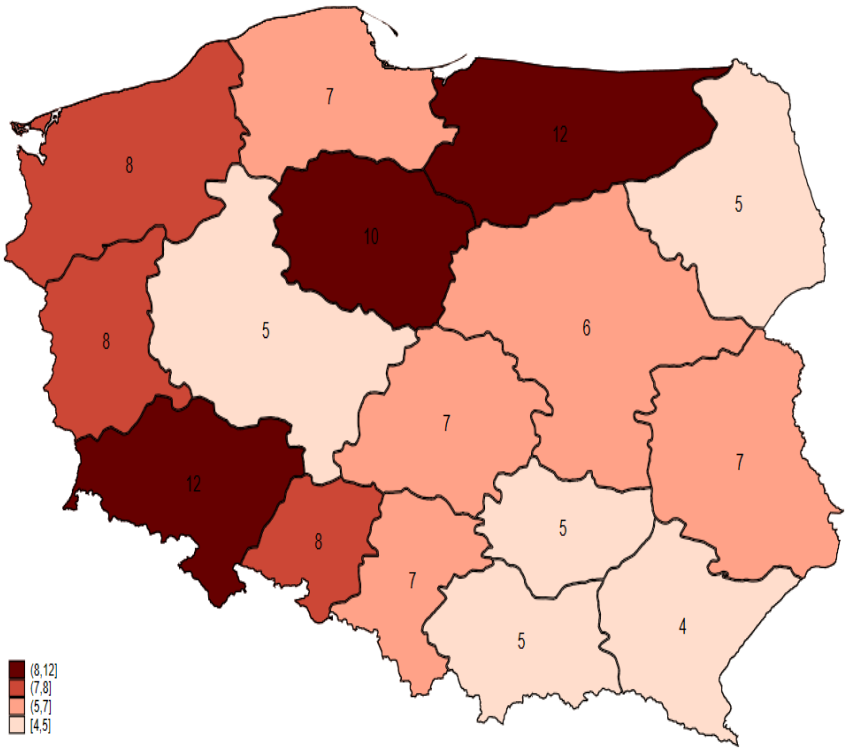
The indicator living in a dwelling with a leaking roof; or damp walls, floors, or foundations shows that the western regions of Poland are at the highest risk of energy poverty (Figure 10). This result is attributable to the large share dwellings in these regions that are old and have low energy efficiency levels. Interestingly, while the people living in the eastern regions (podkarpackie, świętokrzyskie) tend to struggle with energy affordability, they are more likely than people living in the western regions to live in a building that was constructed more recently, and are not at high risk of energy poverty, according to this measure.

Figure 9. Share of energy-poor households in Polish regions according to the inability to pay utility bills on time indicator [% of households]



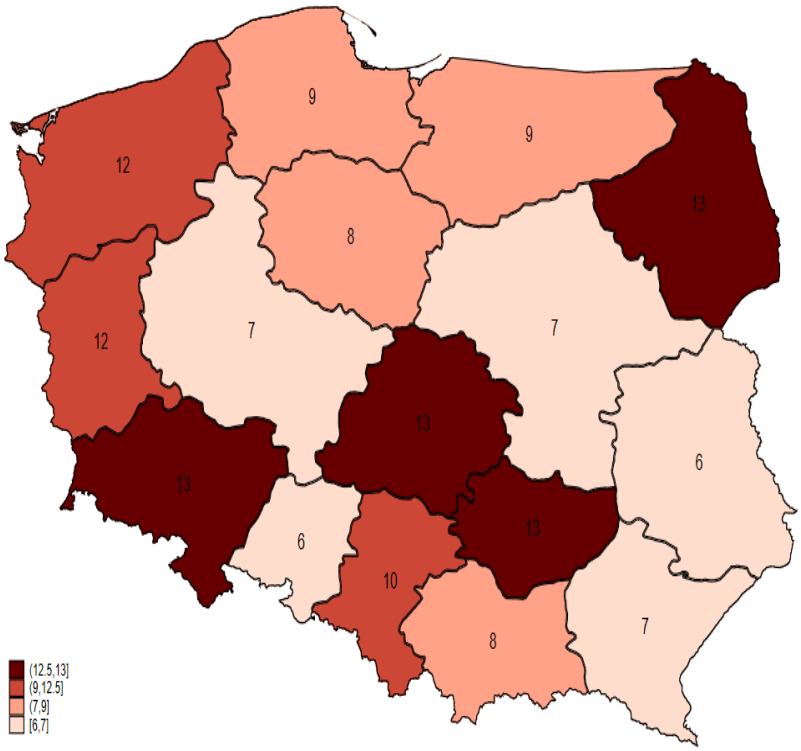
Source: Own calculations based on Household Budget Survey data.

Figure 10. Share of energy-poor households in Polish regions according to the living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors indicator [% of households]



Source: Own calculations based on Household Budget Survey data.

Figure 11. Share of energy-poor households in Polish regions according to the inadequate thermal comfort in winter indicator [% of households]



Source: Own calculations based on Household Budget Survey data.

The subjective measure of energy poverty (inadequate thermal comfort, Figure 11), identifies one western voivodship, dolnośląskie (13%) and two central regions, łódzkie and świętokrzyskie (13%), as being at highest risk of energy poverty. This result is attributable to the buildings in these regions having lower energy-efficiency standards, which can affect the perception of cold. The finding that the north-eastern region of podlaskie (13%) scores high on this measure is probably related to the severe climate conditions in this region.

3.5. Econometric analysis of five indicators

In order to quantify the relative roles of the various factors that contribute to the variation in the incidence of energy poverty at the household level, we have estimated five logistic regressions. In particular models, specific indicators are set as a dependent variable, while the explanatory variables are the same. Building characteristics (period of building construction, type of heating, type of building, and floor area of the house), household characteristics (number of people in the household, main source of income, equivalised income), and location (voivodship, degree of urbanisation) are used as explanatory variables. The results are presented in Table 5.

Floor area of the dwelling

- The risk of energy poverty increases with the floor area when the expenditure-based measures are applied, but it decreases when the self-reported indicators are used. This pattern may be related to higher energy expenditures in larger dwellings.
- Floor area does not have a statistically significant relationship with the probability of energy poverty, according to the BILLS measure.

Period of building construction

- The period of building construction is shown to be a risk factor for all energy poverty indicators; although the relationship is found to be statistically significant only for some of the periods when the 2M and BILLS indicators are applied.
- For most of the indicators, the probability of energy poverty is shown to be the highest in the oldest buildings (constructed before 1946); the exception is the 2M indicator, for which no statistically significant relationship between building age and energy poverty is found.
- For all of the indicators (except the BILLS measure), the probability of energy poverty is found to decrease in the newest buildings constructed after 2007.
- According to the self-reported measures COMFORT and ROOF, the newer the building, the lower the risk of energy poverty.

Type of heating

- Households that use gas as the main source of heating are found to face a higher risk of energy poverty than households that use central heating and are otherwise similar. Only for the BILLS measure is the risk of energy poverty shown to be lower if a household uses a gas stove rather than a central heating system.
- For all self-reported measures (COMFORT, ROOF and BILLS), using coal, wood, and electric stoves is found to be a risk factor of energy poverty, relative to using central heating systems. For expenditure-based indicators, this relationship is not shown to be statistically significant.

Type of building

- Living in a detached house is found to be negatively correlated with the LIHC and BILLS indicators. This result may be surprising since we observe a higher share of energy poverty among households living in single-family houses than among those living in multi-family homes (Lewandowski et al., 2018). Differences in the findings on the shares of energy-poor households living in detached and multifamily dwellings result from their characteristics. When we control for these characteristics, the differences disappear.
- Only the ROOF measure is shown to be positively correlated with living in detached house (in relation to living in a multifamily building).

Number of people in the household

- For the LIHC, 2M, and COMFORT indicators, the risk of energy poverty is found to be higher in one-person households than in two-person households.
- The risk of LIHC poverty is also found to be higher among three- and four-person households.
- The risk of 2M poverty is observed to decline with the size of the household.
- The risk of ROOF poverty is found to increase with the size of the household.
- The household size does not appear to play a significant role when the BILLS measure is applied.

Equivalised income

- The higher the equivalised income, the lower the risk of energy poverty is found to be.

- Equivalised income is shown to have a much stronger relationship to the expenditure-based measures than to the self-reported measures.

Main source of income

- Households of white-collar workers are observed to be less likely to be energy poor than households of blue-collar workers, according to all measures.
- Farmers are found to be less likely to be energy poor than blue-collar workers, according to the 2M, COMFORT, and BILLS indicators.
- Households living on income from self-employment are shown to be less likely to be energy poor, according to the LIHC and ROOF measures.
- Retirees and pensioners are found to face a higher risk of energy poverty, according to the expenditure-based measures. The opposite relationship is observed for the self-reported indicators.
- Households living on social transfers are shown to be less likely to be energy poor according to the LIHC indicator, but are found to be more likely to be energy poor according to the self-reported measures.

Degree of urbanisation

- The degree of urbanisation has no statistically significant relationship to the probability of energy poverty, according to the LIHC indicator.
- For the 2M indicator, the risk of energy poverty is observed to be significantly lower in cities with 100,000-199,000 residents and in rural areas.
- According to the COMFORT indicator, the risk of energy poverty is significantly higher in cities with 100,000-499,000 residents or more.
- When the ROOF measure is applied, the probability of energy poverty is found to be significantly lower in the largest cities than in cities with 20,000-99,000 residents. We draw the same conclusion for the BILLS measure.
- According to the BILLS indicator, the risk of energy poverty is significantly lower in the smallest towns of less than 20,000 residents and in rural areas than in the largest cities.

Voivodship

- When dolnośląskie is used as a reference level, we find a higher probability of energy poverty in the other voivodships for the expenditure-based indicators and a lower probability of energy poverty for the self-reported measures. This result confirms our observations from section 3.4. of the report.
- Podlaskie and śląskie are two voivodships that stand out. The probability of energy poverty in podlaskie is found to be higher for the LIHC and COMFORT indicators, and lower for the 2M and ROOF indicators. In Śląskie, the probability of energy poverty is shown to be higher for the 2M and BILLS measures, but lower for the COMFORT and ROOF indicators.
- Differences between the voivodships are found to be the most pronounced when the COMFORT and ROOF measures are applied, and the least pronounced when the BILLS measure is employed.

Table 5. Mean marginal effects from the logistic regression of the set of indicators

	Dependent variable – energy poverty indicator				
	Low Income High Costs	Twice the median share of energy expenditure	Inadequate thermal comfort	Leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	Inability to pay utility bills on time
	LIHC	2M	COMFORT	ROOF	BILLS
Floor area (log)	0.186***	0.104***	-0.022***	-0.045***	-0.002
Period of building construction	REF: 1961-1980				
Before 1946	0.010**	0.010	0.032***	0.035***	0.006**
1946-1960	0.005	-0.008	-0.032***	-0.040***	-0.000
1981-1995	-0.005	-0.002	-0.052***	-0.056***	0.002
1996-2007	-0.055***	0.004	-0.059***	-0.088***	0.002
After 2007	-0.059***	-0.022**	-0.074***	-0.111***	-0.009
Type of heating	REF: central heating system				
Coal and wood stoves	-0.005	0.001	0.086***	0.060***	0.007***
Gas stoves	0.020**	0.056***	0.065***	0.019**	-0.011*
Electric stoves	0.003	0.006	0.114***	0.064***	0.016***
Type of building	REF: multifamily				
Detached	-0.088***	0.006	-0.006	0.021***	-0.007***
Number of people in the household	REF: 2 people				
1 person	0.013***	0.069***	0.010**	-0.005	0.002
3 people	0.012***	-0.053***	0.005	0.006	-0.000
4 people	0.014***	-0.083***	0.002	0.014***	-0.002
5 people	-0.003	-0.097***	0.011*	0.025***	-0.003
Logarithm of equivalised income	-0.287***	-0.219***	-0.029***	-0.029***	-0.046***
Main source of household income	REF: blue-collar workers				
White-collar workers	-0.012***	-0.030***	-0.015***	-0.013***	-0.006*
Farmers	0.004	-0.022*	-0.040***	-0.006	-0.026***
Self-employed	-0.011*	-0.010	-0.012	-0.016**	0.000
Retirees and pensioners	0.009***	0.016***	-0.008*	-0.014***	-0.006**

Table 5 (continued). Mean marginal effects from the logistic regression of the set of indicators

	LIHC	2M	COMFORT	ROOF	BILLS
Recipients of other non-earned income sources	-0.028***	0.011	0.016**	0.010*	0.007**
Degree of urbanisation	REF: at least 500,000 residents				
200,000-499,000	0.001	-0.013	0.031***	-0.004	-0.001
100,000-199,000	0.000	-0.019*	0.031***	0.001	-0.010**
200,000-99,000	-0.007	-0.002	-0.006	-0.018***	-0.011***
Less than 20,000	-0.006	-0.003	0.002	-0.005	-0.010***
Rural areas	0.003	-0.036***	0.005	0.009	-0.012***
Voivodship	REF: Dolnośląskie				
Kujawsko-pomorskie	0.013*	0.051***	-0.030***	-0.007	0.001
Lubelskie	0.008	-0.056***	-0.029***	-0.007	-0.004
Lubuskie	0.015*	0.014	-0.012	-0.033***	0.006
Łódzkie	0.011	0.018*	0.024***	-0.017**	-0.008*
Małopolskie	0.013**	0.007	-0.005	-0.030***	-0.008*
Mazowieckie	0.004	0.005	-0.008	-0.008	0.006*
Opolskie	0.003	0.010	-0.048***	-0.019**	-0.004
Podkarpackie	0.014**	-0.022*	-0.013	-0.047***	-0.009*
Podlaskie	0.029***	-0.046***	0.035***	-0.025**	-0.008
Pomorskie	0.020***	0.014	-0.018**	-0.020***	0.008*
Śląskie	0.003	0.036***	-0.015**	-0.014**	0.010***
Świętokrzyskie	0.013	-0.006	0.043***	-0.029***	-0.007
Warmińsko-mazurskie	0.030***	0.022*	-0.026***	-0.004	-0.002
Wielkopolskie	0.011*	0.026***	-0.022***	-0.036***	0.000
Zachodniopomorskie	0.020***	0.028**	0.015*	-0.006	-0.009*
Number of observations	34 983				

*Significance levels: ***0.01, **0.05, *0.1. Robust standard errors.*

Source: Own estimations based on Household Budget Survey 2017.

4. Concluding remarks

Definition

We recommend using a general definition of energy poverty for the purposes of national policy planning, and a more specific definition of energy poverty for local administration. This would strengthen the process of policy planning and capture the relevant Polish context of energy poverty. The definition is as follows:

"Energy poverty occurs when a household is unable to afford the energy needed to provide its members with adequate warmth, cooling, lighting, and appliance use due to a combination of factors, which may include having a low income, high energy expenditure requirements, and a home with low levels of energy efficiency. For a household to be classified as energy poor, it has to meet two criteria simultaneously: i.e., it must have high required energy costs (above the national median level) and a low income (residual income below the official poverty line). Specifically, the household's share of actual energy expenditure in income needs to be higher than twice the median of this value in the population. The severity of energy poverty, or the level of the severity of deprivation, is indicated by self-reported measures of the financial capability of the household (measured by the ability to pay utility bills), the physical structure of the dwelling (measured by the presence of rot or damp), as well as the household members' subjective level of thermal comfort".

Indicators

We have selected two indicators to identify energy-poor households:

- Low Income High Costs; and
- Twice the median share of energy expenditures.

We have also selected three indicators to measure the severity of energy deprivation:

- Inability to pay utility bills on time;
- Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors; and
- Inadequate thermal comfort in winter.

Various combinations of all of these indicators can be used depending on to the aim of the policymakers and the specific context of energy poverty in the Polish regions.

Hypothetical energy costs

State-of-the-art methods of measuring energy poverty are based on modelled expenditures, which are vital for the proper identification of energy-poor households. To ensure the proper measurement and monitoring of energy poverty in Poland, we recommend building a Domestic Energy Model for Poland based on a methodology similar to that used to construct the BREDEM in the UK. Such a model would allow for the estimation of the energy consumption of a dwelling based on its characteristics. The output of the model is the estimated energy requirements, which can be converted into energy costs or CO_2 emissions (Henderson and Hart 2015). Thus, the introduction of the model would improve the precision of the process of identifying energy-poor households, and could be used to estimate the relationship between energy poverty and air pollution. We recommend starting the process of developing the model in 2019.

References

Beatty T., Blow L., Crossley T. (2011). Is there a "heat or eat" trade-off in the UK? IFS Working Paper W11/09.

Boardman B. (1991). Fuel poverty: from cold homes to affordable warmth. Belhaven Press.

Boardman B. (2010). Fixing Fuel Poverty: Challenges and Solutions. London: Earthscan.

Bouzarovski S. (2018). Energy Poverty Policies at the EU Level. In: Energy Poverty. Palgrave Macmillan, Cham.

Bouzarovski S., Petrova S. (2015). A global perspective on domestic energy deprivation: Overcoming the energy poverty–fuel poverty binary. Energy Research & Social Science 10, 31-40.

Bouzarovski S., Tirado Herrero (2017) Geographies of injustice: the socio-spatial determinants of energy poverty in Poland, the Czech Republic and Hungary. Available at: https://www.tandfonline.com/doi/full/10.1080/14631377.2016.1242257 [Accessed 15th of November 2018]

Department of Energy & Climate Change (2016). Fuel Poverty. Methodology Handbook.

European Commission. (2017). Proposal for a directive of the European Parliament and of the Council on common rules for the internal market in electricity (recast). http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52016PC0864R%2801%29. [Accessed 9th of September 2018]

Gibbons D., Singer R. (2008). Cold comfort: A Review of Coping Strategies Employed by Households in Fuel Poverty. Centre for Economic and Social Inclusion.

GOV.UK (2018). Fuel poverty statistics. Retrieved from https://www.gov.uk/government/collections/fuel-poverty-statistics

Healy J. D., Clinch J. P. (2002). Fuel poverty in Europe: a cross-country analysis using a new composite measure. Dublin: University College Dublin.

Henderson J., Hart J. (2015). BREDEM 2012 – A technical description of the BRE Domestic Energy Model. Available at: https://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf [Accessed 15th of October 2018]

Hills, J. (2012). Getting the measure of fuel poverty. Final Report of the Fuel Poverty Review. CASE report 72. London: Department of Energy and Climate Change.

IEA (2017) Energy Policies of IEA Countries. Poland: 2016 Review. IEA.

INSIGHT_E (2015). Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures. Available at: http://www.insightenergy.org/static_pages/publications#?publication=15 [Accessed 10th of October 2018]

Lewandowski P., Kiełczewska A. Ziółkowska (Święcicka) K. (2018). Zjawisko ubóstwa energetycznego w Polsce, w tym ze szczególnym uwzględnieniem zamieszkujących w domach jednorodzinnych. IBS Research Report 02/2018.

Lewandowski P., Sałach K. (2018). Pomiar ubóstwa energetycznego na podstawie danych BBGD – metodologia i zastosowanie. IBS Research Report 01/2018.

Liddell C. Morris C., McKenzie S.J.P, G. Rae (2012). Measuring and monitoring fuel poverty in the UK: National and regional perspectives. Energy Policy 38 (49), 27–32.

Lis M., Miazga A., Sałach K. (2017). Location, location, location. What accounts for the regional variation of Energy poverty in Poland. Simcock N., Thomson H., Petrova S., Bouzarovski S. (eds.) Energy Poverty and Vulnerability A Global Perspective (pp. 119-140). London, Routledge.

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

Lis M., Szpor A. (2016). Ograniczenie ubóstwa energetycznego w Polsce – od teorii do praktyki. IBS Policy Paper 06/2016.

Miazga A., Owczarek D. (2015). Dom zimny, dom ciemny – czyli ubóstwo energetyczne w Polsce. IBS Working Paper 16/2015.

Moore R. (2012). Definitions of fuel poverty: Implications for policy. Energy Policy 49(C), 19-26.

Nussbaumer, P., Bazilian, M., Modi, V., and Yumkella, K.K. (2011). Measuring energy poverty: Focusing on what matters. Working paper No. 42, Oxford University: Oxford Poverty and Human Development Initiative.

Rutkowski J., Sałach K., Szpor A., Ziółkowska (Święcicka) K. (2018). How to reduce energy poverty in Poland? IBS Policy Paper 01/2018.

Schuessler R. (2014). Energy Poverty Indicators: Conceptual Issues - Part I: The Ten-Percent-Rule and Double Median/Mean Indicators. ZEW - Centre for European Economic Research Discussion Paper 14-037. Available at SSRN: https://ssrn.com/abstract=2459404 or http://dx.doi.org/10.2139/ssrn.2459404

Statistics Poland (2017a). Regiony Polski 2017. Available at https://stat.gov.pl/obszary-tematyczne/inne-opracowania/miasta-wojewodztwa/regiony-polski-2017,6,11.html [Accessed 15th of October 2018]

Statistics Poland (2017b). Zużycie energii w gospodarstwach domowych w 2015 r. Available at: https://stat.gov.pl/files/gfx/portalinformacyjny/pl/defaultaktualnosci/5485/2/3/1/zuzycie_energii_w_gospodarstwach_domowych_w_2015_r..pdf. [Accessed 20th of October 2018]

Trinomics (2016). Selecting Indicators to Measure Energy Poverty. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/Selecting%20Indicators%20to%20Measure%20Energy%20Poverty.pdf [Accessed on 18th of June 2018]

Appendix I – overview of definitions

A1. Overview energy poverty definitions in EU

Member state	Definition	Reference
European Commission	Energy services are fundamental to safeguard the well-being of the Union citizens. Adequate warmth, cooling, lighting and the energy to power appliances are essential services to guarantee a decent standard of living and citizens' health. Furthermore, access to these energy services empowers European citizens to fulfil their potential and it enhances social inclusion. Energy poor households are unable to afford these energy services due to a combination of low income, high energy expenditure and poor energy efficiency of their homes.	European Commission Electricity Directive
Cyprus	Energy poverty may occur among individuals who face challenges because of their low income (as indicated by their tax statements) in conjunction with their professional status, marital status, and specific health conditions; and who are unable to cover the cost of a supply of electricity that is reasonable to meet their needs, as these costs represent a significant proportion of their disposable income.	The Minister of Energy, Commerce, Industry & Tourism
France	A person is considered energy poor if he/she experiences particular difficulties in getting an energy supply in his/her home that is adequate to satisfy his/her basic needs because he/she lacks resources or has poor housing conditions.	According to article 11 of the "Grenelle II" law from 12 July 2010
Ireland	A situation whereby a household is unable to attain an acceptable level of energy services (including heating, lighting, etc.) in the home due to an inability to meet these requirements at an affordable cost whereas affordable energy describes a situation where a household can attain an acceptable level of energy services at a level of expenditure that is affordable relative to its overall disposable income.	'Warmer Homes – A Strategy for Affordable Energy in Ireland'
Slovakia	Energy poverty occurs when the average monthly household expenditures for the consumption of electricity and gas for heating and hot water represent a significant share of a household's average monthly income.	Act on Regulation in Network Industries 250/2012
England	Fuel poor households were initially defined as needing to spend more than 10% of their income on energy in order to keep the home in a satisfactory condition. A more recent definition sees households as fuel poor if required energy costs are higher than those of the nation-wide median, while pushing them below the official poverty line.	www.gov.uk www.poverty.org.uk

Notes: Fuel poverty and energy poverty tend to be used interchangeably; for a detailed conceptual framework, see Bouzarovski and Petrova (2015).

Source: (INSIGHT_E, 2015) and own elaboration.

Appendix II – selection of indicators

We propose a unified methodology for assessing energy poverty indicators and selecting the most suitable ones for Poland. The scope of the assessment aims to address the main drawbacks of each measure. An indicator can, for example, be sensitive to energy prices, difficult to communicate, or unsuitable in the Polish context. In addition to evaluating the indicators according to their data sources, we have assessed the quality of the indicators.

The characteristics of energy poverty should be thoroughly described and matched by the appropriate policy responses. To advance this goal, we consider different approaches and analyse indicators that are subjective and objective, as well as qualitative and quantitative. Base on the relevant academic literature, reports, and expert knowledge, we understand and accept that all of these approaches are needed when addressing energy poverty. Therefore, rather than offering a one-size-fits-all solutions, we decided to identify a set of indicators that would best capture the specificity of energy poverty in Poland.

Table A3. Evaluation categories for energy poverty indicators

Characteristic	Group	Explanation
Approach	Expenditure-based	In the expenditure-based approach, energy costs are compared to an absolute or a relative threshold.
	Self-reported	Self-reported indicators are based on the individual's own assessments of the household's situation and living conditions.
Category	Income /expenditures	Income /expenditures include income and expenditure drivers (e.g., expenditures on energy, disposable income).
	Physical infrastructure	Physical infrastructure indicators encompass the dwelling size, the building stock age, and the building design (e.g., information on insulation and heating system).
	Financial capability	The financial capability category includes outcomes resulting from energy poverty, such as the perception of the household's ability to pay its bills.
Method of application	A single metric	Reflects how the indicators are applied to energy poverty. A single metric can be read directly from the data sources. Combinatory metrics are calculated using relatively simple methods. Metrics constructed using modelling require detailed analysis.
	Constructed metric	
	Metric constructed using modelling	
Experience of application to the energy poverty issue	Used in policies and literature	Identifies to what extent indicators have been applied to energy poverty in other countries or studies, while differentiating indicators that have been applied in policymaking practice from those that have only been proposed in the literature.
	Recommended in literature	
Country-specific or internationally available and comparable	Country-specific	Classifies indicators by taking into account whether their design allows for their application at a pan-European scale. For example, combinatory or constructed metrics using absolute values might result in bias; i.e., combinatory metrics based on national mean expenditures may not be applicable across different countries.
	Internationally available and comparable	

Source: Trinomics (2016) and own elaboration.

In table A4, we present a description of the assessment approach with scales, characteristics, and explanations.

A4. Energy poverty indicators assessment approach

Category	Abbreviation	Score	Characteristic	Explanation
Recognised advantages	A	1	Low	Recognised advantages form the key category for the qualitative assessment; therefore, each indicator is assessed on a three-point scale. The advantages are based on a literature review, data quality, and expert knowledge. A higher number of advantages means a higher score.
		2	Medium	
		3	High	
Recognised disadvantages	D	1	High	Recognised disadvantages form the key category for the qualitative assessment; therefore, each indicator is assessed on a three-point scale. The disadvantages are based on a literature survey, data quality, and expert knowledge. A lower number of disadvantages means a higher score.
		2	Medium	
		3	Low	
Usefulness for planning and identifying the energy poor	U	0	Limited	We assess whether an indicator has been used in the current or past policies of countries that are actively tackling energy poverty. We also consider whether an indicator has been used by the EU Energy Poverty observatory, while distinguishing between primary and secondary indicators.
		1	Average	
		2	Extensive	
Access	AC	0	Against cost	Comparison of the cost of obtaining the data. Although the cost may be considered negligible for larger institutions, it may present difficulties for individuals and smaller organisations.
		1	Free	
Sample size and representativeness	S	0	Limited	The benchmark is a sample size representative of the entire Polish population (almost 38 million people, as of 2018). Additionally, we analyse the representativeness of the sample at the level of NUTS-2 and subpopulations. A higher degree of representativeness allows for more detailed analysis, with the option of examining geographic and demographic differences in energy poverty in Poland.
		1	Average	
		2	Large	
Coverage over time	T	0	Limited	The more extensive the coverage over time of a given indicator, the better. A longer time horizon allows for a more thorough observation of energy poverty and its changes over time.
		1	Average	
		2	Extensive	
Frequency of collection	F	0	Irregular	When the collection of data is irregular, the future analysis and monitoring of energy poverty may be jeopardised.
		1	Regular	
Proxy for energy poverty	P	0	Indirect	The use of indirect proxies of energy poverty present difficulties for the analysis; i.e., they require additional calculation and are less intuitive for use in communicating and planning policies. Therefore, direct indicators are preferred.
		1	Direct	

Method	M	0	Constructed or constructed using modelling	For reasons of accessibility and simplicity, single metrics are favoured over constructed and modelled measures.
		1	Single metric	
Experience of application to energy poverty	E	0	Limited	Measures proposed in the literature and reports score one point; and metrics applied in policies score two points. Thus, there is a preference for indicators applied in practice.
		1	Average	
		2	Extensive	
Country specific / internationally comparable	C	0	Country specific	Indicators are country specific when their use across countries may result in a bias (e.g., due to a comparison of mean income values or other country-specific aspects of energy poverty). Internationally comparable metrics offer a broader scope of analysis and comparison across countries.
		1	Internationally comparable	
Missing observations [%] for most recent data	MO	0	>61%	Measures the share of missing observations in the most recent data; the more missing observations there are, the less accurate the indicator.
		1	31 – 60%	
		2	0 – 30%	

Source: Own elaboration.

A5. Results of the qualitative assessment

N°	Indicator	Source	∑	A	D	U	AC	S	T	F	P	M	E	C	MO
1	Actual expenditures on electricity	HBS	15	1	2	1	0	2	2	1	1	1	1	1	2
2	Actual expenditures on heat	HBS	15	1	2	1	0	2	2	1	1	1	1	1	2
3	Share of required energy expenditures in income	HBS	15	2	2	1	0	2	2	1	1	0	2	0	2
4	Low Income High Costs (LIHC)	HBS	17	2	2	2	0	2	2	1	1	0	2	1	2
5	Twice the median share of energy expenditures	HBS	16	2	2	2	0	2	2	1	1	0	2	0	2
6	Hidden energy poverty	HBS	16	2	3	2	0	2	2	1	1	0	1	0	2
7	Inadequate thermal comfort in winter	HBS	16	2	2	2	0	2	2	1	1	1	1	0	2
8	Living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors.	HBS	16	2	2	1	0	2	2	1	1	1	1	1	2
9	Inability to pay utility bills on time	HBS	17	2	2	2	0	2	2	1	1	1	1	1	2
10	The dwelling is too small - subjectively	HBS	12	1	3	0	0	2	2	1	0	1	0	0	2
11	The dwelling is too big - subjectively	HBS	12	1	3	0	0	2	2	1	0	1	0	0	2
12	Floor area [m^2 or m^2 per person]	HBS	14	1	3	1	0	2	2	1	0	0	1	1	2
13	Expenditures on consumer goods and services	HBS	12	1	3	0	0	2	2	1	0	0	0	1	2
14	Type of building	HBS	15	1	3	1	0	2	2	1	0	1	1	1	2
15	Period of building construction	HBS	15	1	3	1	0	2	2	1	0	1	1	1	2
16	Dwelling located in a polluted area	HBS	12	1	2	0	1	2	2	1	0	1	0	0	2

17	Leaking roof; damp walls/floors/foundations; or rot in the window frames or floors	SILC	13	1	1	1	1	1	1	1	1	1	1	1	2
18	Ability to keep home adequately warm	SILC	13	1	1	2	1	1	1	1	1	1	1	0	2
19	Arrears on utility bills	SILC	15	2	2	1	1	1	1	1	1	1	1	1	2
20	Problems with the dwelling: too dark, not enough light	SILC	13	1	3	0	1	1	1	1	1	1	1	0	2
21	Dwelling type	SILC	14	1	3	1	1	1	1	1	0	1	1	1	2
22	Capacity to face unexpected financial expenses	SILC	15	2	3	1	1	1	1	1	0	1	1	1	2
23	Ability to make ends meet	SILC	13	2	2	0	1	1	1	1	0	1	1	1	2
24	General health	SILC	13	1	3	0	1	1	1	1	0	1	1	1	2
25	Suffer from any chronic (long-standing) illness or condition	SILC	13	1	3	0	1	1	1	1	0	1	1	1	2
26	Limitation in activities because of health problems	SILC	11	1	3	0	1	1	1	1	0	1	1	1	0
27	Expenditures on water, electricity, gas, and heating	SHARE	12	1	3	1	1	0	1	0	1	1	2	1	0
28	Inability to pay utility bills on time	SHARE	12	2	2	1	1	0	1	0	1	1	1	1	1
29	Limiting heating expenditures despite feeling cold	SHARE	11	1	2	1	1	0	1	0	1	1	1	1	1
30	Ability to make ends meet	SHARE	11	2	2	0	1	0	1	0	0	1	1	1	2
31	Available savings considering the income and the expenditures of the household	SCS	9	1	3	1	0	1	0	0	0	1	0	0	2
32	Technical condition of electrical system	SCS	9	1	3	0	0	1	0	0	0	1	0	1	2
33	Living conditions (from very good to very bad)	SCS	10	1	2	1	0	1	0	0	0	1	1	1	2
34	Ability to make ends meet	SCS	10	2	2	0	0	1	0	0	0	1	1	1	2
35	The minimum income the household needs to make ends meet	SCS	9	1	3	1	0	1	0	0	0	1	0	0	2
36	Managing financial resources (from being able to afford luxury goods to being unable to afford basic needs)	SCS	10	2	2	1	0	1	0	0	0	1	0	1	2
37	Being at risk of poverty	SCS	12	2	3	1	0	1	0	0	0	1	2	0	2
38	Living in a dwelling with a leaking roof; damp walls, floors or foundations; or rot in the window frames or floors	SCS	10	1	1	1	0	1	0	0	1	1	1	1	2
39	Inadequate thermal comfort in winter	SCS	10	1	1	2	0	1	0	0	1	1	1	0	2
40	Dwelling too dark	SCS	11	1	3	0	0	1	0	0	1	1	1	1	2
41	Deterioration of living conditions of the household in last 12 months	SCS	10	1	3	1	0	1	0	0	0	1	0	1	2
42	Type of heating	SCS	13	3	3	1	0	1	0	0	0	1	1	1	2

43	Being exposed to air pollution (dust, smoke, fumes, smog)	SCS	7	1	2	0	0	1	0	0	0	1	0	0	2
44	Arrears on gas or electricity bills in the past 12 months	SCS	12	2	2	1	0	1	0	0	1	1	1	1	2
45	Currently having arrears on gas or electricity bills	SCS	12	2	2	1	0	1	0	0	1	1	1	1	2
46	Only one household living in the dwelling	SCS	9	1	3	0	0	1	0	0	0	1	0	1	2
47	Access to electricity, gas grid, gas in a cylinder, air conditioning	SCS	10	1	3	1	0	1	0	0	0	1	0	1	2
48	Receiving material support (in the past 12 months), including heating fuel	SCS	10	2	3	0	0	1	0	0	0	1	0	1	2
49	Floor area of the dwelling [m^2]	SCS	11	1	3	1	0	1	0	0	0	1	1	1	2
50	High housing costs negatively affecting the financial situation of the household	SCS	8	2	2	0	0	1	0	0	0	1	0	0	2

Source: Own elaboration.

10% share of required energy expenditures in income

We conclude that the 10% indicator is not suitable for monitoring and measuring energy poverty in Poland, since it identifies an extremely high number of households as energy poor (about 50%). A strikingly high level of energy-poor households is found by the measure based on the 10% share of required energy costs in disposable income.

The 10% indicator provides a coherent picture of the distribution of energy poverty across various subpopulations (e.g., it identifies the households that occupy the oldest houses as energy poor), but is clearly inaccurately adjusted to Polish expenditure levels.

Hidden energy poverty

According to the Hidden Energy Poverty indicator, energy-poor households occupy detached and multifamily buildings constructed after 1996. This counterintuitive outcome results from the construction of the measure. It is designed to signal households with abnormally low energy expenditures, which in the Polish case may be households with high levels of energy efficiency rather than energy poverty. The results for the subpopulations seem to prove this conjecture, as they show that the share of households occupying buildings constructed after 2007 (with the highest average energy efficiency) is 36.1% for detached houses and 31.4% for multifamily houses.

The limited suitability of the indicator becomes especially apparent when we compare the incomes of the households identified as energy poor by the Hidden Energy Poverty indicator with the incomes of the rest of the population. The average income per person in a household identified by this measure is 2023 zł, and the median income is 1593 zł (in 2016). Across the population, the average income is 1705 zł, and the median income is 1496 zł. Since the Hidden Energy Poverty indicator tends to identify households with above-average incomes and a greater likelihood of living in a new building, it should not be included in the indicators set.

An additional argument for excluding the Hidden Energy Poverty indicator from the final set of indicators is related to a particular characteristic of the Polish energy sector. According to Statistics Poland (2017b), 49% of

households use solid fuel (wood or coal) for heating purposes, and 14% of households that utilise wood as a heating fuel admit it was acquired "for free". Therefore, this indicator may identify as energy poor households with access to cheap heating fuel acquired by informal means. Although we are aware that using free heating fuel may be a coping strategy of energy-poor households, the indicator does not allow us to distinguish between energy poverty and access to free heating fuel. We conclude that the Hidden Energy Poverty measure is not suitable for monitoring and measuring energy poverty in Poland due to the particular characteristics of the Polish energy sector (including the possibility of acquiring free heating fuel by informal measures).

A6. Results of cross-correlations analysis

We analyse the cross-correlations between indicators in order to assess whether the indicators provide complementary information.

The maximum correlation observed in the group of highest-quality indicators is 0.33 (i.e., twice the median share of energy expenditures and Low Income, High Cost). Additionally, a considerable negative correlation is observed between the lack of thermal comfort in winter and living in a dwelling with a leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors (-0.30).

We do not notice any statistical artefacts. As all of the observed correlations can be deemed coherent and intuitive, we conclude that this group of indicators can be used to assess the scope of energy poverty in Poland.

Indicator	Low Income High Costs	Twice the median share of energy expenditure	Inadequate thermal comfort in winter	Leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	Inability to pay utility bills on time
Low Income High Costs					
Twice the median share of energy expenditure	0.33	0.07			
Inadequate thermal comfort in winter	0.02	-0.06			
Leaking roof; damp walls, floors, or foundations; or rot in the window frames or floors	-0.03	0.17	-0.30		
Inability to pay utility bills on time	0.11	0.07	0.15	-0.14	

Source: Own calculations based on Household Budget Survey 2016.

www.ibs.org.pl