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Economic Determinants of Low-Carbon Development in the Visegrad Group Countries

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Abstract: Low-carbon development is one of the more significant problems of the Visegrad Group countries (Czech Republic, Poland, Slovakia, and Hungary). It is related, among others, to the improvement of life quality in economic terms while taking into account activities for environmental protection. The aim of the article is to identify and explain the problems connected with low-carbon development. The purpose of the analyses is also to prove the negative impact of the emission of greenhouse gas emission (GHG) and other harmful substances into the air on the quality of human life and the natural environment. During the research, an assessment of the eco-efficiency of the used energy resources and technologies that negatively affect the environment was carried out. Moreover, the paper also presents methods to use greener energy sources and analyses the potential of implementing solutions supporting low-carbon development. The study recommends actions that may contribute to the reduction of greenhouse gas emissions. These include the limitation of the use of fossil fuels for the benefit of renewable energy and the development of distributed energy.

Keywords: economic aspects; low-carbon development; energy; renewable energy; greenhouse gas emissions; gross domestic product

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1. Introduction

A low-carbon economy should be understood as an economy in which growth is achieved through the use of innovative and ecological energy solutions, including renewable energy sources (RESs) and the implementation of low-carbon technologies [1–3]. A low-carbon economy assumes the efficient use and production of energy, optimal management of materials and raw materials, and recovery of waste by methods that reduce greenhouse gas emissions [4,5]. Moreover, a low-carbon economy involves removing waste in a way that minimises environmental impact [6]. The economic development that took place in the Visegrad Group countries, especially after their accession to the EU, has largely translated into the quality of life of the inhabitants of these countries [7,8]. However, economic development has not sufficiently reduced the amount of pollution that is emitted into the air [9–11]. Low-carbon development in the Visegrad Group countries consists mainly of maintaining conditions of economic growth while limiting the greenhouse gas emission to the atmosphere [12]. However, the specificity of the region indicates a strong link between the greenhouse gas emission and other pollutants that are emitted along with greenhouse gases [13,14]. This is especially visible in Poland. It should be emphasised that in the Visegrad Group countries, a significant problem is the excessive amount of greenhouse gases emitted into the atmosphere, as well as emissions of other substances that directly affect human health and the environment [15,16].

From the point of view of residents of the Visegrad Group countries, harmful substances such as suspended particulates and benzo(a)pyrene (B(a)P) [17,18], which directly affect human health are more important [19]. Harmful substances contained in the air,

such as particulate matter PM2.5 and PM10 are the cause of respiratory and circulatory system diseases and contribute to the premature death of about 80,000 people per year in the Visegrad Group countries [20].

Although excessive greenhouse gas emission negatively affects the state of the environment, it is not felt in a short period of time. Changes caused by excessive greenhouse gas emissions (including CO_2) occur gradually over time, and it is more difficult for them to attribute a specific number of accidents that occur during violent atmospheric phenomena [21,22]. Thus, it is important to create interdisciplinary research teams providing technically and economically optimised smart solutions, enabling low-carbon development.

The purpose of the analyses in this study is also to prove the negative impact of the emission of GHG and other harmful substances into the air on the quality of human life and the natural environment. During the research, an assessment of the eco-efficiency of the used energy resources and technologies that negatively affect the environment was carried out. Moreover, the paper also presents methods to use greener energy sources and analyses the potential of implementing solutions supporting low-carbon development [23,24]. In some countries, coal fuels account for over 50 percent of electricity production [25,26]. Low-carbon development in the above-mentioned countries is progressing despite various paths to improve energy efficiency. [27]. The study recommends actions that may contribute to the reduction of greenhouse gas emissions. These include the limitation of the use of fossil fuels for the benefit of renewable energy and the development of distributed energy. It is estimated that in the Visegrad Group countries, approximately 77,500 people prematurely die each year due to poor air quality. Particulate matter PM2.5 is particularly dangerous for human health in the Visegrad Group countries, which contribute to 44,500 premature deaths in Poland, 12,800 in Hungary, 10,100 in Czechia, and 2500 in Slovakia. It is necessary to notice that in the coming years, the low-carbon development of EU countries, including the countries belonging to the Visegrad Group, will be influenced by the basics contained in the priorities of the European Green Deal, which is to contribute to achieving climate neutrality in Europe by 2050. Actions planned in the European Green Deal refer in a special way to the countries of the Visegrad Group, as it provides for allocating funds to regions most in need. On the one hand, it is a great benefit for the countries of the Visegrad Group, but on the other hand, it is also a huge challenge, which is related to the need to implement thorough changes in many sectors of the economy.

2. Air Pollution in the Visegrad Group Countries

There are several main sources of air pollution in the Visegrad Group countries. These are both sources of natural origin that are beyond human control (e.g., volcanic eruptions, dust transfer by wind, or emissions of volatile organic compounds from plants) and of anthropogenic origin from the following:

- Industry;
- Waste management;
- Agriculture;
- Burning fossil fuels during electricity generation and heat;
- Transport and households.

It should be emphasised that the amount of gaseous and particulate pollutants in the air can be regulated by people through the use of low-carbon energy generation technologies, including those based on renewable sources [28,29]. A significant part of efforts to improve the quality of the environment is directed at reducing greenhouse gases, including CO_2 [30,31]. According to the European Commission estimates, the level of CO_2 emissions that came from energy consumption in 2018 fell by 2.5% in the EU, compared to 2017. CO_2 emissions account for around 80% of all EU greenhouse gas emissions. It should be noted that, according to data from the European Commission, while the average volume of CO_2 emissions in the entire European Union is falling, in Poland and Slovakia, it has significantly increased. In contrast, in Czechia and Hungary, the level of emissions has been slightly reduced [32,33].

In 2019, Poland was far from achieving the designated share of renewable energy sources in total energy production (Table 1). In turn, Czechia reached the RES share, which was set for 2020 for these countries [34–36]. It was troubling that the share of renewable sources in Poland increased until 2015 and later began to decline. However, recent information indicates that Poland has achieved the RES share planned for 2020. This was due to a decrease in demand for electricity due to the epidemiological situation. The level of energy production was the lowest in 10 years, and in the first place, energy production based on conventional sources was limited. Most of the EU countries did not reach the share of renewable energy set for 2020 in 2019.

Table 1. The share of RES in total energy production in countries belonging to the EU [37].

Specification	2004	2014	2015	2016	2017	2018	2019	Target for 2020	2019 Minus 2020
	%								p.p.
EU-27	9.6	17.5	17.8	18.0	18.5	18.9	19.7	20	−0.3
EU-28	8.6	16.2	16.7	17.0	17.5	18.0	18.9	20	−1.1
Belgium	1.9	8.0	8.0	8.8	9.1	9.8	9.9	13	−3.1
Bulgaria	9.2	18.0	18.3	18.8	18.7	20.6	21.6	16	5.6
Czechia	6.8	15.1	15.1	14.9	14.8	15.1	16.2	13	3.2
Denmark	14.8	29.3	30.9	32.1	34.7	35.4	37.2	30	7.2
Germany	6.2	14.4	14.9	14.9	15.5	16.7	17.4	18	−0.6
Estonia	18.4	26.1	28.5	28.7	29.2	30.0	31.9	25	6.9
Ireland	2.4	8.6	9.0	9.2	10.5	10.9	12.0	16	−4.0
Greece	7.2	15.7	15.7	15.4	17.3	18.1	19.7	18	1.7
Spain	8.3	16.2	16.3	17.4	17.6	17.5	18.4	20	−1.6
France	9.5	14.9	15.5	15.9	16.3	16.4	17.2	23	−5.8
Croatia	23.4	27.8	29.0	28.3	27.3	28.0	28.5	20	8.5
Italy	6.3	17.1	17.5	17.4	18.3	17.8	18.2	17	1.2
Cyprus	3.1	9.2	9.9	9.9	10.5	13.9	13.8	13	0.8
Latvia	32.8	38.6	37.5	37.1	39.0	40.0	41.0	40	1.0
Lithuania	17.2	23.6	25.7	25.6	26.0	24.7	25.5	23	2.5
Luxembourg	0.9	4.5	5.0	5.4	6.2	9.0	7.0	11	−4.0
Hungary	4.4	14.5	14.4	14.3	13.5	12.5	12.6	13	−0.4
Malta	0.1	4.7	5.1	6.2	7.2	8.0	8.5	10	−1.5
Netherlands	2.0	5.4	5.7	5.8	6.5	7.3	8.8	14	−5.2
Austria	22.6	33.6	33.5	33.4	33.1	33.8	33.6	34	−0.4
Poland	6.9	11.6	11.9	11.4	11.1	11.5	12.2	15	−2.8
Portugal	19.2	29.5	30.5	30.9	30.6	30.2	30.6	31	−0.4
Romania	16.8	24.8	24.8	25.0	24.5	23.9	24.3	24	0.3
Slovenia	18.4	22.1	22.4	21.5	21.1	20.9	21.7	25	−3.3
Slovakia	6.4	11.7	12.9	12.0	11.5	11.9	16.9	14	2.9
Finland	29.2	38.8	39.3	39.0	40.9	41.2	43.1	38	3
Sweden	38.7	51.8	52.9	53.3	54.2	54.7	56.4	49	7.4
United Kingdom	1.1	6.7	8.4	9.0	9.9	11.1	12.3	15	−2.7

Problems that took place until 2019 related to Poland and Slovakia achieving the assumed RES share in 2020 are mainly due to the negligence of the authorities of these countries that have taken place over the last few years [38]. The Polish government in documents sent in 2019 to the European Commission admitted that the planned RES share (15%) in 2020 would not be achieved. According to these documents, a 13.8% share of renewable energy will be achieved [39]. Moreover, the Polish budget for 2020 does not plan to significantly increase financial resources for the dynamic development of renewable energy sources. However, as mentioned earlier, the coronavirus pandemic led to a reduction in energy demand, and, in the first place, the use of fossil energy resources for energy production was reduced. Additionally, in the case of Slovakia, according to analyses carried out by the European Commission [32] and the Supreme Audit Office of the Slovak Republic, achieving the assumed RES share in 2020 will be difficult [40]. The publication did not carry

out statistical analyses because it was based on the results of research of institutions that have much more tools to carry out this type of analysis. For instance, in the case of Slovakia, according to analyses carried out by the European Commission and Supreme Audit Office of the Slovak Republic, it will be difficult to achieve the assumed share of renewable energy in 2020. Therefore, no statistical forecasts were conducted regarding the share of renewable energy sources in the coming years in individual countries of the Visegrad Group, because such forecasts are made by several independent institutions, both at the national and EU levels. The above forecasts also did not come true due to the coronavirus pandemic.

3. Economic Development Versus Energy Consumption and Emission Level

The Visegrad Group countries have developed dynamically in recent years, catching up with the so-called old Union (EU 15). There are many reasons for the dynamic economic development of countries in this part of the EU. The most important of them include growing internal demand in the Visegrad Group countries, EU funds, and the development of the world economy. However, despite this, GDP in all Visegrad Group countries still deviates from the EU average. The GDP growth in the Visegrad Group countries ranged from 1.9 to 4.6% in 2019 (Table 2). The highest GDP growth in 2019 took place in Poland and Hungary. However, there was an economic downturn in 2020, triggered by the coronavirus pandemic. Moreover, in Visegrad Group countries in the entire analyzed period (2010–2020), GDP grew faster (or fell more slowly), compared to the EU average. Euro area countries also developed more slowly than Poland. It should be emphasised that in 2020, Poland and Hungary had the lowest real GDP per capita among the Visegrad Group countries and one of the lowest in the EU. In 2020, real GDP per capita in Poland and Hungary was EUR 12,660 and 12,630, in Slovakia EUR 15,010, and in the Czechia EUR 17,260 [37]. The change in GDP is largely linked to the level of greenhouse gas emissions. The countries of the Visegrad Group (especially Poland) could not grow so quickly were it not for the fact that a relatively large proportion of energy is generated by burning coal, which is currently a relatively cheap fuel [41]. Real GDP per capita in the Visegrad Group countries allows assessing how the living conditions of residents have changed.

Table 2. Real GDP per capita in the Visegrad Group countries [37].

Specification	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020/2010
	Real GDP Per Capita (%)											p.p.
Czechia	2.2	2.0	−0.9	−0.1	2.1	5.2	2.3	4.9	2.8	1.9	−5.8	−8.0
Poland	3.6	4.7	1.3	1.2	3.4	4.3	3.2	4.8	5.4	4.6	−2.6	−6.2
Slovakia	5.6	3.5	1.7	0.5	2.5	4.7	2.0	2.9	3.6	2.2	−5.3	−10.9
Hungary	1.4	2.2	−0.9	2.1	4.5	4.1	2.4	4.6	5.5	4.6	−4.8	6.2
EU 28	1.9	1.5	−0.7	0.1	1.5	2.0	1.6	2.4	1.8	1.3	-	-
EU 27	2.0	1.7	−0.9	−0.2	1.4	2.1	1.8	2.6	1.9	1.3	−6.3	−8.3
	Real GDP per capita (EUR thousand)											%
Czechia	15.02	15.31	15.17	15.16	15.48	16.29	17.67	17.49	17.99	18.33	17.26	14.91
Poland	9.40	9.85	9.98	10.10	10.44	10.89	11.24	11.79	12.42	13.00	12.66	34.68
Slovakia	12.56	12.99	13.22	13.29	13.63	14.27	14.55	14.98	15.52	15.86	15.01	19.51
Hungary	9.96	10.18	10.09	10.31	10.77	11.21	11.48	12.01	12.68	13.26	12.63	26.81
EU 28	25.51	25.90	25.73	25.75	26.15	26.67	27.11	27.77	28.25	28.61	-	-
EU 27	24.89	25.32	25.08	25.04	25.39	25.92	26.38	27.08	27.60	27.97	26.22	5.34

Analysing the GDP per capita ratio in 2010–2019 according to purchasing power parity in the Visegrad Group countries, it should be noted that the purchasing power of Czech residents was the highest. On the other hand, Slovaks had the lowest purchasing power, with 70% of the purchasing power of a statistical EU resident, respectively (Table 3).

Table 3. Index of GDP per capita by purchasing power parity in the Visegrad Group countries [37].

Specification	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
	%									
Czechia	84	84	84	86	88	89	89	91	92	93
Poland	66	67	67	67	68	69	69	70	71	73
Slovakia	76	76	77	78	78	78	73	71	71	70
Hungary	66	67	67	68	69	70	69	69	71	73
EU 27	100	100	100	100	100	100	100	100	100	100
EU 19 (EUR)	109	109	108	108	108	108	107	107	107	106

Along with the growth in GDP per capita, final energy consumption in households per capita increased in the Czech Republic and Slovakia (Table 4). When analysing energy consumption in households per capita in the Visegrad Group countries, clearly lower energy consumption in Slovakia and Poland should be noted, which was caused, among others, by the introduction of energy-saving solutions in households and institutional changes [42]. Furthermore, when compared to the EU average, Slovakia and Poland were characterised by lower final energy consumption in households per inhabitant throughout the entire analysed period. It should be emphasised that in 2019 final energy consumption in households per capita in Poland was a bit lower (479 kgoe) than in Slovakia (485 kgoe).

Table 4. Final energy consumption in households per capita and greenhouse gas emissions per capita in the Visegrad Group countries [37].

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019/2009
	Final Energy Consumption in Households Per Capita (in Kilograms of Oil Equivalent)											%
Czechia	623	627	638	711	654	677	690	622	641	670	678	8.83
Poland	524	578	529	547	539	501	501	524	528	512	479	−8.59
Slovakia	399	429	393	383	397	360	366	374	388	378	485	21.55
Hungary	630	665	659	643	628	556	607	629	643	595	581	−7.78
EU 27	595	632	572	597	603	530	552	566	565	553	551	−7.39
EU 19 (EUR)	611	645	577	606	617	534	558	572	569	558	560	−8.35
Specification	**Greenhouse gas emissions per capita (in Mg of CO_2 equivalent per capita)**											%
												2018/2009
Czechia	13.3	13.5	13.4	12.9	12.4	12.2	12.3	12.5	12.4	12.2	-	−8.27
Poland	10.4	10.9	10.9	10.7	10.6	10.3	10.4	10.6	11.0	11.0	-	5.77
Slovakia	8.5	8.6	8.5	8.0	7.9	7.6	7.7	7.8	8.0	8.0	-	−5.88
Hungary	6.5	6.6	6.4	6.1	5.8	5.9	6.2	6.3	6.6	6.6	-	1.54
EU 27	9.5	9.7	9.5	9.3	9.1	8.8	8.9	8.9	8.9	8.7	-	−8.42

In analyses regarding low-carbon development, it is important how greenhouse gas emissions per capita have changed in the Visegrad Group countries, compared to the EU average [43]. In the years 2009–2018, the average greenhouse gas emissions per capita in the EU decreased (Table 4). A similar situation took place in the Czech Republic and Slovakia. In Hungary, greenhouse gas emissions per capita remained at a similar level. However, in Poland, it increased [44]. The reason for this state of affairs should be the economic growth in Poland that took place in the analysed period of time. However, the economic growth did not prevent other countries of the Visegrad Group from reducing greenhouse gas emissions per capita. The lack of smart activities in Poland for the development of non-coal energy and insufficient expenditure on innovative technological solutions related to the development of low-carbon energy should be indicated as significant factors that were not conducive to reducing greenhouse gas emissions per capita. When analysing the current low-carbon development in the Visegrad Group countries, reference should be made to changes in the level of greenhouse gas emission per capita. It should be noted

that Poland was the only country among the Visegrad Group that recorded a noticeable increase in greenhouse gas emission per capita in 2018, compared to 2009. However, in Czechia, despite a decrease in greenhouse gas emissions, there is a higher level of emission per capita than in Poland.

Reducing CO_2 and other greenhouse gas emissions is very important because of the need to slow down global warming. However, particulate matter PM2.5 is particularly dangerous for human health in the Visegrad Group countries, which contribute to 46,200 premature deaths in Poland, 12,800 in Hungary, 11,970 in the Czechia, and 5160 in Slovakia (Table 5).

Table 5. Premature deaths related to exposure to PM2.5, NO_2, and O_3 in the Visegrad Group countries in 2015. Reproduced from [20], European Environment Agency: 2020.

Specification	Population (1000)	PM2.5		NO_2		O_3	
		Annual Average [a]	Premature Deaths [b]	Annual Average [a]	Premature Deaths [b]	SOMO35 [a]	Premature Deaths [b]
Czechia	10,512	17.3	11,970	17.1	1210	3620	350
Hungary	9877	18.9	12,800	18.0	1300	5550	530
Poland	38,018	23.0	46,020	15.1	1700	3425	970
Slovakia	5416	19.1	5160	15.2	100	4344	160
EU 28	502,351	14.0	399,000	18.7	75,000	3507	13,600

Notes: [a] The annual mean (in $\mu g/m^3$) and the SOMO35 (in $\mu g/m^3$ days), expressed as population-weighted concentration, is obtained according to the methodology described by ETC/ACM (2017a) and not only from monitoring stations; [b] total and EU-28 premature deaths are rounded to the nearest thousand (except for O_3, nearest hundred). The national totals are rounded to the nearest hundred or ten.

Despite measures taken to reduce emissions in the Visegrad Group countries, concentrations of harmful substances in the air are still often exceeded. Poor air quality results in the need to incur additional costs related to the absence of sick employees in the workplace and generates the cost of treating people exposed to prolonged inhalation of polluted air. It is estimated that in the Visegrad Group countries, approximately 82,270 people prematurely die each year due to poor air quality (Table 5), which significantly exceeds the EU average [20].

The costs of reducing greenhouse gas emissions are a serious problem for the Visegrad Group countries. This is particularly true of Poland, whose energy sector is based around 80% on fossil fuels. The extent of the problem for the Visegrad Group countries could be observed during the summit on climate neutrality, which took place in December 2019. It should be noticed that a few months before the summit, most of the countries of the Visegrad Group (Poland, Czechia, and Hungary) had doubts largely due to concerns about the costs of reducing CO_2 emissions [45]. However, ultimately, only Poland's authorities, as the only EU country, did not agree to the commitment to achieving climate neutrality by 2050. Poland obtained a few additional months (until the summit of EU heads of state and government in June 2020) to negotiate details of financial reduction instruments CO_2 [46].

Although in recent years, the inhabitants of the Visegrad Group countries have pointed out the excessive gas and dust emissions, which have a noticeable impact on the quality of life, one should not underestimate excessive emissions of greenhouse gases, whose effects are spread over time. Extreme weather phenomena caused by them may, as a consequence, lead to the loss of health or life of many people and paralyse conducting business on a global scale [47]. The resources needed to rebuild damaged infrastructure are often calculated in millions of euros.

4. Prospects for Low-Carbon Development in the Visegrad Group Countries

The activities for low-carbon development in the Visegrad Group countries should be oriented towards the implementation of modern technologies that will be more energy efficient. It is necessary to limit the use of energy resources that contribute to excessive emissions, both as greenhouse gases and other harmful substances [48]. Moreover, the

EU's long-term goals are aimed at achieving air quality levels that will not unduly impact the quality of life and human health [49]. The Council and Commission of the EU can effectively exert pressure on its member countries through a number of instruments they possess. Attention should be paid to the Europe 2020 strategy, in which the EU spends almost EUR 1 trillion on sustainable economic growth, jobs, and competitiveness in the 2014–2020 budget. At least one-fifth of the EU budget for 2014–2020 is allocated to the transition to a low-carbon European economy [50]. Giving up the use of fossil fuels for renewable energy is very difficult and will require a change in the entire energy system [51].

The implementation and maintenance of sustainable low-carbon development in the Visegrad Group countries will require the involvement of significant financial resources. It should be noted that currently, energy efficiency in some countries of the Visegrad Group is almost twice lower than the EU average (Table 6). Expenditure on modern, energy-saving technologies should be combined with the costs of developing coal energy, the costs of which will increase in the future because of the rising costs of coal mining, as well as the rising charges for CO_2 emissions [52,53]. Limiting the burning of fossil fuels is currently one of the most important conditions for reducing greenhouse gas emissions to the air [54]. Solid fuels, especially fossil fuels, are among the most important elements of the energy system in most countries in the world.

Table 6. Energy productivity in the Visegrad Group countries in 2009–2019 [37].

Specification	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019/2020
						EUR/kgoe						%
Czechia	3.60	3.47	3.68	3.69	3.67	3.88	4.08	4.23	4.26	4.39	4.55	26.39
Poland	3.69	3.56	3.73	3.93	3.94	4.23	4.36	4.29	4.29	4.45	4.79	29.81
Slovakia	3.86	3.85	4.08	4.32	4.29	4.69	4.76	4.84	4.72	4.96	5.08	31.61
Hungary	3.81	3.75	3.90	4.04	4.26	4.46	4.38	4.42	4.41	4.64	4.85	27.30
EU 27	6.95	6.84	7.17	7.21	7.29	7.67	7.74	7.83	7.88	8.10	8.36	20.29
EU 19 (EUR)	7.45	7.35	7.74	7.76	7.81	8.23	8.27	8.38	8.46	8.71	8.95	20.13

The implementation of low-carbon development in the Visegrad Group countries is conditioned by many factors. The economic factor is particularly important. The problem is possible to solve because most countries, especially the so-called old EU (EU 15), are facing this matter much better than the countries of the Visegrad Group. To effectively reduce gas and dust emissions to the air, various types of solutions should be implemented in parallel (in the field of methodology for measuring phenomena, analytical techniques, legal solutions, etc.) [55]. Considering that the Visegrad Group countries have a large share in gas and dust emissions to the air in heating single-family buildings, the possibilities of reducing pollution arising from the burning of fossil fuels in home boiler rooms should be analysed [56]. For this purpose, the life cycle assessment (LCA) method is helpful, which indicates how to identify more environmentally friendly ways to generate the energy needed for heating buildings [57,58]. Furthermore, LCA can help when choosing power generation technology in a power plant or to indicate a greener product technology [59,60]. LCA is a method that allows comparing different types of production processes used for energy purposes, such as the production of electricity or the production of heat energy for heating rooms in buildings [61]. LCA helps to identify a solution that will burden the environment the least [62]. The advantage of the LCA assessment is that it takes into account the entire lifetime of the product, from raw material extraction and processing through product manufacturing, distribution, use, reuse, maintenance, recycling and final management, and transport [63].

The International Organisation for ISO Standardisation defines LCA as a method for assessing environmental aspects and potential impacts associated with a product [64–66]. When conducting research, it is possible to use computer programs that significantly reduce the time needed for analyses [67]. In research, it is also possible to use Eco-Indicator 99, whose advantage is to take into account the problem of reducing raw material resources

that are consumed in the manufacture of products. However, the results of the LCA assessment are expressed in points of the eco-indicator (Pt), where 1 Pt is the value of one-thousandth of an annual environmental load per one inhabitant of Europe [68,69].

It should be noted that road transport is currently having an increasing impact on the environment [70]. The activities for low-carbon development should also take into account this area of the economy. The growing number of cars in the Visegrad Group countries significantly contributes to increasing greenhouse gas emissions. Even considering that new cars meet recently stricter ecological standards, their growing number means that it will be difficult to achieve a significant reduction in greenhouse gas emissions in this sector in a short period of time. It should be emphasised that in a country such as Poland, supporting electric cars does not allow achieving a significant ecological effect [71]. The use of electric cars in Poland that produces about 80% of its electricity by burning coal and natural gas causes the changes in greenhouse gas emissions to only appear in locations where electric cars are used [72]. On the one hand, there are fewer greenhouse gas emissions in places where there is a lot of traffic, but on the other, more emissions are generated in coal-fired power plants. Low-carbon development using electric cars will be more effective if the share of renewable energy in electricity generation is also increased. Technical and technological progress, as well as the development of human capital, are very important in the studied subject.

Preliminary data of the Energy Market Information Centre indicate that the share of renewable energy sources in Poland (the largest country of the Visegrad Group) has increased in 2020 [73]. However, this happened due to both the increasing amount of energy produced on the basis of renewable energy sources and the reduction of energy demand. It should be emphasised that the amount of energy produced as a result of burning fossil fuels has been reduced (Figure 1).

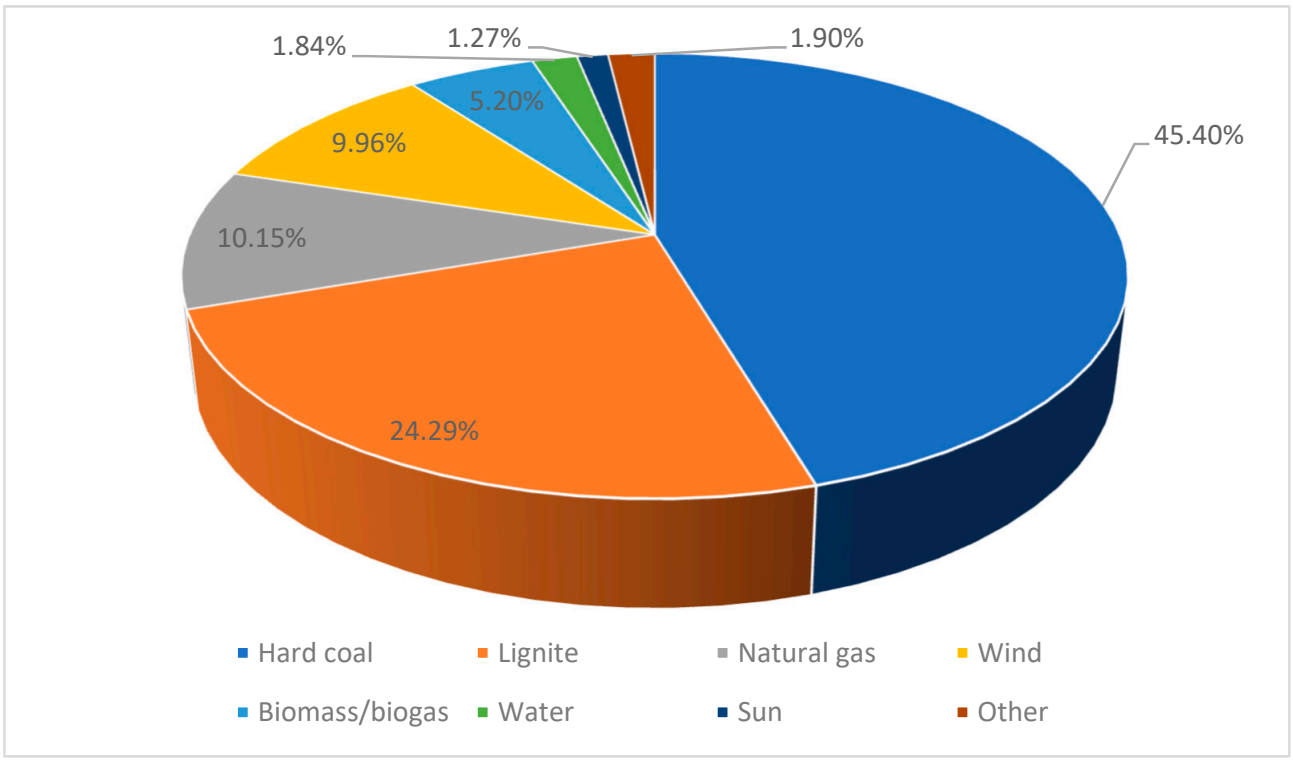

Figure 1. Share of sources in the overall energy balance in Poland (2020). Reproduced from [73], Centrum Informacji o Rynku Energii: 2021.

5. Conclusions

The Visegrad Group countries are obliged to meet EU requirements in the field of the low-carbon economy. The article presents selected aspects of low-carbon development and indicates some of the actions that may contribute to reducing greenhouse gas emissions. It should be noted that the implementation of low-carbon solutions may be more efficient due to the growing public acceptance.

However, educational activities that promote low-carbon solutions should not be restricted. Maintaining economic growth without excessive emission of greenhouse gases will be associated with the implementation of solutions that will promote (e.g., through lowering taxes) low-carbon solutions, including in energy and transport.

An active policy of the state and local governments should be supported by more stringent compliance with current regulations, and in the future, it may also be necessary to tighten them. The Visegrad Group countries have a long road ahead in their efforts to promote low-carbon development, which often deviates significantly from the EU average. An issue that cannot be delayed in the next few decades is the urgent need to reduce the use of fossil fuels, especially contaminated ones, such as hard coal and lignite. As the examples of Czechia and Slovakia show, it was possible to achieve the RES share set for 2020 before the set date. Poland managed to achieve the RES share planned for 2020 due to the situation related to the coronavirus pandemic and a significant reduction in energy production based on fossil sources. Moreover, solutions that have been successful in other countries, e.g., in the field of distributed energy, should be supported. Micro installations can be located near almost every single-family house. The development of distributed energy will also reduce the need to transmit energy over long distances, which is necessary in the case in which large coal power plants dominate the industry.

Furthermore, local governments that have knowledge of local problems related to reducing greenhouse gas emissions should be more involved in low-carbon development efforts. Greater involvement of local governments connected with the increased financing of low-carbon solutions could contribute to increasing the effectiveness of activities implemented so far.

There is also a need for more intensive actions for the benefit of various sectors of the economy. For instance, support for road transport could significantly reduce emissions of greenhouse gases and other harmful substances. In order to achieve the assumed effect, various solutions should be implemented at the same time, e.g., in road transport, it could include increasing co-financing for the purchase of electric cars, development of infrastructure for charging electric car batteries, exemption from registration fees, restriction of entry to strict city centres for non-ecological cars, etc.

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References

1. Truong, A.; Piera, P.; Leduc, S.; Kraxner, F.; Ha-Duong, M. Reducing emissions of the fast growing Vietnamese coal sector: The chances offered by biomass co-firing. *J. Clean. Prod.* **2019**, *215*, 1301–1311. [CrossRef]
2. Guo, R.; Zhao, Y.; Shi, Y.; Li, F.; Hu, J.; Yang, H. Low carbon development and local sustainability from a carbon balance perspective. *Resour. Conserv. Recycl.* **2017**, *122*, 270–279. [CrossRef]
3. Kozłowski, K.; Pietrzykowski, M.; Czekała, W.; Dach, J.; Kowalczyk-Juśko, A.; Jóźwiakowski, K.; Brzoski, M. Energetic and economic analysis of biogas plant with using the dairy industry waste. *Energy* **2019**, *183*, 1023–1031. [CrossRef]
4. Bedir, S.; Yilmaz, V.M. CO_2 emissions and human development in OECD countries: Granger causality analysis with a panel data approach. *Eurasian Econ. Rev.* **2016**, *6*, 97–110. [CrossRef]
5. Jeżowski, P. O niektórych problemach gospodarki niskoemisyjnej. *Studia Polityki Publicznej* **2017**, *13*, 45–64. (In Polish) [CrossRef]
6. Chariri, A.; Nasir, M.; Januarti, I.; Daljono, D. Determinants and consequences of environmental investment: An empirical study of Indonesian firms. *J. Asia Bus. Stud.* **2019**, *13*, 433–449. [CrossRef]
7. Sacio-Szymańska, A.; Kononiuk, A.; Tommei, S.; Valenta, O.; Hideg, E.; Gáspár, J.; Markovič, P.; Gubová, K.; Boorová, B. The future of business in Visegrad region. *Eur. J. Futures Res.* **2016**, *4*, 26. [CrossRef]
8. Czyżewski, B.; Trojanek, R.; Dzikuć, M.; Czyżewski, A. Cost-effectiveness of the common agricultural policy and environmental policy in country districts: Spatial spillovers of pollution, bio-uniformity and green schemes in Poland. *Sci. Total Environ.* **2020**, *726*, 138254. [CrossRef]
9. Klemeš, J.J.; Varbanov, P.S. Heat transfer improvement, energy saving, management and pollution reduction. *Energy* **2018**, *162*, 267–271. [CrossRef]
10. Yuan, H.; Zhou, P.; Zhou, D. What is Low-Carbon Development? A Conceptual Analysis. *Energy Procedia* **2011**, *5*, 1706–1712. [CrossRef]
11. Wójcik, A.; Wąsowicz, J. Greenhouse gas emissions as regards the sectors in the European Union countries. *Public Policy Adm.* **2017**, *16*, 672–685. [CrossRef]
12. Sun, P.; Li, L.; Zhou, K. Carbon Emission and Endogenous Growth between Two Economic Systems. *Front. Energy Res.* **2021**, *9*, 652832. [CrossRef]
13. Barbier, E.B. Is green growth relevant for poor economies? *Resour. Energy Econ.* **2016**, *45*, 178–191. [CrossRef]
14. Piwowar, A.; Dzikuć, M. Poverty and Social Exclusion: Is this a Problem in Rural Areas in the Visegrad Group Countries? *Eur. Res. Stud. J.* **2020**, *23*, 45–54. [CrossRef]
15. Wang, X.; Klemeš, J.J.; Dong, X.; Fan, W.; Xu, Z.; Wang, Y.; Varbanov, P.S. Air pollution terrain nexus: A review considering energy generation and consumption. *Renew. Sustain. Energy Rev.* **2019**, *105*, 71–85. [CrossRef]
16. Bell, A.; Bunning, J.; Genxing, P.; Ishwaran, N.; Yi, Z. Low carbon land development: Is there a future for integration across sectors? *Environ. Dev.* **2019**, *11*, 175–189. [CrossRef]
17. Czyżewski, B.; Matuszczak, A.; Kryszak, Ł.; Czyżewski, A. Efficiency of the EU Environmental Policy in Struggling with Fine Particulate Matter (PM2.5): How Agriculture Makes a Difference? *Sustainability* **2019**, *11*, 4984. [CrossRef]
18. Dzikuć, M.; Dzikuć, M. Ekonomiczne determinanty ograniczenia emisji benzo[a]pirenu na obszarze Środkowego Nadodrza. *Przemysł Chem.* **2019**, *98*, 600–603. (In Polish) [CrossRef]
19. Balmes, J.R. Household air pollution from domestic combustion of solid fuels and health. *J. Allergy Clin. Immunol.* **2019**, *143*, 1979–1987. [CrossRef]
20. *Air Quality in Europe—2020 Report*; European Environment Agency, Publications Office of the European Union: Luxembourg, 2020; Available online: https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report (accessed on 10 May 2021).
21. Zhang, Y.; Zhang, J. Estimating the impacts of emissions trading scheme on low-carbon development. *J. Clean. Prod.* **2019**, *238*, 117913. [CrossRef]
22. Adamczyk, J.; Piwowar, A.; Dzikuć, M. Air protection programmes in Poland in the context of the low emission. *Environ. Sci. Pollut. Res.* **2017**, *24*, 16316–16327. [CrossRef] [PubMed]
23. Kopczyński, M.; Lasek, J.; Iluk, A.; Zuwała, J. The co-combustion of hard coal with raw and torrefied biomasses (willow (Salix viminalis), olive oil residue and waste wood from furniture manufacturing). *Energy* **2017**, *140*, 1316–1325. [CrossRef]
24. Du, H.; Chen, Z.; Mao, G.; Li, R.Y.M.; Chai, L. A spatio-temporal analysis of low carbon development in China's 30 provinces: A perspective on the maximum flux principle. *Ecol. Indic.* **2018**, *90*, 54–64. [CrossRef]
25. Frantál, B.; Nováková, E. A curse of coal? Exploring unintended regional consequences of coal energy in the Czechia. *Morav. Geogr. Rep.* **2014**, *22*, 55–65. [CrossRef]
26. Szatyłowicz, E.; Skoczko, I. Evaluation of the PAH Content in Soot from Solid Fuels Combustion in Low Power Boilers. *Energies* **2019**, *12*, 4254. [CrossRef]
27. Czekała, W.; Bartnikowska, S.; Dach, J.; Janczak, D.; Smurzyńska, A.; Kozłowski, K.; Bugała, A.; Lewicki, A.; Cieślik, M.; Typańska, D.; et al. The energy value and economic efficiency of solid biofuels produced from digestate and sawdust. *Energy* **2018**, *159*, 1118–1122. [CrossRef]
28. Tucki, K.; Mruk, R.; Orynycz, O.; Wasiak, A.; Botwińska, K.; Gola, A. Simulation of the Operation of a Spark Ignition Engine Fueled with Various Biofuels and Its Contribution to Technology Management. *Sustainability* **2019**, *11*, 2799. [CrossRef]
29. Deja, J.; Uliasz-Bochenczyk, A.; Mokrzycki, E. CO_2 emissions from Polish cement industry. *Int. J. Greenh. Gas Control* **2010**, *4*, 583–588. [CrossRef]

30. Zhang, S.; Li, H.; Zhang, Q.; Tian, X.; Shi, S. Uncovering the impacts of industrial transformation on low-carbon development in the Yangtze River Delta. *Resour. Conserv. Recycl.* **2019**, *150*, 104442. [CrossRef]
31. Kozłowski, K.; Dach, J.; Lewicki, A.; Malińska, K.; do Carmo, I.E.P.; Czekała, W. Potential of biogas production from animal manure in Poland. *Arch. Environ. Prot.* **2019**, *45*, 99–108. [CrossRef]
32. European Commission. Available online: https://ec.europa.eu/ (accessed on 4 May 2021).
33. Skjærseth, J.B. Implementing EU climate and energy policies in Poland: Policy feedback and reform. *Environ. Politics* **2019**, *27*, 498–518. [CrossRef]
34. Kruszelnicka, W. Study of Physical Properties of Rice and Corn Used for Energy Purposes. In *Renewable Energy Sources: Engineering, Technology, Innovation*; Springer: Cham, Switzerland, 2020; pp. 149–162.
35. Gavurova, B.; Perzelova, I.; Bencoova, B. Economic aspects of renewable energy use—Application of support schemes based on a particular biogas plant in Slovakia. *Acta Montan. Slovaca* **2016**, *21*, 217–228.
36. Kalinichenko, A.; Havrysh, V. Feasibility study of biogas project development: Technology maturity, feedstock, and utilization pathway. *Arch. Environ. Prot.* **2019**, *45*, 68–83. [CrossRef]
37. Eurostat. Available online: https://ec.europa.eu/eurostat (accessed on 10 May 2021).
38. Koryś, K.A.; Latawiec, A.E.; Grotkiewicz, K.; Kuboń, M. The Review of Biomass Potential for Agricultural Biogas Production in Poland. *Sustainability* **2019**, *11*, 6515. [CrossRef]
39. Krajowy Plan na Rzecz Energii i Klimatu na Lata 2021–2030—National Energy and Climate Plan for 2021–2030, Ministerstwo Aktywów Państwowych—Ministry of State Assets. 2019. Available online: https://www.gov.pl/ (accessed on 27 March 2021). (In Polish).
40. Supreme Audit Office of the Slovak Republic. Available online: https://www.nku.gov.sk/aktuality/-/asset_publisher/9A3u/content/hrozi-ze-slovensko-nesplni-europske-zavazky-v-oblasti-zmeny-klimy-a-energetiky/pop_up?_101_INSTANCE_9A3u_viewMode=print (accessed on 13 May 2021). (In Slovak)
41. Frankowski, J. Attention: Smog alert! Citizen engagement for clean air and its consequences for fuel poverty in Poland. *Energy Build.* **2020**, *207*, 109525. [CrossRef]
42. Lieskovský, M.; Trenčiansky, M.; Majlingová, S.; Jankovský, J. Energy Resources, Load Coverage of the Electricity System and Environmental Consequences of the Energy Sources Operation in the Slovak Republic-An Overview. *Energies* **2019**, *12*, 1701. [CrossRef]
43. Dzikuć, M.; Dzikuć, M.; Sinicakova, M. The social aspects of low emission management in the Nowa Sol district. *Manag. Pol.* **2017**, *21*, 237–249. [CrossRef]
44. Dzikuć, M.; Kułyk, P.; Dzikuć, M.; Urban, S.; Piwowar, A. Outline of Ecological and Economic Problems Associated with the Low Emission Reductions in the Lubuskie Voivodeship (Poland). *Pol. J. Environ. Stud.* **2019**, *28*, 65–72. [CrossRef]
45. Adamczyk, J.; Graczyk, M. Green certificates as an instrument to support renewable energy in Poland-strengths and weaknesses. *Environ. Sci. Pollut. Res.* **2019**, *27*, 6577–6588. [CrossRef]
46. Forbes. Available online: https://www.forbes.com/sites/davekeating/2019/12/13/eu-leaders-agree-2050-climate-targetwithout-poland/#219268fafa4e (accessed on 12 May 2021).
47. Rusin, M.; Dziubanek, G.; Marchwińska-Wyrwał, E.; Ćwieląg-Drabek, M.; Razzaghi, M.; Piekut, A. PCDDs, PCDFs and PCBs in locally produced foods as health risk factors in Silesia Province, Poland. *Ecotoxicol. Environ. Saf.* **2019**, *172*, 128–135. [CrossRef] [PubMed]
48. Yan, J.; Feng, J.C. Visual special issue: Low carbon development and transformation of cities. *Appl. Energy* **2018**, *231*, a1–a3. [CrossRef]
49. Uribe-Toril, J.; Ruiz-Real, J.L.; Milán-García, J.; de Pablo Valenciano, J. Energy. Economy, and Environment: A Worldwide Research Update. *Energies* **2019**, *12*, 1120. [CrossRef]
50. Fitch-Roy, O.; Benson, D.; Monciardini, D. Going around in circles? Conceptual recycling, patching and policy layering in the EU circular economy package. *Environ. Politics* **2019**, *29*, 983–1003. [CrossRef]
51. Romanowska-Duda, Z.; Piotrowski, K.; Wolska, B.; Dębowski, M.; Zieliński, M.; Dziugan, P.; Szufa, S. Stimulating effect of ash from Sorghum on the growth of Lemnaceae A New Source of Energy Biomass. In *Renewable Energy Sources: Engineering, Technology, Innovation*; Wróbel, M., Jewiarz, M., Szlęk, A., Eds.; Springer Proceedings in Energy: Cham, Switzerland, 2020; pp. 341–349.
52. Vershinina, K.Y.; Kuznetsov, G.V.; Strizhak, P.A. Ignition Characteristics of Coal-Water Slurry Containing Petrochemicals Based on Coal of Varying Degrees of Metamorphism. *Energy Fuels* **2016**, *30*, 6808–6816. [CrossRef]
53. Löschel, A.; Lutz, B.J.; Managi, S. The impacts of the EU ETS on efficiency and economic performance—An empirical analyses for German manufacturing firms. *Resour. Energy Econ.* **2019**, *56*, 71–95. [CrossRef]
54. Cutz, L.; Berndes, G.; Johnsson, F. A techno-economic assessment of biomass co-firing in Czechia, France, Germany and Poland. *Biofuels Bioprod. Biorefining* **2019**, *13*, 1289–1305. [CrossRef]
55. Dzikuć, M.; Kuryło, P.; Dudziak, R.; Szufa, S.; Dzikuć, M.; Godzisz, K. Selected Aspects of Combustion Optimization of Coal in Power Plants. *Energies* **2020**, *13*, 2208. [CrossRef]
56. Adamczyk, J.; Dylewski, R. Analysis of the sensitivity of the ecological effects for the investment based on the thermal insulation of the building: A Polish case study. *J. Clean. Prod.* **2017**, *162*, 856–864. [CrossRef]
57. Jiang, P.; Chen, Y.; Dong, W.; Huang, B. Promoting low carbon sustainability through benchmarking the energy performance in public buildings in China. *Urban Clim.* **2014**, *10*, 92–104. [CrossRef]

58. Yu, T.; Wang, K.; Li, Y.; Zhao, Z.; Wang, X.; Yang, N.; Yu, S.; Wang, Y.; Huang, Z. Full Life Cycle Management of Power System Integrated with Renewable Energy: Concepts, Developments and Perspectives. *Front. Energy Res.* **2021**, *9*, 680355. [CrossRef]
59. deLlano-Paz, F.; Calvo-Silvosa, A.; Iglesias Antelo, S.; Soares, I. Power generation and pollutant emissions in the European Union: A mean-variance model. *J. Clean. Prod.* **2018**, *181*, 123–135. [CrossRef]
60. Burchart-Korol, D.; Korol, J.; Czaplicka-Kolarz, K. Life cycle assessment of heat production from underground coal gasification. *Int. J. Life Cycle Assess.* **2016**, *21*, 1391–1403. [CrossRef]
61. Woźniak, J.; Pactwa, K. Possibilities for using mine waters in the context of the construction of heat energy clusters in Poland. *Energy Sustain. Soc.* **2019**, *9*, 13. [CrossRef]
62. Ingaro, C.; Bacenetti, J.; Adamczyk, J.; Ferrante, V.; Messineo, A.; Huisingh, D. Investigating energy and environmental issues of agro-biogas derived energy systems: A comprehensive review of Life Cycle Assessments. *Renew. Energy* **2019**, *136*, 296–307. [CrossRef]
63. Bogacki, M.; Bździuch, P. Predicting the spatial distribution of emissions from urban buses based on previously measured data and scenarios for their modernization in the future. Case study: Krakow, Poland. *Atmos. Environ.* **2019**, *199*, 1–14. [CrossRef]
64. Burchart-Korol, D.; Pustejovska, P.; Blaut, A.; Jursova, S.; Korol, J. Comparative life cycle assessment of current and future electricity generation systems in the Czechia and Poland. *Int. J. Life Cycle Assess.* **2018**, *21*, 1391–1403. [CrossRef]
65. ISO 14040:2006. *Environmental Management. Life Cycle Assessment-Principles and Framework*; International Organization for Standardization: Geneva, Switzerland, 2006.
66. ISO 14044:2006+A1:2018. *Environmental Management. Life Cycle Assessment-Requirements and Guidelines*; International Organization for Standardization: Geneva, Switzerland, 2006.
67. Weldu, Y.W.; Assefa, G.; Jolliet, O. Life cycle human health and ecotoxicological impacts assessment of electricity production from wood biomass compared to coal fuel. *Appl. Energy* **2017**, *187*, 564–574. [CrossRef]
68. Zarębska, J.; Dzikuć, M. Determining the environmental benefits of life cycle assessment (LCA) on example of the power industry. *Sci. J. Marit. Univ. Szczec.* **2013**, *34*, 97–102.
69. Olszowski, T. Influence of Individual Household Heating on PM2.5 Concentration in a Rural Settlement. *Atmosphere* **2019**, *10*, 782. [CrossRef]
70. Bienias, K.; Kowalska-Pyzalska, A.; Ramsey, D. What do people think about electric vehicles? An initial study of the opinions of car purchasers in Poland. *Energy Rep.* **2020**, *6*, 267–273. [CrossRef]
71. Tucki, K.; Orynycz, O.; Wasiak, A.; Świć, A.; Dybaś, W. Capacity Market Implementation in Poland: Analysis of a Survey on Consequences for the Electricity Market and for Energy Management. *Energies* **2019**, *12*, 839. [CrossRef]
72. Adamiec, E.; Dajda, J.; Gruszecka-Kosowska, A.; Helios-Rybicka, E.; Kisiel-Dorohinicki, M.; Klimek, R.; Pałka, D.; Wąs, J. Using Medium-Cost Sensors to Estimate Air Quality in Remote Locations. Case Study of Niedzica, Southern Poland. *Atmosphere* **2019**, *10*, 393. [CrossRef]
73. Centrum Informacji o Rynku Energii. Available online: https://www.cire.pl/ (accessed on 16 June 2021). (In Polish).