SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2024
ORGANIZATION AND MANAGEMENT SERIES NO. 198

ENERGY AND CLIMATE POLICY AS A DETERMINANT OF FUEL POVERTY IN POLAND

Rafał NAGAJ[1*], Bożena GAJDZIK[2]

[1] Institute of Economics and Finance University of Szczecin; rafal.nagaj@usz.edu.pl,
ORCID: 0000-0002-9410-7663
[2] Department of Industrial Informatics, Silesian University of Technology; bozena.gajdzik@polsl.pl,
ORCID: 0000-0002-0408-1691
* Correspondence author

Purpose: The aim of the study is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland.
Design/methodology/approach: The paper applies the method of regression analysis to assess the impact of climate and energy policy factors on fuel poverty in Poland. For this purpose, a literature review was carried out on the factors influencing fuel poverty and the development of climate and energy policy, particularly decarbonisation in the European Union, in order to identify potential determinants of fuel poverty. An empirical analysis was carried out of electricity and gas price developments and decomposition analysis of these prices in Poland in the studied period, and it was assessed using regression analysis which factors, among the instruments of energy and climate policies, determine fuel poverty in Poland.
Findings: The main finding is that climate and energy policies influence fuel poverty in Poland, especially share of renewable energy sources in energy mix and expenditures on environment protection. It was also found that macroeconomic policy instruments, which determine the level of income per capita and thus disposable income, have a statistically significant impact on fuel poverty in Poland. In addition, it was found that such instruments as taxes and social transfers are worth using for this purpose.
Research limitations/implications: It is recommended to deepen long-term research on the impact of these policies on fuel poverty. For the time being, the lack of long-term data limits the possibility for long-term analysis.
Practical implications: Unfortunately, there is a lack of detailed data on income decomposition in decile groups, which limits the possibility to accurately estimate the long-term level of fuel poverty in Poland.
Social implications: The regulation of fuel poverty would make it possible to constantly monitor the phenomenon and to apply instruments that would precisely limit this social phenomenon.
Originality/value: The paper provides information on the impact of climate and energy policy on fuel poverty in Poland. So far there have only been analyses of the scale of the phenomenon, not of the factors. It is addressed to fuel poverty practitioners and policy makers in the field of social and energy policy.
Keywords: fuel poverty, energy policy, climate policy, decarbonisation, Poland.
Category of the paper: research paper.

1. Introduction

The year 2022 represents a period of sharp increases in global energy prices and draws attention to the problem of societies' inability to consume energy at an adequate level. It should be noted, however, that the issues of energy poverty and fuel poverty have been addressed in the literature for a long time (Moore, 2012). Unfortunately, economic practice and policy makers, but also the literature, do not distinguish between these concepts, and in addition, in many countries, including Poland, this topic is either not regulated or is regulated indirectly through other socio-economic phenomena, i.e. social policy, energy policy, construction. Meanwhile, the war in Ukraine and the energy crisis have highlighted the problem of being unable to pay energy bills. Meanwhile, the literature on the subject has dealt with the phenomena of energy poverty and fuel poverty for many years. Furthermore, a distinction is made between energy poverty and fuel poverty, which is analysed in this paper (Moore, 2012). Energy poverty is the lack of access to energy carriers or the inability to consume energy due to either technical or network problems or a lack of an energy commodity or a purchasable good (Day, Walker, Simcock, 2016). Fuel poverty, meanwhile, is the difficulty to consume enough energy or to heat one's residence for financial reasons, i.e. either lack of sufficient income to cover energy expenses or because prices of energy carriers are too high (González-Eguino, 2015).

In addition, especially since the Energy and Gas Directive came into force, the European Union has been making numerous changes to the energy market, liberalising it. In addition, recent years have seen a strong emphasis on the decarbonisation of economies through climate policy. According to climate policy and the European Green Deal (European Commission), Member States are obliged to achieve zero carbon emissions by 2050. However, this involves several measures, such as gradually increasing the share of renewable energy sources (RES) in energy consumption, cutting energy consumption to increase energy efficiency, reducing greenhouse gas emissions (Gajdzik et al., 2024a). All these measures involve increasing state spending on environmental protection and passing on charges to end users in the bills they pay for electricity, gas or oil.

All these measures are accompanied, on the one hand, by an improvement in air quality, but, on the other, by a change in the amount that society, including households, must pay for energy carriers. All of this is linked to the phenomenon of the inability of some members of the public to pay their energy bills, i.e. fuel poverty. As the literature highlights (Kyprianou et al., 2019), not all EU member states, indeed most, including Poland, do not have and do not have policies directly aimed at reducing and monitoring fuel poverty. Moreover, it is often not known exactly how much fuel poverty there is in a country. Analyses are already appearing in the literature indicating how fuel poverty should be measured (Day, Walker, Simcock, 2016; Sałach, Lewandowski, 2018). In the case of Poland, however, there is extraordinarily little

research on fuel poverty (Nagaj, 2022a), and if there is any it concerns energy poverty (Górska, 2022). Similarly, when it relates to energy and climate policy, there is an extensive literature on the analysis of these policies (Gajdzik et al., 2023b; Leeuwen, Monios, 2022), whereas there is a lack of research on its impact on fuel poverty, including in Poland. The authors of this paper have therefore decided to fill this existing research gap in the literature.

The aim of this manuscript is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland. This objective is guided by three research tasks (RTs):

RT1: to estimate the fuel poverty rate in Poland in the studied period,

RT2: to review the literature concerning potential factors that may determine fuel poverty and how fuel poverty has been measured in Poland so far,

RT3: to analyse the impact of energy and climate policies on the level of fuel poverty in Poland by assessing the impact of the basic instruments associated with these two policies.

The research tasks formulated in this way are accompanied by the following research questions (RQs):

RQ1: What is the share of energy expenditure in household income and what is the fuel poverty rate in Poland in 2005-2022?

RQ2: What are determinants of the fuel poverty rate in Poland?

RQ3: Does energy and climate policy have an impact on fuel poverty in Poland?

The analysis covers the period 2005-2022, i.e., after accession to the EU. Climate and energy policy is mainly determined by EU policies and directives, which justifies this time horizon.

The work structure is as follows: first section presents the background of analysis based on narrative literature review about fuel poverty in Poland, and determinants of fuel poverty; second section concerns the materials and methods used during empirical analysis, it presents the methodology of the research, while the next section presents the research results for Poland. The last section of this paper is a set of conclusions and recommendations.

2. Background for analysis

The issue of energy poverty has been in the public debate since the 1970s. (since the oil crisis) but in recent years, energy poverty has increased in many countries, i.e. reducing their own energy consumption, mainly for financial reasons (PEI Report 2023; Schumacher, 1985; Ulucak et al., 2021). The determinants of energy poverty vary in their causes, societal reach and dynamics of changes in energy crisis. Energy poverty is affected by many factors, both objective and subjective, economic and financial, as well as other factors, including factors that are

dependent on and independent of the contributors to poverty. Thus, energy poverty is the result of the overlapping of various global, regional and local trends, as well as the effects of overlapping policies, including energy, fiscal, credit (banking), financial, etc. The determinants of energy poverty can be positive or negative, e. g. the energy crisis, which became apparent strongly after the COVID-19 pandemic (Gajdzik et al., 2024b). Many trends require monitoring and action by the public sector to address energy poverty. According to Shonali Pachauri and Narasimha D. Rao (2013), there is no generally accepted definition of energy poverty. For these authors energy poverty is "a term of a lack of access to adequate, reliable, affordable and clean energy carriers and technologies for meeting energy service needs for cooking and those enabled by electricity to support economic and human development". According to Day et al. (2016), energy poverty is "a situation of inability to realize the essential capabilities as a result of insufficient access to affordable, reliable and safe energy services, and taking into account the alternative means of realizing these capabilities reasonably". Another study defined energy poverty as "when the amount of energy used is lower than the minimum need to sustain a livelihood" (Barners et al., 2011). According to the IEA (2002), energy poverty is defined as a lack of access to commercial and clean fuels, electricity, efficient equipment, and high dependence on biomass, causing pollution. Energy Poverty Observatory 2021 defines energy poverty as the absence of vital energy services to individuals and households. Górska (2022) assumes that energy poverty is understood as a situation where heating costs exceed 10% of income. Winkler et al. (2011) define energy poverty as a state in which households spend a large share of income on energy-related expenditures. The EPEE (European Fuel Poverty and Energy Efficiency Project) defines energy poverty as "the lack of funds to maintain adequate heating at a fair price". Energy poverty refers to people who experience a lack of thermal comfort in their homes or who must limit their consumption of basic goods to pay their energy bills (Boardman, 1991; Hills, 2011). Boardman 2010, and Walker et al. 2012 assume that household income is one of the most important determinants of energy poverty. There are two key areas that need to be distinguished, the first is energy poverty and the second is fuel poverty. The former mostly concerns developing economies and is associated with the inability to consume energy or no energy access. On the other hand, fuel poverty mostly affects wealthier countries and is associated with the inability to consume enough energy carriers for financial reasons (Primc, Dominko, Slabe-Erker, 2021). Income is important for both energy poverty and fuel poverty. In the context of income, GDP per capita in a given country is more important for energy poverty, while for fuel poverty the macroeconomic policy pursued in a given country (Nagaj, 2022a), as it determines the economic situation and the even distribution of income in a country. In addition to macroeconomic policy factors, fuel poverty is determined by energy prices, including fuel prices, and thus the situation on the fuel and energy markets. These two segments are considered crucial, and it is assumed that if fuel prices rise faster than incomes, this may be the cause of energy poverty. There are countries where low incomes and high energy prices, including fuels (gas, coal, oil) are key determinants of energy poverty, e.g. Poland.

This determinant is negatively reinforced by obsolete buildings, "black" energy carriers, coal heating, as well as by market conditions and economic and energy crises. Examples of countries where old buildings are energy inefficient, more exposed to cold spells and heat waves, Italy, Spain, Portugal, Greece, Malta (Górska, 2022). The problem of old buildings affects the entire world of Western Europe, especially historic buildings. Old buildings are also a problem in Poland, such buildings have inadequate sources of heating, and their modernization is expensive. All these measures are being counteracted in the context of the climate and energy policy, which may thus be a factor influencing the level of energy poverty in developing countries (Nagaj, 2020), and fuel poverty in developed countries (Hills, 2012).

Considering the different market and economic determinants of energy poverty, various categories of energy poverty and fuel poverty can be defined. The Polish Economic Institute (in Polish: PIE) singled out the four most important dimensions of energy poverty: fuel (income), structural, municipal and hidden (Report, Dec. 2023). The first (i) occurs when energy expenditure accounts for a large proportion of household expenditure; the second (ii) when poverty increases due to relatively high energy bills relative to income; (iii) when a household cannot meet its energy needs due to lack of access to adequate infrastructure, e. g. central heating, hot water from the network, or when dwellings and buildings require too much energy for modern construction; (iv) last the group concerns households that use coal-fired furnaces as their main source of heat in Poland. The European Observatory on Energy Poverty estimates that around 50 million households in the European Union live in conditions of energy poverty (Górska, 2022). Data for Poland (2022), according to the PRI report (December 2023), are as follows:

- income-related energy poverty: 16-30% of households,
- structural poverty affected 8-12% of households in Poland,
- communal poverty amounted to 3-5% of households,
- hidden poverty was between 13% and 16%.

Locally, the problem of energy poverty is more acute for rural dwellers than for urban dwellers. Most studies show that the problem of energy poverty is concentrated in rural areas due to lower incomes and lower energy efficiency of buildings (Baker et al., 2008; Rugkasa et al., 2007; Walker et al., 2012; Snell, Thomson, 2013; Illsley et al., 2007).

According to surveys – PEI Report (Dec., 2023), 68% of Polish households track fuel and energy prices, and 66% of saving households pointed to economic necessity as the reason for saving energy. In 2022, the proportion of EU citizens declaring that they are unable to heat their homes sufficiently increased from 6.9% to 9.3%. Subjective energy poverty in countries was: Bulgaria (22.5%), Cyprus (19.2%), Greece (18.7%), Lithuania (17.5%), Portugal (17.5%). Studying the relationship between social aggregates related to the national economy, such as income, consumption, investment, leads them to see energy poverty as a form of social consciousness. Ecological awareness has accompanied the development of humanity since time immemorial and its conditions are constantly changing, therefore it must be constantly built

(Gajdzik et al., 2023a). In a situation of energy poverty, there are attitudes (behaviors) that are not ecological, such as burning garbage. According to the PEI Report (Dec., 2023), about 7% of households in single-family homes in Poland admit to smoking garbage. The ecological awareness model can be a starting point for assessing energy poverty of individuals and social groups based on empirical knowledge. Therefore, from a sociological point of view, empirical research should capture the subjective determinants of energy poverty between different social categories and explain the reasons for this differentiation by determining the level of energy awareness of society, which may be e. g. coughing, occupation, age, etc.

Socio-economic determinants can be analysed in the study of energy poverty. The study (Lis et al., 2016) analysed the country's energy poverty in a multi-faceted way and concluded that high energy expenditure and low income (analysis of variance) are more determined by the socio-economic characteristics of households, and subjective energy poverty by the energy efficiency of buildings. As a result, the problem of excessive costs among the energy poor is concentrated in eastern Poland, and the problem of lack of thermal comfort in housing concerns residents of western voivodships. Differences in temperature and energy prices are an important determinant of regional differences in subjective energy poverty.

Recognising the importance of the determinants of energy poverty, which are both subjective and objective, actions are taken to, firstly, steer the actions of societies through support instruments, particularly financial and social (Nagaj, 2022b), and secondly, to make society aware of the importance of the problem and to promote an ecological culture and, consequently, to instill a sense of responsibility for global warming.

Fuel poverty, often called in the EU policy as energy poverty (understood as the share of households experiencing energy poverty in the total number of households measured on the basis of different indicators) has increased policy interest. Energy poverty has been enshrined in EU legislation. In its 2020 Recommendations to Member States, the European Commission presented a legislative package focusing on the diagnosis of energy poverty in Member States and its potential causes and consequences. Energy poverty was also an essential element of the EC Recommendation, 28.09.2021, on the implementation of the "energy efficiency first" principle and the Fit for 55 packages. Within the structures of EU organisations there is a Commission for the Protection of Energy Poverty and operates the Advisory Centre. In addition, energy poverty has been included in the European Green Deal as part of the renovation wave, the EU's 2030 building modernisation policy. In the Energy Efficiency Directive (2023), the European Commission committed Member States to improve energy efficiency in social housing and households of people affected by energy poverty. The programmes are funded by the Social Climate Fund (€86 billion foreseen for the period 2026-2032). More than 75% of the Fund's budget comes from emissions trading for buildings and road transport and fuels for ancillary sectors, which is to apply from 2027.

One of the determinants of energy poverty is recent global initiatives and refocused efforts towards widening access to modern energy carriers and technologies (related to cooking and electricity) for households in developing countries (Cordes, 2011; GEA, 2012). Traditional energy, i.e. "black" is replaced by new energy, i.e. "green" from RES. Regarding the Kyoto Protocol implementation, it was found for EU-27 that an increase in the share of renewable energy sources by one percentage point was related to a decrease of one percentage point in the greenhouse gases index. GDP per capita appeared to be an insignificant driver for reductions in per capita CO_2 emissions, while it proved to be important for economic efficiency models. Thus, increasing GDP per capita by 1000 USD reduces greenhouse gases by 7.1 g per EUR of GDP in EU-27 (Wang et al., 2023). In the last decade, the renewable energy share in the EU (%) has been growing year by year. In 2010, EU countries received slightly less 15% of energy from RES, now more than 20% of energy comes from RES (Eurostat). The increasing share of RES in energy sources is important for climate policy because it helps prevent global warming and the world (EU countries policy and other aware threats) is moving towards a "Net Zero" strategy. In each country, the energy consumption of households would, in general, increase CO_2 emissions, so the net zero strategy is the important and key direction of polities in many countries (Myszczyszyn, Supro´n, 2022). Implementing this strategy requires investment in new industrial and energy technologies and new techniques for building and heating homes. The general tendency toward fast technological transformations could create the expectations that CO_2 emissions would be reduced on a global level and the consequences of climate change would be mitigated. Strongly popularized for more than a decade, the industry development concept called Industry 4. 0, through technologies included in the pillars of Industry 4.0, can improve energy consumption and air quality. For example, Wolniak et al. (2020), analyzing on the energy efficiency in the steel sector in Poland, stated that there is a link between investment in modern technologies and energy efficiency in steel production. Gajdzik, Sroka, and Vveinhardt (2021) argue that increasing the technological investment in electric steel plants results in an energy consumption decrease in steel electric furnaces produced. The general tendency toward fast technological transformations could create the expectations that CO_2 emissions would be reduced on a global level and the consequences of climate change would be mitigated. However, the speed of the development of these technological transformations (such as renewable energy) must be examined in detail and whether those processes are sufficient to improve the environmental situation must be evaluated.

Climate policy, in its current radical form, is needed because, unfortunately, the climate is changing. This is particularly evident in the average annual temperature, which has risen by 1.3ºC over the last 35 years. The European Union wants to ensure coherence between the "net zero" strategy and social problems, including energy poverty. The EU is working towards a reliable, affordable, and sustainable energy system, but there are still too many factors that vary from country to country. World equality and fairness politics aim to deliver sustainable

energy for all. The problem of energy poverty is amongst the United Nations Sustainable Development Goals (UN-SDGs). Goal seven of UN-SDGs mainly targets energy poverty through "ensuring access to affordable, reliable, sustainable and modern energy for all".

Studies on the determinants of poverty are important for climate policy. At the macro-level of economies, energy poverty increases income poverty (Vera et al., 2005) and reduces the social and economic progress of societies (Acharya, Sadath, 2019; Sadath, Acharya, 2017; Khandker et al., 2012) and may constitute a barrier to the development of renewables (Gajdzik et al., 2023). At the micro-level, energy poverty is a barrier to education, a threat to health and well-being of the household members (Kanagawa, Nakata, 2006; Day et al., 2016; Hill, 2012).

3. Materials and Methods

In the previous section authors studied the nature of fuel poverty, how it is measured and how the phenomenon has been analysed in the literature. Many factors were found to influence energy poverty, but less so fuel poverty. Of those which, on the other hand, determine fuel poverty, we can divide into those which shape the level of costs of energy carriers and those which shape household incomes, especially disposable incomes. Furthermore, it was found that fuel poverty, depending on how it is measured, can be defined in diverse ways. Bearing in mind that the aim of this paper is to assess the importance of climate and energy policy instruments in fuel poverty reduction policy in Poland, it is therefore important to specify the measurement methodology. For this purpose, the following stages of the study will be carried out:

The following stages of the study will be carried out:

1. Analysis of spending on energy carriers in Poland.
2. Estimation of the fuel poverty rate in Poland.
3. Development of a model to analyse the impact of energy and climate policies on fuel poverty.
4. Selection for analysis of factors influencing fuel poverty.
5. Searching data in databases.
6. Analysis of the impact of energy and climate policy (including macroeconomic policy instruments) on fuel poverty.

For the purposes of the analysis, the authors adopted the definition proposed by Boardman (2010), according to which fuel poverty concerns those people in households who spend at least 10% on the energy supplied. Based on this definition, the authors analyzed household expenses on energy carriers in Poland in the first stage of the research process. To determine this, the authors will calculate the average share of expenditure on energy carriers per person in households, and what this share is for each of the income quintile groups in households (per person).

The development of the average level of expenditure will allow us to assess how the burden on the entire society caused by expenditure on energy carriers has changed in the studied period.

However, additional analysis in income quintile groups will allow us to assess how the share of energy expenditure varied depending on income. The research period was 2005-2022, i.e., from the full year of Poland's functioning in the structures of the European Union. 2022 is because complete data is available until this year.

In the second stage of the research process, the fuel poverty rate in Poland was estimated. For the purposes of this analysis, it will be examined, based on the adopted definition of fuel poverty, in which income groups of society the share of expenditure on energy carriers exceeds 10%. The authors will be supported here by the distribution of the income structure for decile groups. Such income groups, in which the share of expenditure on energy carriers is above 10%, will be considered fuel poor. The calculation of fuel poverty will consist in summing up those fuel poor income groups. The authors will calculate fuel poverty for 36 periods in the studied period. This number of observations will guarantee the reliability of the statistical analysis in regression analysis.

The third stage of the research process is the developing model to analyse the impact of energy and climate policies on fuel poverty. As mentioned earlier, the aim of this study is to assess the impact of energy and climate policies on fuel poverty in Poland. For this reason, the model developed considers both energy and climate policies and the instruments associated with them, which can shape household spending on energy carriers. However, the literature review indicated that the level of fuel poverty is also influenced by macroeconomic policies and factors that affect the rate of GDP growth and its even distribution across society. Figure 1 shows a model for analysing the impact of energy and climate policies on fuel poverty.

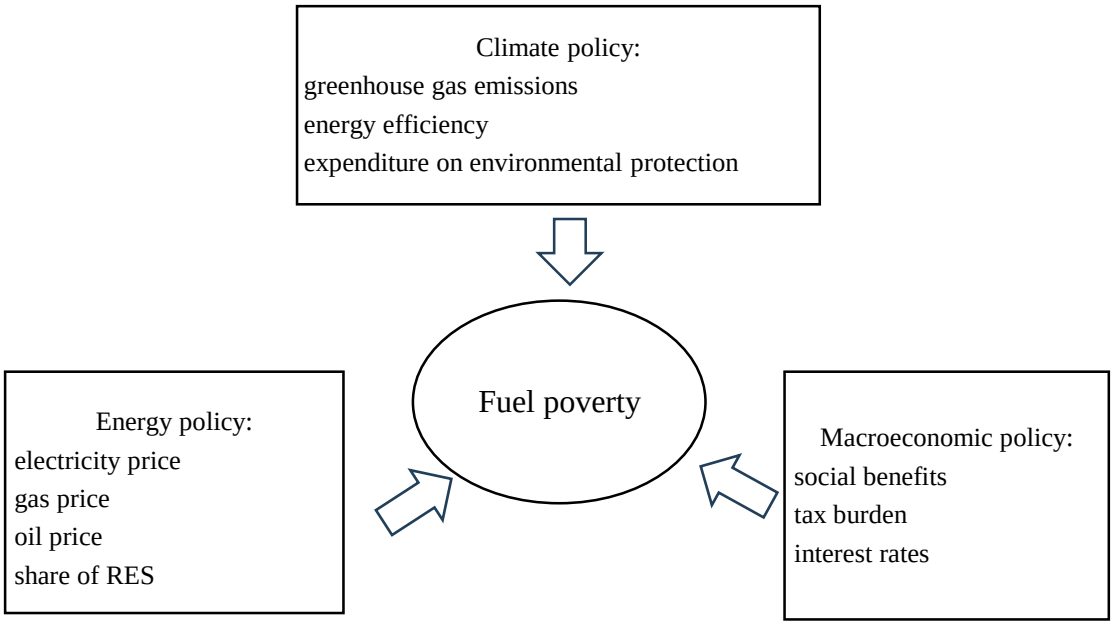

Figure 1. Model for analysing the impact of energy and climate policy on fuel poverty.
Source: own method of analysis.

The next stage of the research process is the identification of factors influencing fuel poverty for regression analysis. The factors were divided into 3 groups of factors, i.e. related to energy policy, climate policy and macroeconomic policy. The literature review indicated that among the factors that may determine the level of fuel poverty are the level of expenditure on energy carriers and the level of income. Therefore, within the group belonging to climate policy, four factors have been identified that can influence fuel poverty. These are: electricity prices, gas prices, oil prices and the share of renewables in electricity consumption. The issue of the role of energy prices was highlighted by Recalde et al. (2019) and Górska (2022), indicating that they have an increasing effect on fuel poverty. Similarly, the role of the share of renewables is most often pointed out, although in this case the cases of countries with a large share of RES in the energy mix indicate that a large share of renewables acts negatively on energy prices. The next group of factors are those grouped under climate policy. In this group, the authors considered three factors: greenhouse gas emissions, energy efficiency and expenditure on environmental protection. In the case of the first factor, a lower level of this factor should have a negative impact on the cost of energy carriers and thus the level of fuel poverty. Meanwhile, in the case of energy efficiency, as pointed out by Snell and Thomson (2013) and Górska (2022). The higher it is, the lower the costs for heating should be, which should translate into lower levels of fuel poverty. In the case of expenditure on environmental protection, they have a similar effect to subsidies. The higher they are, the higher the charges passed on to end users' bills, which should increase the number of people susceptible to fuel poverty. The last group of factors are those affecting income and economic growth, i.e. relating to macroeconomic policy. As indicated by Sharma et al. (2019), fostering economic growth or pursuing macroeconomic policies (Nagaj, 2022a) that increase income should have a downward effect on the level of fuel poverty. Therefore, active fiscal policy instruments, i.e. an increase in social benefits and a reduction in taxes (Nagaj, 2022b), as well as expansionary monetary policy instruments, i.e. an increase in the money supply or a reduction in interest rates to finance investments, should theoretically stimulate a reduction in the level of fuel poverty in the country.

The authors then proceeded to search for data in databases, which are Eurostat, the Central Statistical Office and the OECD. Considering the availability of data and ensuring an equal time range for all variables, the authors decided on the period 2005-2022.

The final step in the research process is the analysis of the impact of energy and climate policy on fuel poverty. Having developed a model for analysing the impact of energy and climate policy on fuel poverty, it is necessary to proceed to the creation of a multiple regression model. In the model for analysing fuel poverty in Poland (independent variable Y), the authors proposed 10 independent variables, of which the first four relate to the impact of energy policy, the next three to the impact of climate policy and the last three to the impact of macroeconomic policy. These include:

- X_1 – Electricity prices for household consumers in Poland - Consumption from 1000 kWh to 2499 kWh (Data source: Eurostat: *Electricity prices for household consumers - bi-annual data*).
- X_2 – Gas prices for household consumers in Poland - band D2 (Data source: Eurostat: *Gas prices for household consumers - bi-annual data*).
- X_3 – Price of Euro 95 petrol in Poland (Data source: Bankier.PL: *Wskaźniki makroekonomiczne: Euro 95 (Polska*).
- X_4 – Share of renewable energy in gross final energy consumption in Poland (Data source: Eurostat: *Share of renewable energy in gross final energy consumption by sector*).
- X_5 – Total net greenhouse gas emissions in Poland - excluding memo items and including international aviation – tonnes per capita (Data source: Eurostat: *Net greenhouse gas emissions).*
- X_6 – Final energy efficiency in Poland - million tonnes of oil equivalent (Data source: Eurostat: *Energy efficiency*).
- X_7 – General government expenditure on environmental protection in Poland - in mln euro (Data source: Eurostat: *General government expenditure by function*).
- X_8 – Social benefits to households as % of GDP in Poland (Data source: OECD: *Social benefits to households (indicator*).
- X_9 – Tax revenue as % of GDP in Poland (Data source: OECD: *Tax revenue (indicator).*
- X_{10} – Interest rate of 10-years government bonds in Poland (Data source: OECD: *Long-term interest rates* (*indicator*).

Based on the proposed model, a multiple regression equation was developed:

$$Y = a + b_i \cdot X_n + \varepsilon, \quad (1)$$

where:

Y– fuel poverty rate in Poland (dependent variable);

a – constant parameter, Y intercept;

b_i – coefficients of the regression function for independent variables (i = 1, …, 10);

$X_1, X_2, \ldots, X_n$ – independent variables affecting the dependent (n = 1, …, 10).

ε – random error component.

Statistical verification will be counted at a statistical significance coefficient of 0.05, and calculations will be made using Statistica 13.3 software (TIBCO Software, Dublin, Ireland).

4. Results

The authors' first calculation activity in this section was to calculate what the average share of expenditure on energy carriers and in various income groups of households in Poland is and based on it the level of fuel poverty in the studied period. The results of these calculations are presented in Table 1.

Table 1.
Share of expenditure on energy carriers in disposable income per person in households and the fuel poverty rate in Poland in 2005-2022

Specification	For average income	Share of expenditure on energy carriers in disposable income (in %) in Quintile groups					Fuel poverty rate (in %)
Year		1	2	3	4	5	
2005	10.36	31.02	16.96	12.32	9.08	4.99	34.9
2006	10.74	32.14	17.58	12.77	9.41	5.17	35.1
2007	9.46	27.44	15.32	11.29	8.43	4.54	35.7
2008	9.57	28.08	15.27	11.29	8.45	4.66	35.9
2009	10.04	29.90	16.02	11.81	8.79	4.90	35.9
2010	10.30	29.62	16.63	12.26	9.13	4.98	35.7
2011	10.49	31.91	16.79	12.37	9.25	5.08	35.6
2012	10.32	31.78	16.65	12.16	9.07	4.98	35.5
2013	10.34	33.08	16.73	12.12	9.08	4.97	35.5
2014	9.56	29.60	15.19	11.04	8.27	4.71	36.1
2015	9.30	27.99	14.58	10.70	8.08	4.61	36.4
2016	8.55	22.40	12.74	9.72	7.49	4.42	28.9
2017	8.10	19.64	11.97	9.26	7.21	4.23	29.8
2018	7.46	18.73	10.98	8.49	6.64	3.87	21.4
2019	6.93	17.75	10.10	7.80	6.12	3.63	21.4
2020	6.62	19.13	9.64	7.37	5.81	3.42	13.3
2021	6.97	22.32	10.23	7.81	6.11	3.52	19.9
2022	7.64	25.58	11.21	8.49	6.64	3.86	19.5

Source: own calculations based on GUS, *Budżety gospodarstw domowych [Household budgets]*, GUS, Warszawa. Publications in 2006-2022.

Analysing the average level of expenditure on energy carriers, it should be noted that, apart from short periods of growth in 2008-2011 and 2021-2022, their share in household income is declining. On average over the whole period, this share has fallen by 2.72 percentage points. In general, the trends are similar in all income groups in Poland and these declines in successive income decile groups (increasing) were (in percentage points) respectively: 5.44, 5.76, 3.83, 2.44, 1.12. It should also be noted that greater variations in the weight of these expenditures in the household budget were observed for those with lower incomes than for those with the highest incomes. Among those in the first income decile group, the difference between the highest share of expenditure on energy carriers and the lowest in the period under study was as much as 15.33 percentage points, while in the second income decile group it was 7.93 percentage points, in the third decile group 5.40 percentage points, in the fourth and fifth decile groups 3.60 and 1.75 percentage points respectively. The results also indicate that fuel

poverty, i.e., the share of expenditure above 10 per cent of disposable income, in the studied period affected all those with the lowest incomes, i.e. from the 1st and 2nd decile groups and, until 2015, also from the third income quintile group. This was reflected with the fuel poverty rate in Poland, which increased with minor fluctuations until 2015, and from 2016 onwards a decrease in the rate was observed, after which the fuel poverty rate in Poland increased again in 2021-2022. It is worth noting that 2016 coincides with the period when new social benefits were introduced in Poland for people with children, the so-called '500+ programme'. This state aid mainly concerned the poorest people. This is reflected in a comparison of the amount of the share of expenditure on energy carriers in income among the poorest (first decile group) and the richest (fifth decile group). Between 2005 and 2015, this ratio among the poorest was 6.0-6.7 times higher than for the richest. In 2016, however, it fell to 5.1, and by 2019 it had fallen to 4.9. From 2020, it rose again to reach 6.6 in 2022. This means that spending on energy in the period under review was a decreasing burden on household budgets, but the poorest section of the population was less affected by these decreases. For this reason, the fuel poverty rate in Poland has been increasing faster again in the recent period, although it has not approached the levels of the 2005-2015 period.

Knowing how the fuel poverty rate evolved over the period under study (Table 1), we proceeded to analyse the impact of energy and climate policies on this phenomenon. For this purpose, before starting the regression analysis, a correlation analysis of the dependent variable with the independent variable was analysed. This will allow us to determine which factors are statistically significantly correlated with the fuel poverty rate in Poland and thus can be subjected to regression analysis. Correlation results show Table 2.

Table 2.
Correlation analysis between the dependent variable and potential determinants of fuel poverty level in Poland

Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Y	-0.72*	-0.22	-0.30	-0.86*	-0.06	-0.88*	-0.57*	-0.80*	-0.81*	0.59*

* independent variables that are statistically significantly correlated with the dependent variable at $p < 0.05$.

Source: own work.

The results of the correlation analysis showed that fuel poverty level in Poland is not statistically significantly correlated with gas price for household consumers, petrol price in Poland, and level of greenhouse gas emissions. On the other hand, in terms of energy policy, a negative strong correlation is observed with electricity price for household consumers and the level of share of renewable energy in gross final energy consumption in Poland. In terms of climate policy in Poland, a strong correlation is observed with the level of energy efficiency and an average strength of the relationship with general government expenditure on environmental protection. However, it is worth noting that all macroeconomic policy instruments that also determine income in Poland are also correlated with the fuel poverty level in Poland.

When proceeding to the regression analysis, co-correlation between the independent variables was also checked. It was found that there was a strong correlation between variables X1 and the other independent variables, so these variables were excluded from further analysis.

In addition, regression analysis indicated that variable X6 does not have a statistically significant effect at $p < 0.05$ on fuel poverty level in Poland. For the remaining variables, i.e. X_4, X_7, X_8, X_9, X_{10}, regression analysis was conducted to determine their impact on fuel poverty level in Poland. The results of the regression analysis are presented in Table 3.

Table 3.
Results of regression analysis for the dependent variable fuel poverty level in Poland for semi-annual data over the period 2005-2022

	Coefficients b^*_i	**Standard Error of b^*_i**	**Coefficients b_i**	**Standard Error of b_i**	**t-statistic**	**p-value**
N = 36	Regression statistics: R = 0.9830; R2 = 0.9664; Adjusted R2 = 0.9607; F(5,30) =172.33; p < 0.0000; Standard error: 1.4921					
Constant			174.1891	8.9366	19.4917	0.0000
Variable X_4	-0.8410	0.0967	-1.9381	0.2228	-8.6970	0.0000
Variable X_7	0.2175	0.0747	0.0027	0.0009	2.9114	0.0067
Variable X_8	-0.3719	0.0467	-3.9579	0.4971	-7.9622	0.0000
Variable X_9	-0.3738	0.0444	-1.8577	0.2204	-8.4270	0.0000
Variable X_{10}	-0.3343	0.0675	-1.6243	0.3282	-4.9488	0.0000

The results of regression analysis indicated that the fuel poverty rate in Poland was influenced by 5 variables, i.e. share of renewable energy in gross final energy consumption (X4), expenditures on environmental protection (X7), level of social benefits in Poland (X8), tax burden (X9), and interest rates in Poland (X10). It means that, in terms of energy policy, only the level of renewables has a statistically significant impact, while in terms of climate policy, expenditure on environmental protection. In the first case, the impact is negative, while in the second case it is positive. The positive impact of environmental expenditure is due to the fact that it is covered by energy charges. Macroeconomic policy instruments were also found to play a key role in stimulating revenues. Regression analysis indicated that when analysing the impact of energy and climate policies, with the additional impact of macroeconomic policies, renewables were found to play the most significant role. It is RES, through their expenditures and charges included in energy bills that have the greatest impact on fuel poverty in Poland.

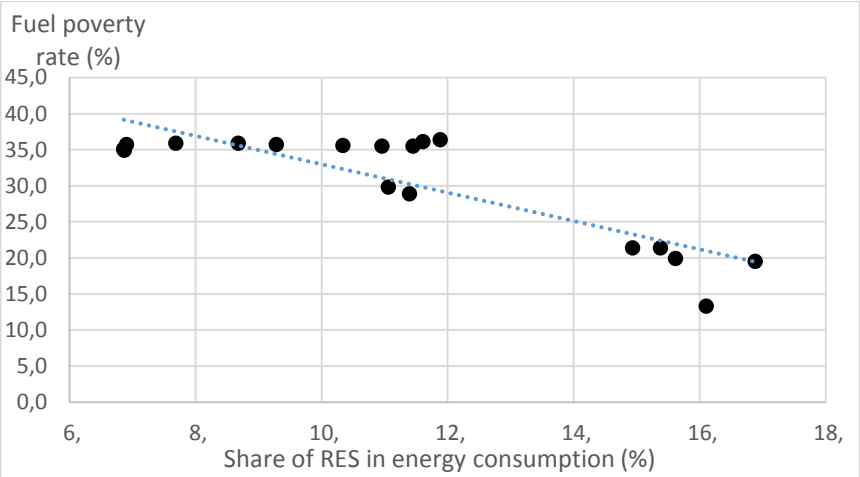

Figure 1. Relationship between fuel poverty rate and the share of RES in the energy mix in Poland. Source: own study.

As Figure 1 shows, the relationship between the two variables is negative, confirming the conclusions about the negative impact of RES on fuel poverty. This is the factor that most strongly determines the fuel poverty rate in Poland. However, it is worth noting that this impact is not uniform, which may suggest that this impact is not similar in all income groups.

Therefore, when analysing the relationships presented above, the authors decided to additionally investigate how the influence of the examined factors on the level of expenditure on energy carriers is shaped in the individual income decile groups. Table 4 presents the results of the regression analysis for these variables.

Table 4.
Results of regression analysis for the share of expenditures on energy carriers in disposable income by income decile group in Poland

	Coefficients b^*_i	**Standard Error of b^*_i**	**Coefficients b_i**	**Standard Error of b_i**	**t-statistic**	**p-value**
For Q1	Regression statistics: R = 0.8871; R2 = 0.7869; Adjusted R2 = 0.7412; p < 0.0001; Standard error: 0.0265					
Constant			0.8388	0.1613	5.2014	0.0001
Variable X_4	-0.8474	0.2166	-0.0133	0.0034	-3.9115	0.0016
Variable X_7	0.5998	0.1916	0.0001	0.0000	3.1313	0.0074
Variable X_9	-0.4809	0.1513	-0.0163	0.0051	-3.1786	0.0067
For Q2	Regression statistics: R = 0.9356; R2 = 0.8753; Adjusted R2 = 0.8587; p < 0.0000; Standard error: 0.0104					
Constant			0.4932	0.0620	7.9581	0.0000
Variable X_4	-0.5631	0.1110	-0.0047	0.0009	-5.0738	0.0001
Variable X_9	-0.4921	0.1110	-0.0089	0.0020	-4.4334	0.0005
For Q3	Regression statistics: R = 0.9447; R2 = 0.8925; Adjusted R2 = 0.8782; p < 0.0000; Standard error: 0.0065					
Constant			0.3393	0.0384	8.8337	0.0000
Variable X_4	-0.5766	0.1013	-0.0032	0.0006	-5.5956	0.0001
Variable X_9	-0.4886	0.1030	-0.0059	0.0012	-4.7412	0.0003
For Q4	Regression statistics: R = 0.9443; R2 = 0.8916; Adjusted R2 = 0.8772; p < 0.0000; Standard error: 0.0043					
Constant			0.2396	0.0257	9.3272	0.0000
Variable X_4	-0.5587	0.1035	-0.0021	0.0004	-5.3991	0.0001
Variable X_9	-0.5066	0.1035	-0.0041	0.0008	-4.8962	0.0002

Cont. table 5.

For Q5	Regression statistics: R = 0.8619; R2 = 0.7429; Adjusted R2 = 0.7268; p < 0.0000; Standard error: 0.0030					
Constant			0.1540	0.0161	9.5754	0.0000
Variable X_9	-0.8619	0.1267	-0.0032	0.0005	-6.7993	0.0000

The results of the regression analysis for the share of expenditure on energy carriers in the income of individual income groups of households in Poland indicated that the more affluent households, the more crucial factor is the tax burden. On the other hand, the lower the income of households, the more key role is played by energy policy in the form of the share of RES in the energy mix and, among the poorest people, expenditure on environmental protection. Thus, the results of the analysis indicate that energy and climate policies influence the level of fuel poverty in Poland, while when analysed from the perspective of the share of expenditures on energy carriers in household's income, it was found that this influence occurs mainly among those with the lowest income. The higher the income, the more important the role of taxes related to macroeconomic policy.

5. Conclusions

The aim of the article was to assess the importance of climate and energy policy in reducing fuel poverty on the example of Poland. The authors examined factors of climate and energy policy influencing the fuel poverty rate in Poland. To achieve this objective, the authors attempted to answer three research questions. Within the framework of RQ1, the authors estimated the share of expenditure on energy carriers in household income and what is the fuel poverty rate in Poland in 2005-2022. The analysis indicated that, despite fluctuations, fuel poverty in Poland falls over the period studied. Admittedly, this phenomenon has increased in the last two years, but the maximum levels of the pre-2016 period have still not been reached. By conducting a literature review, the authors also selected the basic determinants of fuel poverty and thus proceeded to answer RQ2, which reads as follows: What are determinants of the fuel poverty rate in Poland? To this end, an analysis model was developed and a multiple regression analysis was carried out. The analysis indicated that these factors are: renewable energy sources, or more precisely their share in the energy-mix, the scale of energy efficiency, the next is the size of expenditures on enviromental protection, the scale of social expenditures realised by the government and the tax burden, which generate revenues for the realisation of social policy, and the last is interest rates in Poland, which are one of the instruments of macroeconomic policy. Thus, the results of the analysis confirmed the findings indicated in the literature (Rodriguez-Alvarez, Llorca, Jamasb, 2021), that income and income growth policies are one of the most important determinants of the scale of fuel poverty in a country.

By answering the last RQ3, the authors gave an answer to the main objective of the study. It was found that energy and climate policy have an impact on fuel poverty in Poland, however, the lowest income earners are most affected. It can be presumed that the reason for this is that the effects of these policies are implemented in the form of fixed charges included in household energy bills.

The article has some research limitations. The main one is the lack of more detailed data on household incomes, i.e. by deciles, which would allow for more accurate estimates of fuel poverty. However, despite this limitation, the authors succeeded in accurately estimating the phenomenon under study and identifying the impact of climate and energy policies. In the future, it would be worthwhile to carry out similar analyses for other European countries.

References

1. Acharya, R.H., Sadath, A.C. (2019). Energy poverty and economic development: household level evidence from India. *Energy Building, Vol. 183*, 785-91. https://doi.org/10.1016/j.enbuild.2018.11.047.
2. Baker, W., White, V., Preston, I. (2008). *Quantifying rural fuel poverty. Report of Centre for Sustainable Energy for Eaga Partnership Charitable Trust*. CSE, Bristol.
3. Bankier.PL, *Wskaźniki makroekonomiczne: Euro 95 (Polska) [Macroeconomic indicators: Euro 95 (Poland)]*. Retrieved from: https://www.bankier.pl/gospodarka/wskazniki-makroekonomiczne/eu-95-pol, 1.06.2024.
4. Barnes, D.F., Khandker, S.R., Samad, H.A. (2011). Energy poverty in rural Bangladesh. *Energy Pol., 39*, pp. 894-904, https://doi.org/10.1016/j.enpol.2010.11.014.
5. Boardman, B. (1991). *Fuel Poverty: From Cold Homes to Affordable Warmth*. London: Belhaven Press.
6. Boardman, B. (2010). *Fixing fuel poverty: challenges and solutions*. London/New York: Earthscan, pp. 1-272.
7. Cordes, L. (2011). *Igniting Change: A Strategy for Universal Adoption of Clean Cookstoves and Fuels*. Global Alliance for Clean Cookstoves (GACC).
8. Day, R., Walker, G., Simcock, N. (2016). Conceptualising energy use and energy poverty using a capabilities framework. *Energy Policy, Vol. 93*, pp. 255-264.
9. EREE. *European Fuel Poverty and Energy Efficiency Project*, https://www.precarite-energie.org/IMG/pdf/EPEE_Project_presentation.pdf
10. European Commission. *European Green Deal*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en, 8.02.2024.

11. Eurostat. *Electricity prices for household consumers - bi-annual data*. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_204/default/table?lang=en&category=nrg.nrg_price.nrg_pc, 30.05.2024.
12. Eurostat. *Energy efficiency*. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_eff__custom_9531378/default/table?lang=en, 26.01.2024.
13. Eurostat. *Gas prices for household consumers - bi-annual data*. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_202/default/table?lang=en&category=nrg.nrg_price.nrg_pc, 30.05.2024.
14. Eurostat. *General government expenditure by function (COFOG)*. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/gov_10a_exp__custom_11105433/default/table?lang=en, 28.04.2024.
15. Eurostat. *Net greenhouse gas emissions*. https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10__custom_11104852/default/table?lang=en, Retrieved from: 28.04.2024.
16. Eurostat. *Share of renewable energy in gross final energy consumption by sector*. Retrieved from: https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en, 26.04.2024.
17. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W.W., Romanyshyn, T. (2023b). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies, Vol. 16, No. 21*, 7364. https://doi.org/10.3390/en16217364.
18. Gajdzik, B., Wolniak, R., Nagaj, R., Žuromskaitė-Nagaj, B., Grebski, W.W. (2024b). The Influence of the Global Energy Crisis on Energy Efficiency: A Comprehensive Analysis. *Energies, Vol. 17, No. 4*, 947. https://doi.org/10.3390/en17040947.
19. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny, R., Grebski, W.W. (2023a). Energy Behaviors of Prosumers in Example of Polish Households. *Energies, 16*, 3186.
20. Gajdzik, B., Nagaj, R., Wolniak, R., Bałaga, D., Žuromskaite, B., Grebski, W.W. (2024a) Renewable Energy Share in European Industry: Analysis and Extrapolation of Trends in EU Countries. *Energies, 17*, 2476. https://doi.org/10.3390/en17112476.
21. Gajdzik, B., Sroka, W., Vveinhardt, J. (2021). Energy Intensity of Steel Manufactured Utilising EAF Technology as a Function of Investments Made: The Case of the Steel Industry in Poland. *Energies, Vol. 14*, 5152.
22. GEA (2012). *Global Energy Assessment. Toward a Sustainable Future*. Cambridge, UK / New York, NY, USA / Laxenburg, Austria, Cambridge University Press, International Institute for Applied Systems Analysis; ISBN 9781 10700 5198 hardback; 9780 52118 2935 paperback, www.globalenergyassessment.org.
23. González-Eguino, M. (2015). Energy poverty: an overview. *Renewable & Sustainable Energy Reviews, Vol. 47, No. C*, pp. 377-385. https://doi.org/10.1016/j.rser.2015.03.013.
24. Górska, A. (2022). Wpływ pandemii COVID-19 na ubóstwo energetyczne w UE. Impact of the COVID-19 Pandemic on Energy Poverty in the EU. *PP, 1(23)*, 109-127, DOI : 10.14746/pp.2022.28.1.8

25. GUS. *Macroeconomic indicators*. Retrieved from: https://stat.gov.pl/wskazniki-makroekonomiczne/, 30.05.2024.
26. Hills, J. (2011). Fuel poverty. The problem and its measurement. *CASE report, 69.* London: Department of Energy and Climate Change.
27. Hills, J. (2012). *Getting the measure of fuel poverty: final report of the fuel poverty review*. London.
28. IEA (2002). *World energy outlook. Policy model in energy use*, 21. https://iea.blob.core.windows.net/assets/11bc7b29-db2a-46fb-a515-1f5e7d2c7dfd/WorldEnergyOutlook2002.pdf
29. Illsley, B., Jackson, T., Lynch, B. (2007). Addressing Scottish rural fuel poverty through a regional industrial symbiosis strategy for the Scottish forest industries sector. *Geoforum, 38*, pp. 21-32.
30. Kanagawa, M., Nakata, T. (2006). *Socio-economic impacts of energy poverty alleviation in rural areas of developing countries*. Proc. 26th USAEE/IAEE North Am. Conf 2006, 24-7. Ann Arbor, MI, USA.
31. Khandker, S.R., Barnes, D.F., Samad, H.A. (2012). Are the energy poor also income poor? Evidence from India. *Energy Policy, vol. 47*, 1-12. https://doi.org/10.1016/j.enpol.2012.02.028.
32. Kyprianou, I., Serghides, D.K., Varo, A., Gouveia, J.P., Kopeva, D., Murauskaite, L. (2019). Energy poverty policies and measures in 5 EU countries: A comparative study. *Energy & Buildings, Vol. 196*, pp. 46-60. https://doi.org/10.1016/j.enbuild.2019.05.003
33. Leeuwen, J. van, Monios, J. (2022). Decarbonisation of the shipping sector – Time to ban fossil fuels? *Marine Policy, vol. 146*, 105310, https://doi.org/10.1016/j.marpol.2022.105310.
34. Lis, M., Miazga, A., Sałach, K. (2016). Zróżnicowanie ubóstwa energetycznego w Polsce. *IBS Working paper, 19.* Warszawa.
35. Moore, R. (2012). Definitions of fuel poverty: implications for policy. *Energy Policy, Vol. 49*, pp. 19-26. https://doi.org/10.1016/j.enpol.2012.01.057.
36. Myszczyszyn, J., Supro´n, B. (2022). Relationship among Economic Growth, Energy Consumption, CO_2 Emission, and Urbanization: An Econometric Perspective Analysis. *Energies, 15*, 9647.
37. Nagaj, R. (2020). Polityka klimatyczno-energetyczna a ubóstwo energetyczne w Polsce [Climate and energy policies and its impact on energy poverty in Poland]. *Rynek Energii, Vol. 146, No. 1*, pp. 3-10.
38. Nagaj, R. (2022a). Macroeconomic Policy Versus Fuel Poverty in Poland—Support or Barrier. *Energies, Vol. 15, No. 13*, 4710. https://doi.org/10.3390/en15134710
39. Nagaj, R. (2022b). Polityka fiskalna a ubóstwo energetyczne w Polsce [Fiscal policy and fuel poverty in Poland]. *Rynek Energii, Vol. 158, No. 1*, pp. 3-10.

40. OECD (2021). *Social benefits to households (indicator).* Retrieved from: https://doi.org/10.1787/423105c6-en, 30.05.2024.
41. OECD (2024). *Long-term interest rates (indicator).* Retrieved from: https://doi.org/10.1787/662d712c-en, 30.05.2024.
42. OECD (2024). *Tax revenue (indicator).* Retrieved from: https://doi.org/10.1787/d98b8cf5-en, 30.05.2024.
43. Pachauri, Sh., Rao, N.D. (2013). Gender impacts and determinants of energy poverty: are we asking the right questions? *Current Opinion in Environmental Sustainability*, *No. 5*, pp. 205-215, http://dx.doi.org/10.1016/j.cosust.2013.04.006.
44. Polish Economic Institute (Polski Instytut Ekonomiczny) (2023). *Raport 2023: Cztery oblicza ubóstwa energetycznego Polskie gospodarstwa domowe w czasie kryzysu 2021-2023. Ubóstwo energetyczne.* Warszawa. https://pie.net.pl/wp-content/uploads/2024/02/PIE-Raport_Ubostwo_energetyczne_2023.pdf
45. Primc, K., Dominko, M., Slabe-Erker, R. (2021). 30 years of energy and fuel poverty research: A retrospective analysis and future trends. *Journal of Cleaner Production, Vol. 301*, 127003. https://doi.org/10.1016/j.jclepro.2021.127003.
46. Recalde, M., Peralta, A., Oliveras, L., Tirado-Herrero, S., Borrell, C., Palencia, L., Gotsensb, M., Artazcoz, L., Mari-Dell'Olmo, M. (2019). Structural energy poverty vulnerability and excess winter mortality in the European Union: Exploring the association between structural determinants and health. *Energy Policy, Vol. 133, No. C*, 110869. DOI: 10.1016/j.enpol.2019.07.005.
47. Rodriguez-Alvarez, A., Llorca, M., Jamasb, T. (2021). Alleviating energy poverty in Europe: Front-runners and laggards. *Energy Economics, Vol. 103*, 105575. https://doi.org/10.1016/j.eneco.2021.105575.
48. Rugkasa, J., Shortt, N.K., Boydell, L. (2007). The right tool for the task: 'boundary spanners' in a partnership approach to tackle fuel poverty in rural Northern Ireland. *Health and Social Care in the Community, 15(3),* pp. 221-230.
49. Sadath, A.C., Acharya, R.H. (2017). Assessing the extent and intensity of energy poverty using Multidimensional Energy Poverty Index: empirical evidence from households in India. *Energy Policy, 102,* 540-50. https://doi.org/10.1016/j.enpol.2016.12.056
50. Sałach, K., Lewandowski, P. (2018). *Ubóstwo energetyczne w Polsce 2012-2016: Zmiany w czasie i charakterystyka zjawiska [Energy poverty in Poland 2012-2016: Changes in time and characteristics of the phenomenon]*. Warszawa: IBS. https://ibs.org.pl/publications/ubostwo-energetyczne-w-polsce-2012-2016-zmiany-w-czasie-i-charakterystyka-zjawiska/, 12.06.2024.
51. Schumacher, D. (1985). *Energy: Crisis or opportunity? An Introduction to Energy Studies*. London: Palgrave Macmillan.

52. Sharma, V., Han, P., Sharma, V.K. (2019). Socio-economic determinants of energy poverty amongst Indian households: A case study of Mumbai, *Energy Policy, Vol. 132*, pp.1184-1190.
53. Snell C., Thomson H. (2013). Reconciling fuel poverty and climate change policy under the Coalition government: Green deal or no deal. *Social Policy Review, Vol. 25*, pp. 23-45.
54. Ulucak, R., Sari, R., Erdogan, S., Castanho, A.R. (2021). Bibliometric Literature Analysis of a Multi-Dimensional Sustainable Development Issue: Energy Poverty, *Sustainability, No. 13, Vol. 9780.*
55. Vera, I.A., Langlois, L.M., Rogner, H-H, Jalal, A.I., Toth, F.L. (2005). Indicators for sustainable energy development: an initiative by the international atomic energy agency. *Nat Resour Forum, 29*, pp. 274-83. Wiley Online Library.
56. Walker, R., McKenzie, P., Liddell, C., Morris, C. (2012). Area-based targeting of fuel poverty in Northern Ireland: An evidenced-based approach. *Applied Geography, 34*, pp. 639-649.
57. Wang, W., Melnyk, L., Kubatko, O., Kovalov, B., Hens, L. (2023). Economic and Technological Efficiency of Renewable Energy Technologies Implementation. *Sustainability, 15*, 8802. https://doi.org/10.3390/su15118802.
58. Winkler, H., Sim˜oes, A.F., Rovere, EL la, Alam, M., Rahman, A., Mwakasonda, S. (2011). Access and affordability of electricity in developing countries. *World Dev., Vol. 39,* pp. 1037-50, https://doi.org/10.1016/j.worlddev.2010.02.021.
59. Wolniak, R., Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Identification of Energy Efficiency Trends in the Context of the Development of Industry 4.0 Using the Polish Steel Sector as an Example. *Energies, Vol. 13,* 2867.