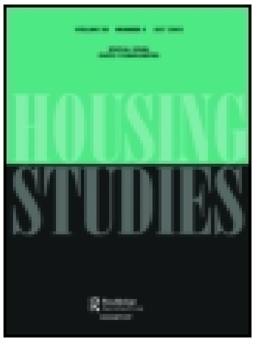

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Energy poverty, housing conditions, and self-assessed health: evidence from Poland

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ABSTRACT

Energy poverty, i.e., inefficient heating and insufficient access to energy services, can turn a shelter into a health hazard. We find that substandard housing and ineffective heating is associated with a higher risk of poor health in an urban context. We surveyed people living in two middle-sized cities in a coal-dependent region of Poland and used objective and subjective indicators of energy poverty and self-assessed health status. We demonstrate that people who live in substandard housing are more likely to exhibit poor musculoskeletal and cardiovascular outcomes, by 10 and 6 pp, respectively than otherwise similar people living in suitable housing conditions. We show that energy-poor people who use coal or a wood stove have a 24 pp higher likelihood of respiratory disease than the energy-poor who live in flats connected to district heating. We also find that a significant amount of the explained variance in the probability of respiratory disease is attributable to energy poverty. To improve the housing conditions and reduce the risk of poor health outcomes, we recommend two policy instruments: 1) a full subsidy for thermal retrofits and connecting multi-family buildings to the district heating network and 2) a targeted energy voucher for clean heating.

SUBJECT CLASSIFICATION CODES: I14; I32; D10; Q53

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energy poverty; heating; housing; health; air pollution

1. Introduction

The quality of housing can affect people's health. Living in low-quality housing can expose an individual to several health risks, from an injury on a loose step, poor respiratory outcomes due to mould and indoor pollution, and stress due to high energy bills or rent arrears (Krieger & Higgins, 2002). In particular, a housing situation can become a health threat if it does not provide the inhabitants with proper heating or cooling or adequate access to electricity and energy appliances (Hernández, 2016). These characteristics of substandard housing are in line with a widely used definition of energy poverty, which is generally understood as the inability of the

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inhabitants to adequately warm, cool, and use energy appliances in their houses (Boardman, 2010).

It is essential to recognise the heterogeneity of housing stock when analysing the energy–health nexus, particularly in Central and Eastern European (CEE) cities. During a centrally planned economy in Poland, i.e. 1945–1989, most CEE cities simultaneously experienced rapid industrialisation, demographic growth and housing shortage (Ulman & Ćwiek, 2021). Since the 1990s, the transition from a centrally planned to a market economy reduced the share of social housing in housing stock and increased the incidence of unmet energy needs (Chapman & Murie, 1996; Sýkora & Bouzarovski, 2012; Tsenkova & Polanska, 2014). While several studies examined the consequences of energy poverty in CEE cities (Bouzarovski, 2017), the direct link between energy efficiency, housing and health conditions in an urban environment remained understudied. In this paper, we study the relationship between energy poverty, housing conditions, and poor health outcomes in the context of industrial cities in Poland. We strive to make three key contributions.

First, we examine whether particular housing deprivations are associated with the risk of a specific disease. Most energy deprivation and health studies have focused on indoor pollution and respiratory diseases among households in the Global South (Agrawal, 2012; Hulin *et al.*, 2012; Oxlade & Murray, 2012). The research on this topic conducted in the Global North has been focused on the housing environment and health improvements resulting from retrofit interventions, particularly in Anglo-Saxon countries (Gilbertson *et al.*, 2012; Grey *et al.*, 2017; Heyman *et al.*, 2011; Maidment *et al.*, 2014; Preval *et al.*, 2010) with primarily technical works devoted to the energy efficiency of residential buildings in Poland (Attia *et al.*, 2022; Kozielska *et al.*, 2020). Our contribution is to distinguish between multiple energy poverty deprivations, particularly monetary deprivation and poor housing conditions. We also differentiate between various diseases – respiratory, cardiovascular, and musculoskeletal – and quantify the associations between particular forms of deprivation and the likelihood of each of them. Moreover, we place our paper in the strand of research that emphasises the regional and urban dimensions of energy poverty (Bouzarovski & Thomson, 2018; Frankowski & Herrero, 2021). Recent quantitative studies based on large-scale household surveys (such as EU Statistics on Income and Living Conditions) found a significant association between the intensity of energy poverty and poor health outcomes on the pan-European level (Oliveras *et al.*, 2020; Thomson *et al.*, 2017), as well as in selected EU countries (Kahouli, 2020; Lacroix & Chaton, 2015; Llorca *et al.*, 2020). These studies based on large scale household surveys provided only a general overview of health and living conditions. Our study, by contrast, is more detailed and allows examining how the risk of particular diseases is related to exposure to specific housing deprivations and heating sources.

Second, we examine whether the risk factors of specific diseases differ substantially between people who are in energy poverty and those who are not. Living in an "unhealthy home" can be detrimental to people's mental and physical health, particularly if they have pre-existing diseases (Poortinga *et al.*, 2018). There is evidence that living in substandard housing and cold exposure are associated with poor respiratory outcomes (Ormandy & Ezratty, 2012; Thomson & Thomas, 2015); and that low income is associated with increased exposure to environmental risk (Braubach & Ferrand, 2013). However, the relationship between experiencing energy poverty and diseases within different social and occupational groups is still under-researched. The initial studies on this topic have underlined the need to investigate and address the impact of experiencing energy poverty on the health of vulnerable groups (Liddell & Morris, 2010). Researchers have pointed out the severity of energy poverty among ethnic minorities in the United States (Jessel *et al.*, 2019), young people in New Zealand (Mohan, 2021; O'Sullivan *et al.*, 2015), and solitary elderly residents in Ireland (Goodman *et al.*, 2011). Our study adds to this knowledge by providing evidence on how the energy-poor and non-energy-poor subpopulations differ in terms of their exposure to health risks associated with living in various housing and heating conditions.

Third, we add to the knowledge about socio-spatial patterns of residential energy usage in industrial cities (Baborska-Narożny *et al.*, 2021; Sýkora & Bouzarovski, 2012). There is a significant gap in the understanding of the relationship between having poor health outcomes, living in substandard housing conditions, and dependence on inefficient heating sources in the urban setting in the CEE countries. This issue is particularly relevant for Poland, as more than 45% of households use coal or wood to heat their houses (Statistics Poland, 2018). Additionally, more than 16% of the population suffers from 'hidden energy poverty', either cutting their energy bills by using low-quality fuels or limiting their energy consumption (Karpinska & Śmiech, 2020, 2021).

For our study, we collected data from a randomly selected sample of 700 households in two cities in the industrial and mining region of Upper Silesia in Southern Poland. Upper Silesia is the largest coal mining region in Europe, and 13 out of the 50 European cities with the highest air pollution levels are located in it (WHO, 2018a). We selected two cities with similar demographics but different economic characteristics: Ruda Śląska, a mining city that emerges from its historic dependence on coal, and Tychy, a city with a recent history of dynamic socio-economic transformation driven by manufacturing. Using this approach, we can quantify the relationship between energy poverty and health outcomes in two different urban settings.

We find that people living in substandard housing face a higher risk of musculoskeletal and cardiovascular diseases (on average, by 10.6 and 6 pp, respectively) than otherwise similar people living in suitable housing conditions. Previous studies investigating the relationship between health and housing conditions have rarely assessed this relationship, as they focused primarily on general subjective health assessments or specific diseases (e.g., asthma). We show that among the energy-poor, the type and the location of the primary heating source are related to the higher risk of respiratory disease. Specifically, we find that among people in energy poverty, those living in an apartment with coal or a wood stove have a higher risk of poor respiratory outcomes (by 24.1 pp on average) than those living in an apartment connected to district heating. We demonstrate that 16% of the explained variance in the probability of having poor respiratory outcomes is attributable to energy poverty. These results show that indoor air pollution is an issue with potentially serious consequences in high-income countries such as Poland. To our knowledge, this study is the first to provide a detailed analysis of the relationship between energy poverty and health in CEE using a purposefully and locally collected dataset.

2. Methodology and data

2.1. Data collection

To investigate the relationship between energy poverty, housing conditions and poor health outcomes, we collected survey data in two middle-sized, industrial cities in Southern Poland: Ruda Śląska and Tychy, in Upper Silesia. Upper Silesia is the most urbanised Polish region; in 2020, it had a population of 4.5 million (12% of the total Polish population). We used a computer-assisted personal interview (CAPI) with randomly selected households. The questionnaire included 20 questions concerning health conditions and services, and household energy practices and expenditures. We instructed the pollsters to ask only people who were well-acquainted with issues related to household energy consumption and budgets to complete the questionnaire. The data were collected in February 2020. We obtained 700 complete answers (350 households in each city for a total of 1,735 individuals, 895 in Ruda Śląska and 840 in Tychy).[1] The average response rate was 30.9%, which we consider acceptable due to the nature of the particular questions, which touched on physical and mental health (OECD, 2013b). We further validated the results of the survey through geolocalization (total sample), via telephone, and in-person (13% of addresses). In each city, the sample covered 0.65% of the population. We weighted the sample with population weights representative of the age and gender composition in Ruda Śląska and Tychy and the household structure in Upper Silesia.[2]

We selected Ruda Śląska and Tychy for our study because these industrial cities are similar in size and population but differ in economic profile and spatial structure. The cities have a comparable number of inhabitants (136,423 – Ruda Śląska, 126,871 – Tychy in 2020; (Statistics Poland, 2021)), and both border Katowice, the capital of Upper Silesia. Ruda Śląska and Tychy are similar in their area, demographic structure, and registered unemployment rate (Table 1). However, in 2020, Ruda Śląska was a town dominated by state-led heavy industries: the coal mining sector with two active coal mines and metallurgy (Mazurkiewicz & Frankowski, 2020). Tychy, by contrast, had no coal mining. Still, it did have large, carbon-intensive manufacturing (e.g. automotive) sector and a growing service cluster. It has adopted a development pathway driven by foreign direct investments (FDI; Micek *et al.*, 2022). Selecting these cities also allowed us to uncover the socio-spatial and cultural patterns of mining city that shape specific practices, including heating (Allen, 2021). We found them in Ruda Śląska, using Tychy as a non-mining reference town.

Tychy and Ruda Śląska also differ in their urban structures. Among the most characteristic elements of Ruda Śląska's urban structure are the 20 multi-family estates near the coal mines (Szweda, 2018), which can be seen as a material metaphor for how the mining industry is related to the everyday lives of the city's inhabitants. Ruda Śląska also has large-scale apartment blocks built in the 1960s and 1970s, i.e., during the period of the most intense development of the mining sector. Tychy grew mainly in the 1960s and 1970s and was deemed a "socialist role-model city" in which a clear division between the residential and the industrial areas persists until today (Bierwiaczonek, 2016). The differences between the cities illustrate the heterogeneity of the Polish housing stock, as it includes multi-family

Table 1. Characteristics of the two cities.

Indicator	Ruda Śląska 2004	Ruda Śląska 2020	Tychy 2004	Tychy 2020
Number of inhabitants	147,403	136,423	131,547	126,871
Area (km^2)	78	78	82	82
Density (people/km^2)	1,890	1,749	1,604	1,547
People in pre/working/post-working age (%)	20/65.5/14.5	18.1/59.3/22.6	18.2/68.9/12.9	17.6/57.5/24.9
Average useful floor area of dwelling (m^2)	53.1	54.3	59.3	63.3
Average useful floor area per 1 person (m^2)	20.3	24	20.5	26.8
Dwelling stock (per 1000 population)	381.4	431.6	345.3	408.7
Gas supply network (per 100 km^2)	310.1	364.0	296.3	419.6
Average monthly gross wages and salary (%, PL = 100)	85.5	87.2	94	95.4
Registered unemployment rate (%)	14.2	3.4	13.1	3.0
Entities entered in REGON register (per 10,000 inhabitants)	980.4	1330.6	1506.1	1946.3
Employed in industry and construction (%)	59.2*	43.8	49.1*	54.8
Active hard coal mines	5	3	0	0
Areas in Katowice Special Economic Zone	No	No	Yes	Yes

Notes: "*" means the data are from 2005.
Source: Own elaboration on the basis of Local Data Bank Poland (2021).

buildings constructed before the 1930s, large-scale housing estates from the 1970s, and individual, single-family houses built throughout the decades.

Finally, Ruda Śląska and Tychy are the best cases to compare, as no other pair of medium-sized cities in Silesia meet all the criteria (demographic similarities with socio-economic differences, e.g. presence/absence of coal mines and large FDIs) at once.

2.2. Definitions and indicators

We define energy poverty as an inability to adequately warm, cool, and use energy appliances within a household (Boardman, 2010). However, there are various approaches to defining domestic energy deprivation. First, one can understand energy poverty in terms of limited or insufficient access to energy services (Casillas & Kammen, 2010; Halff *et al.*, 2014; González-Eguino, 2015). Second, the relation of energy expenditure to income (Pachauri, 2010; Herrero & Ürge-Vorsatz, 2012) can determine energy poverty. The definition we apply affects the indicators we need to use to capture each deprivation (Herrero, 2017).

We use five well-established energy poverty indicators (Table 2): two based on incomes and expenditures, and three based on the self-assessed situation of

Table 2. Energy poverty indicators used in the study.

Indicator	Description
Low Income, High Cost	A household is classified as energy-poor if it fulfils two criteria simultaneously: it has high required energy expenditures and a low income. The high required energy expenditure criterion is met if the household's required equivalent energy expenses are higher than the median of the equivalent energy expenditures in the sample. The low-income criterion is based on two conditions that must be met simultaneously: (i) the equivalent household income is in the lowest 30% of incomes in the sample, and (ii) the equivalent household income after housing costs is lower than the individual income threshold.
High actual costs	A household is classified as energy-poor if the share of its income it spends on energy is at least double the median of this share in the sample.
Indicators based on the following survey questions:	
Housing faults	"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 classified as energy-poor.
Inadequate thermal comfort	"In your view, is your apartment warm enough in the winter?" The households answering "no" are classified as energy-poor.
Difficulties paying bills	"How often, exclusively due to financial reasons, did you give up on paying energy bills?" The households answering "often", "very often", and "always" are classified as energy-poor.

Source: Own elaboration based on European Energy Poverty Observatory (2021).

Table 3. Health indicators used in the study.

Indicator	Indicator based on the following survey items:	Answer that classifies a respondent as ill
Self-diagnosed disease	"Name each member of your household who has experienced the following disease in the last 12 months"	"Yes, but the disease was not confirmed by a doctor"
Disease confirmed by a doctor/nurse		"Yes, and the disease was confirmed by a doctor"
At least one visit to the doctor's/nurse's office during the last 12 months due to a particular disease.	"How many times, and due to what condition, has a member of your household visited a doctor/nurse?"	"Yes" and naming a specific disease
At least one 12-hour stay in the hospital during the last 12 months due to a particular disease.	"How many times, and due to what conditions, has a member of your household stayed in the hospital for at least 12 hours?"	"Yes" and naming a specific disease

Note: Own elaboration based on (OECD, 2013a; DECC, 2016).

households (Romero *et al.*, 2018). We consider an individual energy-poor if they are suffering from any of the five energy-poverty dimensions.

We consider three[3] self-reported health outcomes (DECC, 2016; OECD, 2013b), in line with previous studies on the relationship between energy poverty and health (Bosch *et al.*, 2019; Carrere *et al.*, 2020; Oliveras *et al.*, 2020). Self-reported health indicators included:[4]

1. Respiratory diseases (respiratory failure, flu, pharyngitis, pneumonia, asthma, chronic obstructive pulmonary disease, chronic cold)
2. Cardiovascular diseases (high blood pressure, coronary disease, diabetes, atherosclerosis, stroke)
3. Musculoskeletal diseases (muscle and joint pain or inflammation, arthritis, rheumatism, osteoporosis)

We consider the survey respondents to have a health issue if they meet at least one of the following conditions (Table 3), following the operationalisation and specification of the indicators in the literature on the relationship between energy poverty and health (Awaworyi Churchill & Smyth, 2021; Banerjee *et al.*, 2021; Kose, 2019).

Finally, we did not aggregate the indicators of energy poverty or health indicators into a single metric as we aimed to capture the relation between particular deprivation and health issues. In particular, we analysed each disease separately as only 8-9% of respondents experienced multiple illnesses.

2.3. Logistic regression model

We estimate logistic regressions to analyse the factors related to the coincidence of energy poverty and self-reported health issues at the individual level. We chose this particular estimation strategy as it aligns with previously applied methods in studies at the intersection of poverty and health (Achia *et al.*, 2010; Chow *et al.*, 2003; Do & Finch, 2008).[5] In particular models, we assign a value of one if an individual reports a specific health condition (e.g. poor respiratory outcome) as a dependent variable. Formally:

$$\Pr\left(health\,outcome_i = 1\right) = H(\beta_0 + \beta_1 X_i + \beta_2 B_i + \beta_3 \gamma_i + c_i + \epsilon) \quad (1)$$

where $\left(H\right) = \frac{e^H}{1+e^H}$, i stands for the individual, X_i is a vector of deprivations (e.g. housing faults, difficulty to pay the bills), B_i is a matrix of the building's characteristics (e.g., heating source, year of construction), γ_i stands for a matrix of socio-economic controls (i.e. indicator variables for occupations, following the ISCO classification, and being a student), and c_i is the city fixed effect. We control for socio-economic characteristics (equivalised income, social transfers) to account for the observed differences in living conditions. We use individual controls (age, gender) to account for differences among the household members.

Our sample includes individuals who reported their household income (we have excluded 520 individuals who did not report their household income). To make income comparable between households with different compositions, we have equivalised incomes using the OECD equivalisation scale (OECD, 2013a).

We estimate our models on two samples (Oliveras *et al.*, 2020). First, we estimate the model on a total sample of 1,215 observations. We cluster the standard errors at the household level. Second, we re-estimate the model by applying the Heckman sample correction (Heckman, 1974) to account for a non-random distribution of the energy-poor in our sample. Heckman correction is a commonly used approach to correct for selection on observables (e.g. in health-related and energy-poverty studies, e.g., Akotey & Adjasi, 2016; Alem & Demeke, 2018; Brinda *et al.*, 2015; Sommers & Oellerich, 2013), and provide an unbiased estimation of coefficients. We use the Heckman correction to control for potential reverse causality between health outcomes and energy poverty, i.e. the fact that poor health may relate to a higher risk of energy poverty pertaining to poor health outcomes. In the first stage (selection equation), we regress for the probability of being energy-poor against

Table 4. Variable groups for the Shapley decomposition and data description for selected variables.

#	Groups for Shapley decomposition	Variable	Description
1	Socio-economic	Age in 2020, binary variables	0–20
			21–40
			41–60
			61 and more
		Female	Binary variable
		The logarithm of placement on the subjective health scale	Self-assessed health scale, where 0 is the lowest and 100 the highest
		The logarithm of equivalised income	A sum of the household's income from all sources (wages, social transfers, etc.)
		Labour market status, binary variables	Manager/professional
			Technician/clerical support
			Services
			Crafts
			Machines/elementary
			Unemployed
			School/university student
			Retired or pensioner
			A beneficiary of a social transfer
2	City	Tychy	Binary variable
3	Building characteristics	Multifamily building	Binary variable
		Year of construction, four binary variables	before 1945
			1946-1960
			1961-1980
			After 1980
		Ownership and responsibility for renovations, binary variables	Outright, individual ownership
			Municipal, i.e. the city of Ruda Śląska or Tychy is the sole proprietor of the house/apartment
			Housing association/cooperative
		The logarithm of floor area	Floor area in square meters
		Construction material, binary variables	Wood
			Concrete/panel building
			Bricks
			District heating
		Main heating source, binary variables	Coal/wood stove in the apartment
			Coal/wood stove in the boiler room
			Oil/gas/other
		Uninsulated	Binary variable
		Leaking doors/windows	
		Unventilated house	
4	Social transfers	A beneficiary of housing/energy/heating allowance	Binary variable
		A beneficiary of social/unemployed allowance/charity	
		A beneficiary of coal allowance	
5	Energy poverty indicators	Low income high cost	Binary variable
		High actual energy costs	
		Housing faults	
		Difficulties paying bills	
		Inadequate thermal comfort	

Source: Own elaboration.

three variables: (i) the logarithm of equivalised income; (ii) being a beneficiary of housing/energy/heating allowance; (iii) being a beneficiary of social/unemployed allowance/charity. Formally:

$$\Pr\left(EP_i = 1 \mid Z\right) = \varphi(Z\delta) \tag{2}$$

where EP indicates the energy poverty of an individual i ($EP = 1$ if the respondent is energy-poor according to at least one of the energy poverty indicators, and $EP = 0$ otherwise), Z is a vector of explanatory variables, δ is a vector of unknown parameters, and φ is the cumulative distribution function of the standard normal distribution.

In the second stage, we correct the self-selection by using the probability in (2) as an explanatory variable and excluding the three variables used in the first stage. Combining Eqs. (1) and (2), we specify the conditional probability of a particular health outcome as:

$$E\left(health\,outcome_i \mid F, EP_i = 1\right) = F\left(\beta_0 + \beta_1 X_i + \beta_2 B_i + \beta_3 \gamma_i + c_i\right) + \rho\sigma_\epsilon \lambda\left(Z\delta\right) \quad (3)$$

where ρ is the correlation between the unobserved determinants of energy poverty and unobserved determinants of particular health outcomes ϵ, and λ is the inverse Mills ratio evaluated at $Z\delta$.

Finally, to assess the relative effects of the energy poverty indicators, the building characteristics, and the individual and household traits on the probability of having particular health outcomes, we use the Shapley decomposition method proposed by Shorrocks (2013). The Shapley decomposition originated with income poverty decomposition and provides estimates of the relative contribution of particular variables (or their groups) to the variance of a given outcome, in our case – the probability of a given disease. In the decomposition, we distinguish between five groups of variables (Table 4).

3. Results

3.1. Descriptive results

3.1.1. Housing and energy poverty

Almost 30% of the respondents in Ruda Śląska and more than 20% of the respondents in Tychy reported living in a house with substandard conditions, i.e., in a mouldy house with leaking windows or a leaking roof (Figure 1). More than 10% of the respondents indicated that they could not heat their homes adequately, and 8% of both cities' inhabitants suffered from at least one deprivation.

In general, a higher share of people in Ruda Śląska was energy-poor than in Tychy, according to four of five energy poverty indicators. The higher risk of energy poverty among inhabitants of Ruda Śląska is likely related to the differences in the socio-spatial characteristics of these cities. First, compared to Tychy, Ruda Śląska has an older urban structure: 47% of the respondents in Ruda Śląska, but only 25% in Tychy live in a building constructed before 1960. The year a building was constructed and the type of building are major energy poverty risk factors (Bouzarovski & Herrero, 2017). In Poland, the oldest multi-family buildings are usually less energy efficient and tend to be inhabited by people with lower incomes, retirees or social transfer beneficiaries (Sokołowski *et al.*, 2020).

Second, a higher share of households uses solid fuels as a heating source in Ruda Śląska (57%, compared to 25% in Tychy), and a lower share of households lives in multi-family estates connected to district heating (31% in Ruda Śląska compared to 56% in Tychy). According to most indicators, the share of individuals who suffer

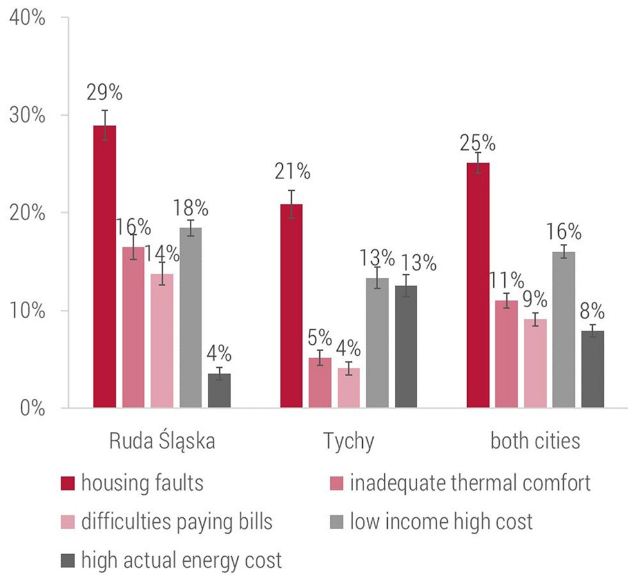

Figure 1. Share of the population in Ruda Śląska and Tychy identified as energy-poor (%). *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

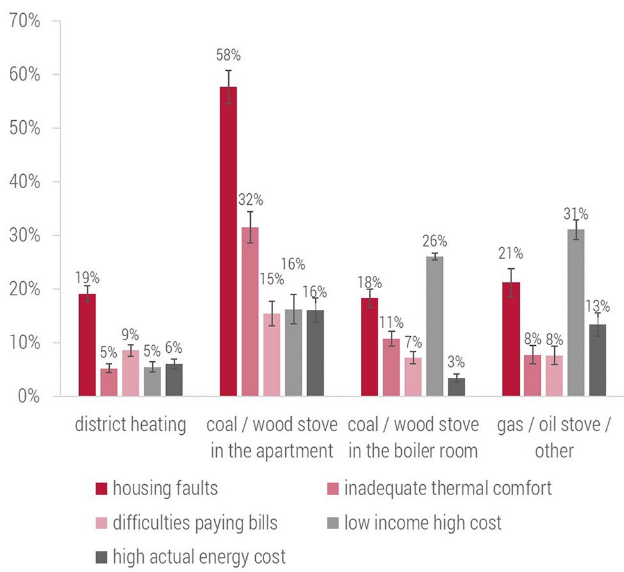

Figure 2. Share of the population in Ruda Śląska and Tychy identified as energy-poor by their primary heating source and its location (%). *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

from energy poverty is significantly lower among those respondents who said they are connected to district heating. Most (almost 60%) of the respondents who reported living in an apartment with coal or a wood stove also said they have a faulty house. One in three respondents who reported using a solid fuel stove indicated that they find their house too cold (Figure 2).

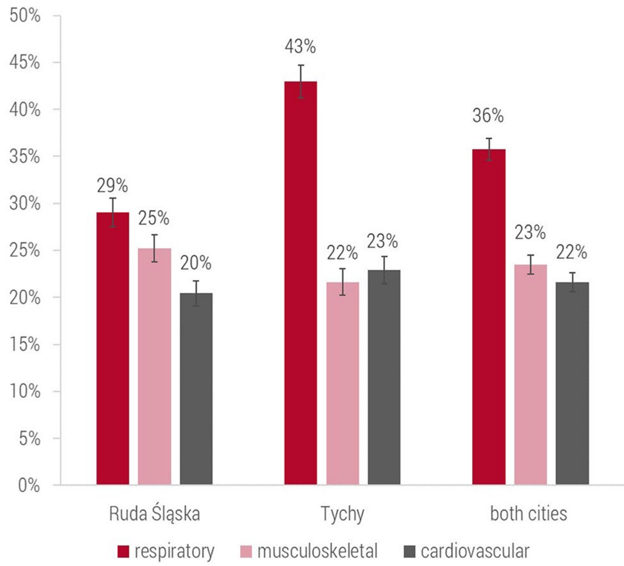

Figure 3. Share of the population in Ruda Śląska and Tychy reporting poor health outcomes (%). *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

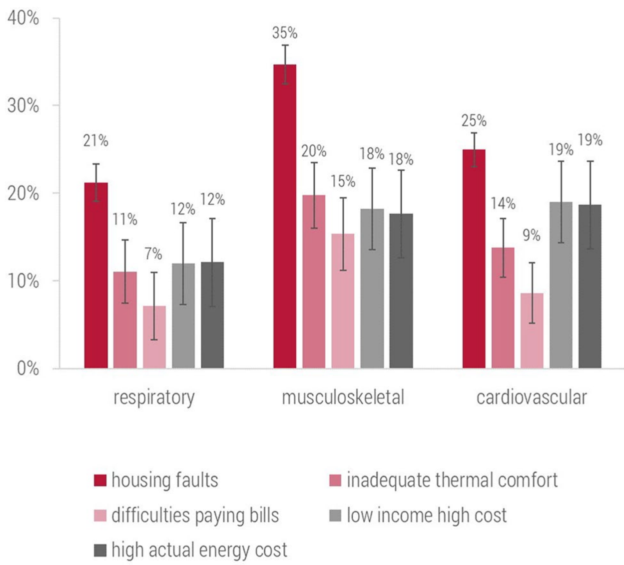

Figure 4. Share of people reporting a given medical condition by deprivations (%). *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

3.1.2. Health outcomes

We find that poor respiratory outcomes are our sample's most common health condition, followed by cardiovascular and musculoskeletal disorders (Figure 3). The high prevalence of respiratory conditions is related to people's socio-economic status and environmental exposure to risk factors, e.g. indoor and outdoor air pollution, which is especially important in coal-intensive regions with highly polluted air (WHO, 2018a).

For each type of disease, living in substandard housing conditions (e.g., mould; leaking windows, doors, or roof) is the most common deprivation observed among the individuals who reported a health issue (Figure 4). The shares of respondents who indicated that they suffer from any deprivation are found to be high among those who reported having musculoskeletal or cardiovascular disease. These patterns align with previous research demonstrating that living in substandard housing conditions and inadequate thermal comfort was related to the risk of musculoskeletal disorders (Pienimäki, 2002), while social status was associated with the risk of having poor cardiovascular outcomes (Tang *et al.*, 2016).

3.2. Econometric results: risk factors of poor health outcomes

The descriptive results suggest a link between poor housing conditions and poor health outcomes. Next, we investigate the relationship between living in housing with inefficient heating and other deprivations as correlates of poor health. To this aim, we estimate regressions that allow us to compare the correlates of particular diseases (i.e., musculoskeletal, cardiovascular, and respiratory) for individuals suffering from deprivation.[6]

We distinguish between health risk factors related to housing and socio-economic factors. First, we discuss the correlates of poor health related to building characteristics and deprivations. Second, we analyse the differences between people who own their apartments and those who rent an apartment in a municipal building. Third, we discuss the relationship between having inefficient heating sources and respiratory diseases. Finally, we discuss the socio-economic characteristics associated with being in poor health.

We find that two deprivations are associated with poor health outcomes to the largest extent. First, individuals who live in a faulty house (with mould or a leaking roof) have a significantly higher risk of musculoskeletal and cardiovascular disease (on average by 10.6 and 6 pp, respectively) than people who live in suitable housing conditions (Table 5). Second, individuals who spend a relatively large share of their income on heating are significantly more likely to suffer from respiratory disease (by 18.5 pp on average) than people who do not experience such deprivation.

Our results also show that people who live in municipal housing are at higher risk of poor health outcomes than those who own their apartments, even if we account for differences in incomes and housing costs. Inhabitants of municipal buildings have a significantly higher risk of a musculoskeletal condition (by 11.1 pp on average) than apartment owners. This higher risk of musculoskeletal diseases can be explained by the fact that, in Poland, the multi-family buildings owned by municipalities are often in poor condition and lack basic amenities. Additionally, people's ownership status may limit their capability to perform small-scale improvements and renovations (insulating windows and doors, getting rid of mould), and especially to make more expensive investments, such as deep retrofits (Muzioł-Węcławowicz & Nowak, 2018).

Importantly, we find that among the energy-poor, the type and the location of the primary heating source are related to their risk of having poor health outcomes.

Table 5. Marginal effects of selected correlates of particular health outcomes and energy poverty.

Independent variable	Dependent variable: Total sample – Musculoskeletal	Total sample – Respiratory	Total sample – Cardiovascular	Model limited to the energy-poor sample – Musculoskeletal	Model limited to the energy-poor sample – Respiratory	Model limited to the energy-poor sample – Cardiovascular
Logarithm of placement on the subjective health scale	−0.179***	−0.062	−0.306***	−0.107	−0.082	−0.342***
	(0.062)	(0.096)	(0.061)	(0.069)	(0.094)	(0.102)
Logarithm of equivalised income	−0.003	0.148**	−0.053	—	—	—
	(0.051)	(0.062)	(0.036)			
Age	Reference level: < 20					
21–40	0.023	−0.234***	−0.089	0.319**	−0.154*	−0.143
	(0.084)	(0.072)	(0.086)	(0.136)	(0.093)	(0.154)
41–60	0.179**	−0.153*	0.026	0.505***	−0.092	−0.113
	(0.091)	(0.080)	(0.078)	(0.142)	(0.107)	(0.153)
>60	0.216**	−0.213**	0.169**	0.480***	−0.106	0.228
	(0.091)	(0.096)	(0.081)	(0.143)	(0.134)	(0.163)
Male	Reference level: female					
	−0.037	−0.005	0.054**	0.007	0.013	0.090*
	(0.023)	(0.022)	(0.022)	(0.036)	(0.041)	(0.046)
Tychy	Reference level: Ruda Śląska					
	0.043	0.133***	0.019	−0.009	0.136**	0.051
	(0.031)	(0.045)	(0.026)	(0.045)	(0.062)	(0.067)
Year of building construction	Reference level: before 1946					
1946–1960	−0.018	0.049	−0.020	−0.072	0.025	−0.053
	(0.043)	(0.066)	(0.037)	(0.072)	(0.075)	(0.086)
1961–1980	−0.057	0.046	0.003	−0.122	0.130	−0.058
	(0.046)	(0.073)	(0.040)	(0.086)	(0.086)	(0.093)
After 1980	−0.178***	0.029	0.035	−0.327***	0.137	−0.007
	(0.062)	(0.083)	(0.045)	(0.119)	(0.124)	(0.115)
Municipal	Reference level: outright ownership					
	0.111***	−0.010	0.002	0.098	−0.033	0.015
	(0.042)	(0.064)	(0.038)	(0.063)	(0.073)	(0.077)
Housing association	0.031	0.060	0.043	0.020	0.064	0.081
	(0.041)	(0.052)	(0.037)	(0.069)	(0.071)	(0.081)
Heating system type	Reference level: district heating					
Coal/wood stove in the apartment	−0.132**	0.054	−0.081	−0.163	0.241***	−0.146
	(0.060)	(0.081)	(0.050)	(0.103)	(0.089)	(0.097)
Coal/wood stove in the boiler room	−0.120*	−0.059	−0.132***	−0.178*	0.124	−0.289***
	(0.063)	(0.082)	(0.040)	(0.095)	(0.101)	(0.091)
Gas/oil stove/other in the apartment/ boiler room	−0.016	0.042	−0.047	−0.112	0.212**	−0.160*
	(0.058)	(0.079)	(0.040)	(0.083)	(0.087)	(0.089)
	Reference level: absence of given characteristic					
High actual energy costs	0.034	0.185***	−0.017	—	—	—
	(0.041)	(0.067)	(0.033)			
Housing faults	0.106***	−0.054	0.060**	—	—	—
	(0.035)	(0.055)	(0.029)			
Adjusted R^2	0.3954	0.129	0.4978			
Number of observations	1215					

Notes: Standard errors clustered at the household level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The model limited to the energy-poor calculated with the Heckman sample correction equation described in (3).
Source: Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

Energy-poor people who heat their homes with a solid fuel stove located in their apartment are significantly more likely to suffer from respiratory disease (by 24.1 pp on average) than energy-poor people who live in apartments connected to district heating. Similarly, energy-poor people who heat their homes with gas or oil stoves have a higher risk of respiratory disease (by 21.2 pp on average) than those who live in apartments connected to district heating. However, the primary heating source is not a significant risk factor in the total sample. Therefore, we suppose that people with substandard living conditions, high energy bills, and low incomes are more likely to use inefficient heating sources and low-quality fuel (Brunner *et al.*, 2012; González-Eguino, 2015). They also may face higher levels of indoor air pollution related to poor respiratory outcomes. The non-deprived households are more likely to afford better fuel and heat the house with an efficient stove (Sokołowski & Frankowski, 2020).

Next, we discuss the role of socio-economic characteristics. Focusing on musculoskeletal and cardiovascular diseases, we find that socio-economic characteristics related to the risk of these diseases are similar. People who are generally in better health (according to their placement on a subjective health scale) have a significantly lower risk of cardiovascular and musculoskeletal diseases (by more than 17 and 30 pp, respectively). Also, the older the person is, the higher the person's risk of musculoskeletal and cardiovascular diseases.

However, the main socio-economic characteristics associated with risk of respiratory diseases differ from those related to having poor musculoskeletal and cardiovascular outcomes. The largest of these differences is that older people have a lower risk of suffering from respiratory diseases than younger people (by 20 pp on average). A higher risk of respiratory diseases among the youth is in line with other studies that found children and younger people to be especially prone to developing respiratory disorders, such as flu and asthma (WHO, 2018b). We also find that the higher the equivalised income is, the higher the risk of a respiratory disease is (by 14.8 pp on average). Following, e.g. Kahneman & Deaton (2010) or Levin-Zamir *et al.* (2016), we think this feature can be attributed to a greater awareness of health issues among better-situated individuals.

Next, we use the Shapley decomposition to assess the relative contribution of energy poverty and other controls in our models to the variance in the likelihood of having a given disease in our sample. In the total sample, the energy poverty risk is the third most important factor behind the differences in the likelihood of poor health outcomes (Figure 5). About 16% of the explained variance in the probability of having poor respiratory outcomes is attributable to energy poverty indicators, compared to almost 9% and 8% in the case of musculoskeletal and cardiovascular disorders, respectively. Age and occupation contribute the most (on average, around 50%) to the variance in the likelihood of each disease.

Building and heating characteristics also play an essential role in the likelihood of suffering from a given disease, especially respiratory disease. In the total sample, 15% of the variance in the probability of a respiratory disorder can be attributed to the differences in building and heating characteristics. In the case of the variance in the likelihood of musculoskeletal and cardiovascular diseases, it is 5% and 4%, respectively. However, the role of the building and heating characteristics is larger among energy-poor individuals: they explain 24% of the variance in the risk of respiratory diseases, 15% for musculoskeletal diseases, and 12% for cardiovascular

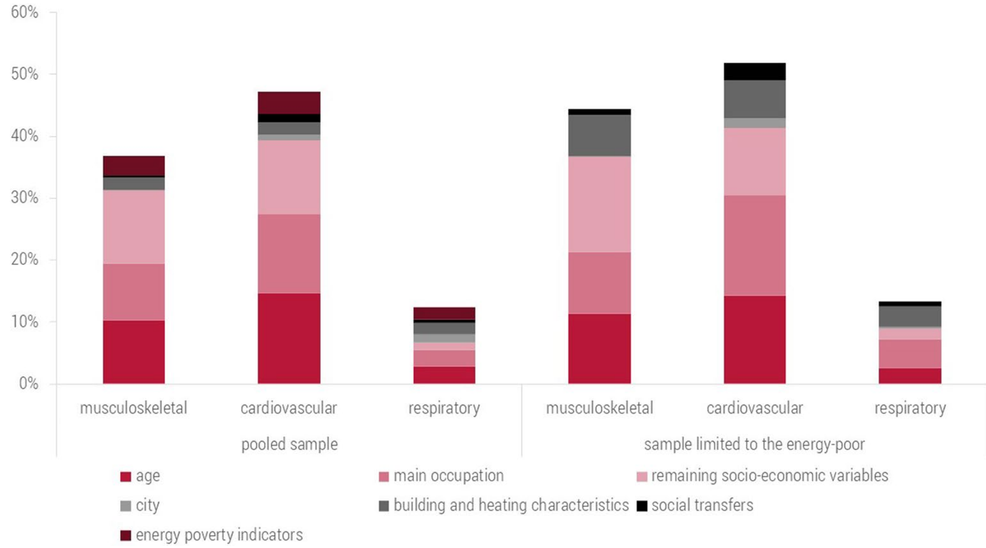

Figure 5. Shapley decomposition of the probability of having a particular disease. *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

diseases. In the total model (and its re-estimated version on the energy-poor sample), individual traits explain around 80% of the variance in the probability of having poor musculoskeletal and cardiovascular outcomes (and 50% for respiratory diseases).

Finally, the explained variance in the likelihood of respiratory disorders is lower than in the models for cardiovascular and musculoskeletal diseases. We hypothesise this is because many respiratory diseases are infectious, and we could not control for various factors associated with rates of infection and transmission among individuals, such as humidity, temperature, seasonal changes in behaviour, or pre-existing immunity (Pica & Bouvier, 2012). Moreover, our data collection period overlapped with the flu season in Poland (there were almost 70,000 flu cases in Upper Silesia in three weeks of the data collection, i.e., 2% of the population; the average daily incidence was 72 cases per 100,000 people).

4. Discussion

Our findings allow us to forumalate recommendations for energy and housing policies in Poland. In particular, we recommend: (1) a full subsidy for thermal retrofit and connecting multi-family buildings to the district heating network and (2) a targeted energy voucher for clean heating.

First, we recommend a full subsidy for thermal retrofits that are likely to provide significant energy savings if targeted at energy-poor households (Tonn *et al.*, 2021). Connecting low-quality multi-family buildings to district heating with retrofits should help to improve the living conditions of people in energy poverty. As the energy-poor households concentrate in hot spots beyond the range of district heating networks (Figure 6), these areas make a relevant case for further targeted interventions and

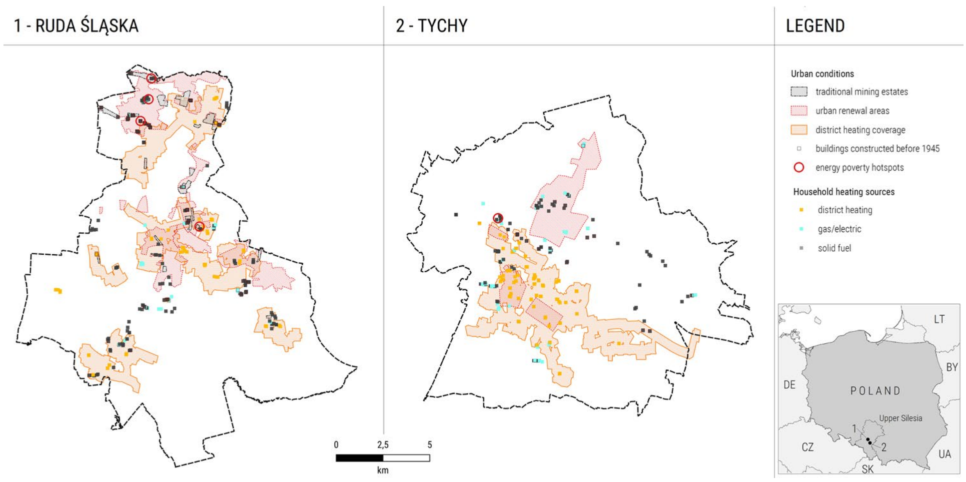

Figure 6. Spatial patterns of energy poverty in Ruda Śląska and Tychy. *Source:* Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

policies. Therefore, we argue for fully-funded retrofits matched with district heating connections introduced within the scope of urban renewal policies. Urban renewal via thermal retrofits and district heating connections would combine social, economic, and environmental aims. A full subsidy for thermal retrofit and connecting multi-family buildings to district heating would improve the technical condition of buildings and increase the inhabitants' quality of life. The benefits of a full subsidy would most likely exceed the previously applied approaches to urban renewal, limited to aesthetic public space improvements. Moreover, in the case of municipal buildings, the rent after the investment with public support should remain stable to avoid gentrification. The information about the costs after investment should be communicated at the very early stage of a particular thermal retrofit, as the scarcity of information about future housing costs can lead to displacements within municipal buildings (Bouzarovski *et al.*, 2018).

Second, we suggest introducing an energy voucher to protect energy-poor households from an increase in energy expenditures due to investment in a new heating source. The voucher could be adjusted to income and the household's heating fuel. Changing the amount of support to the different heating fuels used by households would promote sustainable technologies and, consequently, help progress towards energy transition in countries and regions that heavily depend on coal. On the eve of the most challenging heating season in Europe, in August 2022 Polish government introduced a 'coal allowance' (635 EUR one-time per household) which favours households with coal stoves, regardless of their incomes. The scarcity of coal resources and the rapid increase in fuel prices justified this funding scheme. We suggest broadening the support for district heating, pellet, seasoned wood, gas, and oil but targeted to low-income households, as it would be a more equitable and less expensive solution for the state budget.[7]

The energy efficiency interventions in the housing stock could positively affect public health by reducing the risk of musculoskeletal and cardiovascular diseases

(Poortinga *et al.*, 2018). Better housing conditions would also improve the general quality of life of people in energy poverty by, for example, lowering their spending on heating and increasing their disposable income that could be used to cover other expenses. Additionally, improving the efficiency of the heating sources used by the energy-poor population may lower their risk of respiratory disorders.

Finally, we suggest stepping up efforts in tackling energy poverty resulting from the recent public policy challenges: the COVID-19 pandemic and decarbonisation (Sokołowski, 2020). Housing conditions, limited access to health services and air pollution can all increase the risk of infection and mortality due to respiratory failure. As a result of the pandemic, EU countries have introduced additional measures to reduce housing hardship and energy poverty. The most common forms of support in the EU countries included eviction bans, utility disconnection bans, a cap on rent increases or more accessible housing benefits (Hesselman *et al.*, 2021). We suggest maintaining these policy instruments or increasing the funds allocated to repairs of municipal housing and compensation for higher energy expenses among the most vulnerable population.

5. Conclusions

In this paper, we have studied the relationship between energy poverty, housing conditions and poor health outcomes. We used data from a purposefully structured survey on a sample of 1,735 individuals (700 households) in two middle-sized industrial cities in Southern Poland. For the first time, we studied the relationship between energy poverty and health in Poland based on a detailed dataset designed and implemented with this aim in mind.

Our findings indicate that living in substandard housing increases the risk of musculoskeletal and cardiovascular diseases. We have highlighted a significant difference between the energy-poor and the non-poor population in their exposure to the risk of respiratory diseases. Among the energy-poor households, living in an apartment with coal or a wood stove was associated with a higher risk of respiratory diseases. This finding suggests that using inefficient stoves and fuel is associated with significantly higher levels of indoor air pollution and, in turn, a higher probability of respiratory disorders. Finally, we showed that substandard housing conditions are the most common energy poverty factor among people who reported having any disease.

Our study has limitations. It is based exclusively on self-reported health assessments. It is also a cross-sectional study, which does not allow us to conclude causality. Our study is situated in the local context of two cities in Poland. However, we believe that the findings confirm intuitional knowledge and can offer valuable insights for policymakers seeking to improve the living conditions of people in poverty or to design transition policies to reduce solid fuel consumption. Finally, we scheduled the fieldwork one month before the start of the pandemic crisis and the lockdown. On the one hand, our data do not consider the pandemic's effect or its relationship to energy poverty. On the other, our dataset may be helpful to researchers assessing the effects of the pandemic, especially if similar surveys are conducted in the future or if our research is extended to additional locations.

Notes

1. Descriptive statistics of our sample are shown in Table A1 in the Appendix.
2. The weighting procedure is described in Appendix B.
3. We also included questions on psychiatric/other disorders in the questionnaire. The response rates for these questions were low, and would not allow for detailed modelling. We matched the diseases from the "other" category to the three main disorders in all of the cases the data allowed. We decided against modelling the remaining responses, as they differed substantially; e.g., allergies and cancer would be included in one category of disorders.
4. Each indicator provides supplementary information: the correlation between particular indicators is relatively low. The highest observed correlation between the components of an indicator is 0.81 between a cardiovascular disease confirmed by a physician and a doctor's appointment.
5. We decided against using a multinomial probit because particular outcomes (diseases) can overlap, even though it affects only a small share of our sample (8-9%). We run a probit model for robustness and report the results in the Appendix A, Table A5.
6. While the methods we apply are in line with previous research (e.g., Llorca *et al.*, 2020; Oliveras *et al.*, 2020), we focus on detailed health outcomes, and on differences between individuals who are and are not in energy poverty.
7. The social proposition of the energy allowance included a one-off, 3,000 PLN (approx. 635 EUR) allowance for people with low incomes living in single-family houses and 1,000 PLN (approx. 170 EUR). The social project is aimed at households with the lowest incomes, regardless of the heat source they use, meeting the income criteria under the so-called "Anti-inflation Shield" enacted by the Polish government in 2021.

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Appendix A

Table A1. Descriptive statistics of selected variables in the sample

Variable	Value	%
City	Frequency	%
Ruda Śląska	895	51.59
Tychy	840	48.41
Gender	Frequency	%
Women	913	52.62
Man	822	47.38
Type of building	Frequency	%
Detached house	769	44.27
Multifamily building	967	55.73
Year of building construction	Frequency	%
Before 1945	278	16.02
1946–1960	415	39.04
1961–1980	738	42.54
After 1981	304	17.52
Main heating source	Frequency	%
District heating	709	40.86
Coal/wood stove in the apartment	253	14.58
Coal/wood stove in the boiler room	524	30.2
Gas/oil stove/other	249	14.35
Main occupation	Frequency	%
Employed	848	48.88
Unemployed	113	6.51
Student	250	14.41
Retired/pensioner	404	23.29
Social transfer beneficiary	120	6.92
Age	Frequency	%
0–20	342	19.71
21 – 40	515	29.68
41–60	496	28.59
61 and more	382	22.02
Monthly income	Mean	SD
	3681.11	3502.46

Source: Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

Table A2. Correlations between specific health indicators

Respiratory	Confirmed by a physician	Self-diagnosed	Doctor's appointment (last 12 months)
Self-diagnosed	−0.121		
Doctor's appointment (last 12 months)	0.636	0.002	
Hospital visit (last 12 months)	0.085	0.045	0.104
Musculoskeletal	Confirmed by a physician	Self-diagnosed	Doctor's appointment (last 12 months)
Self-diagnosed	−0.0904		
Doctor's appointment (last 12 months)	0.731	0.014	
Hospital visit (last 12 months)	0.320	−0.005	0.412
Cardiovascular	Confirmed by a physician	Self-diagnosed	Doctor's appointment (last 12 months)
Self-diagnosed	−0.047		
Doctor's appointment (last 12 months)	0.817	0.077	
Hospital visit (last 12 months)	0.342	0.079	0.382

Source: Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735)

Table A3. Marginal effects of selected correlates of particular health outcomes and energy poverty

	Dependent variable					
	Total sample			Model limited to the energy-poor sample		
Independent variable	Musculoskeletal	Respiratory	Cardiovascular	Musculoskeletal	Respiratory	Cardiovascular
	Reference level:					
Manager/professional	−0.028	−0.063	−0.007	0.102	−0.083	0.066
	(0.074)	(0.088)	(0.055)	(0.095)	(0.106)	(0.124)
Technician/clerical support	−0.038	−0.069	−0.021	−0.268***	−0.364**	−0.119
	(0.061)	(0.085)	(0.052)	(0.095)	(0.144)	(0.121)
Services	−0.003	−0.100	−0.000	−0.021	−0.284***	0.083
	(0.051)	(0.087)	(0.054)	(0.084)	(0.106)	(0.121)
Craft	−0.158***	−0.049	0.020	−0.236***	−0.081	0.029
	(0.061)	(0.107)	(0.047)	(0.078)	(0.105)	(0.099)
Machines/elementary	0.043	−0.115	−0.139*	−0.046	−0.057	−0.212*
	(0.055)	(0.090)	(0.072)	(0.069)	(0.084)	(0.114)
School/university student	−0.065	0.035	−0.181*	0.021	0.007	−0.306*
	(0.103)	(0.096)	(0.098)	(0.138)	(0.109)	(0.184)
Retired or pensioner	0.103*	0.058	0.026	0.186**	0.005	−0.022
	(0.053)	(0.099)	(0.048)	(0.075)	(0.103)	(0.103)
Beneficiary of a social transfer	−0.047	0.046	−0.109	0.211	−0.097	−0.086
	(0.107)	(0.110)	(0.100)	(0.149)	(0.126)	(0.169)
Multifamily building	Reference level: single-family building					
	−0.074	0.133*	−0.046	−0.100	0.204**	−0.064
	(0.066)	(0.071)	(0.043)	(0.093)	(0.094)	(0.089)
Logarithm of floor area	0.029	0.063	0.019	0.005	0.116*	−0.043
	(0.042)	(0.054)	(0.032)	(0.063)	(0.061)	(0.075)
Concrete/panel	Reference level: wooden building					
building	0.020	−0.134	−0.056	0.030	−0.257*	0.017
	(0.071)	(0.089)	(0.056)	(0.101)	(0.120)	(0.110)
Concrete/panel building	0.019	−0.134	0.030	0.048	−0.131	0.050
	(0.062)	(0.083)	(0.047)	(0.088)	(0.106)	(0.103)
	Reference level: absence of given characteristic					
Uninsulated house	−0.035	0.072	−0.013	−0.050	−0.025	−0.031
	(0.030)	(0.047)	(0.021)	(0.054)	(0.058)	(0.053)
Leaking windows/ doors	0.090**	0.102	0.012	0.013	0.149**	−0.113
	(0.040)	(0.075)	(0.039)	(0.055)	(0.067)	(0.074)
Unventilated house	0.078*	0.035	0.012	0.025	0.036	−0.073
	(0.047)	(0.074)	(0.047)	(0.059)	(0.068)	(0.075)
Beneficiary of housing/ energy/heating/ allowance	−0.035	−0.132*	0.111***	—	—	—
	(0.046)	(0.075)	(0.034)			
Beneficiary of social/ unemployed allowance/charity	0.022	0.045	−0.100***	—	—	—
	(0.041)	(0.061)	(0.036)			
Beneficiary of coal allowance	−0.098	−0.103	0.067*	−0.121	−0.037	0.039
	(0.065)	(0.079)	(0.038)	(0.083)	(0.076)	(0.082)
Low income high cost	0.024	0.058	0.022	—	—	—
	(0.041)	(0.063)	(0.035)			
Difficulties paying bills	0.008	−0.017	−0.012	—	—	—
	(0.047)	(0.089)	(0.047)			
Inadequate thermal comfort	−0.017	0.041	−0.161***	—	—	—
	(0.049)	(0.071)	(0.041)			
Adjusted R^2						
Number of observations	1,215					

Notes: standard errors clustered at the household level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The model limited to the energy-poor calculated with the Heckman sample correction equation described in (3).
Source: own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735)

Table A4. Marginal effects of correlates of particular health outcomes and energy poverty in the selection equation of the Heckman sample correction

Independent variable	Dependent variable: Musculoskeletal	Respiratory	Cardiovascular
Logarithm of placement on the subjective health scale	0.067	0.072	0.067
	(0.088)	(0.086)	(0.088)
Logarithm of equivalised income	−0.242***	−0.231***	−0.227***
	(0.072)	(0.072)	(0.068)
Age	Reference level: < 20		
21–40	−0.039	−0.040	−0.037
	(0.081)	(0.081)	(0.082)
41–60	0.030	0.029	0.031
	(0.092)	(0.092)	(0.093)
> 60	0.077	0.077	0.078
	(0.104)	(0.104)	(0.105)
Male	Reference level: female		
	−0.021	−0.022	−0.023
	(0.028)	(0.028)	(0.027)
Tychy	Reference level: Ruda Śląska		
	0.028	0.035	0.034
	(0.051)	(0.051)	(0.050)
Year of building construction	Reference level: before 1946		
1946–1960	0.110	0.112	0.107
	(0.076)	(0.075)	(0.076)
1961–1980	0.148*	0.145*	0.146*
	(0.084)	(0.083)	(0.083)
After 1980	0.055	0.049	0.053
	(0.098)	(0.097)	(0.097)
Ownership	Reference level: outright ownership		
Municipal	−0.023	−0.026	−0.023
	(0.068)	(0.067)	(0.067)
Housing association/cooperative	−0.059	−0.057	−0.059
	(0.062)	(0.062)	(0.061)
Heating system type	Reference level: district heating		
Coal/wood stove in the apartment	0.268***	0.277***	0.283***
	(0.088)	(0.087)	(0.086)
Coal/wood stove in the boiler room	−0.047	−0.034	−0.028
	(0.093)	(0.093)	(0.091)
Gas/oil stove/other in the apartment/ boiler room	0.092	0.105	0.104
	(0.093)	(0.094)	(0.091)
Multifamily building	Reference level: single-family building		
	0.100	0.100	0.106
	(0.089)	(0.088)	(0.087)
Logarithm of floor area	0.191***	0.182***	0.184***
	(0.064)	(0.064)	(0.062)
Main construction material	Reference level: wooden building		
Concrete/panel building	−0.081	−0.078	−0.095
	(0.103)	(0.104)	(0.102)
Building made of bricks	0.018	0.018	−0.000
	(0.093)	(0.094)	(0.094)

(Continued).

Table A4. (Continued).

Independent variable	Dependent variable: Musculoskeletal	Respiratory	Cardiovascular
Reference level: unemployed			
Manager/professional	0.032	0.036	0.034
	(0.080)	(0.079)	(0.079)
Technician/clerical support	0.024	0.026	0.030
	(0.072)	(0.072)	(0.072)
Services	−0.073	−0.069	−0.068
	(0.071)	(0.071)	(0.071)
Craft	0.063	0.061	0.058
	(0.071)	(0.070)	(0.070)
Machines/elementary	0.064	0.072	0.077
	(0.074)	(0.075)	(0.075)
School/university student	−0.007	−0.004	−0.001
	(0.099)	(0.098)	(0.099)
Retired or pensioner	−0.002	−0.000	0.007
	(0.069)	(0.068)	(0.069)
Beneficiary of a social transfer	0.033	0.034	0.036
	(0.099)	(0.099)	(0.099)
Reference level: absence of given characteristic			
Uninsulated house	0.071	0.071	0.075
	(0.047)	(0.047)	(0.046)
Leaking windows/doors	0.141*	0.141*	0.134*
	(0.074)	(0.072)	(0.073)
Unventilated house	0.260***	0.257***	0.273***
	(0.079)	(0.076)	(0.081)
Beneficiary of housing/energy/ heating/allowance	0.212**	0.231***	0.230***
	(0.083)	(0.077)	(0.073)
Beneficiary of social/unemployed allowance/charity	0.001	−0.009	−0.012
	(0.080)	(0.074)	(0.071)
Beneficiary of coal allowance	0.099	0.109	0.105
	(0.072)	(0.071)	(0.070)
Number of observations		1,215	

Notes: Standard errors clustered at the household level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Source: Own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735)

Table A5. Marginal effects of selected correlates of particular health outcomes and energy poverty (probit model)

	Dependent variable					
	Total sample			Model limited to the energy-poor sample		
Independent variable	Musculoskeletal	Respiratory	Cardiovascular	Musculoskeletal	Respiratory	Cardiovascular
Logarithm of placement on the subjective health scale	−0.180***	−0.063	−0.292***	−0.062	−0.162	−0.252***
	(0.058)	(0.095)	(0.057)	(0.073)	(0.119)	(0.080)
Logarithm of equivalised income	0.002	0.144**	−0.049	−0.109**	0.013	−0.060
	(0.048)	(0.061)	(0.035)	(0.053)	(0.083)	(0.051)
Age	Reference level: <20					
21–40	0.036	−0.239***	−0.060	0.379***	−0.186	−0.134
	(0.070)	(0.076)	(0.065)	(0.127)	(0.116)	(0.122)
41–60	0.174**	−0.162*	0.048	0.573***	−0.136	−0.077
	(0.077)	(0.083)	(0.062)	(0.135)	(0.137)	(0.117)
>60	0.216***	−0.221**	0.198***	0.558***	−0.170	0.201*
	(0.079)	(0.098)	(0.068)	(0.138)	(0.163)	(0.119)
Reference level: female						
Male	−0.041*	−0.008	0.048**	0.013	0.032	0.065*
	(0.022)	(0.032)	(0.022)	(0.039)	(0.051)	(0.039)
Reference level: Ruda Śląska						
Tychy	0.036	0.129***	0.014	−0.039	0.206***	0.044
	(0.030)	(0.044)	(0.026)	(0.045)	(0.075)	(0.052)
Year of building construction	Reference level: before 1946					
1946–1960	−0.025	0.053	−0.021	−0.102	0.022	−0.036
	(0.044)	(0.066)	(0.036)	(0.070)	(0.100)	(0.071)
1961–1980	−0.058	0.045	0.003	−0.169**	0.152	−0.024
	(0.047)	(0.072)	(0.038)	(0.084)	(0.112)	(0.073)
after 1980	−0.169***	0.032	0.029	−0.416***	0.196	0.000
	(0.059)	(0.082)	(0.043)	(0.131)	(0.155)	(0.089)
Reference level: outright ownership						
Municipal	0.107**	−0.006	−0.013	0.127*	−0.009	−0.003
	(0.041)	(0.064)	(0.037)	(0.071)	(0.092)	(0.061)
Housing association/cooperative	0.025	0.064	0.036	0.003	0.086	0.066
	(0.039)	(0.052)	(0.035)	(0.073)	(0.095)	(0.062)
Reference level: district heating						
Coal/wood stove in the apartment	−0.122**	0.045	−0.070	−0.201**	0.271**	−0.065
	(0.058)	(0.081)	(0.047)	(0.095)	(0.116)	(0.075)
Coal/wood stove in the boiler room	−0.108*	−0.059	−0.132***	−0.184*	0.161	−0.239***
	(0.058)	(0.080)	(0.038)	(0.096)	(0.118)	(0.068)
Gas/oil stove/other in the apartment/boiler room	−0.015	0.042	−0.038	−0.093	0.231**	−0.093
	(0.053)	(0.078)	(0.037)	(0.078)	(0.101)	(0.061)

(Continued).

Table A5. (Continued).

	Dependent variable					
	Total sample			Model limited to the energy-poor sample		
Independent variable	Musculoskeletal	Respiratory	Cardiovascular	Musculoskeletal	Respiratory	Cardiovascular
Reference level: detached building						
Multifamily building	−0.057	0.131*	−0.040	−0.058	0.222**	−0.023
	(0.059)	(0.072)	(0.041)	(0.094)	(0.110)	(0.066)
Logarithm of floor area	0.035	0.066	0.016	0.068	0.097	0.011
	(0.041)	(0.055)	(0.030)	(0.063)	(0.082)	(0.054)
Main construction material						
Concrete/panel building	0.016	−0.128	−0.049	0.067	−0.285*	−0.036
	(0.064)	(0.088)	(0.052)	(0.102)	(0.152)	(0.086)
Building made of bricks	0.012	−0.131	0.035	0.080	−0.144	0.026
	(0.057)	(0.082)	(0.045)	(0.089)	(0.137)	(0.076)
Reference level: unemplyed						
Manager/professional	−0.026	−0.072	−0.012	0.179*	−0.130	0.061
	(0.065)	(0.086)	(0.049)	(0.098)	(0.142)	(0.109)
Technician/clerical support	−0.022	−0.079	−0.024	−0.253**	−0.521***	−0.101
	(0.058)	(0.082)	(0.047)	(0.106)	(0.139)	(0.100)
Services	0.000	−0.101	−0.002	0.008	−0.409***	0.053
	(0.047)	(0.082)	(0.050)	(0.089)	(0.125)	(0.100)
Craft	−0.135**	−0.044	0.015	−0.216**	−0.170	0.053
	(0.055)	(0.100)	(0.047)	(0.084)	(0.124)	(0.075)
Machines/elementary	0.049	−0.111	−0.109*	−0.036	−0.118	−0.135
	(0.052)	(0.085)	(0.059)	(0.077)	(0.107)	(0.089)
School/university student	−0.048	0.026	−0.147*	0.067	−0.014	−0.248*
	(0.087)	(0.098)	(0.075)	(0.147)	(0.144)	(0.150)
Retired or pensioner	0.116**	0.053	0.033	0.212***	−0.032	−0.002
	(0.052)	(0.094)	(0.047)	(0.082)	(0.130)	(0.078)
Beneficiary of a social transfer	−0.009	0.033	−0.086	0.319**	−0.164	−0.060
	(0.094)	(0.110)	(0.081)	(0.151)	(0.163)	(0.131)
Reference level: absence of a given characteristic						
Uninsulated house	−0.035	0.068	−0.011	−0.065	−0.052	−0.004
	(0.030)	(0.047)	(0.021)	(0.053)	(0.076)	(0.040)
Leaking windows/doors	0.090**	0.099	0.012	0.005	0.185**	−0.060
	(0.040)	(0.074)	(0.036)	(0.057)	(0.086)	(0.057)
Unventilated house	0.080*	0.040	0.014	0.057	−0.003	−0.035
	(0.045)	(0.074)	(0.043)	(0.057)	(0.082)	(0.060)
Beneficiary of housing/energy/heating/allowance	−0.037	−0.124*	0.119***	−0.060	−0.143	0.097*
	(0.045)	(0.075)	(0.033)	(0.063)	(0.090)	(0.050)

Beneficiary of social/unemployed allowance/charity	0.028	0.044	−0.092***	0.130*	−0.062	−0.059
	(0.040)	(0.061)	(0.035)	(0.070)	(0.083)	(0.055)
Beneficiary of coal allowance	−0.104*	−0.110	0.081**	−0.134	−0.096	0.076
	(0.060)	(0.079)	(0.036)	(0.090)	(0.100)	(0.064)
Low income high cost	0.028	0.057	0.021	—	—	—
	(0.041)	(0.064)	(0.034)			
Difficulties paying bills	0.011	−0.018	−0.014	—	—	—
	(0.046)	(0.086)	(0.043)			
Inadequate thermal comfort	−0.016	0.041	−0.162***	—	—	—
	(0.047)	(0.071)	(0.040)			
High actual energy costs	0.038	0.184***	−0.018	—	—	—
	(0.041)	(0.068)	(0.034)			
Housing faults	0.099***	−0.050	0.059**	—	—	—
	(0.032)	(0.053)	(0.028)			
Number of observations	1,215					

Notes: standard errors clustered at the household level. ***p < 0.01, **p < 0.05, *p < 0.1.
Source: own elaboration based on the survey data collected in Ruda Śląska and Tychy (n = 1,735).

Appendix B: Weighting procedure

We used population weights based on information from Statistics Poland (GUS) for 2018 (the most recently available information at the time of writing). We weighted the composition of our sample with the shares of age groups and gender in Ruda Śląska and Tychy. Next, we re-weighted the sample according to the shares of households with different numbers of adults and children in Upper Silesia voivodship. Formally:

$$w_j = \frac{m}{M_j} * \frac{k_j}{K_j}$$

where w_{hi} is the weight in the city j, m is the share of households with the particular composition of adults and children in Silesian voivodship, M_j is the share in the sample in city j, k_j is the share of individuals of particular gender and age in city j and K_j is the share in the sample.