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Analyzing Socio-Economic Development and Energy Dynamics Across Polish Voivodeships

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Abstract:

Purpose: *The purpose of the article is to examine whether there are correlations between the level of socio-economic development of the voivodeships and energy prices as well as the amount of energy (coal, electricity and gas) consumed by households in the period from 1999 to 2022.*
Design/Methodology/Approach: *The data source for the performed analysis is the Local Data Bank of Statistics of Poland. A taxonomic analysis, a non-pattern method, was used for the study. Seventeen variables were analysed over the study period. They were divided into development variables: economic (3 variables), social (8 variables) and technical (6 variables).*
Findings: *It was observed that with the increase in the level of socio-economic development, energy prices and the amount of consumed energy increased. The social component of the level of socio-economic development shows a decrease in energy prices as the social level increases. In the case of the economic and technical components, an increase in that level is observed. When analysing the amount of consumed energy, an increase in energy consumption with the increase in the level of socio-economic development is noticed. Furthermore, in the case of electricity, the index of the dynamics of energy consumption decreases as the level of socio-economic development of the voivodeships increases.*
Practical Implications: *The results of the study can be used as recommendations for regional development policies based on energy sources, depending on the level of development of individual Polish voivodeships.*
Originality/Value: *Based on the conducted analysis, an increase in the level of socio-economic development in the period under review was found.*

Keywords: *Development, socio-economic development, taxonomic analysis, Polish voivodeships, energy.*

JEL Classification: *A10, O10, Q41, R11.*

Paper type: *Research article.*

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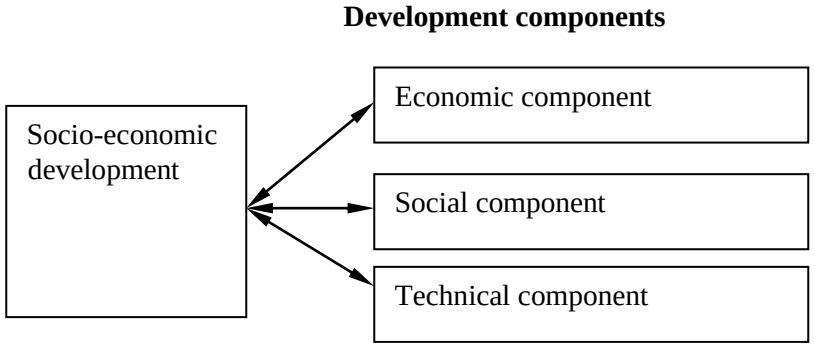
1. Introduction

Geographical and natural conditions as well as the impact of heterogeneous socio-economic factors are the reason for the situation that individual regions of the country are characterised by a different economic situation, and thus a different level of development. The processes that take place within the separate regions translate directly into the living conditions and well-being of the inhabitants (Malina, 2020).

The presence of significant disproportions in the economic potential of regions is one of the characteristics of contemporary development conditions. Such a situation is also the case in Poland (Malina, 2020).

Sixteen Polish voivodeships were analysed; however, many limitations were encountered during the analysis of the dynamics taking place on the voivodeship level. One of such limitations was the lack of availability of comparable data for different time periods, as noted by Rosner (2007). Therefore, 17 features, which were available in the analysed period, i.e., the years 1999-2022, were used for the analysis. The presented diagram (Figure 1) shows the analysis of the concept of the level of socio-economic development (Krawczyk, 2017).

Figure 1. *The structure of the analysis of the concept of socio-economic development*



Source: *Krawczyk 2023.*

The main objective of the article is to assess the degree of correlation between the level of energy prices and the amount of consumed energy with the diversification of the level of socio-economic development of Poland in terms of voivodeships as well as the classification of the voivodeships according to the synthetic measure of development.

The main motive for undertaking the assessment of the impact of change in energy prices on the Polish economy was the increase in global prices of energy resources

observed for many years and the prospect of that trend continuing in the future (Boratyński *et al.,* 2010).

A concept of sustainable development is a key for regional planning (Kavaliauskas, 2008). Energy plays an important role in the economic development of regions. The following paper refers to the long-run relationship between energy consumption and the level of socio-economic development of voivodeships from 1999 to 2022. Energy consumption has an essential influence in the economy on both the demand and the supply. It means that there should be a cause-and-effect relationship between energy consumption and socio-economic development as well as vice versa. (Krkošková, 2021).

It is believed that the reasons for the increase in energy prices are the depletion of natural resources, the dynamic development of the economies of Asian countries, the growing pressure from environmental circles to protect the climate, the use of natural resources as a tool of pressure in international politics or the unstable political situation in regions where natural resources are available.

This diagnosis raises concerns that the rise in the prices of raw materials may turn into a permanent phenomenon, which puts the issue of the impact of energy prices on the economy at the centre of interest for economists and politicians (Boratyński *et al.,* 2010).

2. Literature Review

One of the characteristics of contemporary development conditions is the presence of significant disproportions in the economic potential of regions. This is also the case in Poland. In spite of measures taken to reduce regional disparities in our country for many years, certain regions are still better developed economically.

The reasons for the above, besides the historical conditions of individual regions, may be, e.g., the implementation of new investments, the creation of new job places, the inflow of foreign capital, the increase in the income of the population, the provided services, the development of educational opportunities, the urbanisation process (Kłos-Adamkiewicz *et al.,* 2023). Those mutual causes of economic and social progress are reflected in the concept of socio-economic development (Malina, 2020; Pociovalisteanu *et al.,* 2010; Thalassinos *et al.,* 2022).

Electricity and generally access to energy, influences the socio-economic development of countries and regions. The growing demand for electricity translates into environmental problems. Therefore, energy is the key element of the Sustainable Development Strategy of the European Union (Siemiński *et al.,* 2021).

The overall environmental, climate and energy crisis has caused a growth of interest in the concept of the green economy (GE), the purpose of which is to deal

with environmental issues while enhancing economic growth, social stability and enabling convenient conditions for sustainable economic growth (Jezierska-Thöle *et al.*, 2022).

However, locally, based on available studies, there have been no investments in wind farms, hydropower plants or biogas plants in Poland. Municipalities do not show interest in huge, capital-intensive investments and limit themselves to local activities of a small spatial scope and low economic significance, although they realize the advantages of renewable energy (Struś *et al.*, 2023).

However, the energy transition in the countries belonging to the European Union continues (Chomać-Pierzecka *et al.*, 2022; Velinov *et al.*, 2023).

Poland, a member of the European Union since 2004, has committed to fulfilling its obligation to increase its share in energy generation coming from renewable sources. The target which was set for 2020, which was to achieve a 15 per cent share of energy from renewable sources in gross final consumption, was achieved by Poland. New targets which are set for 2030, included in the draft Energy Policy of Poland until 2040, establish a predicted increase to at least 23 per cent share of energy coming from renewable sources in gross final energy consumption (Zbroński *et al.*, 2023).

Permanent and stable access to various energy sources determines EU countries' economic development. Since every member state possesses different energy resources, energy balance, and technologies involved in electricity generation, the European energy markets integration will definitely prove to be a long-term process (Bluszcz and Manowska, 2020).

A constant growth in energy demand is caused by increasing population, progress in technology and development in economics. Sources of fossil energy such as coal, oil and natural gas are used to create energy. Their combustion leads to considerable air pollution in the form of greenhouse gases (CO_2, CH_4, NH_3 and N_2O) and particulate matter ($PM_{2.5}$ and PM_{10}) (Sewastianik and Gajewski, 2021, Sobol and Dyjakon, 2020). They are considered to be the cause of global warming and air pollution. Wind, water, solar (Izdebski and Kosiorek, 2023) and biomass energy are all used to prevent producing harmful emissions (Szyba and Mikulik, 2022).

The damaging effects of climate change and global warming have had an impact on different sectors of the international community. In order to mitigate climate change numerous policies concerning energy have been implemented in countries as well as globally. Renewable energy technologies play the key role in improving sustainable solutions that remarkably contribute to the reduction of greenhouse gas emissions (Juszczyk *et al.*, 2022).

Renewable energy sources (RES) are becoming more and more popular. Poland almost doubled its share, from 6.9% in 2010 to 12.7% in 2019, and further increased it to 16.1% in 2020. The share of hard coal and lignite in Poland fell from 87.8% in 2010 to 73.5% in 2019. Wind power (9.2%) and natural gas (9.2%) constitute the most crucial renewable energy sources in electricity generation (Bórawski *et al.,* 2022).

In 2022, the world's total anthropogenic CO2 emissions coming from fossil fuels constituted 91%, and coal combustion alone created approximately 40% of CO2 emissions. When we analyze the year 1990, approximately 95% of CO2 emissions were generated by the combustion of fossil fuels in the European Union.

Sectors dealing with electricity generation and industry are the ones in which the most energy and fuels with the highest sulfur content is consumed, therefore, they are responsible for the largest amount of emissions. Simultaneously, in the EU, almost 50 per cent of electricity is generated in heat and power plants relying on fossil fuels (mainly coal, oil and gas) (Struś *et al.,* 2023).

Being the main source of energy, natural gas accounts for approximately 20% of global energy generation. Since its main role is stabilising RES, it also plays the role of the key element in reducing CO_2 emissions. At the same time, the use of natural gas, which is a fossil fuel emitting CO_2, should be gradually decreased (Rogala *et al.,* 2023).

The rapid increase in the purchase prices of natural gas on energy commodity stock markets has triggered a correspondingly dynamic growth of the prices of gas fuel for households. The price data for Poland was analyzed and compared with parallel data from other member states of the EU. It was found that in the period from the first half of 2021 to the first half of 2022, gas prices in the EU rose on average by over 34% (maximum by 150%).

It was noticed that two factors significantly influenced the prices of natural gas for households in Poland, presented in the officially approved distribution tariffs of PGNiG SA: the purchase prices of energy raw materials on Towarowa Giełda Energii SA and the purchase prices on foreign markets (Bohdan *et al.,* 2023).

From Poland's point of view, taking into consideration the changes in prices of natural gas, being a consequence of numerous international events, gas investments have no economic justification in the current situation and will not be justified as far as anticipated changes are concerned. Such investments would only be justified in case of highly improbable global changes (Zych *et al.,* 2023).

Efforts to change the linear economy into a closed-loop carbon one can be supported by domestic coal resources. They can constitute an alternative being used rather than conventional imported fossil raw materials (oil, natural gas) for

chemical production, which would give Poland an opportunity to address issues of higher competitiveness, supply's security and sustainable development of different branches of industry. It is crucial in case of Poland as it is a chance for a long-lasting perspective of growth and development in economy, following global trends and EU legislation (Sobolewski *et al.,* 2022).

Energy which comes from renewable sources is a crucial element of the sustainable development strategy of the European Union including its member states [56] (Ślusarz *et al.,* 2021). The first months of 2022 saw a sharp shift in the energy policy of the European Union, initially triggered by rising energy prices and escalated by the Russian invasion of Ukraine afterwards (Woźniak *et al.,* 2023).

The energy crisis in Poland and Europe which was created by the conflict in Ukraine has reignited the debate in some countries on the legitimacy of moving away from local fossil fuels. The increase in oil and gas prices with minor change in the cost of extracting lignite from opencast mines has not been without effect. It caused reconsideration of using lignite as the cheapest source of energy.

That is only partially true because the calculations of the level of costs in power plants do not take into account many external costs incurred by energy producers but borne by other entities or the general public (Pepliński, 2023).

The energy system is likely to transform in a gradual shift away from natural gas from Russia and an increase in the use of renewable and nuclear energy. The electricity sector plays the main role not only in changing the energy landscape of the EU but also in putting Europe as the first climate-neutral continent in the world (Koval *et al.,* 2023).

A more environmentally friendly, low-carbon Europe, promoting clean and fair energy transition, green investments and the circular economy, inter alia is one of the thematic objectives of the new EU financial goal (Klemens *et al.,* 2022). Such a transformation will not only cause an increase in energy security but also speed up the pace of reducing greenhouse gas emissions in Europe (Bartela *et al.,* 2022).

EU member states have to implement the adopted Community Energy Strategy defined as part of the European Green Deal. In accordance with the EU policy, all member states are obliged to reach climate-neutral and zero-carbon economies by the year 2050. The diversification of the used energy sources, with a predominance of renewable energy sources (RES) will be the basis of the future energy transition (Igliński *et al.,* 2022).

Taking into account the use of renewable energy, the European Union's direction is distributed generation and a rise in the use of by-products and organic waste, particularly in the new-generation biofuels production (Gradziuk *et al.,* 2020).

In countries that have left the centrally planned economy regime, the increase in energy prices may also be the result of their release (i.e., the state's resignation from controlling energy prices), which is one of the measures and actions aiming to make the energy sector more market-oriented. In this case, the factor counteracting the upward trends is the demonopolisation and liberalisation of the energy market.

This is bound to lead to an improvement in the efficiency of the energy sector, and thus to slowing down the increase in energy prices. Technological progress, changes in the energy intensity of production and the development of alternative energy sources can have similar effects (Boratyński *et al.*, 2010).

The consequences of rising energy prices may have a different impact on the standard of living referring to different population groups, hence it is interesting to analyse the distribution of costs incurred by households in all the existing voivodeships. A hypothesis was put forward that along with the increase in the level of socio-economic development of voivodeships in the years 1999-2022, energy prices as well as the amount of consumed energy (coal, natural gas, electricity) increased. The following research questions were posed:

1. Do energy prices increase with the increase in the level of the economic component?
2. Do energy prices increase with the increase in the level of the social component?
3. Do energy prices increase with the increase in the level of the technical component?
4. Does the amount of consumed energy increase with the increase in the level of the economic component?
5. Does the amount of consumed energy increase with the increase in the level of the social component?
6. Does the amount of consumed energy increase with the increase in the level of the technical component?
7. Is the energy price index correlated with the level of socio-economic development?
8. Is the index of the dynamics of energy consumption correlated with the level of socio-economic development?

3. Materials and Methods

The analysis of the potential of municipalities in Polish voivodeships in the light of the selected categories of socio-economic development covering from 1999 to 2022, is a sort of synthesis of three components: economic potential, social potential and technical potential.

The taxonomic analysis was performed using the taxonomic method repeatedly implemented in regional analyzes by A. Niedźwiedzki (2002a; 2002b), B. Madras-Kobus (2001), J. Pociecha, B. Podolec, A. Sokołowski, K. Zając (1988), A. Rosner (2007), Ponikowski (2004), G. Krawczyk (2017; 2023).

For the m-element set of the voivodeships under study (m = 384 = 16 voivodeships * 24 years) and n = 17 development characteristics, the following two-dimensional data matrix was created for each of the three development components (Ponikowski, 2004).

$$X_c = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

where:

X_c - matrix of diagnostic features for the c component (c= 1...3), xik -elements of the X_c matrix denote the value of examined features for the i-th (i=1,2,...,m) object (voivode-ship) in a given year and the k-th (k=1,2,...,n) development characteristic.

The applied variables from the Xc set should indicate a significant level of potential differentiation. The higher the given volatility index, the more objective the selection of the corresponding variable characterising the potential should be considered (Niedźwiecki 2002a).

Therefore, the coefficient of variation was calculated as (Ponikowski, 2004):

$$V_k = \frac{S_k}{\bar{x}_k} 100 \quad (2)$$

where:

$\bar{x}_k$ - is the arithmetic mean of the k-th development characteristic, while S_k is the standard deviation.

To bring the characteristics under study to comparability, they need to be normalised. The adjusted observation matrix X_c' was transformed into a matrix of standardised observations of partial potential indicators (Niedźwiecki, 2002a; Ponikowski, 2004):

$$Z_c = \begin{bmatrix} z_{11} & z_{12} & \dots & z_{1n} \\ z_{21} & z_{22} & \dots & z_{2n} \\ \dots & \dots & \dots & \dots \\ z_{m1} & z_{m2} & \dots & z_{mn} \end{bmatrix} \quad (3)$$

Whereas:

$$z_{ik} = \frac{x'_{ik} - \bar{x}_k}{S_k} \quad (4)$$

where:

zik – normalised k-th feature for the i-th object (voivodeship), x_{ik} – the initial value of the k-th feature for the i-th object, and Sk - the arithmetic mean and standard deviation, respectively, of the k-th potential feature.

The next stage consisted of constructing synthetic measures obtained in each of the analysed components. This task was solved by synthesising all partial indicators which were considered to be diagnostic (Kosiedowski, 2001) through the creation of an indicator of the relative level of development of W_i, which could take values in the <0,1> range. It turned out that the higher its value, the higher the potential of the ana-lysed voivodeship (Krawczyk, 2017).

$$W_i = \frac{\sum_{k=1}^{n} z_{ik}^*}{\sum_{k=1}^{n} max_i[z_{ik}^*]} \quad (5)$$

Where:

$$z_{ik}^* = z_{ik} + |min_i[z_{ik}]| \quad (6)$$

In the final step, 3 indicators (components) were aggregated into a single indicator. Such an indicator represented the level of socio-economic development (formulas 3-6). For each voivodeship, a relative synthetic indicator of development in the years 1999-2022 was determined.

The outcome of the study provided interesting data. A specific map of the economic development of the voivodeships was obtained. The purpose of this map was to classify the studied objects in space and time (Krawczyk, 2017).

The interpretation of the different ranges of values of the r-Pearson coefficient is as follows (Bedyńska and Brzezicka, 2007):

0-0.3 no or very weak correlation,
0.3-0.5 moderate correlation,
0.5-0.7 strong correlation,
0.7-1 very strong correlation.

Table 1 presents the features selected to measure the level of socio-economic development of voivodeships.

Table 1. *Features used to measure the level of socio-economic development of voivodeships in the years 1999-2022*

Features	Feature symbol	Specification	Coefficient of variation	S/D*
Economic	E1	Entities entered into the REGON (National Business Register Number) register per 10 thousand population	20.96	S
	E2	Average gross monthly pension of individual farmers in PLN	12.72	S
	E3	Average gross monthly pension of people from outside the agricultural sector in PLN	21.55	S
	E4	Unemployed in relation to the working-age population	32.82	D
Social	S1	Population density per 1 km^2	57.64	S
	S2	Working-age population to total	3.45	S
	S3	Post-working age population to total	40.89	D
	S4	Birth rate per 1 thousand population	371.27	S
	S5	Balance of inter-voivodeship migration per 1 thousand population	307.16	S
	S6	Number of deaths per 1,000 persons	25.49	D
	S7	Number of people per 1 library facility.	30.81	D
	S8	Number of cinemagoers per year per 1,000 population	47.83	S
	S9	Population per theater	30.53	D
Technical	T1	Hard surfaced public roads per 100 km^2	35.60	S
	T2	Number of registered passenger cars per 1,000 people	32.62	S
	T3	Railway lines per 100 km^2	43.57	S
	T4	Number of offered overnight stays per 1,000 population	90.98	S
	T5	Number of overnight stays offered to foreign tourists per 1,000 population	125.55	S
	T6	Usable area of apartments to the number of inhabitants	13.93	S
	T7	Number of residential rooms to the number of people	11.52	S

Note: **S/D- stimulant/destimulant.*

Source: *Own elaboration based on: Jerczyński 1971, Swianiewicz 1989, Ziółkowski 1997, Ratajczak 2000, Wiatrak 2000, Kosiedowski 2001, Rakowski, Pakulska 2001, Ponikowski 2002, Roeske-Słomka 2003, Wysoki, Łuczak 2004, Ponikowski 2004, Kapusta 2004, Brol 2004, Tokarski, Stepień, Wojnarowski 2006, Młodak 2005; Roszkowska 2005, Lira, Wysocki 2004, Rosner, Stany 2007a, Rosner, Stany 2007b, Rosner, Stany 2007c, Czornik 2008, Ziemniańczyk 2010, Głuszczuk 2011, Kocura-Bera 2011, Szubska-Włodarczyk 2014, Kołodziejczyk 2014, Kiniorska 2014, Ludwiczak 2014, Adamowicz, Janulewicz 2016, Chądzyńska 2016, Krawczyk 2017; Konecka-Szydłowska, Maćkowiak 2016, Parysek 2018, Kozubek, Konecka-Szydłowska 2022, Krawczyk 2023 GUS 2023.*

The degree of correlation of variables within each domain was examined. In many cases, strong correlations between variables describing a particular domain were observed. To ensure the representativeness of the variables, variables that are not very strongly correlated with the others in a given category and of a higher discriminatory ability (higher coefficient of variation in the examined time period) were introduced into the final set (Malina, 2020). As a result of the conducted analysis, the following features were excluded from further consideration: E2, S6, T7, based on the analysis of Tables 1- 4.

Table 2. *Correlations between features of the economic component*

	S1	S2	S3	S4	S5	S6	S7	S8	S9
S1	X								
S2	0.054	X							
S3	-0.070	0.554**	X						
S4	-0.059	0.481**	0.750**	X					
S5	0.284**	0.039	0.097	0.313**	X				
S6	-0.069	0.530**	0.794**	0.922**	0.195**	X			
S7	-0.350**	0.048	0.179**	-0.036	-0.483**	0.106*	X		
S8	0.283**	-0.035	-0.365**	0.113*	0.589**	-0.023	-0.580	X	
S9	0.185**	0.056	-0.126*	-0.105*	0.442**	-0.172**	-0.627**	0.448**	X

Note: ***Significant correlation at the 0.01 level*
Source: *Own elaboration based on Statistics Poland data*

Table 3. *Correlations between features of the social component*

	E1	E2	E3	E4
E1	X			
E2	0.510**	X		
E3	0.634**	0.901**	X	
E4	0.545**	0.698**	0.823**	X

Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level*
Source: *Own elaboration based on Statistics Poland data*

Table 4. Correlations between features of the technical component

	T1	T2	T3	T4	T5	T6	T7
T1	X						
T2	0,241**	X					
T3	0.671**	-0.020	X				
T4	-0.146**	0.139**	-0.110*	X			
T5	-0.083	-0.116*	-0.114*	0.925**	X		
T6	0.264**	0.918**	-0.029	0.076	0.111*	X	
T7	0.172**	0.897**	0.016	0.164**	0.179**	0.965**	X

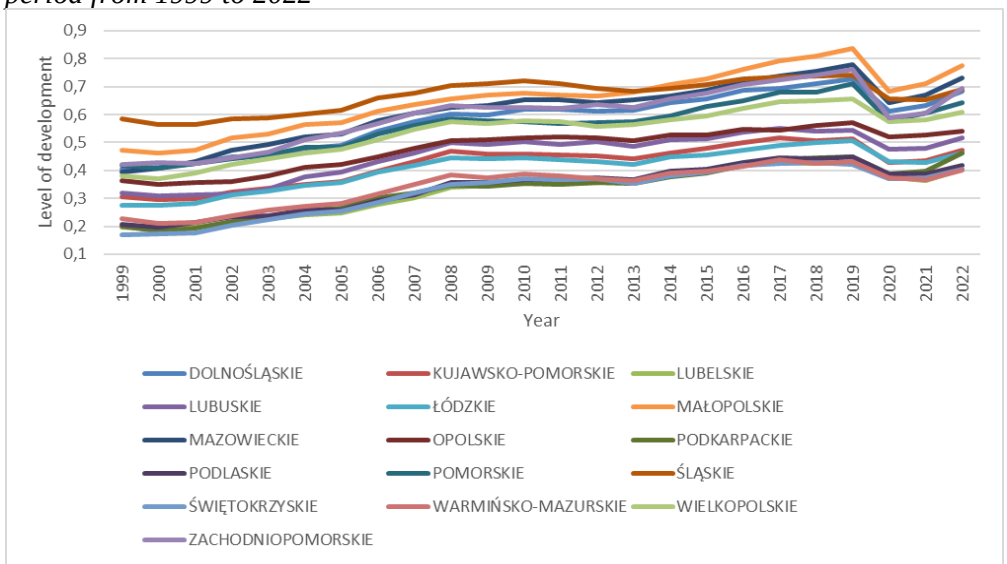
Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level.*
Source: *Own elaboration based on Statistics Poland data.*

4. Results

In the analysed period, the level of socio-economic development of voivodeships increased (Figure 2). A decrease in that level was observed in 2020 and 2021, there was an increase again in 2022, sadly to a level lower than in 2019 (Figures 3-4). In 2022, the most developed voivodeship was the Małopolskie Voivodeship.

Table 5 presents the ranking of cities by years: 1999 – the beginning of the analysed period, 2003 – the state before joining the EU, 1999 – the state before the COVID 19 pandemic, 2022 – the end of the examined period, the state after the COVID 19 pandemic. In the table, in the an-lysed period, slight changes in the ranking are observed.

Figure 2. *The level of socio-economic development of Polish voivodeships in the period from 1999 to 2022*



Source: *Own elaboration based on Statistics Poland data.*

Figure 3. *The level of socio-economic development of Polish voivodeships in 1999*

Source: *Own elaboration based on Statistics Poland data*

Figure 4. *The level of socio-economic development of Polish voivodeships in 2022*

Source: *Own elaboration based on Statistics Poland data*

Table 5. *Ranking of Polish voivodeships by selected years according to the level of socio-economic development*

Item*	1999	2003	2019	2022
MAŁOPOLSKIE	2	2	1	1
MAZOWIECKIE	6	3	2	2
ZACHODNIOPOMORSKIE	3	4	3	3
ŚLĄSKIE	1	1	4	4
DOLNOŚLĄSKIE	5	6	5	5
POMORSKIE	4	5	6	6
WIELKOPOLSKIE	7	7	7	7
OPOLSKIE	8	8	8	8
LUBUSKIE	9	10	9	9
KUJAWSKO-POMORSKIE	10	9	10	10
ŁÓDZKIE	11	11	11	11
PODKARPACKIE	14	14	13	12
PODLASKIE	13	13	12	13
ŚWIĘTOKRZYSKIE	16	16	16	14
LUBELSKIE	15	15	15	15
WARMIŃSKO-MAZURSKIE	12	12	14	16

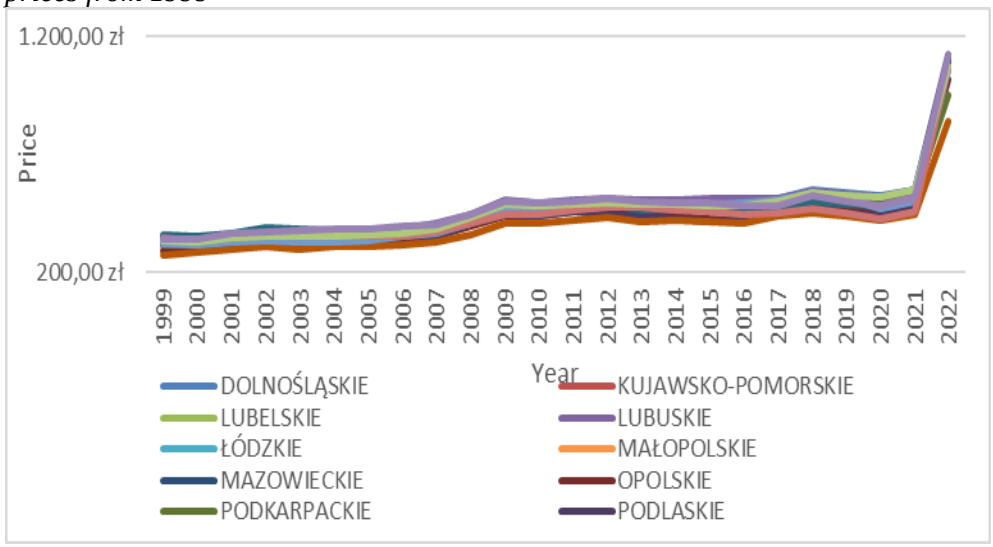
Note: **Order according to the 2022 ranking*
Source: *Own elaboration based on Statistics Poland data*.

The basis for the development of the goods and services price indices is the observation of representative prices. Hard coal is characterised as the price per tonne in PLN in the years 1999-2022. Electricity for households (tariff G-11) per 1 kWh in PLN in the years 1999-2022.

High-methane natural gas from the network for households (tariff W-1.1) per 1 m3 in PLN in the years 1999-2011. High-methane natural gas from the network for households (tariff W-1.1) per 1 kWh in PLN in the years 2015-2022. In the case of gas, there is no continuity of data in the period from 1999 to 2022, due to a change in the unit of measurement from m3 to kWh.

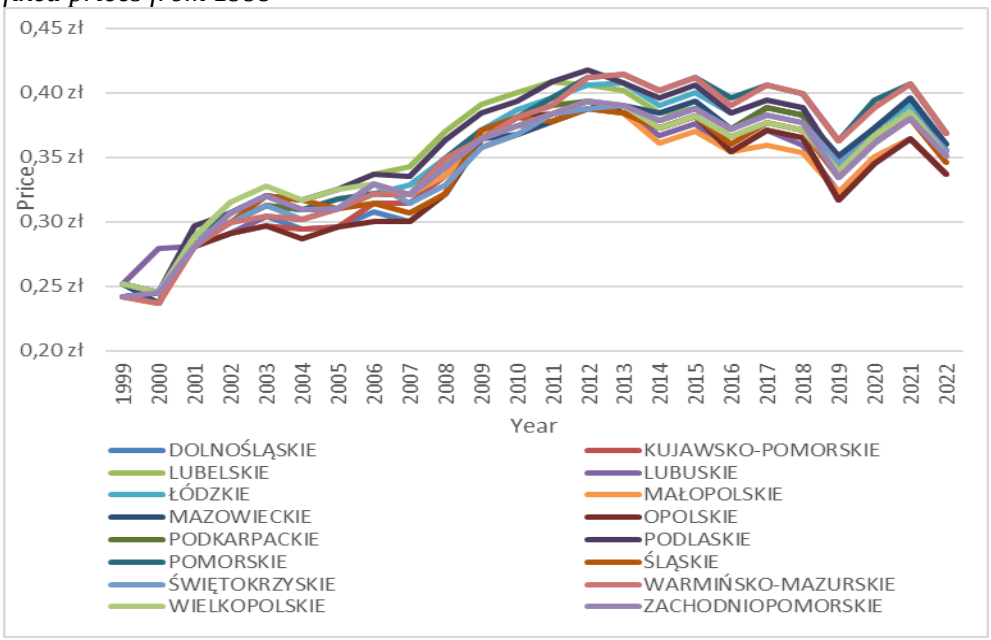
An increase in electricity prices was observed over the 1999-2022 study period (Figure 5). There was also an increase in the prices of hard coal over the 1999-2022 study period, with a sharp jump in prices in 2022 (Figure 6). For gas, a price increase in the period from 1999 to 2011 was noticed (Figure 7). In turn, a slight decrease in the prices of gas was recorded in the period from 2015 to 2022 (Figure 8).

Figure 5. *The level of coal prices by voivodeship in the years 1999-2022, in fixed prices from 1999*



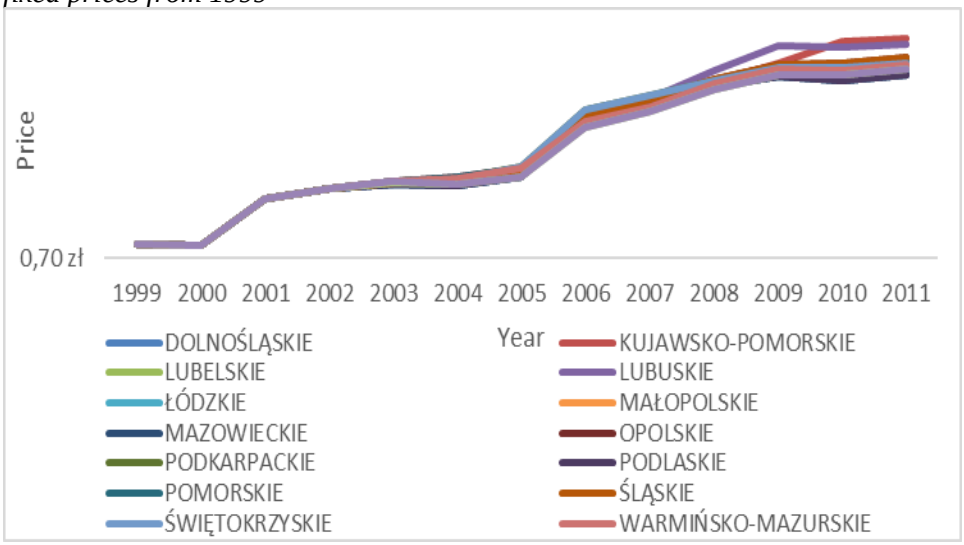
Source: *Own elaboration based on Statistics Poland data*.

Figure 6. *The level of electricity prices by voivodeship in the years 1999-2022, in fixed prices from 1999*



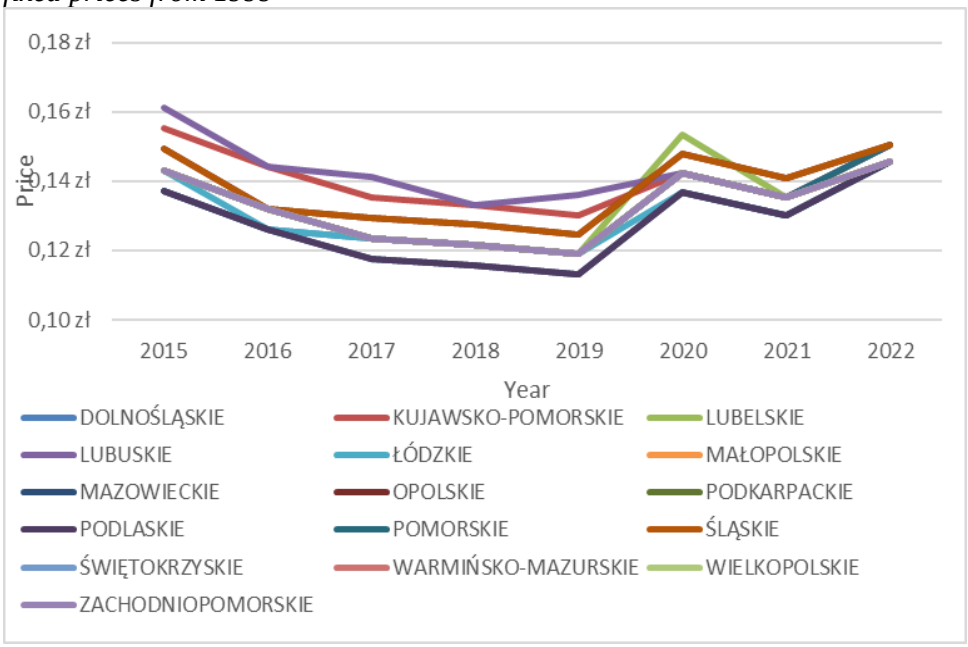
Source: *Own elaboration based on Statistics Poland data*.

Figure 7. *The level of natural gas prices by voivodeship in the years 1999-2011, in fixed prices from 1999*



Source: *Own elaboration based on Statistics Poland data.*

Figure 8. *The level of natural gas prices by voivodeship in the years 2015-2022, in fixed prices from 1999*



Source: *Own elaboration based on Statistics Poland data.*

As a result of the conducted analysis of the energy price dynamics indices, the highest dynamics index was the case of the Opolskie, Dolnośląskie and Małopolskie voivodeships and the lowest of the Podkarpackie Voivodeship.

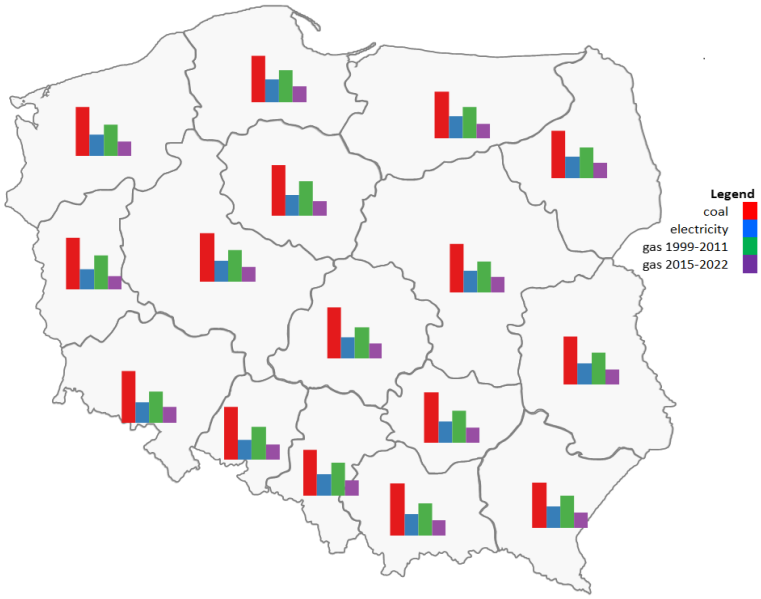
For electricity, the highest dynamic index was the case of the Pomorskie and Warmińsko-Mazurskie voivodeships. The lowest one was the case of the Lubuskie and Opolskie voivodeships. For gas, the highest dynamic index was the case of the Dolnośląskie Voivodeship. The lowest one was the case of the Kujawsko-Pomorskie Voivodeship. Detailed results are presented in Table 6 and Figure 9.

Table 6. *Index of the dynamics of changes in energy prices in Polish voivodeships in the years 1999-2022*

Item	Index of the dynamics of changes in coal prices in the years 1999-2022, 1999 = 100%	Index of the dynamics of changes in electricity prices in the years 1999-2022, 1999 = 100%	Index of the dynamics of changes in the prices of high-methane natural gas from the network for households (tariff W-1) - per 1m3 in the years 1999-2011 1999 = 100%	Index of the dynamics of changes in the prices of high-methane natural gas from the network for households (tariff W-1.1) - per 1 kWh in the years 2015-2022 2015 = 100%
DOLNOŚLĄSKIE	343.93	139.09	208.06	109.52
KUJAWSKO-POMORSKIE	334.19	139.36	227.49	96.88
LUBELSKIE	319.70	141.17	211.30	101.77
LUBUSKIE	337.86	133.93	224.25	90.47
ŁÓDZKIE	337.01	141.17	204.82	101.77
MAŁOPOLSKIE	342.88	139.09	212.92	101.77
MAZOWIECKIE	319.97	142.98	204.82	106.20
OPOLSKIE	346.50	133.93	215.35	100.76
PODKARPACKIE	299.19	139.36	212.11	101.77
PODLASKIE	317.12	146.60	204.82	106.20
POMORSKIE	305.12	152.24	212.92	104.95
ŚLĄSKIE	304.24	142.85	215.35	100.76
ŚWIĘTOKRZYSKIE	328.35	141.17	212.11	101.77
WARMIŃSKO-MAZURSKIE	308.32	152.24	211.30	101.77
WIELKOPOLSKIE	319.93	139.36	208.87	101.77
ZACHODNIOPOMORSKIE	326.75	144.72	208.87	101.77

Source: *Own elaboration based on Statistics Poland data*.

Figure 9. *Index of the dynamics of changes in energy prices in the years 1999-2022 in Polish voivodeships*



Source: *Own elaboration based on Statistics Poland data*.

When examining the correlations between the index of the dynamics of changes in energy prices and the level of socio-economic development of the voivodeships, no statistically significant correlation was noticed (Table 7).

The analysis of the correlation between energy prices and the level of so-cio-economic development (Table 8) shows moderate significant correlations at the 0.01 level for coal (0.321) (Figure 10), for electricity (0.399) (Figure 11), for natural gas (1999-2011) (0.489) (Figure 12), which means that with the increase in the level of socio-economic development the prices of coal, electricity and gas increase moderately.

Examining the economic component alone, a strong significant correlation at the 0.01 level can be observed for coal (0.587), electricity (0.584), natural gas (1999-2011) (0.674), which means that as the economic component increases the prices of coal, electricity and gas increase.

Analysing the social component alone, a moderate negative significant correlation at the 0.01 level can be noticed for coal (-0.361), electricity (-0.176), natural gas (1999-2011) (0.215), natural gas (2015-2022) (-0.365), which means that the prices of coal, electricity and gas (2015-2022) decrease with the increase in the social component.

Table 7. *Correlations between the level of socio-economic development of the voivodeships and the index of the dynamics of changes in energy prices in Polish voivodeships.*

Item	Coal price dynamics index in the years 1999-2022,		Energy price dynamics index in the years 1999-2022,		Index of dynamics of changes in the prices of high-methane natural gas from the network for households (tariff W-1) - per 1m3 in the years 1999-2011;		Index of dynamics of changes in the prices of high-methane natural gas from the network for households (tariff W-1.1) - for 1 kWh in the years 2015-2022	
The level of socio-economic development	1999	0.095	1999	-0.047	1999	0.090	2015	0.208
	2022	0.154	2022	-0.054	2011	-0.035	2022	0.266
Economic component	1999	0.101	1999	-0.057	1999	-0.131	2015	0.229
	2022	0.142	2022	-0.090	2011	-0.155	2022	0.238
Social component	1999	0.107	1999	-0.014	1999	0.192	2015	0.199
	2022	0.046	2022	-0.072	2011	0.043	2022	0.288
Technical component	1999	0.053	1999	-0.065	1999	0.091	2015	0.145
	2022	0.206	2022	-0.049	2011	-0.018	2022	0.164

Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level*
Source: *Own elaboration based on Statistics Poland data*.

Analysing the technical component alone, a moderate significant correlation at 0.01 level can be noticed for coal (0.472), electricity (0.458), natural gas (1999-2011) (0.477), which means that with the technical growth, the prices of coal, electricity and gas increase.

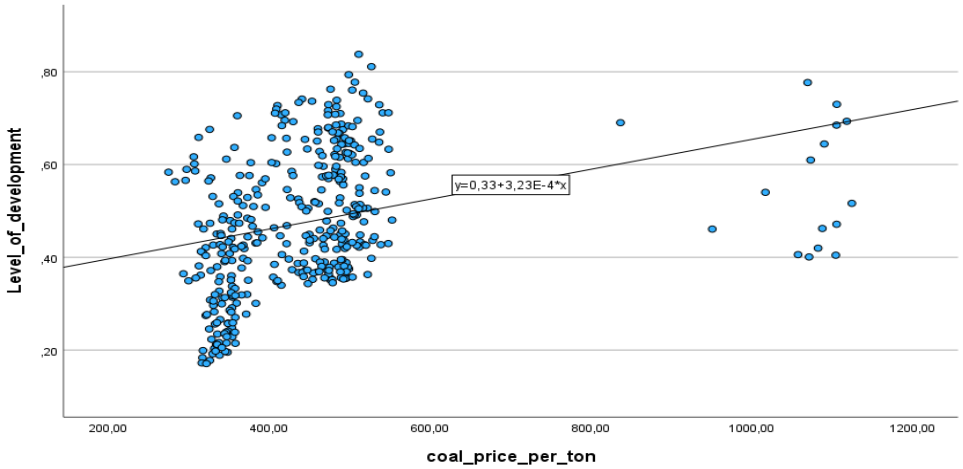
Table 8. *Correlations between the level of socio-economic development of Polish voivodeships and energy prices in the years 1999-2022*

Item	hard coal - for 1 tonne 1999-2022	electricity for households (tariff G-11) - for 1 kWh 1999-2022	high-methane natural gas from the network for households (tariff W-1) - for 1m3 1999-2011	high-methane natural gas from the network for households (tariff W-1.1) - for 1 kWh 2015-2022

Socio-economic development	0.321**	0.399**	0.489**	-0.170
Economic component	0.587**	0.584**	0.674**	0.077
Social component	-0.361**	-0.176**	0.215**	-0.365**
Technical component	0.472**	0.458**	0.477**	-0.001

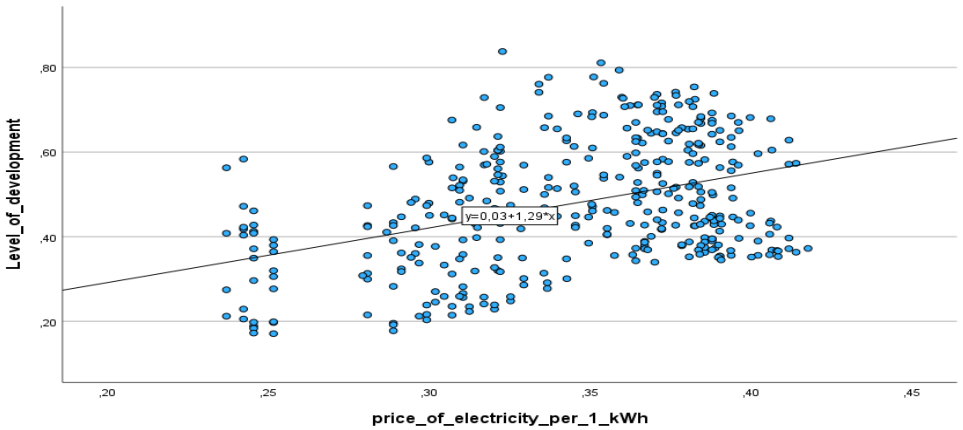
Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level*
Source: *Own elaboration based on Statistics Poland data.*

Figure 10. *Correlations between the level of socio-economic development of Polish voivodships and coal prices per 1 tonne in the years 1999-2022*



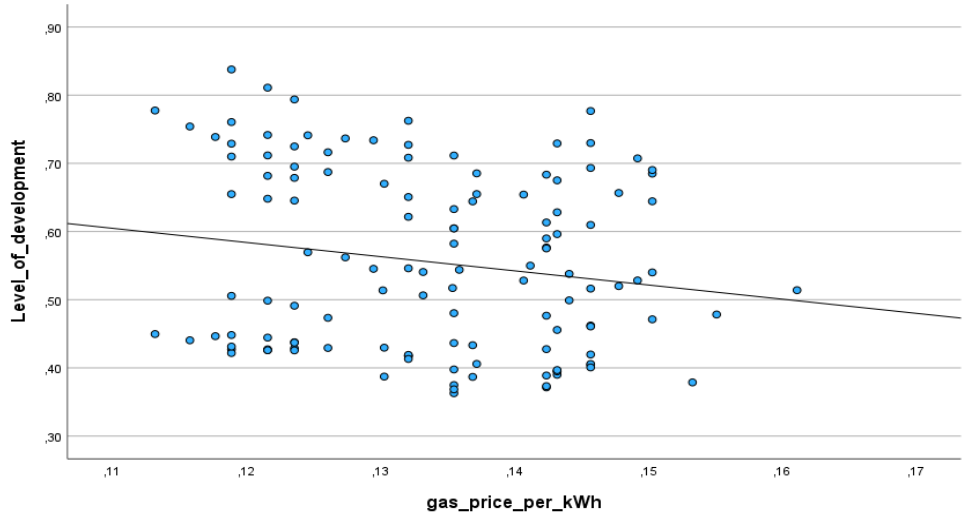
Source: *Own elaboration based on Statistics Poland data.*

Figure 11. *Correlations between the level of socio-economic development of Polish voivodeships and electricity prices per 1 kWh in the years 1999-2022*



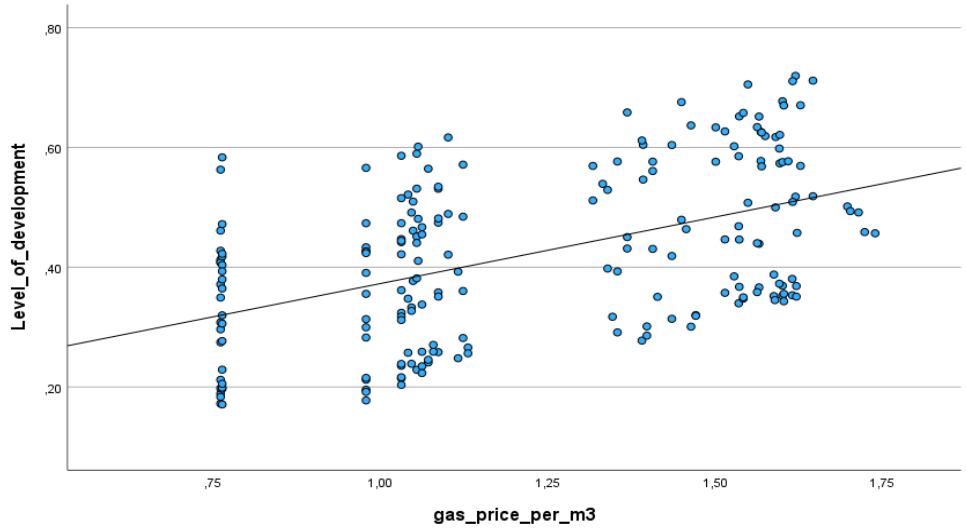
Source: *Own elaboration based on Statistics Poland data.*

Figure 12. *Correlations between the level of socio-economic development of Polish voivodeships and gas prices per 1 kWh in the years 2015-2022*



Source: *Own elaboration based on Statistics Poland data*.

Figure 13. *Correlations between the level of socio-economic development of Polish voivodeships and gas prices per 1m3 in the years 1999-2011*



Source: *Own elaboration based on Statistics Poland data*.

An increase in the electricity consumption was noticed in the analysed period, the years 2000 - 2021 (Figure 14). There is no data for hard coal consumption. In the years 2002-2016, there was an increase in the consumption of gas (Figure 15). In the years 2013-2020, an increase in the consumption of gas was also noticed (Figure 16).

Figure 14. *The level of electricity consumption in Polish voivodeships over the period from 1999 to 2022*
Source: *Own elaboration based on Statistics Poland data.*

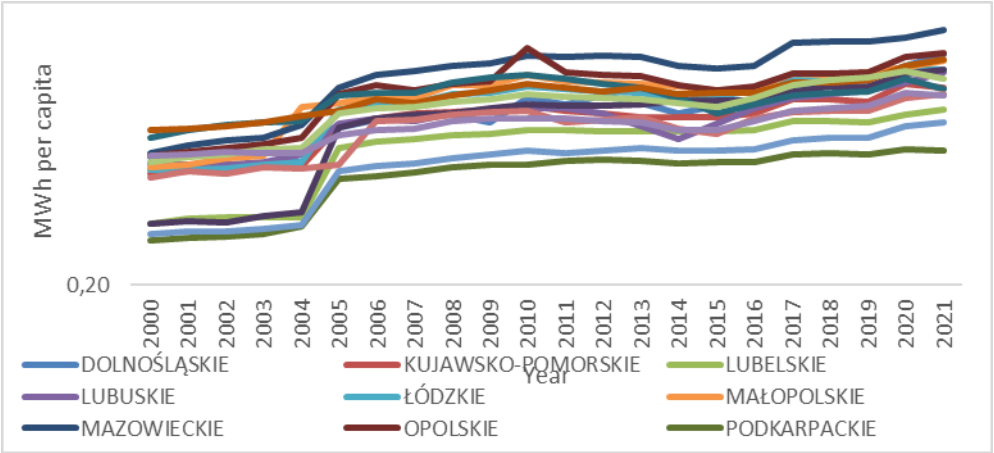
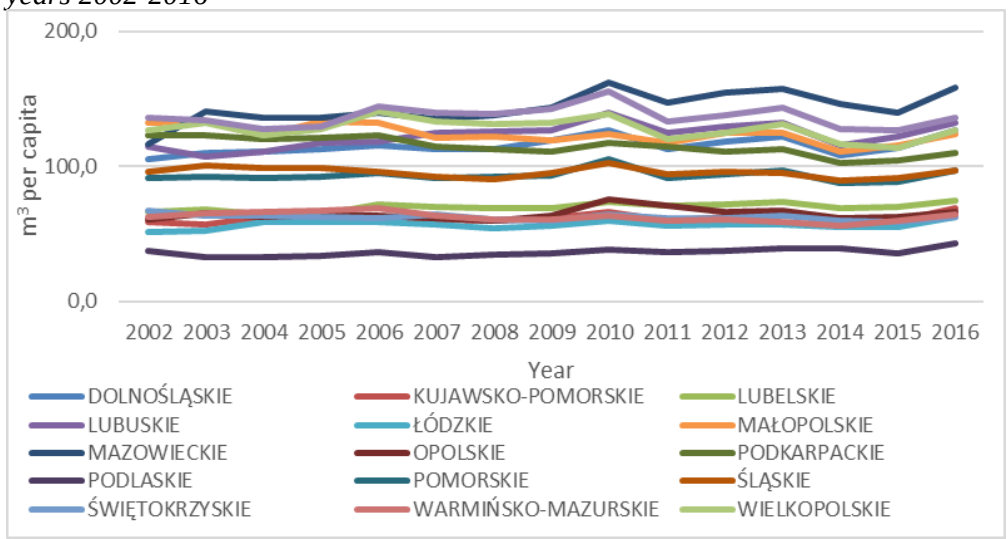


Figure 15. *The level of gas consumption in Polish voivodeships, in m3, in the years 2002-2016*



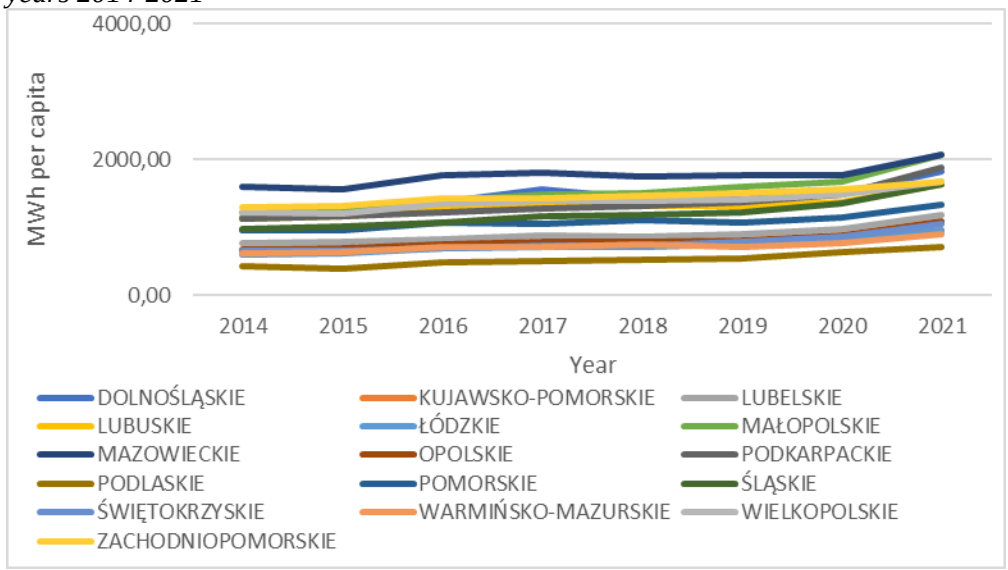
Source: *Own elaboration based on Statistics Poland data.*

As a result of the analysis of the indices of the dynamics of changes in the amount of consumed energy, it can be concluded that for electricity, the highest dynamics index was the case of the Lubelskie and Podkarpackie voivodeships. The lowest one was the case of the Pomorskie Voivodeship.

For gas (1999-2011), the highest dynamics index was the case of the Mazowieckie Voivodeship. The lowest one was the case of the Świętokrzyskie Voivodeship. For gas (2015-2022), the highest dynamics index was the case of the Małopolskie

and Podkarpackie voivodeships. The lowest one was the case of the Mazowieckie and Zachodniopomorskie voivodeships. Detailed results are presented in Table 9 and Figure 17.

Figure 16. *The level of gas consumption in Polish voivodeships, in mWh, in the years 2014-2021*



Source: *Own elaboration based on Statistics Poland data.*

Table 9. *Index of the dynamics of changes in the amount of energy consumed by Polish voivodeships in the years 1999-2022.*

Item	Index of the dynamics of changes in electricity consumption in the years 1999-2022, 1999 = 100%	Index of the dynamics of changes in the consumption of high-methane natural gas from the network for households (tariff W-1) - per 1m3 in the years 2002-2016, 1999 = 100%	Index of the dynamics of changes in the consumption of high-methane natural gas from the network for households (tariff W-1) - per kWh in the years 2014-2021, 2014 = 100%
DOLNOŚLĄSKIE	152.11	119.87	157.40
KUJAWSKO-POMORSKIE	147.50	116.07	146.38
LUBELSKIE	189.52	112.41	155.43
LUBUSKIE	147.71	115.04	144.14
ŁÓDZKIE	155.34	120.93	157.37
MAŁOPOLSKIE	158.46	94.24	169.69
MAZOWIECKIE	162.25	135.59	128.84
OPOLSKIE	152.05	110.08	161.45
PODKARPACKIE	180.60	89.81	167.21
PODLASKIE	220.38	115.55	166.19
POMORSKIE	122.61	105.45	138.25
ŚLĄSKIE	131.19	100.21	166.79

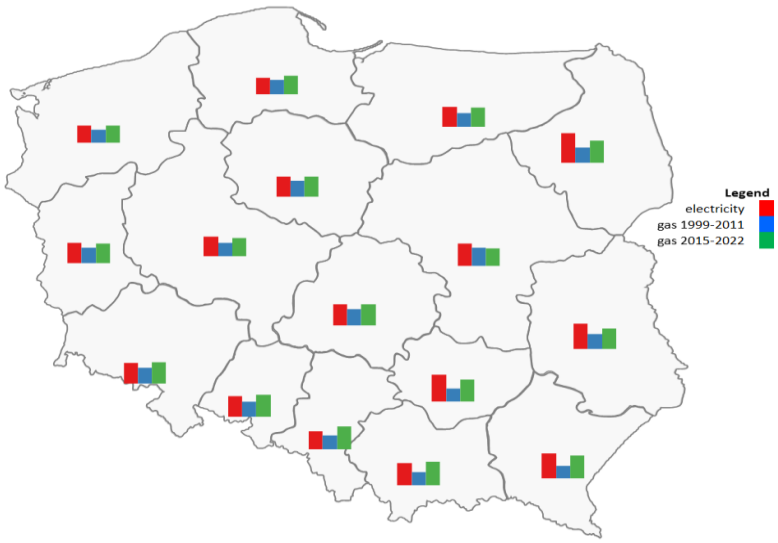
ŚWIĘTOKRZYSKIE	194.01	93.29	159.03
WARMIŃSKO-MAZURSKIE	147.56	103.38	146.36
WIELKOPOLSKIE	144.54	100.24	136.51
ZACHODNIOPOMORSKIE	130.45	99.85	129.83

Source: *Own elaboration based on Statistics Poland data*.

Having analysed the correlations between the index of the dynamics of changes in energy prices and the level of socio-economic development of the voivodeships, statistically significant negative correlations at the 0.01 level were found for the amount of energy consumed and the level of socio-economic development and each of the development components (Table 9).

The above means that with the increase in the level of socio-economic development (economic, social and technical components), the dynamics index decreases, and thus the amount of consumed energy decreases (Table 10).

Figure 17. *Index of the dynamics of changes in the amount of energy consumed by Polish voivodeships in the years 1999-2022*



Source: *Own elaboration based on Statistics Poland data*.

The analysis of the correlation between the amount of consumed energy and the level of socio-economic development showed moderate (Table 11), significant correlations at the 0.01 level for electricity (0.757) (Figure 18), for natural gas (2002-2016) (0.599) (Figure 19), for gas (2014-2021) (0.647) (Figure 20), which means that the consumption of electricity and gas strongly increases with the increase in the level of socio-economic development.

Table 10. *Correlations between the level of socio-economic development of Polish voivodeships and the index of the dynamics of changes in the amount of consumed energy.*

	Index of the dynamics of changes in electricity consumption in the years 1999-2022,		Index of the dynamics of changes in the consumption of high-methane natural gas from the network for households (tariff W-1) - per 1m3 in the years 2002-2016		Index of the dynamics of changes in the consumption of high-methane natural gas from the network for households (tariff W-1.1) - per 1 kWh in the years 2014-2021	
The level of socio-economic development	1999	-0.722**	2002	0.072	2014	-0.268
	2022	- 0.585*	2016	0.073	2021	-0.224
Economic component	1999	-0.539*	2002	0.270	2014	-0.428
	2022	-0.622*	2016	0.276	2021	-0.481
Social component	1999	-0.809**	2002	0.178	2014	-0.248
	2022	-0.396	2016	0.169	2021	-0.092
Technical component	1999	-0.585*	2002	-0.229	2014	-0.100
	2022	-0.545*	2016	-0.168	2021	-0.073

Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level*
Source: *Own elaboration based on Statistics Poland data.*

Analysing the economic component alone, a strong significant correlation at the 0.01 level can be observed for electricity (0.815), natural gas (2002-2016) (0.408), natural gas (2014-2021) (0.288). This means that as the economic component increases, the consumption of electricity and gas increases.

Examining the social component alone, a moderate, significant correlation at the 0.01 level was observed for electricity (0.233), natural gas (2002-2016) (0.447), natural gas (2014-2021) (0.719). This means that the consumption of electricity and gas in-creases with the increase in the social component.

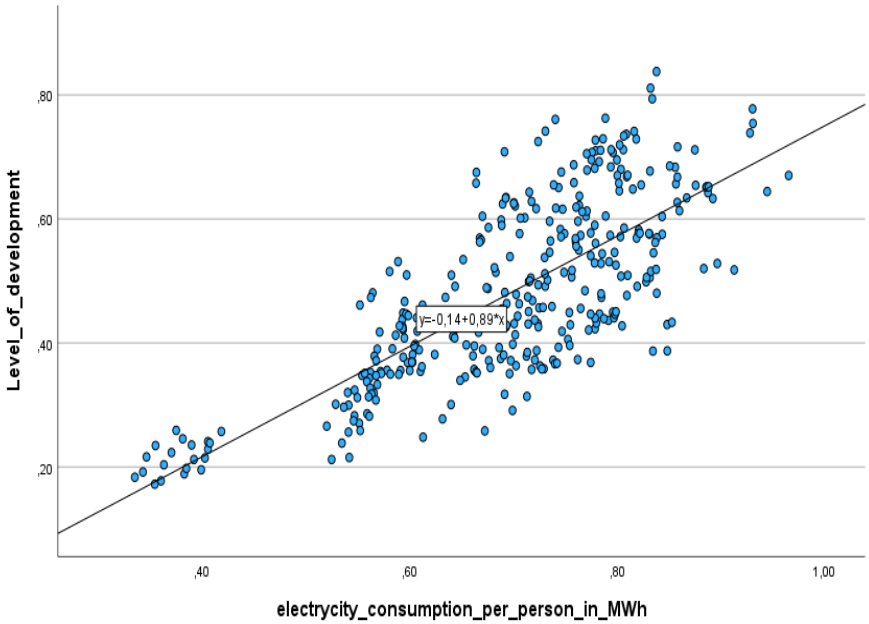
Analysing the technical component alone, a strong significant correlation at the 0.01 level was noticed for electricity (0.640), natural gas (2002-2016) (0.408), natural gas (2014-2021) (0.588). The above means that as the technical component increases, electricity and gas consumption increases.

Table 11. *Correlations between the level of socio-economic development of Polish voivodeships and the amount of consumed energy.*

Item	electricity for households (tariff G-11) - 1 kWh 2000-2021	high-methane natural gas from the network for households (tariff W-1) - 1m3 2002-2016	high-methane natural gas from the network for households (tariff W-1.1) - 1 kWh 2014-2021
Socio-economic development	0.757**	0.599**	0.647**
Economic component	0.815**	0.408**	0.719**
Social component	0.233**	0.668**	0.288**
Technical component	0.640**	0.447**	0.588**

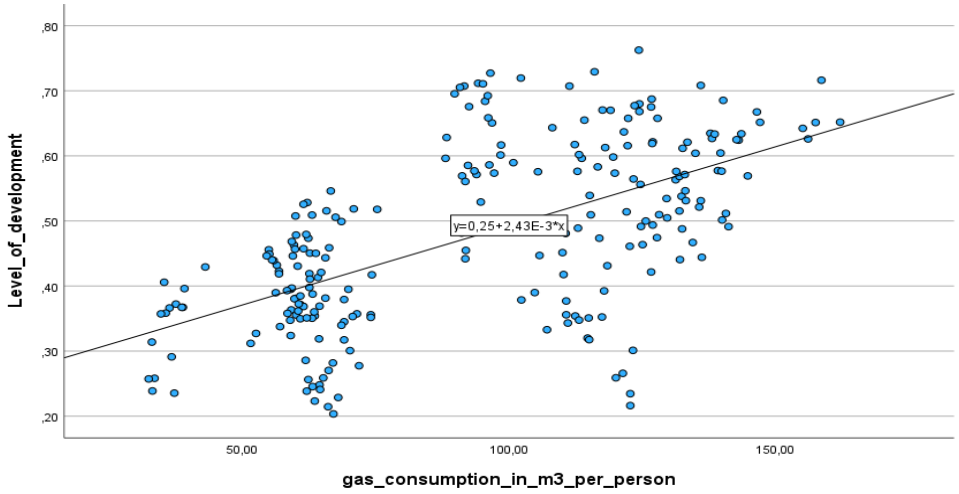
Note: ***Significant correlation at the 0.01 level, *Significant correlation at the 0.05 level*
Source: *Own elaboration based on Statistics Poland data.*

Figure 18. *Correlations between the level of socio-economic development of Polish voivodeships and the amount of consumed electricity, in MWh*



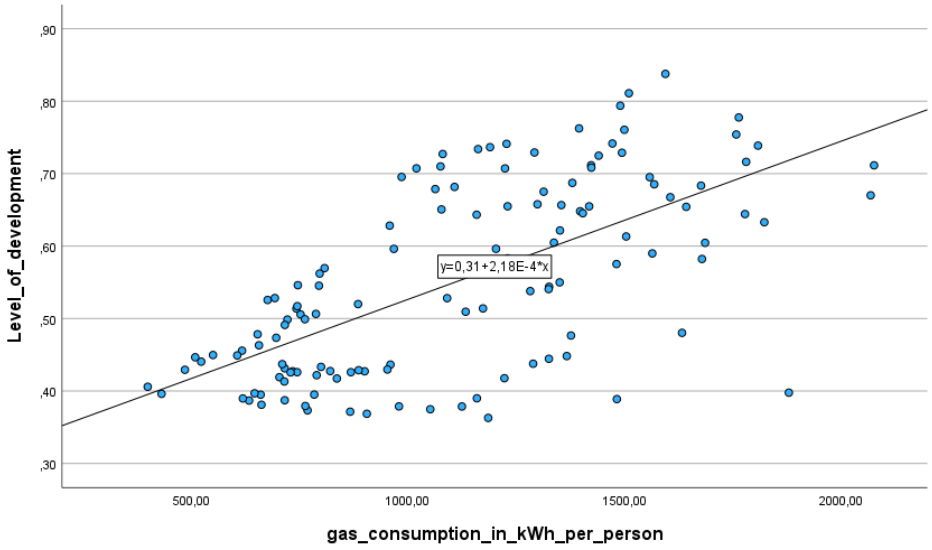
Source: *Own elaboration based on Statistics Poland data.*

Figure 19. *Correlations between the level of socio-economic development of Polish voivodeships and the amount of gas consumed in the period from 2002 to 2016, in m3*



Source: *Own elaboration based on Statistics Poland data*.

Figure 20. *Correlations between the level of socio-economic development of Polish voivodeships and the amount of gas consumed in the period from 2014 to 2021, in kWh*



Source: *Own elaboration based on Statistics Poland data*.

5. Discussion

Based on the conducted research, in 2022, the socio-economic situation in Poland generally improved compared to previous years. In the period under study, the level of socio-economic development of the voivodeships increased. A decrease in that level was observed in 2020 and 2021 (due to the COVID 19 pandemic), there was an increase again in 2022, sadly to a level lower than in 2019.

Despite an increase in the average value of the development indicator in the successive years under review, disproportions in the level of development of the voivodeships remained at a high level, whereas the discrepancy between the voivodeships with the highest and the lowest levels of development in 2022 slightly decreased compared to the previous years (Boratyński *et al.*, 2010).

The conducted analyses also confirmed significant discrepancies in the development between the eastern and western parts of the country. According to Boratyński *et al.* (2010), better-developing voivodeships could be found in western and central part of Po-land. This is not as surprising as one might think, considering the significant and vivid discrepancies in the development of individual areas and the potential of each of them. A positive aspect is that the maximum value of the synthetic indicator of development increased in successive periods under study.

However, the above fact does not mean that the disproportions between the regions with the highest and lowest levels of development are leveling off. The discrepancies still exist (Boratyński *et al.*, 2010).

Due to development, more and more energy resources are required to meet the needs of society as well as production. There is an upward trend in electricity consumption all over the world. Polish voivodeships also show an increase in electricity and gas consumption.

In Poland, an increase in electricity prices was noticed over the study period - the years 1999-2022 (at fixed prices in 1999). There was also an increase in the prices of hard coal over the 1999-2022 study period, with a sharp jump in the prices in 2022 (at fixed prices in 1999). The prices of gas increased in the period from 1999 to 2011 (at fixed prices in 1999).

In turn, in the period from 2015 to 2022, a slight decrease in the prices of gas was observed (at fixed prices in 1999). Based on the conducted analysis, an increase in the level of socio-economic development in the period under review was found. It was observed that with the increase in the level of socio-economic development, energy prices and the amount of consumed energy increased. To sum up, the following was noticed:

- With the increase in the level of socio-economic development, the prices of coal, electricity and gas increased moderately.
- As the level of the economic component increased, the prices of coal, electricity and gas increased.
- As the level of the social component increased, the prices of coal, electricity and gas decreased (2015-2022).
- With the increase in the level of the technical component, the prices of coal, elec-tricity and gas increased (1999-2011).
- With regard to coal prices, the highest dynamics index was the case of the Opol-skie, Dolnośląskie and Małopolskie voivodeships. The lowest one was noticed for the Podkarpackie Voivodeship.
- In terms of electricity prices, the highest dynamics index was the case of the Po-morskie and Warmińsko-Mazurskie voivodeships. The lowest one was observed for the Lubuskie and Opolskie voivodeships.
- As regards gas prices, the highest dynamics index was the case of the Dolnośląskie Voivodeship. The lowest one was the case of the Kujawsko-Pomorskie Voivode-ship.
- With the increase in the level of socio-economic development, the consumption of electricity and gas strongly increased.
- As the level of the economic component increased, the consumption of electricity and gas increased.
- With the increase in the level of the social component, the consumption of elec-tricity and gas increased.
- As the level of the technical component increased, the consumption of electricity and gas increased.
- When it comes to electricity consumption, the highest dynamics index was the case of the Lubelskie and Podkarpackie voivodeships. The lowest one was the case of the Pomorskie Voivodeship.
- In terms of gas consumption (1999-2011), the highest dynamics index was recorded for the Mazowieckie Voivodeship. The lowest one was the case of the Świętokrzyskie Voivodeship.
- As far as gas consumption is concerned (2015-2022), the highest dynamics index was the case of the Małopolskie and Podkarpackie voivodeships. The lowest one was the case of the Mazowieckie and Zachodniopomorskie voivodeships.
- With the increase in the level of socio-economic development (also for the eco-nomic, social and technical components), the index of dynamics of consumed electricity decreased, and thus the energy consumption decreased.

Abolhosseini *et al.* (2014) state that electricity consumption will account for a growing share in global energy demand over the next twenty years. This will further contribute to climate change and environmental pollution. Therefore, energy is the key element of the sustainable development of the European Union (Siemiński *et al.*, 2021).

Considering environmental protection and carbon dioxide emissions, coal is the most harmful fossil fuel. In a large number of countries, it is more and more often re-placed by natural gas in the area of electricity generation. Nevertheless, coal reserves can last for a long time and still play an important role in meeting primary demand for energy (Altawell *et al.*, 2020).

In Poland there are rich energy resources, including hard coal and lignite. These are energy resources whose environmental impact is considered potentially significant (Bałamut, 2017). The electricity market occupies a supreme position among other energy markets (heat, car fuel, etc.) as far as the scale of production is concerned (Siemiński *et al.*, 2021).

While conventional energy sources play the main role in the EU, there has been a decline in production recently (e.g. between 2017 and 2019, average annual production was around 7% lower and it dropped to 1.166 million GWh). The second most important energy source in the EU is nuclear energy (0.729 GWh in 2019) (Siemiński *et al.*, 2021).

The results of the study can be used as recommendations for regional development policies based on energy sources, depending on the level of development of individual Polish voivodeships.

6. Conclusions

The purpose of the article was to determine whether there were correlations between the level of socio-economic development of the voivodeships and energy prices and the amount of consumed energy in the period from 1999 to 2022. The data source for the performed analysis was the Local Data Bank of Statistics Poland. A taxonomic analysis, a non-pattern method, was used for the study.

Seventeen variables were analysed over the study period. They were divided into development variables: economic (3 variables), social (8 variables) and technical (6 variables). Based on the conducted analysis, an increase in the level of socio-economic development in the period under review was found. The performed analyses confirmed significant discrepancies in the development between the eastern and western parts of the country. Better-developing voivodeships could be found in western and central Poland.

It was observed that with the increase in the level of socio-economic development, energy prices increased. The social component showed a decrease in energy prices as the social level increased. In the case of the economic and technical components, an increase in that level was observed. Having analysed the amount of consumed energy, an increase in energy consumption with the increase in the level of socio economic development was noticed.

Moreover, as regards electricity, the index of the dynamics of consumed energy (in the years 2000-2021) decreased as the level of socio-economic development of the voivodeships increased.

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