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Impacts of COVID-19 on Energy Expenditures of Local Self-Government Units in Poland

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Abstract: Measures taken by the public administration to prevent the spread of the COVID-19 pandemic have led to drastic consequences for the economy. The full identification of its effects is hindered due to the delay in publishing the results of public statistics. The use of financial reports prepared by self-government authorities of all municipalities in Poland made it possible to obtain preemptive information in relation to the public statistics regarding the impact of COVID-19-related limitations on the energy expenditures incurred by local government units (LGUs), as well as an assessment of to what extent the LGUs had rationalized the energy consumption. By contrast, data from reports of energy companies made it possible to determine the impact of restrictions arising from the pandemic on the amount of energy sold and revenues from sales made by these companies. The analyses use indexes of the dynamics of changes in energy prices as well as indexes of the dynamics of changes in energy expenditures incurred by LGUs. Additionally, distributions of these indexes for the populations of municipalities are analyzed. To assess the effect of economic activity on energy expenditures incurred by LGUs, classification trees are utilized. It is established that the total production and sales of energy in Poland, in volume, in each quarter of 2020 were lower than in the corresponding period of the preceding year. However, as a result of an increase in energy prices by approximately 25%, the sales of electric power generating companies, in amounts, were higher in 2020 than in 2019. The increase in energy prices was also a cause of slightly increased total expenditures for purchasing energy in LGUs in Poland, which increased by 2.15% in 2020 compared to 2019. However, a substantial diversity in expenditure indexes was observed. That concerned both total expenditures and expenditures within individual sections of the budgets of municipalities.

Keywords: COVID-19; self-government units; energy consumption; energy consumption; monitoring; energy consumption effectiveness

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1. Introduction

The emergence of COVID-19 forced the public authorities of countries worldwide to put into action measures to mitigate the negative impacts of the spread of the virus [1–4]. To contain the spread of the infection, governments have introduced a series of social distancing measures, along with lockdowns and shutting down businesses. The wide use of containment measures by the public administrations of almost all countries has had far-reaching consequences for the global economy [5,6]. In many regions of the world, a significant decline in economic activity has been reported [7].

Understanding the effects of governments' actions on the economy and international trade would be helpful in defining an adequate economic policy framework, which would additionally limit the negative effects of restrictions on the economy [5].

Common policies of public authorities have caused chain reactions in economic systems. Due to diminishing production and reduced demand in certain product groups, governments' interventions have had a significant impact both on the national economy and on international trade.

Referring to the model-based estimates, Guan et al. [8] suggest that, depending upon the scale of the implementation of containment measures, the global industry's value added may have fallen by 25–40%. Publications suggest significant variations in the consequences of government-led countermeasures [9,10]. There are also significant sectoral and geographic discrepancies in the governments' actions impacts on economic activity. The largest drops in production, up to 12%, were experienced by the manufacturing sectors. The negative effects of the lockdown diminish over time. However, Fezzi and Fanghella [10] estimated that the few weeks of the most severe lockdown reduced the corresponding Italian GDP by roughly 30%.

Results of some studies show meaningful trade losses, particularly in China, Western Europe, and the Middle East [11]. From a major perspective, the collapse of international trade was the aftermath of disrupted supply chains [8,11].

Quantifying the effects of various mitigation measures on the economy is essential for the formulation of effective policy responses. However, an assessment of the degree of disruption caused to the global economy by mitigating measures is difficult due to the following reasons:

- Traditional macroeconomic indicators are usually published with a significant delay;
- The aggregate nature of traditional macroeconomic indicators makes it difficult to isolate the impact of various mechanisms of influence;
- The limited availability of macroeconomic indicators for countries with a low level of development makes it difficult to assess the economic effects of turbulence in the global economy.

Owing to the fact that official statistics are published with a delay (at least a few months), there is a need to estimate the causal short-run impacts of COVID-19 on the economy. Discernment, in this regard, can be used for shaping the possible future lockdown and economic policy.

Having the right real-time indicators of economic activity can be helpful in the impact assessment phase of individual policies on the economy. Additionally, adequate allocation of funds to the hardest hit sectors of the economy can support efforts aimed at stimulating economic recovery.

In response to the demand from decision makers for up-to-date information, some authors are trying to develop methods of analysis that will make it possible to assess the effects of implemented restrictions with a relatively short delay. For example, to assess the global maritime trade losses during the first months of the pandemic, Verschuur, Koks, and Hall, formed a high-frequency index of economic activity based on empirical vessel tracking data [11]. The authors used high-frequency data representing information related to vessel tracking data to estimate the global trade disturbances. The impact of governments' interventions on maritime exports served as a proxy of economic activity. The research showed that during the eight months of 2020, global maritime trade was reduced by 7.0–9.6%, which is equal to 412 billion USD in value losses. In addition to the relationship between the level of activity of economic sectors and the intensity of trade, the authors unexpectedly identified the negative impact of pandemic-related school closures and public transport restrictions on country-wide exports.

An increasing number of authors are using high-frequency data to track the economic impact of remedial programs created by public authorities to help prevent the spread of the pandemic. Such research is carried out both on a national and global scale. To track the impact of pandemic evolution on economic and social systems, the growing body of literature increasingly refers to such data sources as follows:

- Degree of human mobility [12–14];
- Air pollution indicators [5,15,16];
- Night-time light intensity [17–19];
- Level of electricity consumption [9,10,17,20,21].

From the perspective of this study, studies that use data on electricity consumption to assess the effects of the restrictions introduced are the most important reference points.

The findings on the long-run relationship indicate that a sufficiently large supply of electricity can ensure a higher level of economic growth [20].

An assessment of the costs and benefits of various mitigation measures for the economy and international trade is essential for effective countermeasures in the process of shaping appropriate economic policies. Various authors emphasize that the goal of effective policies is to find a compromise between inhibiting the spread of the epidemic and reducing the negative effects of the applied restrictions [5,7,9].

In recent years, up to 2019, the Polish economy had been developing steadily. The increase in gross domestic product amounted to 1.1% in 2013, 3.4% in 2014, 4.2% in 2015, 3.1% in 2016, 4.8% in 2017, 5.4% in 2018, and 4.5% in 2019 [22]. Observation of the listed increases showed that the trend continued in subsequent years. Unfortunately, in 2020, Poland, as the rest of the world, was affected by the COVID–19 pandemic. One of the effects of this pandemic was a sudden economic downturn, evidenced by a 2.7% decline in the Polish GDP in 2020, compared to the preceding year [23].

The COVID-19 pandemic made it necessary for public authorities to undertake a series of actions. In Poland, one of them was the introduction (on 2 March 2020) of the Act on specific solutions related to the preventing, counteracting, and combating of COVID-19 and other infectious diseases and crisis situations caused by them [24]. That act allowed employers to order their employees to work from home. It also made it possible to provisionally reduce the determined extent of entrepreneurs' activities and introduced the obligation to be subjected to quarantine.

In a regulation issued on 20 March 2020, the Minister of Health declared a state of pandemic within the territory of Poland [25]. Rail transport of passengers related to crossing the Polish border was suspended by that regulation, as was the activity of restaurants (except takeaway sales), organizing events, congresses, etc., activities connected with all collective forms of culture and entertainment, sports and recreational activities, and the activities of libraries and spas. It was also possible to reduce the activities of public administration units solely to the tasks indispensable for providing help to citizens. It was also allowed to carry out tasks without direct client service. Restrictions were also introduced in schools and universities. In the period from March 2020 to June 2021, teaching was conducted remotely.

The introduced restrictions had an impact on the functioning of LGUs. Restricting their activities ought to reduce energy consumption in many areas and, by extension, lower the costs incurred for this purpose. The aim of this study is to determine the effect of restrictions arising from the pandemic on the amount of energy sold and revenues from the sale of energy companies, as well as to examine to what degree LGUs have rationalized energy consumption under restricted activities and how this has been reflected in the costs incurred by them.

2. Materials and Methods

The study covered two areas. The energy market in Poland was the first. The study focused on the activities of energy companies. The volume of sales of electric and thermal energy in 2019 and 2020 as well as average sale prices of electric energy in individual quarters were analyzed. Revenues and financial results of these companies were also analyzed. The study covered Polish listed companies in the energy sector. The Warsaw Stock Exchange qualifies 9 companies for the energy sector. These companies are the following: Elektrociepłownia Będzin S.A., ENEA S.A., ENERGA S.A., PGE Polska Grupa Energetyczna S.A., Polenergia S.A., TAURON Polska Energia S.A., Zespół Elektrociepłowni

Wrocławskich KOGENERACJA S.A. and Zespół Elektrowni Pątnów-Adamów-Konin S.A. and ML System S.A. The last company was not taken into account in the analysis since it does not deal with the production and distribution of energy but with the assembly of renewable energy installations, e.g., photovoltaics. All of the analyzed companies form corporate groups. They are obliged to publish annual, semi-annual, and quarterly consolidated reports. The analysis took into account consolidated reports, which are prepared every quarter and include the dominant entity as well as other companies from the corporate group. Stock reports of the companies constituted the source of data [26]. The data on energy sales come from the website of the Energy Regulatory Office [27].

Energy expenditures of municipal governments were the second study area. The study was based on financial data coming from all municipal government units in Poland. The data were obtained from Rb-28S budgetary reports, made available by the Ministry of Finance. Reports for the last quarter of 2019 and 2020 were used in the analysis. The report for the last quarter contains data on budgetary expenditures of municipalities for the entire fiscal year. The RB28S report is made in accordance with the municipality's budget. Sections are the fundamental elements of the budget classification. Sections are divided into subsections, and they specify the type of activity. Expenditure groups within individual sections are indicated by an appropriate numeric code called an article. Data specified by Article 426—"purchase of energy"—are the subject of the analysis. This article includes expenditures for the supply of electric, thermal, and other energy as well as gas and water.

To determine the share of expenditures for water within individual sections, computations were made based on the data obtained from several selected municipalities. The results are shown in Table 1.

Table 1. Share of water consumption costs in costs within Article 426.

Section of the Budget Classification	Share of Water Cost in 2019 [%]	Share of Water Cost in 2019 [%]	Ratio of Water Consumption Cost 2020/2019
70005 Housing economy	15.67	11.94	1.01
75023 Public administration	3.56	1.53	1.01
80101 Education and upbringing—schools	3.18	2.60	0.90
80104 Education and upbringing—kindergartens	3.55	1.51	0.44
90015 Lighting of streets, roads and squares	0.00	1.51	

Source: Own calculations based on data from municipalities.

In the analyzed sections, the percent share of water costs in the costs within Article 426 is low. The highest was recorded under the 'Housing economy' section. It is the consumption associated with people inhabiting municipal amenity buildings.

Table 2 shows expenditures within individual sections of Article 426 for the years 2019 and 2020. Sections are arranged in order of the highest energy expenditure.

The first five sections were selected for the analysis, on account of their large share of energy consumption costs (87% of total expenses). From individual sections, sections with the largest share of energy expenditures were selected for the analysis, as presented in Table 3.

Table 2. Budgetary expenditures of municipalities in Poland in 2019 and 2020 for Article 426 according to sections.

Section No.	Section Name	Expenditure in 2019 PLN	Expenditure in 2020 PLN	Share in Total Expenditure in 2019 in %	Share in Total Expenditure in 2020 in %
801	Education and upbringing	1,613,339,028	1,520,746,092	34.56	31.90
900	Municipal economy and environmental protection	1,103,893,587	1,241,630,291	23.65	26.04
700	Housing economy	830,763,739	847,365,555	17.80	17.77
926	Physical culture	298,264,259	288,897,533	6.39	6.06
750	Public administration	214,276,715	230,827,369	4.59	4.84
400	Producing and supplying electrical energy, gas, and water	114,412,978	120,508,002	2.45	2.53
852	Social service	111,177,352	116,729,787	2.38	2.45
754	Public safety and fire protection	77,396,314	80,360,878	1.66	1.69
754	Public safety and fire protection	77,396,314	80,360,878	1.66	1.69
854	Educational care	64,698,698	62,672,552	1.39	1.31
855	Family	56,188,382	59,422,497	1.20	1.25
600	Transport and communication	45,521,812	51,994,857	0.98	1.10
010	Agriculture and hunting	44,356,870	50,354,824	0.95	1.06
921	Culture and protection of national heritage	38,859,244	38,351,447	0.83	0.80
710	Service activities	20,955,162	23,183,679	0.45	0.47
851	Health protection	9,425,502	9,093,862	0.20	0.19
925	Botanical and zoological gardens as well as natural areas and nature protected areas	8,664,896	9,100,020	0.19	0.19
853	Other tasks within social policy	7,996,895	8,360,348	0.17	0.18
630	Tourism	3,999,145	4,209,755	0.09	0.09
150	Industrial processing	1,328,286	1,458,911	0.03	0.03
500	Trade	1,060,926	1,452,383	0.02	0.03
720	Computer science	201,687	251,809	0.004	0.005
730	Higher education and research	199,630	228,442	0.004	0.005
751	Offices of supreme state authorities, control and protection of law and judiciary	190,788	121,744	0.004	0.00255
550	Hotels and restaurants	173,648	208,894	0.004	0.004
020	Forestry	152,238	185,902	0.003	0.004
755	Judicial system	127,054	111,779	0.003	0.002
050	Fishing	85,214	84,423	0.002	0.002
758	Various accruals	7018	0	0.0001	0.000
756	Income from legal persons, natural persons and other units without legal personality, and expenses related to its collection	3328	335	0.00007	0.00001
100	Mining and quarrying	580	581	0.00001	0.00001
	Total	4,667,720,975	4,767,914,550		

Source: Own calculations based on data from the Ministry of Finance [28].

Table 3. Sections selected for analysis.

Section No.	Section Name	Share of the Section in the Costs of the Section in 2020
80101	Primary schools	60.33%
80104	Kindergartens	116.73%
90015	Lighting of streets, squares and roads	88.51%
70005	Land and real estate management	56.89%
92604	Institutions of physical culture	45.95%
75023	Municipal offices	93.35%

Source: Own calculations based on data from the Ministry of Finance [28].

To extract interesting information from reports of energy companies, methods of cause-and-effect analysis were used, in particular the method of chain substitutions. [29,30]. Revenues from energy sales and the amount of energy sold were extracted from the company's report. Based on that, the average unit price of energy was established. Indexes were used to assess the changes in this price in the 2019–2020 period.

For the purpose of analyzing the expenditures of local government units, indexes were created. Those indexes describe dynamic changes in energy expenditures within individual sections and also changes in total energy expenditures incurred by respective municipalities. Population of municipalities described with a set of these indexes was then analyzed using average and dispersion measures [31]. Distribution of indexes is presented using a histogram.

To assess the effect of economic activity on energy expenditures incurred by LGUs, classification and regression trees were also utilized. A classification tree is a directed graph with a root and nodes in which conditions concerning variables are checked, and also branches with certain decision-making rules. Analysis using the classification tree algorithm involves finding a set of logical conditions for dividing a set of objects into possible homogeneous classes. The CART (Classification and Regression Trees) algorithm proposed by Breiman et al. is one of the most effective ones. It consists of considering all combinations of levels of independent diagnostic variables in order to find the best division. This division is performed recursively in the N-dimensional object space [32]. The advantage of using trees is that it is relatively simple to interpret the results, present them clearly, and obtain good results from predictions [33,34]. Some of the results were verified through individual interviews with financial services staff of individual municipalities.

3. Literature Review

The impact of the pandemic on energy consumption has been the subject of research by several research teams. Already in 2020, H.M. Alhajeri et al., when analyzing the case of Kuwait, examined the impact of the pandemic on energy demand. The study concluded that the pandemic had reduced energy demand in the first half of 2020, both in comparison with the planned amounts and compared to an analogous period in 2019 [35]. The same problem in Italy was addressed in the paper by E. Ghiani, M. Galici, M. Mureddu, and F. Pilo. They concluded that electricity consumption had decreased in Italy by 37% compared to the same period in the previous year [36]. Syksnelyte-Butkienie [37] concludes that energy demand decreased during the pandemic. Demand from households increased but declined in business and industry. In their paper, Abu-Rayash and Dincer analyzed energy demand [38]. The authors focused on the Canadian case study. They saw a significant decrease (14%) in energy demand in April 2020 compared to April 2019. The impact of COVID-19 restrictions on electric energy consumption in Europe was addressed in an article by A. Bahmanyar, A. Estebsari, and D. Ernst. They compared countries that had applied strict restrictions (Spain, Italy, Belgium, and Great Britain) to those where restrictions were more lenient (Netherlands and Sweden). Their analysis concluded that in countries with severe restrictions, energy consumption decreased on working days, whereas at weekends it remained at the same level as in the previous year, while in countries with light restrictions, energy consumption remained substantially unchanged, and in Sweden, it even

increased [39]. In their paper, P. Mastropietro, P. Rodilla, and C. Batlle analyzed the impact of COVID-19 restrictions on the ability of households to pay energy bills. They concluded that the most vulnerable households needed financial assistance [40]. E. Bompard et al. focused their paper on the impact of the pandemic on the energy system in Europe. The authors concluded that energy demand fell by around 15% in countries where restrictions were the most severe. The impact of the pandemic on the energy and electrical systems depends on how long the pandemic will last and how it will affect the economy [41]. K. Dmytrów, J. Landmesser, and B. Bieszk-Stolorz focused their paper on the relationship between the pandemic and the prices of energy raw materials. They concluded that their prices initially dropped in 2020, only to rise later on. The prices of raw materials changed in a similar way [42]. A significant decrease in electric energy consumption in France and Spain between 15 March and 5 April 2020 compared to the same period in previous years was also observed by A. Navon, R. Machlev, and D. Carmon [43]. The impact of the pandemic on household electric energy consumption has been addressed by S. Bielecki et al. The authors point to an increase in household energy consumption during the day, due to the shift of work to the remote form [44]. In their paper, M. Malec, G. Kinelski, and M. Czarnecka analyzed the business customer demand for energy in Poland. They concluded that the first lockdown caused a fall in energy demand of about 15–23% and the second one of about 11% [45].

Due to the set research objectives, particular attention was paid to the sector of local government units. Pursuant to Article 3 of the European Charter on Local Self-government [46], "local self-government denotes the right and the ability of local authorities, within the limits of the law, to regulate and manage a substantial share of public affairs under their own responsibility and in the interests of the local population". In Poland, local governments have become unquestionable landlords, jointly responsible for the living conditions of the population within a municipality and for its socio-economic development [47]. The importance of LGUs in the performance of public sector tasks is highlighted in scientific literature. Local government units of the public finance sector perform tasks in such sensitive areas as education, health protection, transport, road and technical infrastructure, support for people with disabilities, unemployment prevention, water supply and wastewater disposal, fire protection and public order [48]. The role of public finances in the country's financial system is highlighted by S. Owsiak [49]. In Poland, this system is composed of the state budget, municipal budgets, district budgets, provincial government budgets, and special purpose state funds. The role of public finances in the new economic governance of the European Union was presented in the collective work edited by the same author [50]. The public finance system, due to its role, is a subject of great interest in the source literature. S. Owsiak focused his paper on general public finance rules [51]. The author provides various concepts of public finances. He mainly emphasizes the so-called Golden Rule of public finances, defining it in such a way that the source of funding provided for in the plan (budget) should be ensured [51]. Malinowska-Misiąg, Misiąg [52] focused their paper on the management of public finances. The main problems raised by these authors are the maximum permissible debt limits of public finance entities and the rules on public expenditure. Expenditures may be incurred for the purposes and at the rate laid down in the relevant resolution or plan. The principles of purposefulness and cost savings (obtaining the best results from a given expense and optimal choice of methods and measures to achieve the objectives pursued) apply in such a way as to enable the tasks to be carried out on time, in the amount and timing arising from the commitments previously entered into [52].

The crisis caused by the COVID-19 pandemic affected the budgets of local government units in 2020, but to a much lesser extent than had been feared. Total income increased by 9.5% to 304.9 bn PLN. Income growth was recorded in all types of LGUs. LGUs' own income increased slightly less (by 7.8% to 146.4 billion zlotys), and their own basic income (i.e., excluding PIT and CIT) increased by 16.3% to 80.0 billion zlotys. Tax income from natural and legal persons dropped by 1.0%, to 66.4 billion zlotys. PIT proceeds, with

a higher share (18.1%) of total income, decreased by 1.9%, and CIT proceeds managed to continue to grow (3.9%). Real estate tax income increased by 3.9% in 2020 [53]. The pessimistic forecasts of the first months of the pandemic had not come true (according to the BGK's study from June 2020, LGUs expected an 11% and 15% drop in PIT and CIT proceeds, respectively, and a 4% drop in real estate tax income [54]. The financing of LGUs involves several different sources of financial resources, i.e., grants, subventions, and own resources. Such a structure makes local government proceeds more stable over time while being less dependent on the current economic situation than if they were based on a single source of financing [55].

Governance in the public sector consists of harmonizing management measures to ensure that the objectives of public organizations are properly set, and that people can act efficiently [56]. General governance rules apply to public governance, taking into account social, economic, organizational, and management criteria [57]. Proceeding according to the rule of purposefulness and saving is directly linked to incurring costs. Information on the amount of costs incurred is essential for each organization because it reflects the quality of the organization's activities. Local government units are not profit-making but have public funds, which obliges them to operate in a rational manner, providing both savings and efficiency. That is why the issue of cost formation and rationalization is a key area of interest for management and society [58]. Any unnecessary expense should therefore be eliminated. An internal audit, among other things, helps to implement these proposals. The implementation of audit tasks should take into account the risks associated with COVID-19 [59]. According to Gonet, Suchodolski [60], crisis situations have a negative impact on the budgets of the state and local government units. Financial crises have a stronger impact on the state budget than cataclysms on the budgets of local government units. It is therefore very important to avoid unnecessary expenditure in the event of a cataclysm, even if it was originally planned in the budget.

The question of the reasonableness of the expenditure incurred is of interest to the audit authorities. In Poland, for example, the Supreme Audit Office carried out audits concerning the optimization of electric energy costs in the public finance sector [61]. The scope of this audit was limited to the issue of distribution fees, where many irregularities were found. The problem of adjusting the amount of energy consumed depending on demand is a more complex issue, but there are many possibilities for optimization. The problem was also recognized by the Energy Regulatory Office, which made the following recommendations: The current challenges for energy and climate policy, as well as the related increase in energy prices, require a search for the most effective means of managing not only its production, but also its informed and cost-effective use. Such measures are necessary to ensure energy efficiency, to safeguard the operation of the electricity system and to achieve climate objectives, but they can also benefit consumers in the form of lower electricity bills [62]. During the pandemic, local authorities in many countries have highlighted the need to optimize energy systems. The desired future sustainable urban energy system should be optimized to reduce the consumption of fossil energy while providing the required energy services to increase energy efficiency at competitive costs [63].

4. Results

4.1. Production and Sales of Energy in Poland in 2019–2020

In 2019 and 2020, there were significant differences in the amount of electric energy sold. Figure 1 presents data on the volume of electric energy sales in Poland in the individual quarters of 2019 and 2020. Changes can be attributed to the impact of the COVID-19 pandemic. The introduction of measures to reduce the spread of the epidemic has resulted in a very large reduction in activities in different sectors of the economy, which has translated into a reduction in energy consumption. Electric energy sales in 2020 decreased by around 8.3% compared to 2019.

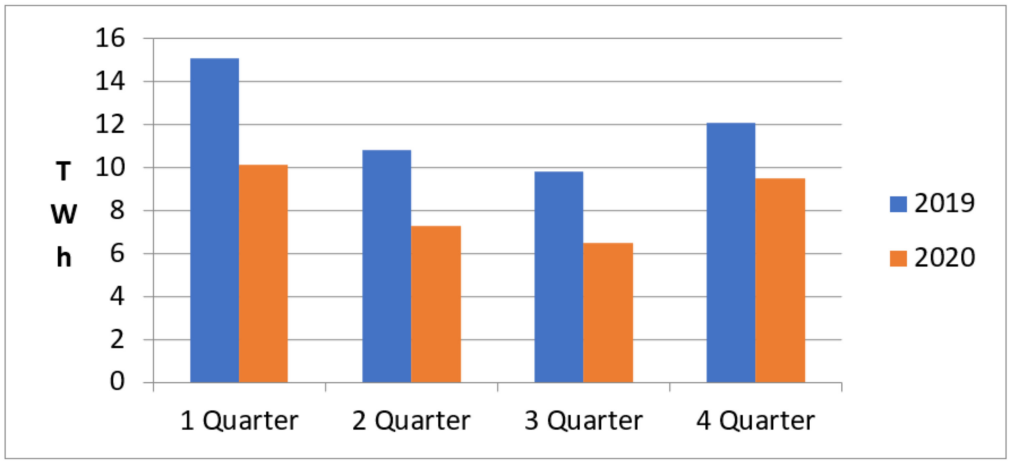

Figure 1. Volume of electric energy sales in the individual quarters of 2019 and 2020. Source: Authors' own elaboration based on the data from reports of said companies [27].

Figure 2 shows the value of revenue from energy sales for individual quarters of 2019 and 2020. The data show that despite a significant decrease in the amount of energy sold, sales revenues increased.

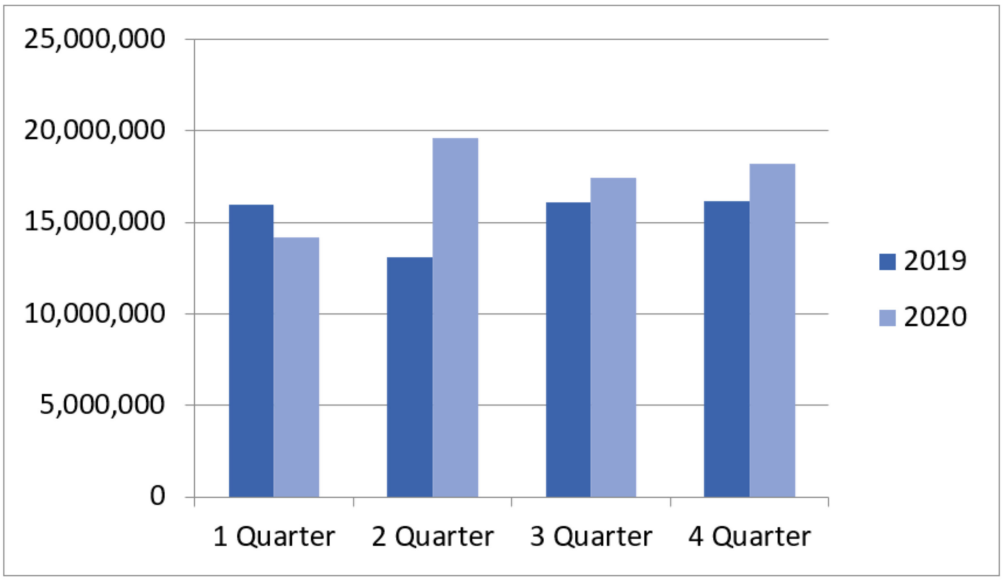

Figure 2. Electric energy sales in the individual quarters of 2019 and 2020. Source: Authors' own elaboration based on the data from reports of said companies [26].

The average quarterly price of electric energy not subject to public sales as calculated based on company report data is presented in Figure 3.

There is clearly a significant increase in electric energy prices in 2020 compared to the same period in 2019. In 2018, the Sejm of the Republic of Poland adopted an act amending the act on excise tax and certain other acts, commonly referred to as the 'current act' or the 'act on electricity prices'. It was intended to maintain electricity prices from the first half of 2018 until the end of 2019. After the expiry of the act on electricity prices (after 1 January 2020), electricity prices increased [64]. The compensation resulting from the price difference was paid to energy trading companies. The average total sales revenues of energy companies increased by 13.8% in 2020 compared to the previous year. On average, energy sales revenues of these companies represent 69.77% of total sales revenue, while energy sales revenues are largely dominated by electric energy (93.25%). On the other hand,

in volume (MWh), electricity sales decreased in 2020 by an average of 7.65% compared to 2019. The average unit price of electricity increased on average by 24.61%, whereas thermal energy increased by 5.81%. Thus, the increase in revenues from sales, in amounts, was a result of the increase in prices. The financial performance of these companies is a negative phenomenon. Most of them (especially in 2020) suffer significant losses despite the rise in prices and the increase in sales revenue. Other conclusions can be drawn from the analysis of fuel companies. In the capital group of the Polish Oil Concern 'Orlen S.A.', sales in volume decreased significantly in 2020, while the unit price of fuel sales decreased, resulting in a decrease in revenues [26].

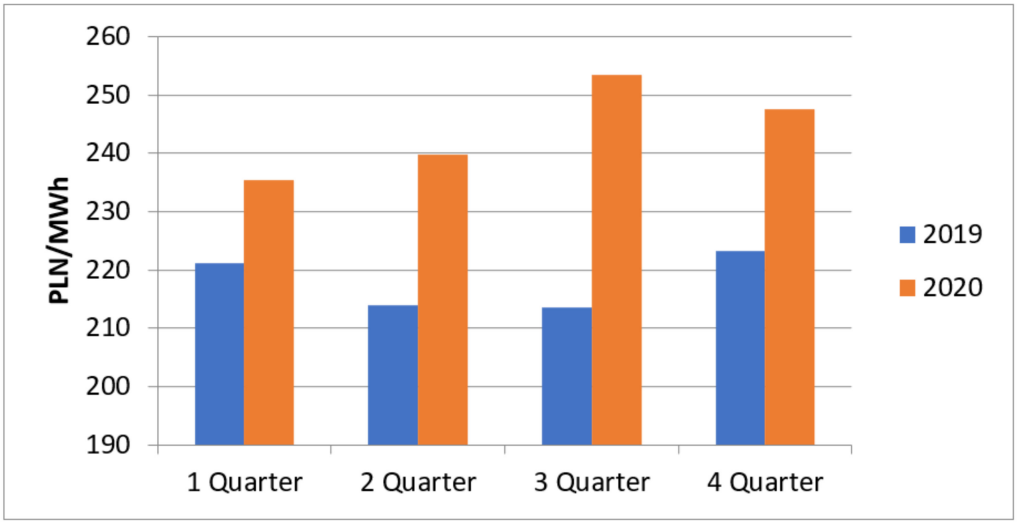

Figure 3. Electric energy sales prices for the individual quarters of 2019 and 2020. Source: Authors' own elaboration based on the data from reports of said companies [27].

4.2. Changes in Energy Expenditures Incurred by Local Government Units

The restrictions introduced to reduce the spread of SARS-CoV-2 have had a significant impact on the functioning of most entities in Poland. One of the sectors affected by the pandemic was the public administration sector. Energy consumption may, to some extent, be an indicator of economic activity in LGUs. Thus, the impact of the pandemic on energy expenditures in municipalities has been analyzed. According to the assumptions in the methodology, dynamic changes in energy expenditure incurred by local authorities within selected activities were analyzed.

4.2.1. Section 90015—Lighting of Streets, Squares, and Roads

Section 90015—lighting of streets, squares, and roads accounts for more than 88% of the energy expenditure for the whole of Section 900. It is characteristic since electricity is the only energy cost here. The index of lighting costs for 2020/2019 amounts to almost 1.247. This value coincides with the electricity unit price index obtained in the energy market analysis, which amounted to 1.246. The increase in lighting costs in 2020 can therefore be considered to be linked to the increase in electricity prices.

The mean index calculated for all municipalities in Poland is 1.175. It is characterized by substantial variability. The coefficient of variation amounts to 137.6%. Objects with the index between 1.1 and 1.2 constituted the largest group (21.07%) (Figure 4). In Section 90015, there are few cases with significant index increases or decreases. Increases are linked to the adoption of new lighting sections, and decreases are the result of ongoing modernization projects.

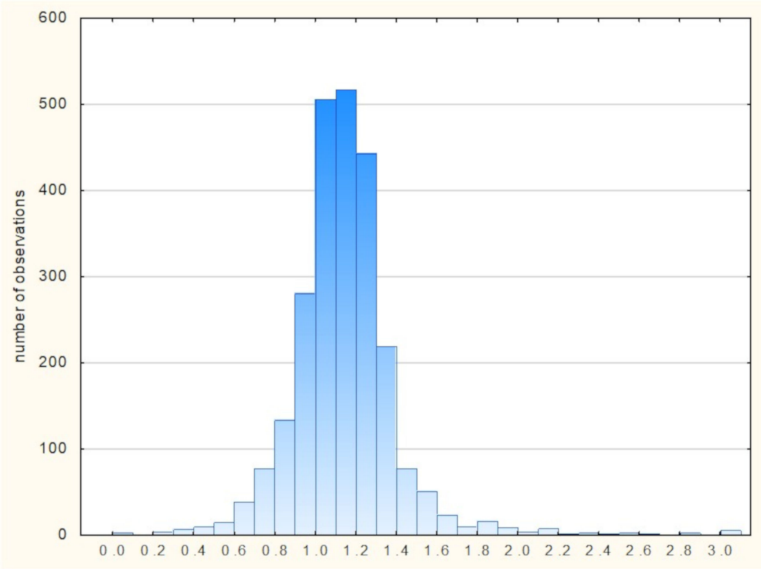

Figure 4. Histogram of the distribution of cost indices in Article 426 for Section 90015. Source: Authors' own calculations.

4.2.2. Section 80101—Primary Schools

Actions to reduce the spread of the pandemic were implemented, among other things, in education. Most educational facilities provided remote teaching, which involved the absence of students in these facilities. School buildings were used only to a limited extent. Overall, the amounts spent on energy in the education and upbringing section in 2020 decreased compared to 2019. Primary schools and kindergartens have the largest share of energy spending within Section 801.

An analysis of the change in expenditure under Article 426 'Purchase of energy' for Section 80101 shows an average slight increase in expenditure—an average index of 1.065. However, it is not due to an increase in energy consumption but to an increase in electricity prices. In addition, as a result of the transformation of the education system in 2020, Section 80101 included energy expenditure for facilities that had formerly been junior high school facilities. Despite this, almost half of the municipalities (49.31%) recorded a decrease in energy expenditure under this section (Figure 5). This indicates savings that stemmed from the COVID-19 pandemic restrictions.

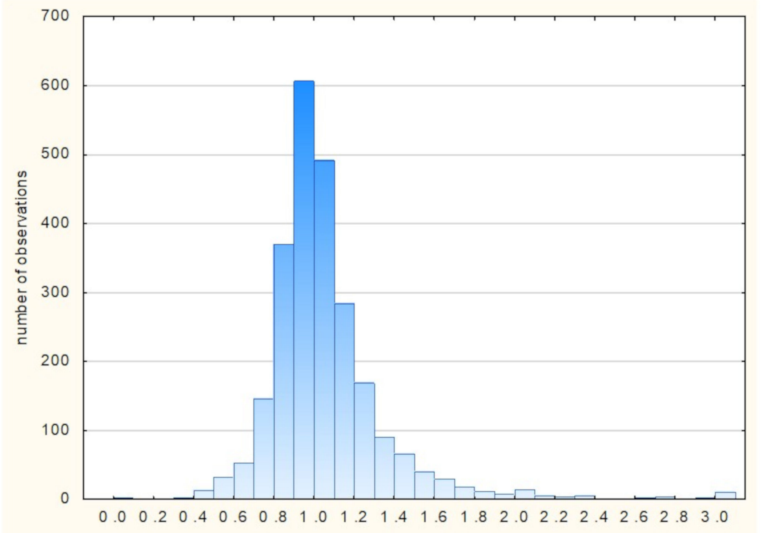

Figure 5. Histogram for the distribution of cost indices in Article 426 for Section 80101. Source. Authors' own calculations.

4.2.3. Section 80104—Kindergartens

The change in costs in Section 80104—Kindergartens in 2020 is small compared to 2019, as it is only about 3%. Taking into account the evolution of electricity prices, it can be concluded that the decrease in energy consumption is much higher. The average energy purchase cost index is 1.134, but it should be noted that for 62.13% of units, the index is less than one (Figure 6). However, the population of municipalities shows a large internal variation, as evidenced by the high standard deviation. A significant increase in energy costs was most often the result of the launch of new kindergartens; more than three times the increase in energy costs was observed in 31 municipalities. Despite the lower intensity of restrictions on the functioning of kindergartens than schools during the pandemic period, there is a noticeable drop in energy expenditure, which could be caused by actions to counter the spread of the SARS-CoV-2 virus.

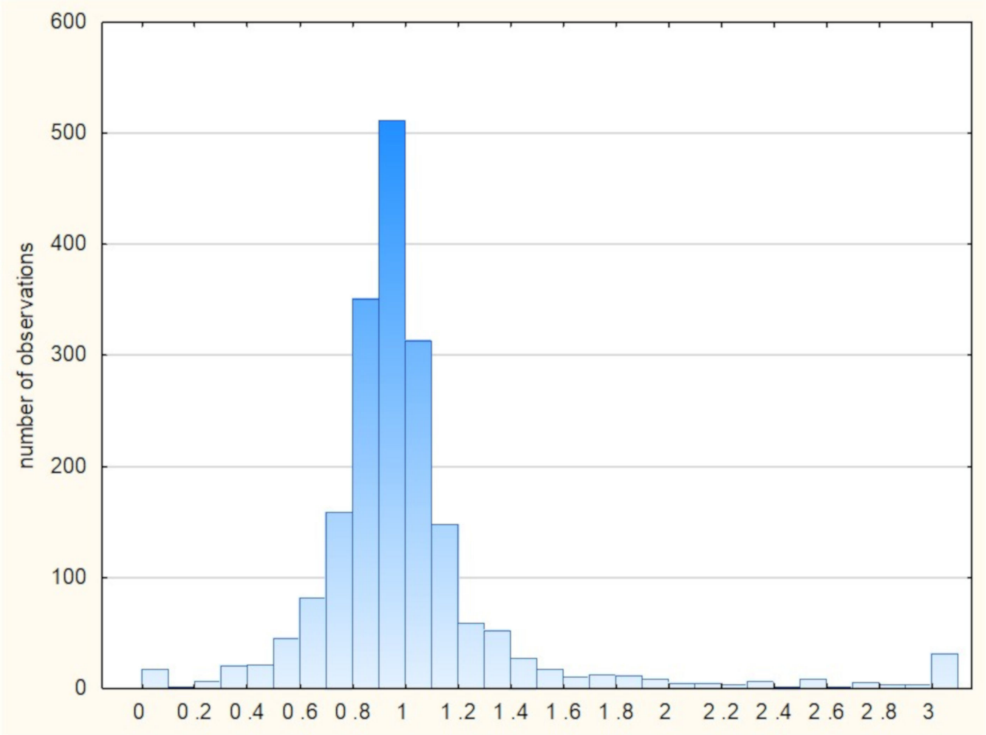

Figure 6. Histogram of the distribution of cost indices in Article 426 for Section 80104. Section 70005—Land and real estate management.

Under Section 700 (Housing economy), expenditure increased by almost 3.8%. Section 70005—Land and real estate management has the largest share of expenditure under this section. This section covers, among other things, expenditure on amenity housing. The total expenditure under this section increased by 3.5%, but the population of municipalities is highly differentiated in this respect (standard deviation of 6.21, coefficient of variation of 374%). The average cost index was 1.665, with 44.11% of units having an index lower than one (Figure 7). In the group in question, there are as many as 70 municipalities with an index above 3.0. The reason for this high cost increase is the opening of new amenity buildings. Electricity has little impact on the change in costs due to its low contribution to the consumption pattern. As a rule, the cost of electricity consumed by residents is not included in these expenditures as they have individual contracts with the electricity supplier.

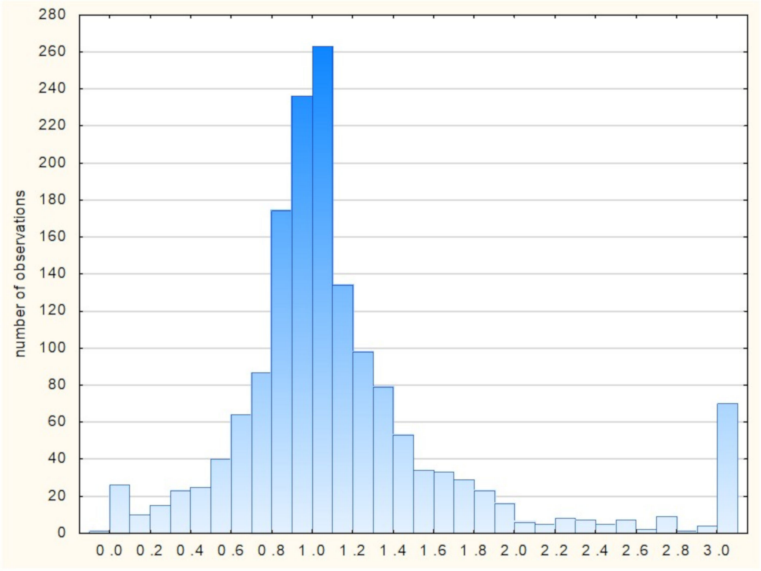

Figure 7. Histogram of the distribution of cost indices in Article 426 for Section 70005. Source: Authors' own calculations.

4.2.4. Section 92604—Institutions of Physical Culture

The costs under Article 426 for Section 926 were reduced by approximately 3.14%. Section 92604—Institutions of physical culture is the section with the highest share of energy costs in this section. This section includes expenditure on the operation of units engaged in the dissemination of physical culture. In municipalities, these units manage sports facilities. The average energy cost index under this section is lower than one (0.998), with as much as 70.59% of units spending less on energy in 2020 than in 2019 (Figure 8). Moderate variability is observed within the population of municipalities, and the coefficient of variation is 44.12%. Electricity contributes significantly to the costs of the physical cultural facilities. Increased energy tariffs did not reduce the costs proportionally to the reduction in consumption. The physical culture units were quite heavily affected by restrictions related to the containment of COVID-19. They were completely excluded from the operation during the period of the increase in the number of COVID-19 cases. Despite a total reduction in activity, energy costs did not fall proportionally to the scale of the reduction.

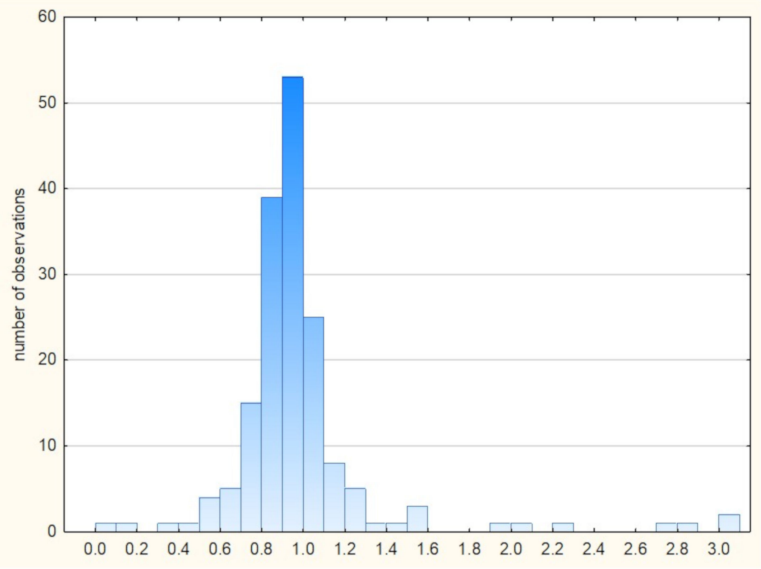

Figure 8. Histogram for distribution of cost indices of Article 426 for Section 92604. Source: Authors' own calculations.

4.2.5. Section 75023—Municipal Offices

Section 750 is fifth in the amount of energy expenditure. Its share of the total energy costs in 2020 was about 4.84%. Energy expenditure increased by around 7.72% in 2020 compared to 2019. Section 75023—Municipal offices (of cities and cities on the rights of the district) represents the largest share of the cost of Section 750. It accounts for almost 94% of the expenditure in this section. The total expenditure under Section 75023 increased by approximately 7.86%. The average index is 1.156, with a coefficient of variation of 112.38%, with expenditure indices below one appearing in approximately 17.18% of municipalities (Figure 9). These figures indicate the limited impact of the pandemic on energy consumption within Section 75023. Municipal offices were functioning during the pandemic period, while restrictions were only related to public access.

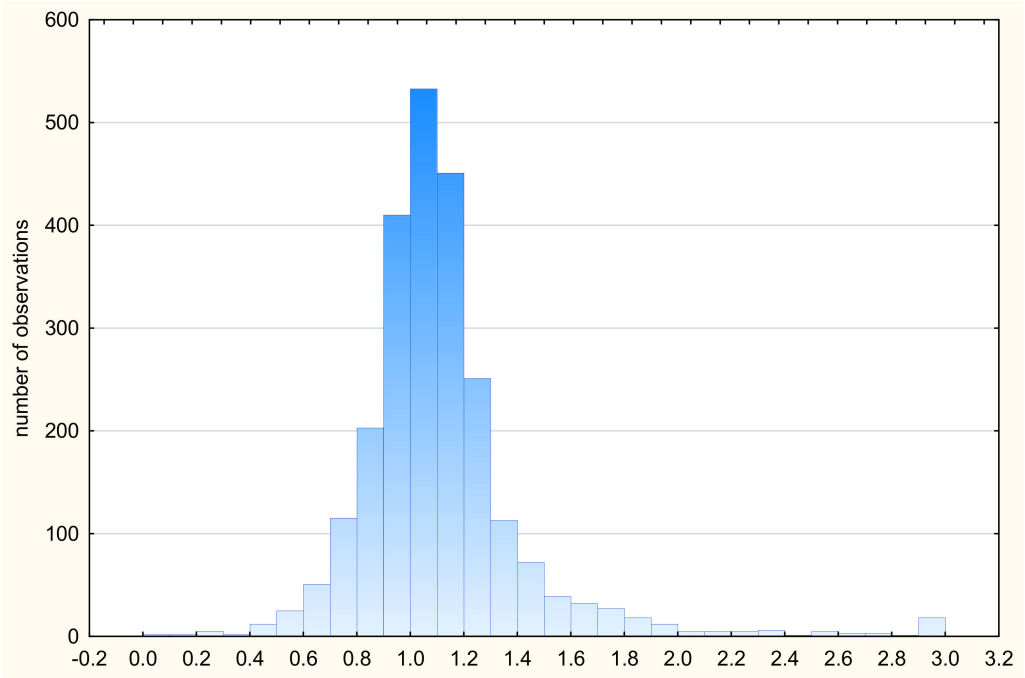

Figure 9. Histogram of the distribution of cost indices in Article 426 for Section 75023—Municipal offices. Source: Authors' own calculations.

Contact with the office staff was limited to phone contact or via electronic channels. Office visits were limited to the minimum necessary. Some employees were working remotely. This did not reduce energy consumption significantly.

4.2.6. Total Energy Expenditure in Municipalities

For each of the municipalities covered by the study, the rate of change in total energy expenditure in 2020 compared to 2019 was calculated. The distribution of this index is presented in Figure 10 in the form of a histogram. The average index is 1.038, with a coefficient of variation of 14.55%, a minimum of 0.523, and a maximum of 2.939. There was no change or reduction in energy expenditure in 39.90% of municipalities. The low coefficient of variation indicates the homogeneity of the collectivity of municipalities due to changes in energy expenditure. When analyzing expenditure within sections, outlier index values were observed, which do not appear when analyzing the total expenditure. This means that some significant changes within individual sections did not significantly affect the index value for the total expenditure.

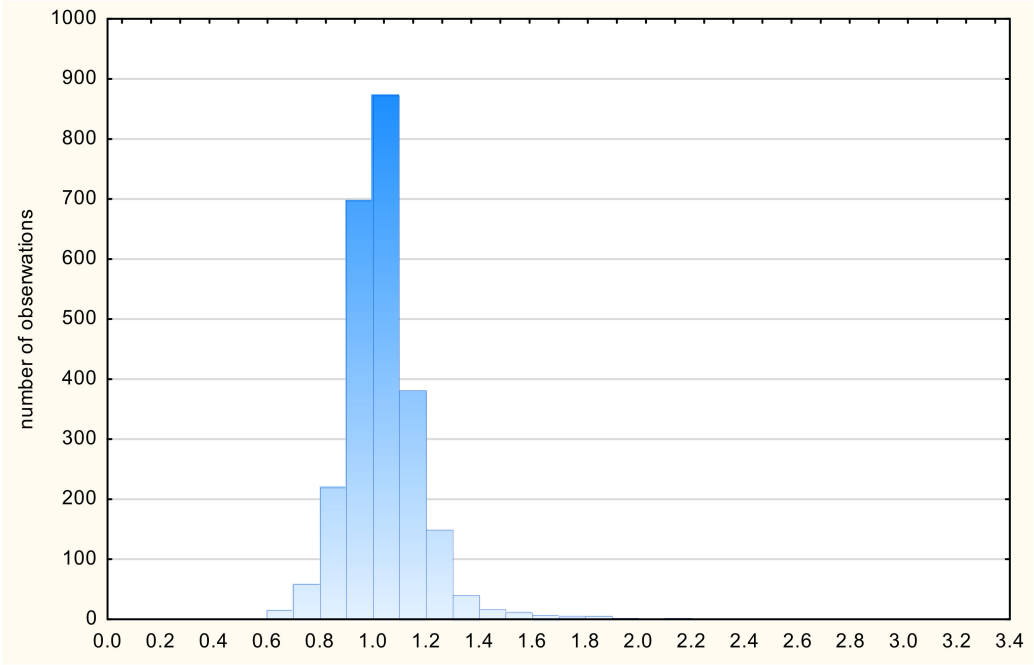

Figure 10. Histogram for distribution of cost indices of Article 426 for total expenditure within a municipality. Source: Authors' own calculations.

4.2.7. Analysis of Factors That Determine Changes in Energy Expenditure Using Classification and Regression Trees

Changes in the cost of electric energy for street lighting had the greatest impact on the changes in the total energy expenditure in municipalities. This is probably due to significant increases in the price of electric energy during the studied period (Figure 11). Section 90015 is characteristic because it exclusively contains expenses for electric energy. The other sections have both electric energy and other energy in their cost structure. Despite the increase in unit energy prices on the market, 218 municipalities recorded a decrease in lighting expenditure (an index below 0.862). The reasons for this are savings resulting from the decision of the municipal authorities to reduce budgetary expenditure. It was anticipated that restrictions to reduce the spread of the COVID-19 pandemic would have a negative impact on the income of municipalities' budgets. Some municipalities chose to temporarily turn off the street lighting when looking for savings. Another reason for reducing lighting costs was the modernization of light points by replacing lamps with less energy-intensive lamps. A larger amount of savings could have occurred in those municipalities where the unit price of energy in 2019–2020 did not change, as an energy supply contract was concluded for a period longer than the financial year.

Nearly 48% of municipalities were in the ID3 group, for which the average rate of increase in total energy costs is 1.105. All these municipalities have high indices of change in the cost of street lighting (above 1.140). A high aggregate change rate is the result of an increase in the price of electricity.

The dependency analysis used data describing the energy expenditure totals (a dependent variable) and a set of indexes for selected sections of the budget classification, thus obtaining 8621 objects. The first node is divided according to the index value criterion for each section, and the result is that the ID3 group is isolated, covering 25.58% of all objects with subindices greater than 1.19 (Figure 12). These are the objects with the highest increase in energy expenditure. The other objects form group ID2, which is divided into two child nodes according to the sub index value criterion at the level of 0.93. Among the index values under consideration, 44.15% represent more than 0.93 results, and 30.27% of the analyzed indices had values of less than 0.93. A characteristic group was extracted by dividing the ID4 node. It is group ID6, which includes objects for which the value of the expenditure

index for street and square lighting is lower than or equal to 0.93. This means, in the face of rising prices for electric energy, switching off street lighting or implementing measures to reduce the amount of energy consumed. Another characteristic group is ID20, with objects from eight provinces that have a low average GDP per capita [65]. The average rate of total expenditure in this group is 0.98, so the very low incomes of these municipalities forced savings.

The analysis of the dependency of the light expenditure index on the location of the municipality indicates a significant variation of these indices (the coefficient of variation is 137.6%). The group of municipalities from the Mazowieckie Province, for which the highest average index (1.39) was recorded, is clearly different from the rest of the objects, and this group is not homogeneous, as indicated by the high standard deviation (4.48) (Figure 13). This variation is due to the adoption of new lighting sections, which results in a significant increase in the cost index of these municipalities.

The node which remained after the group of Mazowieckie municipalities was separated, including relatively homogeneous objects, the standard deviation remains at 0.286. There is no significant spatial differentiation of the indices. All other provinces apart from Mazowieckie have an average index at a similar level, with the lowest average values of these indices recorded in Świętokrzyskie (1.08) and Podkarpackie (1.10) provinces.

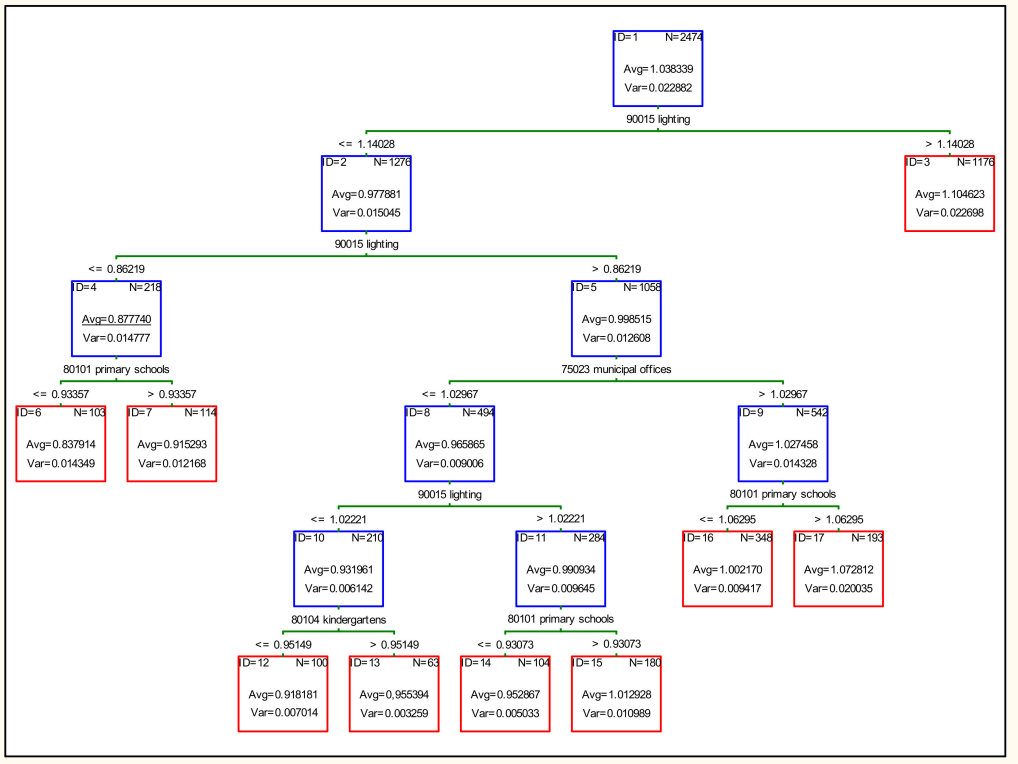

Figure 11. Regression tree describing the dependency of the indices of total energy expenditure on the index of changes in sections: 90015-Lighting of streets, squares and roads, 80101-Primary schools, 80104-Kindergartens, 70005-Land and real estate management, and 75023-Municipal offices. Source: Authors' own calculations.

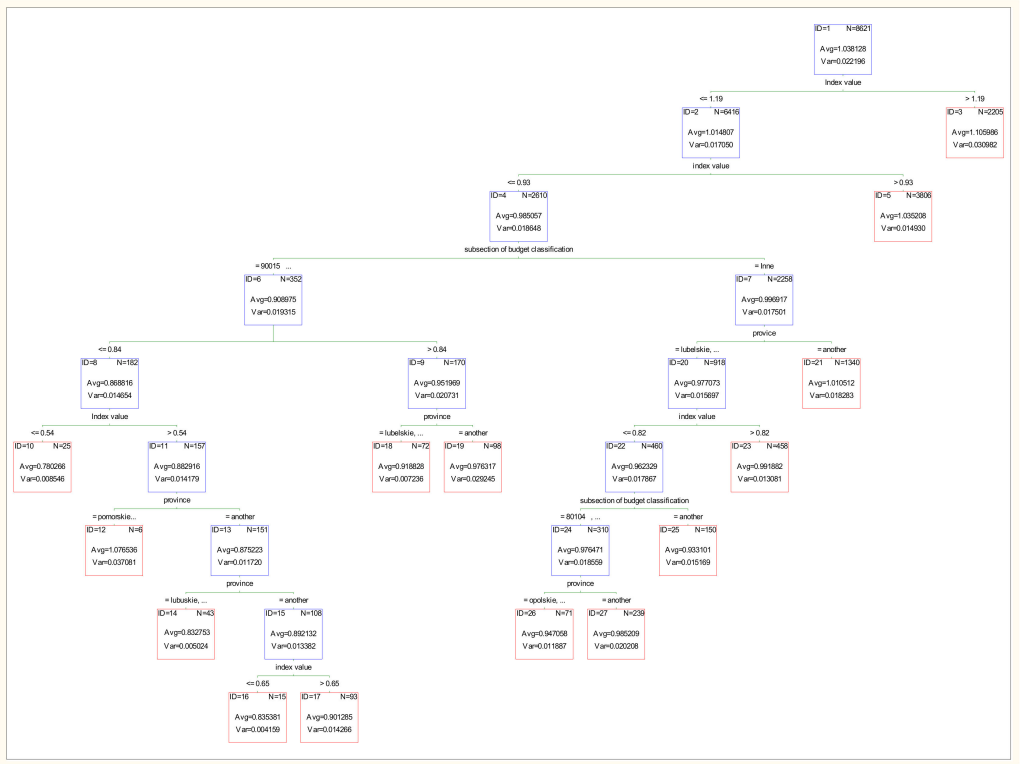

Figure 12. Regression tree describing the dependency of total energy expenditure indexes on the change indexes in the analyzed sections and locations. Source: Authors' own calculations.

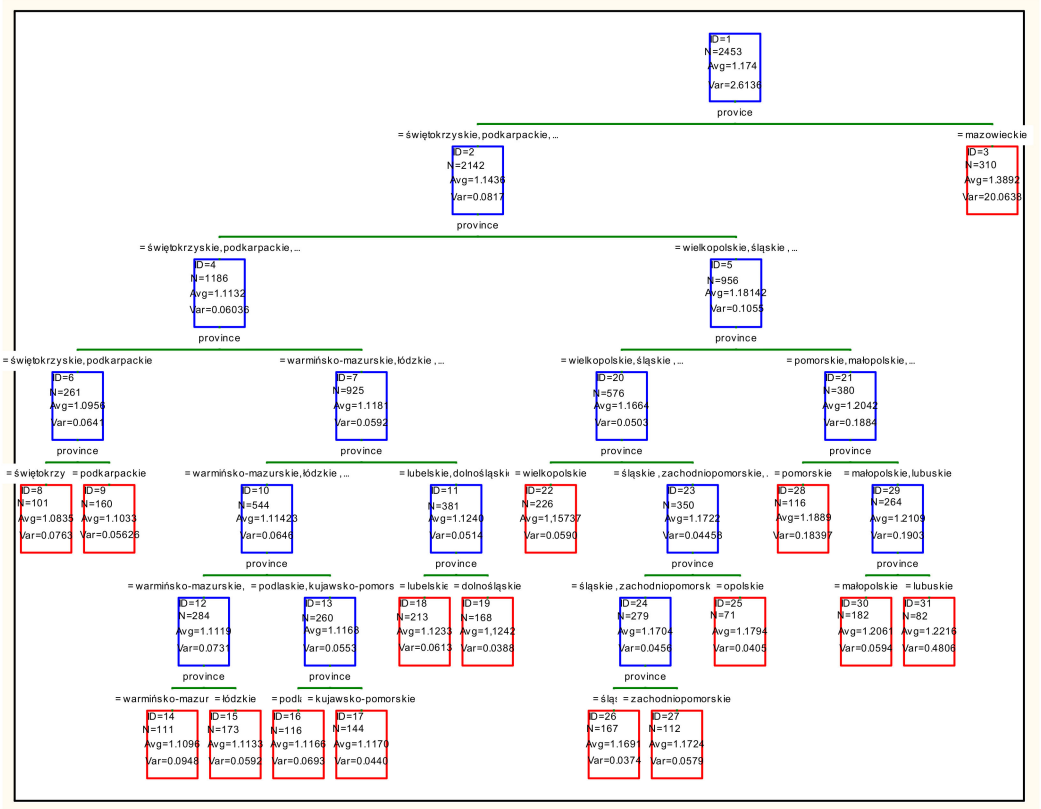

Figure 13. Regression tree describing the dependency of the lighting expenditure index on the location of the municipality. Source: Authors' own calculations.

5. Conclusions

5.1. Discussion and Policy Implications

The outbreak of the COVID-19 pandemic required an immediate and comprehensive response from governments. In the first place, governments had to put in place measures to contain the spread of the virus. Actions taken by public authorities based on lockdowns blocked economies and had far-reaching negative micro- and macroeconomic effects. Following the impending economic crisis, governments have been attempting to mitigate the impact of the economic crisis on the economic well-being of the population. Apart from the problem of population health and the need to control the economy, governments also had to reevaluate the principles on which the functioning of public management systems was based. In particular, the basic tasks of public administration fall under the provision and responsibility of public services [66]. When considering the state's contribution to counteracting the COVID-19 pandemic, the role of public administration in this respect cannot be overlooked [67].

Governments of all developed countries have taken steps to ensure the provision of essential services to citizens and businesses. In response to new circumstances, to maintain the continuity of the provision of services to citizens and enterprises, the public administration modified its activities, applied simplifications, and used alternative tools [68]. This led to the introduction of new administrative services and procedures but the suspension of others [69]. In all countries, public administration increasingly relies on IT solutions. In Poland, the public administration was forced to change the following areas of operational activity: internal organization, inter-institutional cooperation, customer service, and performing specific tasks commissioned by the government administration.

During the crisis caused by the pandemic, the provision of public services, such as education and health, was put to the test. To counteract the effects of the pandemic on a global scale, a number of measures have been taken to ensure the health security of citizens. In Poland, initial precautionary measures were recommended consisting of maintaining social distance and wearing protective masks and gloves. Due to the increasing number of infections in other countries, restrictions on the movement of people were introduced. As the number of infections increased, additional measures were taken, such as recommending that people stay at home. In Poland, the restrictions were instated on 20 March 2020.

One of the special effects of the economic slowdown resulting from the closing of the economy and limiting the activities of public institutions is the impact on energy consumption. As a result of the economic slowdown in the first quarter of 2020, the demand for energy in the global economy decreased by 3.8% compared to the corresponding quarter of 2019 [70,71]. The magnitude of changes in energy consumption varied significantly between countries and time periods. For example, Bompart et al. reported that compared to 2019, in 2020 in France and Spain, the demand for energy decreased by 15% [41]. According to Abu-Rayash and Dincer, during this period, Canada's energy consumption decreased by 14% [38]. Similar trends were recorded in Poland where, in annual terms, sales of electricity in quantitative terms decreased in 2020 compared to the previous year by approximately 8.3% [27].

Despite the negative impact of the decline in economic activity as a result of lockdowns during the pandemic, the reduction in energy consumption and the accompanying increase in energy efficiency is an opportunity to reduce CO_2 emissions [72]. The significant contribution of the energy sector to the generation of the carbon footprint was emphasized, for example, by Buenano et al. [73] and Percebois and Pommeret [74]. This problem is of particular importance in Poland, where electricity is generated predominantly on the basis of coal, and the production of electricity causes the emission of 758 g of CO_2 for every 1 kWh of electricity produced in power plants and combined heat and power plants [75]. Hence, the decrease in electricity sales in the period under consideration resulted in a reduction of CO_2 emissions by 3 MT.

The economy has suffered greatly as a result of the restrictions connected with the epidemic. The most affected sectors include transport, tourism, gastronomy, and the hotel

industry. Nevertheless, the effects of the introduced restrictions have also affected cultural institutions, such as cinemas, theaters, philharmonics, museums, and art galleries. During the pandemic, educational institutions and universities were closed, and many institutions switched to working remotely. The education sector reacted to the challenges related to the limitations in interpersonal contact by relatively quickly incorporating technological progress in teaching [76]. The academic community has rapidly migrated from an interactive face-to-face learning system to remote learning using a digital environment [77,78]. Including information technology into the teaching process was particularly challenging for the younger primary school students, but also for university students. To take part in classes, participants in the teaching process had to adapt to sometimes asynchronous audiovisual sessions without any interaction. Compared to the period before 2020, the education system has undergone far-reaching changes. Its evolution continues, and the academic community has become resistant to dynamic changes in the environment and has improved its adaptation skills [79].

The pandemic and the manner in which its effects were counteracted by public institutions have had wide economic repercussions, both for the population and students, and due to the change in the forms of operation for educational institutions. The impact of the pandemic and related lockdowns on energy use by the education sector has been studied relatively extensively. These studies have led to the general conclusion that the energy consumption of the education sector has decreased as a result of the COVID-19 pandemic.

The study by Samuel et al., carried out in South African primary and secondary schools, led to the conclusion that energy consumption decreased by 30% to 40% [80]. Electric lighting plays an important role in educational institutions. Research conducted in the USA has shown that electric lighting is responsible for about 14% of energy consumption in schools [81]. Research that quantifies the impact of the COVID-19 pandemic on energy consumption in educational institutions is an important source of information at the stage of creating plans to restore these institutions to their full operating condition.

Changes in the form of university functioning have had an ambiguous impact on the level of energy consumption—including electricity. In general, except in Europe, where declines of 10% to 40% have been recorded [81], in other regions of the globe, closing universities and switching to remote education have not had a major impact on the amount of electricity consumed [82,83]. In some universities in various parts of the world, energy consumption fell by more than 10% after the closure of university buildings. This was the result of closing university buildings as well as reducing the use of air conditioning systems [38,82]. The study conducted by Birch et al. reports a significant reduction in electricity demand in European universities due to the decommissioning of various buildings and laboratories, which reduces energy costs [84]. For example, at the University of Almeria in Spain, energy consumption has been reduced most in library buildings and least in research facilities [81]. The demand for electricity in extracurricular spaces (student dormitories) in some states in the US, as a result of their closure, has decreased by up to 40% [85].

The analysis of the expenditure of local self-government units on energy carried out by the authors of the study showed a significant impact of the pandemic on the amount of energy consumption in the studied entities. The reduced energy consumption resulted directly from the reduction of activity in many sectors of the economy. In 2020, there was also a significant increase in energy prices in Poland—the average price of electricity increased by approximately 24%. Despite such significant growth, companies from the energy sector recorded losses, which can be treated as an announcement of further increases in energy prices in Poland.

Expenditure on energy represents one of the main budget lines of local self-government units. The scope of changes in energy consumption in individual units has been diversified. Hence, estimating the impact of restrictions on the activities of entities managed by local self-government units on the change in energy expenditure has potentially wide implications. In particular, energy consumption rationalization programs can be very effective in improving

the financial condition of municipalities. There are ready-made solutions that can be implemented in local self-government units. A number of examples of good practices in terms of energy efficiency and the use of renewable energy sources were presented as part of the cooperation project "Polish-Norwegian cooperation platform for climate and energy conservation". One of the partners of this project was the local self-government of the City of Częstochowa, where was implemented the system enabling the ongoing control of the effectiveness of media use and the correctness of settlements. As a result of the implemented rationalization measures, real savings due to the reduction of utility consumption amounted to approximately PLN 27 million. The total consumption of fuels and energy in 2014 for a group of 118 educational facilities, covered by detailed monitoring and reporting, was lower by 38.5%, and CO_2 emissions decreased by 36.9%, while the total consumption of water decreased by 37.9% (compared to 2003).

Saving (unused) energy is the cleanest method of reducing the emission of harmful substances without negative ecological effects, and the improvement of energy efficiency is the most effective way to reduce the cost of energy consumption [86]. Energy consumption rationalization activities may have positive effects both at the level of a single organization and when implemented on a wider scale, may contribute to an increase in the competitiveness of a given country's economy in the global market [87].

It is estimated that currently, buildings use 80% more energy than they would if they were all equipped with modern technologies and smart building solutions. Appropriate management of energy consumption and its ongoing control could bring savings in this respect, even up to 20% [88]. From this perspective, there is a surprisingly low level of implementation of energy management systems in Poland.

The benefits of implementing the energy management system are the reduction of its consumption and thus the reduction of the costs of current operations of the entities under consideration, as well as the reduction of the negative impact on the environment, among others, as a result of the reduction of greenhouse gas emissions [86]. The most widely used are energy management systems based on ISO 50001. According to estimated data, energy savings, thanks to their implementation, may reach even several dozen percent [89].

In Poland, public funds are available for municipalities for measures aimed at improving energy efficiency, saving energy and reducing CO2 and other pollutants' emissions into the environment. In addition to public funds, private funds are also available. Especially promising is the ESCO formula, where the partner—usually a company—proposes the scope of rationalization and implements the project, financing it from its own resources. Payment for completed tasks is made in installments from the savings generated by the project.

The issues raised in the study are important due to the potential for considerable savings in financial resources and promising outlooks for limiting the negative impact on the natural environment. Expanding and propagating knowledge in that scope is part of the sustainable development strategy.

The research conducted also has some limitations. Although reference was made to data describing all LGUs in Poland, the statistical data refers to financial information reflecting energy expenditures. The authors did not have information about the amount of energy consumed—such databases are not available. This limits the possibility of conducting an in-depth analysis of energy consumption within individual sections of the budget classification. Additionally, significant changes in energy prices took place in the analyzed period. This made estimations and drawing conclusions difficult.

5.2. Conclusions and Implication for Future Research

1. Total production and sales of energy in Poland, in volume, in each quarter of 2020 were lower than in the corresponding period of the preceding year;
2. Electricity prices in 2020 increased by around 25% compared to 2019;
3. Thanks to the price increase, the sales of energy from electricity producing companies in 2020 were higher than in 2019;

4. In 2020, there were large cumulative losses in the analyzed corporate groups of energy companies. This may result in an increase in energy prices in Poland in the future;
5. Total expenditure under Article 426 'Purchase of energy' in self-government units in Poland in 2020 increased by 2.15% compared to 2019. However, different municipalities had different levels of change;
6. The cost of purchasing energy by municipalities was influenced by the increase in electricity prices. Taking into account the rising electricity prices, it is appropriate to conclude that energy consumption in self-government units in Poland during the COVID-19 pandemic has decreased;
7. The increase in lighting costs in 2020 is linked to the increase in electricity prices. Despite the increase in unit energy prices on the market, 218 municipalities recorded a decrease in lighting expenditure (an index below 0.862). One of the reasons for the savings is the decision of the municipal authorities to limit the lighting time required to reduce budgetary expenditure;
8. Energy costs spent under the education and upbringing section have decreased; However, the decline is not adequate to reduce the activity in schools and kindergartens;
9. The effects of the increased costs of purchasing electricity by LGUs in 2020 were mitigated by reduced energy consumption within certain sections where COVID-19 business restrictions were introduced;
10. Savings in the education and upbringing—primary schools, kindergartens, as well as in physical culture—physical culture institutions divisions reduced the spending of local government units on energy during the COVID-19 pandemic. Despite a total reduction in activity, energy costs have not fallen in proportion to the scale of the reduction in economic activity;
11. There was no significant reduction in energy consumption in Section 75023—Municipal offices. Municipal offices were functioning during the pandemic period; restrictions were only related to public access.
12. The imbalance in the cost of energy consumption in the restricted areas associated with preventing the spread of COVID-19 is due to the different technical possibilities of controlling energy systems and the quality of management. In some self-government units, despite operating restrictions, there were no corresponding savings in energy expenditure. In these units, it is desirable to analyze the reasons for this state of affairs. As a result of this analysis, a unit should be given recommendations for the solutions necessary to implement in order to improve energy efficiency.

The issue of managing energy consumption in local self-government units requires in-depth research. It is particularly important to diagnose the current state in this regard, which may be the basis for recommending solutions leading to a reduction in energy consumption. This would directly save money and reduce the negative impact on the environment.

It would be very useful to analyze the energy consumption of individual local self-government units with the use of indicator data, allowing for the rating of the status of energy consumption. The estimated indicators could be used by the management of LGUs to diagnose the condition of energy systems and plan the direction of their development. Based on the estimates of the indicators, it would also be possible to compare the efficiency of energy consumption demand between individual LGUs.

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