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POLAND'S ENERGY DEPENDENCE AT THE TURN OF THE 21ST CENTURY

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ABSTRACT: The following article is an attempt to assess Poland's energy independence in the years 1993-2020. The main aim of the paper is to present Poland's dependence on raw materials from foreign partners - in the field of imports of electricity, natural gas, crude oil, non-renewable energy resources, i.e., hard coal and lignite, and the country's dynamics in the amount of imports. In addition, the aim of the work is to answer research questions pertaining to the level of Poland's energy dependence on foreign sources, countries from which Poland imported energy or energy resources, the structure of imports, as well as the country's energy balance in the period under study. The research methods used in the paper include a descriptive research method, an analysis of Eurostat data as well as the literature review in the field of the subject study. The main results posit that, in the analyzed period, Poland was highly dependent on foreign energy sources, especially in the field of gas and crude oil. What is more, between 1993-2020, a growing diversification of energy resources sources was noted.

KEYWORDS: energy, energy policy, energy security, Poland, energy prices

Introduction

Presentation of the general research framework

Poland does not have vast resources of non-renewable energy and no nuclear power plants, therefore the issue of the energy dependence of the state (which affects the level of energy security of the country) is an extremely important factor. It depends on both the volume of imports of energy raw materials and the policy of diversification in the sources of supply regarding this type of raw materials. Energy infrastructure, which allows for the transmission, distribution and storage of raw materials and energy, is of great importance in terms of security.

Recent political situation has had a significant impact on the prices of energy resources in Central and Eastern Europe; they were primarily shaped by politics, and not economics. On the other hand, Poland's energy dependence on imported raw materials was influenced by the policy of the European Union, which aimed to limit the use of certain energy resources for climate reasons.

The research questions

The aim of the work is to present Poland's dependence on raw materials from foreign partners – in the field of imports of electricity, natural gas, crude oil, non-renewable energy resources, i.e., hard coal and lignite, and the country's dynamics in the amount of imports. The second part of the work shows the dynamics of exports of energy resources in Poland. A novel aspect of the work is the presentation of the dynamics of changes in Poland's dependence on imports of crude oil, gas, electricity and coal in the analyzed period. Additionally, the authors took into account the re-export of energy resources by Poland.

Therefore, the research questions include:

1. What was the level of Poland's dependence on external sources of energy between 1993-2020?
2. What were the countries Poland imported energy sources between 1993-2020?
3. How did the structure of import change during the analyzed period?
4. What was the energy balance, measured in PJ, in the analyzed period for the examined raw materials and electricity?

The main contributions

The research period covers the years from 1993 to 2020. The study uses Eurostat statistical data on imports and exports, as well as literature on the

possession of energy resources by Poland, scenarios of providing raw materials with substitute solutions, and energy security. The literature still lacks studies that would comprehensively analyze the Polish energy market and present the sources of energy acquisition after the fall of communism era in Poland, just after the financial crisis and before the outbreak of the COVID-19 pandemic. The period of research was chosen on purpose, as the full data availability falls between 1993 and 2020. Due to the purpose of the work and the limitation of the research period, the authors did not attempt to assess the energy market in 2021-2023, e.g. due to the complex and extensive nature of this phenomenon.

The state of research

In Polish and foreign literature, the problem of energy dependence is perceived in two ways. In the first, the researchers put emphasis on determining the amount of energy resources in Poland and on replacing them with other sources (e.g. with renewable sources and nuclear power plants). In the second trend, the researchers show the impact of the raw materials possessed – mainly non-renewable ones – on energy security, taking into account international relations, contacts with countries importing raw materials, and the guidelines of the European Union. The latter is especially pertinent, since the EU climate and energy policy is contrary to the possibilities of the Polish economy and is perceived by some Polish authors as unfair (Jeżewski, 2011; Szczerbowski, 2015; Motowidlak, 2018; Stavytsky et al., 2018).

In Poland, the demand for primary energy was and is covered, to a large extent, by fossil fuel resources, mainly hard coal. This is supplemented by crude oil and natural gas. In the European Union, the main raw materials to meet the demand for electricity are crude oil and natural gas, followed by coal and nuclear power. Individual EU countries depend, to varying degrees, on external supplies. Moreover, the degree of diversification of energy sources is uneven within the EU member states (Kiedrowska-Pryka, 2014). Poland's energy dependence on imported raw materials is lower than that of other European Union countries (Gawlik & Mokrzycki, 2017; Ministerstwo Gospodarki, 2009).

The most difficult situation occurs on the Polish crude oil market, as domestic sources of this raw material account for only 3% of the demand (Kamyk & Kot-Niewiadomska, 2019). It is possible to replace crude oil with gas, electricity and hydrogen, but this largely depends on the economic possibilities of a given country. What is important however, is the fact that Poland is part of the EU, therefore, all the solutions of the energy market should be resolved on the EU level (Misiągiewicz, 2019).

The gas market in Poland is characterized by the increased consumption of this raw material in the period under review, therefore it is necessary to work on the exploration of deposits. Further successful exploration of natural gas in Poland could increase the use of domestic resources and reduce the energy dependence of the country from external suppliers. However, the implementation of such a scenario may be determined by economic considerations, as the technology of obtaining gas from shale is expensive and requires the appropriate infrastructure, which Poland does not currently have and is unable to create in a short period of time (Kryzia & Gawlik, 2012; Szurlej, 2008; Albrycht et al., 2014). Therefore, within the next two or three decades, hard coal and lignite will serve as the basic source of energy carriers (Kielierz et al., 2018; Siemek et al., 2008; Olkulski et al., 2017). The problem for Poland is the implementation of sustainable development postulates, which is related, among other things, to the reduction of greenhouse gas emissions and the gradual resignation from the use of solid fuels. Poland's accession to the European Union was also of great importance for this process, associated with the adoption of EU environmental standards, including the reduction of emissions of harmful compounds into the atmosphere (Czech, 2018). The emission of pollutants as a result of hard coal combustion in the years 1990-2011 was significantly reduced thanks to the modernization of power plants. The reduction of particulate matter emissions in the years 1990-2011 amounted to 97%, and the reduction of SO₂ emissions – 76%. During this time, the ash content of coal burned in power plants decreased by 19%, and the sulfur content decreased by 17% (Grudziński, 2013; Jędrak, 2022). Whether hard coal will still be used to a large extent for the production of electricity depends on the level of emissions into the atmosphere of harmful substances generated in the combustion process. Attempts by the Polish government to define a new energy strategy model were based on the assumptions of using its own resources of raw materials, securing the needs of recipients (cheap energy and raw materials) and, on the other hand, meeting the requirements set by the EU.

The strategic document titled “Energy Policy of Poland until 2040” adopted in February 2021 assumes that the national policy will be correlated with the EU climate and energy policy (Portal Interoperacyjności i Architektury, 2021). The goal is attaining energy security, while ensuring the competitiveness of the economy, energy efficiency and reducing the impact of the energy sector on the environment; all taking into account the optimal use of own energy resources.

The document distinguishes 8 specific objectives. The first objective posits covering the demand for hard coal and lignite from domestic resources and, by 2030, a maximum of 56% of coal may be used in electricity generation. Natural gas and oil will continue to be imported from third countries.



One of the objectives emphasized the need to diversify supplies, and to expand the network structure of natural gas, crude oil and liquid fuels. The fourth specific objective defines the creation of the EU's internal energy market, with the simultaneous expansion of the gas transmission and trading centers. The fifth objective is the construction of a nuclear power plant, which would contribute to a significant increase in the level of Poland's independence from foreign sources. The following goals emphasize the development of renewable energy sources (Portal Interoperacyjności i Architektury, 2021). The second trend of the undertaken research is to link Poland's energy dependence with security (Stańczyk, 2019). Tylec (2013) considers both global and regional determinants of energy security. The author emphasizes that interstate alliances, such as Germany-Russia, the objectives of the European Union's energy policy, and the adoption of innovative solutions in the energy sector by Poland all have an impact on energy security (Koryl, 2019; Ogarek, 2019). One of the main problems, in terms of access to crude oil and natural gas, was that Poland mainly depended on one supplier (Ostrowski, 2021). It is not only an economic problem, as the monopolist can impose a higher price, but also one that is incorrect from a political point of view. This aspect has been discussed by several scientists and is not a new problem on the European energy market (Zhou et al., 2023).

Braun (2018) points out that the level of energy security in a country can be measured, among other ways, by using the World Bank's net import model, which presents the percentage change in GDP in the conditions of a sharp increase in the price of energy, depending on the volume of net energy imports in relation to GDP and the price elasticity of energy demand. The energy dependency ratio is also often used, showing the share of net energy imports in relation to gross domestic energy consumption plus stored energy. Factors that also have a significant impact on energy security include: the size and diversity of the domestic fuel base, the degree of diversification of sources of supply (domestic and foreign) of energy resources, the technical condition and forms of ownership of infrastructure, and the possibility of storing fuels. Poland lacks an adequate number of natural gas storage facilities that could ensure its security in the event of a longer-term demand for this raw material (Matkowski & Musiał, 2012; Paliński, 2018; Steinhoff, 2022).

At the same time, there is a need to develop new sources of non-emission energy, green industry and distributed energy. However, due to Poland's resources and geopolitical conditions, energy security, including the security of supply and concern for low prices of raw materials and electricity, have become national priorities (Brauers & Oei, 2020). The volume of emissions in energy generation is an important problem, but Poland simply cannot afford to give up cheap fossil resources (Gawlik & Mokrzycki, 2017). In addition, the

Polish energy sector is technologically backward which, when confronted with EU demands to meet, means large necessary investment outlays in the energy sector (PLN 450-500 billion) and an increase in energy prices, which is difficult for a large proportion of household budgets to accept (Jeżewski, 2011). The purchase prices of fuels and energy are also a very important element of energy security (Rybak & Manowska, 2018). The closer the countries that are exporters of raw materials are to the recipient, the lower the price of such resources should be (Kruyt et al., 2009). Energy security also means efficient supply chains. Dependence on imported raw materials and energy means that a country cannot meet its energy needs from its own resources alone. Dependence on external supplies most often applies to crude oil, natural gas and solid fuels (Sokołowski & Zięcina, 2013; Soroka, 2015; Minister Klimatu i Środowiska, 2021; Lorek, 2017). For many years, Poland purchased gas and crude oil mainly from Russia – due to the lower price of this raw material than from other suppliers (Morozowska et al., 2021). The move away from the Russian market and the diversification of supplies mean higher raw material prices, e.g., purchases of liquefied gas from the USA and Qatar are at a higher price, but importers guarantee certain long-term supplies (Braun, 2018; Misiągiewicz, 2019). External threats, causing the possibility of interruptions in the supply of raw materials or energy, derives from the relationship between the supplier and recipient countries. Too strong dependence on supplies from politically unstable countries may pose a threat to the importer's energy security (Pangsy-Kania & Wierzbicka, 2022).

Research

The presented data do not differentiate between primary and secondary energy sources. However, in order to present the energy balance, the data was divided into imports and exports of individual energy carriers and electricity. Such action allows one to assess the level of energy dependence, as well as to show the degree to which Poland is the so-called re-exporter, i.e. exports previously imported goods abroad.

As part of the work, an easy-to-compare scale was used to assess energy independence (dependence), understood as a deficit of own sources of energy carriers or electricity to the total demand. In this way, the degree of Poland's dependence on foreign suppliers was assessed. The analysis was supplemented by the presentation of data on exports which in most cases, apart from hard coal, should be understood as re-exports of energy carriers or electricity. A comparison of the percentage deficit together with the presentation of the overall consumption of the analyzed carriers allows for draw-

ing conclusions and assessing the extent to which Poland was dependent on foreign supplies in the analyzed period.

Although the subject of the analysis is not the assessment of reasons why Poland imports electricity from specific parts of the world, it is worth noting that, despite possessing large hard coal resources, Poland imported significant amounts of it from Russia in the analyzed period. This state of affairs was caused primarily by the phasing out (closing) of unprofitable mines, often for political reasons, including in connection with the EU's climate and energy policy, and the much lower cost of Russian raw material (Stala-Szlugaj & Grudziński, 2019). In addition, Polish coal is characterized by a high content of ashes and heavy metals, as well as low calorific value and thus higher emissions. High coal prices are generated by the geological conditions of Polish mines, which are deep, methane-covered and located in urbanized areas. Raw material prices are increased by high labor costs in mining and its low efficiency. These factors caused an increase in coal imports and a decrease in coal exports in the analyzed years. A partial solution to the above problems could be to increase efficiency and reduce costs in the mining industry (Lorenz, 2016).

Dynamics of electricity, crude oil, gas and coal imports

In the European Union, renewable energy sources supported by climate policy, play an increasingly important role, but conventional sources are still significant for the energy security of countries (Schreurs, 2018; Directive, 2018). Poland, despite global trends and the energy crisis, emphasizes the key role of those types of fuels (Czech, 2018). The significance of natural gas and crude oil have been defined by the Polish government in the "Poland's energy policy until 2040" document.

Before the onset of the COVID-19 pandemic, the Polish economy was characterized by a decade of strong economic growth. In the years 2010-2019, GDP in Poland increased by 38%, and the average annual rate of economic growth was much higher than the European Union average. It should be noted that economic growth in Poland has also resulted in an increase in demand for energy. Between 2010 and 2019, total final consumption (TFC) increased from 70 million tonnes of oil equivalent (Mtoe) to 75 Mtoe (International Energy Agency, 2022; Wojtkowska-Łodej, 2020), which was caused mainly by the demand for energy in industry and transport. Poland could have experienced an even greater increase in demand for energy, if it had not been for the measures implemented to reduce the energy intensity of the entire economy. The improvement of energy efficiency contributed to the fact that the energy intensity of the Polish economy (TFC per GDP) decreased from 79 tonnes of oil equivalent (toe) to 61 toe per million USD.



According to 2022 data, the energy supply in Poland is still dominated by fossil fuels, with coal (40%) having the largest share, followed by crude oil (28%) and natural gas (17%) (International Energy Agency, 2022). Coal plays a key role in Poland's energy system and economy. Among the member countries of the International Energy Agency (IEA), in 2020 Poland had the highest share of coal in energy production and electricity production, as well as the second largest share in heat production.

Table 1. Poland's energy dependence in 2011-2020 [in %]

Energy dependence	Area	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	European Union	56.4	54.9	53.9	54.4	56.1	56.2	57.6	58.1	60.5	57.5
	Poland	34.0	31.6	26.3	29.4	29.8	30.8	38.3	43.5	45.2	42.8
Solid fossil fuels	European Union	57.4	50.6	56.5	54.9	59.2	58.9	68.2	76.8	102.0	104.3
	Poland	0.0	0.0	0.0	0.0	0.0	106.4	144.8	100.0	95.9	105.4
Natural gas	European Union	71.6	69.2	68.3	71.9	74.5	75.7	80.2	83.3	89.6	83.6
	Poland	75.1	73.4	74.2	72.0	72.2	78.4	77.8	77.6	82.4	78.3
Crude oil	European Union	94.1	95.1	95.0	94.6	96.0	95.2	95.7	95.8	96.8	96.2
	Poland	97.2	97.4	94.8	96.5	100.5	94.5	97.2	98.3	96.7	96.6
Electricity	European Union	0.03	0.23	-0.06	-0.18	-0.23	0.02	-0.16	0.30	0.10	0.49
	Poland	-3.31	-1.78	-2.83	1.34	-0.20	1.19	1.32	3.24	6.09	7.75

Source: authors' work based on Eurostat (2023c).

When analyzing the data contained in Table 1 regarding the energy dependence of Poland and the European Union on external sources of electricity and selected raw materials, it should be emphasized that the energy dependence on average level of EU countries is stable in the 2011-2020 years (approx. 55%). However, Poland is increasingly dependent on external energy sources and energy resources.

Analyzing the situation of Poland, one can come to the conclusion that energy dependence is high (especially when it comes to crude oil and natural gas) (Minister Klimatu i Środowiska, 2021). In addition, the dependency ratio is growing every year – in 2011 it was 34%, while in 2020 it was 42.8%. Although this result is lower than the average of all European Union countries, it should be emphasized that this ratio for all EU countries was relatively constant (in 2011-2020 it ranged between 53.9% and 60.5% dependence on foreign sources). Moreover, the growing dependence of Poland on the supply of electricity sources is worrying. While in 2011 Poland belonged to the group of countries that exported electricity (about 3.3% of own demand), since 2016 Poland has in fact become a country that is not fully

self-sufficient. The shortage of electricity is constantly growing and in 2020 was 7.75%.

Table 2. Electricity imports to Poland in 1993-2020 [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Germany	15.93	15.88	14.04	14.53	14.91	10.86	7.03	7.22	4.74	6.74	9.94	11.36	8.15	9.17
Sweden	0	0	0	0	0	0	0	1.53	6.12	4.04	0.04	0.77	2.94	0.95
Ukraine	3.79	0	1.21	2.45	2.3	2.89	2.62	2.26	2.12	2.12	3.35	3.07	3.54	3.18
Czech Republic	0.44	0.54	0.43	0.3	0.23	0.38	0.28	0.23	0.22	0.31	0.21	0.29	0.23	0.16
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	17.6	20.07	20.22	19.19	18.49	21.77	19.63	33.13	38.37	31.51	26.43	25.4	36.31	40.45
Sweden	7.96	7.43	5.02	2.74	5.45	9.62	3.66	11.13	12.64	9.95	11.25	11.15	11.08	13.64
Ukraine	2.31	2.8	0.73	0	0.22	3.62	3.7	2.47	0.24	3.45	3.22	5.08	4.96	5.34
Czech Republic	0.07	0.1	0.46	0.49	0.16	0.27	0.66	1.87	0.75	1.82	1.35	2.19	3.68	6.71

Source: authors' work based on Eurostat (2023b).

Table 3. Dynamics of electricity imports [in %]

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Germany	0	-12	3	3	-27	-35	3	-34	42	48	14	-28	12	92
Sweden	-	-	-	-	-	-	-	300	-34	-99	2040	282	-68	738
Ukraine	-100	-	103	-6	25	-9	-13	-6	0	58	-8	15	-10	-27
Czech Republic	23	-21	-29	-23	63	-26	-18	-5	41	-34	40	-21	-29	-56
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Germany	14	1	-5	-4	18	-10	69	16	-18	-16	-4	43	11	
Sweden	-7	-32	-45	99	77	-62	204	14	-21	13	-1	-1	23	
Ukraine	22	-74	-100	-	1575	2	-33	-90	1350	-6	58	-2	8	
Czech Republic	45	345	6	-68	70	143	186	-60	143	-26	63	68	83	

Source: authors' work based on Eurostat (2023b).

Poland imports electricity from its closest neighbors. This is mainly due to the technological possibilities of transmission. The amount of energy purchased is constantly growing. As presented in Table 2, Poland buys the largest amount of electricity from Germany. In 2020, the second largest seller of electricity to Poland is Sweden, although this country began to export elec-

tricity to Poland only in 2000. The third largest supplier is the Czech Republic, followed by Ukraine in the fourth place.

Analyzing the data contained in Table 3 and Figure 1, which present the dynamics of electricity imports measured year-on-year, we note that it is extremely variable. Although the share of individual countries in imports is growing, only Germany is relatively stable. In the case of other suppliers, a significant change should be noted (positive and negative). This may mean that Poland buys electricity ad hoc – depending on its current price and availability on the market. In the case of electricity, due to the ease and speed of its contracting and transmission, such a state of affairs should not cause concern.

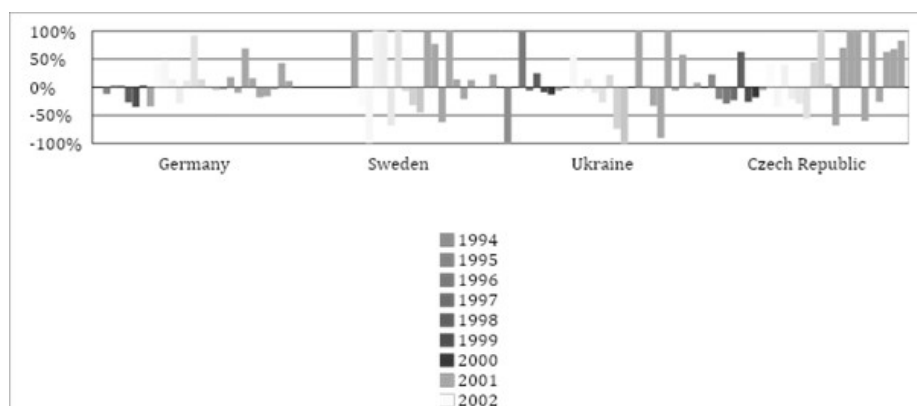


Figure 1. Dynamics of electricity imports [in %]

Source: authors' work based on Eurostat (2023b).

When analyzing the above data, it should be noted that Poland lacks stable electricity suppliers. Only in the case of Germany, an increase in electricity supplies to Poland can be noted. In the remaining cases, imports are unstable, and significant fluctuations in dynamics were recorded in the analyzed period.

In the case of natural gas, the important role of Russia as a supplier of natural gas to Poland should be noted. The amount of imported raw material was constantly growing, and the dynamics of change, especially in 2008-2019 years, was high (Weiner, 2019; Antosiewicz et al., 2022). Russia has been a strategic source of this raw material for years. Imports from other countries grew every year (in the case of Germany, however, one cannot speak of a classic import of gas, because Germany is a re-exporter of gas purchased in the Russian Federation). Other destinations gained importance, such as Qatar and Norway, countries from which Poland started to buy gas in 2014-2015.

Table 4. Natural gas imports to Poland in 1993-2020 [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Russia	216.9	231.2	268.9	266.2	252	289	227.7	250.4	279.6	268.9	275.6	236.4	262.6	286.2
Germany	0.8	1.3	1.4	3.9	7.4	12.8	17.9	17.8	16.3	16.1	16.8	15.6	14.1	20.4
Qatar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Norway	0	0	0	0	0	0	0	0.7	11	19.8	19.6	19.4	19.4	14.5
Czech Republic	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Russia	260.5	295.7	311.2	371.3	384.3	372.9	368.4	342.1	337.4	421	397.3	373.6	369	369
Germany	32.7	34.4	41.3	43.1	65.2	71.9	86.9	90	121.7	101.9	136.3	113.3	150.8	138.8
Qatar	0	0	0	0	0	0	0	0	5	40.1	60.7	90.4	90.3	90
Norway	0	0	0	0	0	0	0	3.3	0	3.3	3.4	13.5	8.1	13.4
Czech Republic	0	0	0	0	0	22.5	22.4	15.9	0.6	0.2	4.5	14.1	17.7	13

Source: authors' work based on Eurostat (2023b).

Table 5. Dynamics of natural gas imports [in %]

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Russia	7	16	-1	-5	15	-21	10	12	-4	2	-14	11	9	-9
Germany	63	8	179	90	73	40	-1	-8	-1	4	-7	-10	45	60
Qatar	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Norway	-	-	-	-	-	-	-	1471	80	-1	-1	0	-25	-100
Czech Republic	-50	-100	-	-	-	-	-	-	-	-	-	-	-	-
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Russia	14	5	19	4	-3	-1	-7	-1	25	-6	-6	-1	0	
Germany	5	20	4	51	10	21	4	35	-16	34	-17	33	-8	
Qatar	-	-	-	-	-	-	-	-	702	51	49	0	0	
Norway	-	-	-	-	-	-	-	-100	-	3	297	-40	65	
Czech Republic	-	-	-	-	-	0	-29	-96	-67	2150	213	26	-27	

Source: authors' work based on Eurostat (2023b).

When analyzing the dynamics of changes in natural gas imports, one should note the high annual growth of Germany's share in imports of this raw material. Imports from Russia are characterized by stable dynamics.

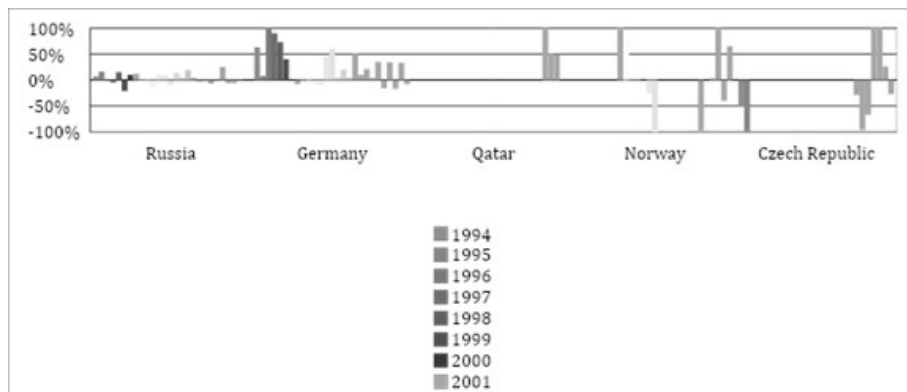


Figure 2. Dynamics of natural gas imports [in %]

Source: authors' work based on Eurostat (2023b).

In terms of supplies, the importance of countries such as Norway and Qatar is increasing, although in this case it is still difficult to establish a trend line regarding the dynamics of year-to-year changes because of short term of transactions.

Table 6. Crude oil imports to Poland in 1993-2020 [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Russia	572.5	532.6	542.5	587.2	485.6	520.8	567.5	703.4	696	724.7	696.7	697.9	731.3	802
Norway	0	0	0	0	19.2	24.5	29.6	4.4	0	2.2	0	5.5	5.4	5.7
Great Britain	0	0	0	0	75.4	61.7	16.9	15.4	0	3.3	0	0	3.6	6.7
Kazakhstan	0	0	0	0	2.6	2.9	9.8	12.3	11.4	6.2	7.2	7.7	6.2	2.1
Lithuania	0	0	0	0	0	10.3	9.6	12.8	14.4	1.3	0	0	0	0
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Russia	835.9	805.6	792.6	884	914.9	984.7	932.4	927	979.2	867	824	868.4	762	751.1
Norway	21	47.6	11.6	51.3	56	34.7	31.7	21.7	14.2	7.4	16.2	34.6	22.5	22.3
Great Britain	14.2	6.8	13.5	7	20	0	10.3	6.6	0	0	3.3	27.7	27.7	5.1
Kazakhstan	3.1	1	0.3	0	0	0	0.2	23.7	20.9	7.7	36.9	29.1	29.9	28.6
Lithuania	0	0	0	0	0	0	2.6	2.6	2.1	2	1.3	1.9	1.8	1.8

Source: authors' work based on Eurostat (2023b).

Poland is practically fully dependent on foreign crude oil supplies (Kamyk et al., 2021; Olkulski et al., 2018; Antosiewicz et al., 2022). The main source

of imports of this raw material is the Russian Federation, from which most of the crude oil has been imported for years. However, Poland tries to diversify its sources of supplies, including importing from countries such as Norway, Kazakhstan and Great Britain. Nevertheless, these sources of supplies, as alternatives to Russia, did not exceed 10-15% of the level of supplies from the main source (Paszkowski, 2023).

Table 7. Dynamics of crude oil imports [%]

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Russia	-7	2	8	-17	7	9	24	-1	4	-4	0	5	10	4
Norway	-	-	-	-	28	21	-85	-100	-	-100	-	-2	5	266
Great Britain	-	-	-	-	-18	-73	-9	-100	-	-100	-	-	83	114
Kazakhstan	-	-	-	-	11	233	26	-7	-46	18	7	-20	-67	49
Lithuania	-	-	-	-	-	-7	34	12	-91	-97	-100	-	-	-
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Russia	-4	-2	12	4	8	-5	-1	6	-11	-5	5	-12	-1	
Norway	127	-76	344	9	-38	-9	-32	-34	-48	118	114	-35	-1	
Great Britain	-52	98	-49	187	-100	-	-36	-100	-	-	726	0	-82	
Kazakhstan	-66	-72	-100	-	-	-	11240	-12	-63	379	-21	3	-5	
Lithuania	-	-	-	-	-100	-	0	-22	-2	-33	44	-4	-2	

Source: authors' work based on Eurostat (2023b).

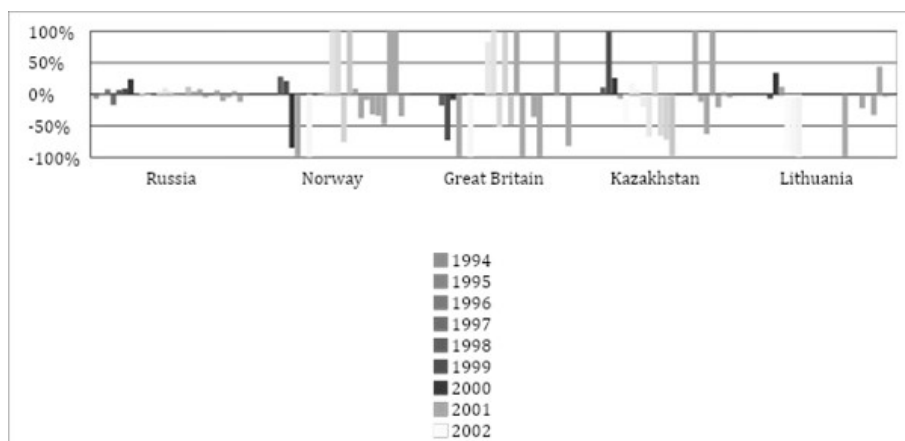


Figure 3. Dynamics of crude oil imports [%]

Source: authors' work based on Eurostat (2023b).

Analyzing the dynamics of crude oil imports in the years 1994-2020 (lack of 1993 data), it can be noted that only supplies from Russia were characterized by relative stability and low fluctuations. Other suppliers, i.e., Norway, Great Britain, Kazakhstan and Lithuania, cannot be regarded as suppliers offering a stable source of supply, because the dynamics of changes in the analyzed period were extremely positive or negative, as presented in Table 7 and Figure 3.

Table 8. Imports of solid fossil fuels to Poland in 1993-2020 [in thousands of tonnes]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Russia	0	70	135	691	2039	2445	1089	749	913	1466	1730	1459	2390	3330
Czech Republic	0	658	1327	1194	1163	1599	952	594	348	379	499	620	587	1570
Columbia	0	0	0	0	0	0	25	4	8	32	0	30	56	80
Kazakhstan	0	0	0	0	0	0	0	0	395	500	103	13	87	160
Ukraine	0	25	27	22	0	27	24	77	193	168	125	181	187	118
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Russia	3046	5039	7075	8155	9310	6568	6541	6506	4938	5180	8563	13006	10734	9396
Czech Republic	2061	1804	1749	2189	2928	1572	1648	1480	809	471	382	359	177	78
Columbia	175	505	255	344	323	87	60	107	313	646	702	1460	1192	902
Kazakhstan	140	387	298	267	340	283	182	65	36	6	94	504	867	843
Ukraine	176	329	352	402	568	394	377	248	24	41	19	1	0	0

Source: authors' work based on Eurostat (2023b).

Although Poland belongs to the group of countries that have large resources of hard coal and lignite, the import of these raw materials is growing every year (Fuksa, 2021). It should be noted that in the 1990s, the amount of imports was only about 10-15% of the 2020 value. Such dynamic growth means a growing role of foreign sources. In 2020, the largest supplier of fossil fuels to Poland was the Russian Federation. The amount of imports from the other countries did not exceed 10% of the amount supplied to Poland from the Russian direction (Nyga-Łukaszewska et al., 2020).

Analyzing the dynamics of the changes presented in Table 9 and Figure 4, a growing, constant level of imports from Russia can be noted. In the case of Colombia, Kazakhstan and Ukraine, the dynamics of changes in the purchase volume varied and fluctuated. Analyzing the situation regarding the Czech Republic, one can note the decreasing importance of import of this country

year-on-year. Since 2014, Poland has been buying less and less coal from this country every year (constant negative dynamics).

Table 9. Dynamics of imports of solid fossil fuels [in %]

Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Russia	-	93	412	195	20	-55	-31	22	61	18	-16	64	39	-9
Czech Republic	-	102	-10	-3	37	-40	-38	-41	9	32	24	-5	167	31
Columbia	-	-	-	-	-	-	-84	100	300	-100	-	87	43	119
Kazakhstan	-	-	-	-	-	-	-	-	27	-79	-87	569	84	-13
Ukraine	-	8	-19	-100	-	-11	221	151	-13	-26	45	3	-37	49
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Russia	65	40	15	14	-29	0	-1	-24	5	65	52	-17	-12	
Czech Republic	-12	-3	25	34	-46	5	-10	-45	-42	-19	-6	-51	-56	
Columbia	189	-50	35	-6	-73	-31	78	193	106	9	108	-18	-24	
Kazakhstan	176	-23	-10	27	-17	-36	-64	-45	-83	1467	436	72	-3	
Ukraine	87	7	14	41	-31	-4	-34	-90	71	-54	-95	-100	-	

Source: authors' work based on Eurostat (2023b).

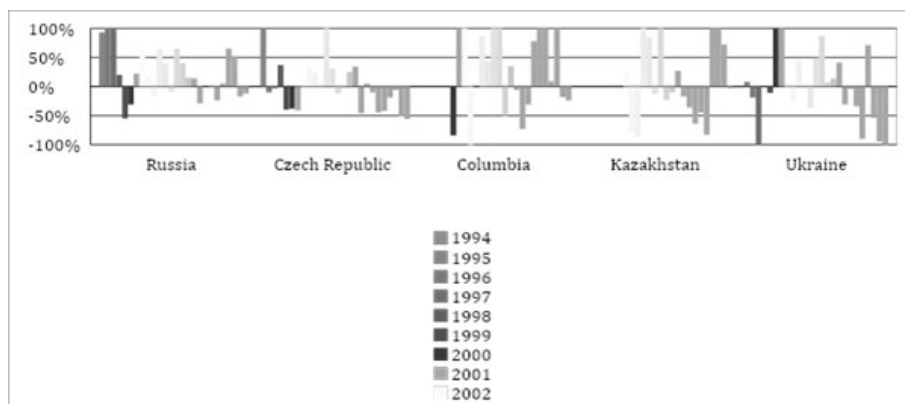


Figure 4. Dynamics of imports of solid fossil fuels [in %]

Source: authors' work based on Eurostat (2023b).

The high instability of individual sources of delivery of solid fossil fuels for Poland should therefore be noted, except for Russia, whose share has been constantly growing over the years. This is a dangerous situation, as it makes the country largely dependent on a single source of supply. In addi-

tion, the number of suppliers is also worrying. In the analyzed period, the five largest suppliers (countries) were identified, which means a relatively low diversification of sources.

Table 10. Amount of imports for selected energy resources and electricity [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	878.3	899	990.3	1132.1	1233.2	1265.5	1217.6	1244.3	1286.3	1317.5	1340.8	1417	1511.9	1672.9
Solid fossil fuels	3.9	29.6	45.2	58.6	95.8	121.7	67.9	42.7	52.9	74.5	67.4	68.9	90.1	140.7
Natural gas	196.1	209.3	244.3	265.1	276.9	271.6	261.9	278	301.9	281.2	315.5	341.5	358.7	374.2
Crude oil	570.4	529.8	539.7	596	625.2	652.9	682.2	764.9	746.6	762.9	741.9	736.3	761.1	842.1
Electricity	20.2	16.4	15.7	17.3	19.3	16.6	12.6	11.8	15.5	16.1	17.9	19.1	18	17.2
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	1761.4	1868.9	1801.8	1983.8	2090	1982.8	1923.3	1988	2081.2	2171.8	2423.4	2686.1	2651.4	2448.9
Solid fossil fuels	161.3	272	273.6	346.2	370.6	256.3	270	268.9	211.9	210.5	328.5	507.4	421.6	324
Natural gas	346.9	383.4	341.5	373.1	404.6	420.5	430	406.5	418.4	510.2	545.4	547.5	605.7	605.9
Crude oil	887.6	883.4	854.1	964.1	1011.2	1046.8	992.2	1007.7	1125.8	1044.3	1047.5	1141	1131.4	1058.4
Electricity	27.9	32.5	26.7	22.7	24.4	35.3	28.1	48.6	52.1	50.5	47.8	49.7	64.3	74.2

Source: authors' work based on Eurostat (2023a).

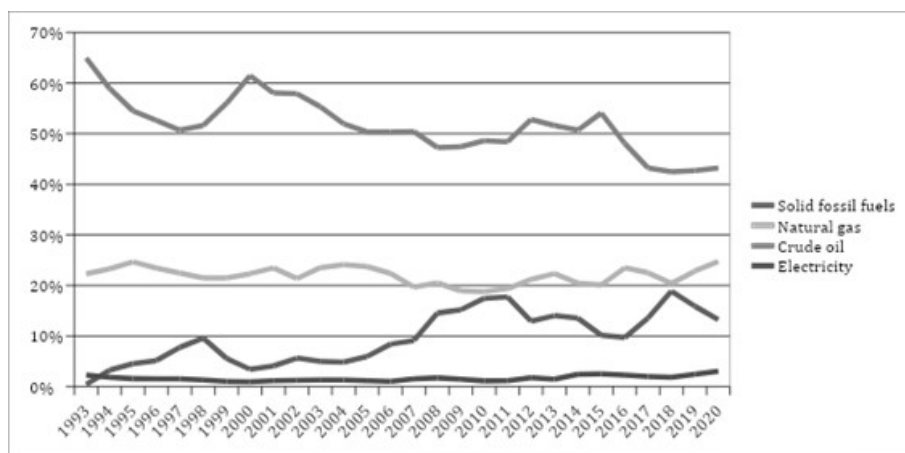


Figure 5. Shares of selected energy resources and electricity in total energy import

Source: authors' work based on Eurostat (2023b).

The data contained in Table 10 present the volume of imports of individual energy sources and electricity in the years 1993-2020. It should be noted that Poland significantly increased the level of imports over the analyzed period. This is due to the growing demand for energy in view of dynamic economic development. It is worrying, because the increase in imports also means Poland's increased dependence on foreign sources of energy.

Figure 5 shows the volume of shares of selected energy resources and electricity in total energy import. These figures present a growing dependence of Poland on external sources of energy. This is mainly because we import more electricity, which is a ready product in terms of the energy market, as well as increasing the amount of imported crude oil, because Poland does not possess its own sources at all.

Poland is an exporter of some resources, even though it may not have its own. In addition, Poland exports electricity. Most often, this is a form of re-export. This is due to technological characteristics (transmission grids) or the current demand of neighboring countries.

Table 11. Export volume for selected energy resources and electricity in 1993-2020 [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	767	895.5	998.2	895.6	950.7	923.4	829.3	842.6	892	890.8	831.3	851.3	821.5	847.6
Solid fossil fuels	695.1	830.8	933.2	816.3	861.9	828	721.3	725.5	735.3	727.7	683.6	695.5	634	655
Natural gas	0.5	0.8	1.1	1.4	1.3	1.4	1.4	1.4	1.4	1.4	1.6	1.6	1.5	1.6
Crude oil	0	0	0	0	0	0	0	5.5	18.7	21.1	6.8	5.9	8.7	12.1
Electricity	28.8	26.1	25.8	28.5	27.2	29.1	30.3	34.8	39.7	41.5	54.5	52.6	58.3	56.8
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	709.7	595.4	534.1	638	639.5	685.9	839.1	818.4	880.7	874.1	733.2	677.9	637.2	599.9
Solid fossil fuels	518	421.6	384.3	460.9	393.5	391.7	496.6	445.6	443.5	453.2	390.1	337.8	311.1	318.3
Natural gas	1.5	1.3	1.4	1.6	1	0.1	3.2	2.6	1.9	30	42.5	23.7	46	34.5
Crude oil	12.2	10.6	9.5	9	12.4	9	17.1	17.9	10.7	9.5	8.9	12.6	10	8.4
Electricity	47.2	34.9	34.5	27.6	43.3	45.5	44.4	40.8	53.3	43.3	39.5	29.2	26.1	26.5

Source: authors' work based on Eurostat (2023b).



Poland exports selected energy resources. However, this is mainly in the form of re-export. The exception is coal (solid fuels), which until 2018 had a positive balance (i.e., Poland exported more than it imported). Since 2018, Poland has also become dependent on this raw material, although it should be noted that the level of dependence was lower than in the case of oil or gas, because of its own sources.

As presented in figure 6, Poland is not an exporter of main sources of energy i.e. natural gas, crude oil, electricity. Poland can be rather treated as the re-exporter, which means that whatever is exported was first imported from other countries, as Poland does not have its own resources of these particular sources of energy. The exception is coal – Poland has been a significant producer of solid fossil fuels for decades. But, year by year, the significance of those activities is decreasing in total energy export.

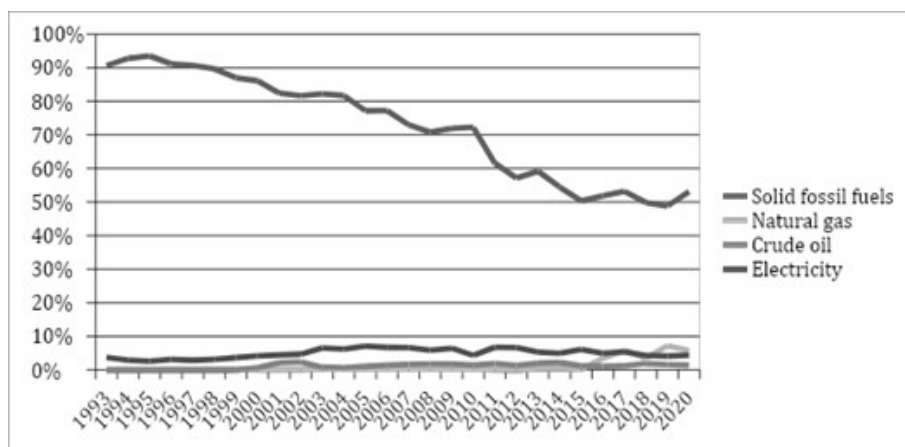


Figure 6. Shares of selected energy resources and electricity in total energy export

Source: authors' work based on Eurostat (2023b).

The actual breakdown of Poland's dependence on foreign energy sources shows the amount of net exports – Table 12. The data show that Poland is practically dependent on all energy sources. For all analyzed sources, the difference between exports and imports is negative, which means that Poland imports both electricity and solid fuels (including hard coal), natural gas and crude oil.

The amount of imports is constantly increasing. In 1993, the amount of total imports calculated in PJ was 111.3, while in 2020 this value increased to 1,849. The most disturbing data concern solid fuels and electricity, because in the years 1993-2015, Poland exported electricity, and in the case of solid fuels, this trend lasted until 2017. The last 3 analyzed years show that

Poland's energy dependence has increased, which is a worrying phenomenon.

Table 12. Net exports for selected energy resources and electricity [in PJ]

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total	-111.3	-3.5	8	-236.6	-282.5	-342.1	-388.3	-401.8	-394.3	-426.7	-509.4	-565.6	-690.4	-825.3
Solid fossil fuels	691.2	801.1	888	757.7	766.1	706.2	653.4	682.8	682.4	653.2	616.1	626.6	543.9	514.3
Natural gas	-195.5	-208.5	-243.3	-263.7	-275.6	-270.2	-260.5	-276.6	-300.5	-279.7	-314	-339.9	-357.2	-372.6
Crude oil	-570.4	-529.8	-539.7	-595.9	-625.2	-652.9	-682.2	-759.4	-727.9	-741.8	-735.1	-730.4	-752.4	-829.9
Electricity	8.7	9.7	10	11.2	7.8	12.5	17.8	22.9	24.2	25.5	36.6	33.5	40.3	39.5
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	-1051.8	-1273.5	-1267.8	-1345.8	-1450.5	-1296.9	-1084.2	-1169.6	-1200.5	-1297.7	-1690.3	-2008.1	-2014.2	-1849
Solid fossil fuels	356.7	149.6	110.7	114.8	22.9	135.4	226.5	176.7	231.6	242.8	61.6	-169.6	-110.4	-5.7
Natural gas	-345.4	-382	-340.1	-371.5	-403.6	-420.4	-426.7	-403.9	-416.5	-480.2	-502.9	-523.9	-559.6	-571.4
Crude oil	-875.4	-872.9	-844.5	-955.2	-998.8	-1037.8	-975	-989.8	-1115.1	-1034.8	-1038.6	-1128.4	-1121.4	-1050
Electricity	19.3	2.4	7.9	4.9	18.9	10.2	16.3	-7.8	1.2	-7.2	-8.2	-20.5	-38.2	-47.7

Source: authors' work based on Eurostat (2023b).

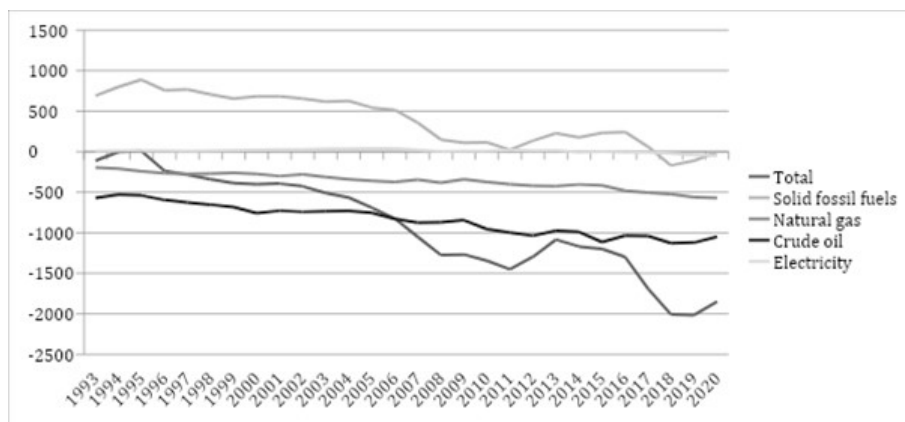


Figure 7. Net exports for selected energy resources and electricity [in PJ].

Source: authors' work based on Eurostat (2023b).

Figure 7 shows the amount of net exports, i.e. the actual level of energy dependence of the country. The trends presented in the chart show that the level of dependence measured by net exports is increasing. The greatest

dependence is recorded in the case of crude oil and natural gas. The growing dependence on electricity and solid fuels is also worrying.

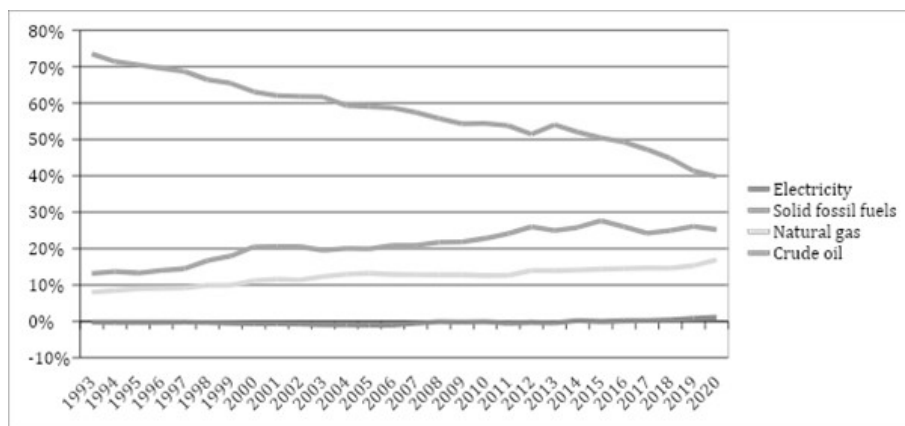


Figure 8. Ratio of the consumption of selected energy resources and electricity to total energy consumption

Source: authors' work based on Eurostat (2023a).

Figure 8 shows the ratio of the share of individual selected energy resources and electricity in the total energy consumption in Poland. Each year, there has been a decrease in the share of solid fuels (mainly hard coal) in the so-called energy mix, although this share is still high, and consumption at such a level still ranks Poland high in terms of such consumption in Europe. This is caused, among other factors, by changes in household heating (a transition from coal-based sources to gas stoves and cookers), the expansion of gas power plants, as well as a rapid increase in the number of cars in Poland in the last two decades of the 21st century.

Conclusions

In the analyzed period, Poland was highly dependent on foreign energy sources, especially in the field of gas and crude oil. The successively growing dependence of Poland on electricity sources is worrying. Until 2015, Poland was a net exporter of electricity, since 2016 the country's economy has consumed more electricity than it generated.

The level of Poland's dependence on external energy sources is still lower than the average for all European Union countries. However, it is necessary to take into account the proposed changes in the EU energy policy, which will promote renewable energy sources. The direction of EU changes was noted



in the document Energy Policy of Poland until 2040. The share of RES should be 23%, while hard coal in 2030 may contribute to 56% of electricity generation.

In the analyzed period, a growing diversification of energy sources was noted. The importance of the Russian Federation as a supplier of crude oil and natural gas is decreasing and the share of other countries such as Norway, Qatar or Great Britain is growing. However, the possibility of importing from these countries requires the provision of appropriate transshipment infrastructure, i.e. oil and gas ports. It was also noted that the dynamics of changes in the supply of raw materials differs depending on the country. The most stable supplier of oil is the Russian Federation, natural gas; Russia and Germany, electricity; Germany and coal; Russia. Other suppliers of resources are characterized by a high volatility in the volume of supplies. This means that they cannot be considered as strategic partners (Qatar and Norway were not included in the assessment, as Qatar supplied gas only in the three years 2016-2018, and Norway in the period of 2002-2007 and then in 2015-2020).

Coal has played a special role in Polish energy policy for years. Poland has significant resources of this raw material, both hard coal and lignite. However, the raw material present in Poland is characterized by poor quality, low calorific value and its prices are higher than those of imported coal. This justifies the imports.

Attention should be paid not only to the energy dependence of a given country, but also to the so-called energy mix, i.e. the share of individual sources in the total consumption. In the analyzed period, Poland reduced the share of coal consumption from 54% in 2011 and 40% in 2020, in favor of oil and gas. It means the increase of dependence on foreign sources from 34% in 2011 to 42.8% in 2020.

In the analyzed period, a growing negative energy balance was observed. Only in 1995 a positive balance result measured in PJ was recorded for the analyzed raw materials and electricity. In the following years, the energy balance was negative. In 2020, compared to 1993, it was worse than 16 times.

The outbreak of COVID-19 pandemic, resulted in rapid changes in the energy market. In 2020, i.e. at the beginning of the pandemic, a significant decrease in the prices of energy raw materials can be noted, caused by a sharp reduction in demand and business activity around the world. Analysis of the effects of the pandemic and the outbreak of the Russian-Ukrainian war may be an interesting material for further research and analysis from the energy market point of view. Considering the above, the authors are aware of the limitations in the conducted research and conclusions, and above all, recommendations for the future.

In the following years, the Polish energy market will have to change (Kochanek, 2021). One of the discussed ways is to transform the market more

into renewable sources or atomic power plants (Bielska et al., 2020). Such solutions however need several years to be launched into practice and it is a matter of time (Pietrzak et al., 2021). It is worth noting, however, that each energy transition is not only time consuming but also expensive (Zych et al., 2023).

The contribution to the authors

Conceptualization, K.G. and P.K.; literature review, K.G.; methodology, K.G. and P.K.; formal analysis, P.K.; writing, K.G. and P.K.; conclusions and discussion, K.G. and P.K.

References

- Albrycht, I., Bigaj, W., Dvořáková, V., Francu, J., Garpel, R., Osička, J., Mathews, A., Sikora, A., Sikorski, M., Smith, K. C., Tarnawski, M., & Wagner, A. (2014). *Rozwój sektora gazu łupkowego w Polsce i jego perspektywy w Czechach – analiza i rekomendacje*. Kraków: Instytut Kościuszki. https://infolupki.pgi.gov.pl/sites/default/files/czytelnia_pliki/1/raport_gaz_lupkowy_ik_czechy.pdf (in Polish).
- Antosiewicz, M., Lewandowski, P., & Sokołowski, P. (2022). *The Economic Effects of Stopping Russian Energy Imports in Poland*. IBS Research Report. <https://ibs.org.pl/app/uploads/2022/05/The-economic-effects-of-stopping-Russian-energy-imports-in-Poland.pdf>
- Bielska, R., Bielski, S., Pík, K., & Kurowska, K. (2020). The Importance of Renewable Energy Sources in Poland's Energy Mix. *Energies*, 13(18), 4624. <https://doi.org/10.3390/en13184624>
- Brauers, H., & Oei, P.-Y. (2020). The political economy of coal in Poland: Drivers and barriers for a shift away from fossil fuels. *Energy Policy*, 144, 111621. <https://doi.org/10.1016/j.enpol.2020.111621>
- Braun, J. (2018). Bezpieczeństwo energetyczne jako dobro publiczne – miary i czynniki wpływające na jego poziom. *Studia Ekonomiczne*, 358, 23-32. (in Polish).
- Czech, A. (2018). Analiza wybranych wskaźników bezpieczeństwa energetycznego Polski w kontekście zrównoważonego rozwoju. *Studia i Prace WNEiZ*, 53(2), 23-35. (in Polish).
- Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Pub. L. No. 32018L2001, 328 OJ L (2018). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32018L2001>
- Eurostat. (2023a). *Complete energy balances*. https://ec.europa.eu/eurostat/data-browser/view/NRG_BAL_C/default/table?lang=en
- Eurostat. (2023b). *Energy Trade 2021*. https://ec.europa.eu/eurostat/cache/info-graphs/energy_trade/entrade.html
- Eurostat. (2023c). *Energy imports dependency*. https://ec.europa.eu/eurostat/data-browser/view/NRG_IND_ID/default
- Fuksa, D. (2021). Opportunities and Threats for Polish Power Industry and for Polish Coal: A Case Study in Poland. *Energies*, 14(20), 6638. <https://doi.org/10.3390/en14206638>

- Gawlik, L., & Mokrzycki, E. (2017). Paliwa kopalne w krajowej energetyce – problemy i wyzwania. *Energy Policy Journal*, 20(4), 6-26. (in Polish).
- Grudziński, Z. (2013). Koszty środowiskowe wynikające z użytkowania węgla kamiennego w energetyce zawodowej. *Rocznik Ochrona Środowiska*, 15, 2249-2266. (in Polish).
- International Energy Agency. (2022). *Poland 2022 Energy Policy Review*. https://iea.blob.core.windows.net/assets/310a49d2-771a-43f4-86b7-b935179b7c3f/Poland2022_Executivesummary_Polish.pdf (in Polish).
- Jędrak, J. (2022). *Emisje CO₂ w 2022: zamiast maleć, znów rosną*. <https://naukaoklimacie.pl/aktualnosci/emisje-co2-w-2022-zamiast-malec-znow-roсна/> (in Polish).
- Jeżewski, P. (2011). Polityka klimatyczna UE a rozwój polskiej energetyki konwencjonalnej. *Kwartalnik Kolegium Ekonomiczno-Społecznego Studia i Prace*, (2), 141-164. (in Polish).
- Kamyk, J., & Kot-Niewiadomska, A. (2019). Wydobycie i import – struktura pokrycia zapotrzebowania na ropę naftową w Polsce w latach 1990–2017. *Przegląd Geologiczny*, 67(11), 891-897. (in Polish).
- Kamyk, J., Kot-Niewiadomska, A., & Galos, K. (2021). The criticality of crude oil for energy security: A case of Poland. *Energy*, 220, 119707. <https://doi.org/10.1016/j.energy.2020.119707>
- Kiedrowska-Pryka, M. (2014). Zależność Unii Europejskiej od zewnętrznych dostaw surowców energetycznych – struktura zużycia nośników energii i ich dywersyfikacja w krajach członkowskich UE. In P. Kwiatkiewicz (Ed.), *Bezpieczeństwo Energetyczne. Rynki surowców i energii teraźniejszość i przyszłość. Tom I – Polityka – Gospodarka – Zasoby naturalne- logistyka* (pp. 419). Poznań: Fundacja na rzecz czystej energii. (in Polish).
- Kielcerz, A., Beuch, W., & Marzec, R. (2018). Węgiel w energetyce zawodowej a polski miks energetyczny. *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk*, 105, 85-94. <https://doi.org/10.24425/124380> (in Polish).
- Kochanek, E. (2021). Evaluation of Energy Transition Scenarios in Poland. *Energies*, 14(19), 6058. <https://doi.org/10.3390/en14196058>
- Koryl, K. (2019). Bezpieczeństwo płynące z budowy gazociągu Baltic – Pipe. In M. Ruszel & S. Podmiotko (Eds.), *Bezpieczeństwo energetyczne Polski i Europy. Uwarunkowania – wyzwania – Innowacje* (pp. 33-42). Rzeszów: Instytut Polityki Energetycznej im. I. Łukasiewicza. (in Polish).
- Kruyt, B., van Vuuren, D. P., de Vries, H. J. M., & Groenenberg, H. (2009). Indicators for energy security. *Energy Policy*, 37(6), 2166-2181. <https://doi.org/10.1016/j.enpol.2009.02.006>
- Kryzia, D., & Gawlik, L. (2012). Perspektywy gazu z łupków w Polsce. *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią*, 82, 5-19. (in Polish).
- Lorek, M. (2017). Bezpieczeństwo energetyczne a bezpieczeństwo wewnętrzne państwa. *Modern Management Review*, 24(3), 95-104. (in Polish).
- Lorenz, U. (2016). Węgłe energetyczne o obniżonej jakości w handlu międzynarodowym. *Polityka Energetyczna – Energy Policy Journal*, 19(3), 19-34. (in Polish).
- Matkowski, A., & Musiał, P. (2012). Systemowe magazyny gazu w Polsce. *Archiwum Energetyki*, 1, 82-92. (in Polish).
- Minister Klimatu i Środowiska. (2021). *Sprawozdanie z wyników monitorowania bezpieczeństwa dostaw paliw gazowych za okres od dnia 1 stycznia 2020 r. do dnia 31*

- grudnia 2020 r. https://bip.mos.gov.pl/fileadmin/user_upload/bip/Energetyka/Sprawozdania_z_wynikow_monitorowania_bezpieczenstwa_dostaw_paliw_gazowych/1._Sprawozdanie_MKIS_z_monitorowania_bezpieczenstwa_dostaw_paliw_gazowych_za_2020.pdf (in Polish).
- Ministerstwo Gospodarki. (2009). *Polityka energetyczna Polski do 2030 roku*. https://www.gov.pl/documents/33372/436746/DE_Polityka_energetyczna_ost_2030.pdf/78b689ec-62ec-af88-b0d7-decf95abdb70 (in Polish).
- Misiągiewicz, J. (2019). *Bezpieczeństwo energetyczne Unii Europejskiej. Implikacje nowych projektów infrastruktury gazociągowej w Europie*. Lublin: Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej. (in Polish).
- Morozowska, S., Wendt, J., & Tomaszewski, K. (2021). The Challenges of Poland's Energy Transition. *Energies*, 14(23), 8165. <https://doi.org/10.3390/en14238165>
- Motowidlak, T. (2018). Dylematy Polski w zakresie wdrażania polityki energetycznej Unii Europejskiej. *Energy Policy Journal*, 21(1), 5-20. (in Polish).
- Nyga-Łukaszewska, H., Aruga, K., & Stala-Szlugaj, K. (2020). Energy Security of Poland and Coal Supply: Price Analysis. *Sustainability*, 12(6), 2541. <https://doi.org/10.3390/su12062541>
- Ogarek, P. (2019). Przyszłość odnawialnych źródeł energii w Polsce w oparciu o politykę Energetyczną Polski do 2040 roku. In M. Ruszel & S. Podmiotko (Eds.), *Bezpieczeństwo energetyczne Polski i Europy. Uwarunkowania – wyzwania – Innowacje* (pp. 97-120). Rzeszów: Instytut Polityki Energetycznej im. I. Łukasiewicza. (in Polish).
- Olkuski, T., Szurlej, A., Tora, B., & Karpiński, M. (2018). Polish energy security in the oil sector. *Energy and Fuels*, 108, 1-8. https://www.e3s-conferences.org/articles/e3sconf/pdf/2019/34/e3sconf_ef18_02015.pdf
- Olkuski, T., Wyrwa, A., & Pluta, M. (2017). Prognozy popytu na paliwa i energię w Polsce i na świecie. *Inżynieria Mineralna*, 18(2), 145-152. (in Polish).
- Ostrowski, W. (2021). Russia, Transition and Poland Energy security a retrospective view. *Journal of Contemporary Central and Eastern Europe*, 29(2-3), 195-207. <https://doi.org/10.1080/25739638.2021.2007605>
- Paliński, A. (2018). Hurtownie danych i eksploracja danych w progowaniu popytu na gaz i usługi magazynowania gazu. *Nafta – Gaz*, 4, 283-289. <https://doi.org/10.18668/NG.2018.04.04> (in Polish).
- Pangsy-Kania, S., & Wierzbička, K. (2022). Niezależność od importu surowców energetycznych jako kluczowy element bezpieczeństwa ekonomicznego państwa. *Polska na tle krajów UE. Optimum Economic Studies*, 3(109), 85-101. (in Polish).
- Paszkowski, M. (2023). Wątpliwe źródło dostaw ropy naftowej do rafinerii w Europie Środkowej. *Komentarze IEŚ*, 753(1). <https://ies.lublin.pl/komentarze/kazachstan-watpliwie-zrodlo-dostaw-ropy-naftowej-do-rafinerii-w-europie-srodkowej/> (in Polish).
- Pietrzak, M., Iglinski, B., & Kujawski, W. (2021). Energy Transition in Poland = Assessment of the Renewable Energy Sector. *Energies*, 14(8), 2046. <https://doi.org/10.3390/en14082046>
- Portal Interoperacyjności i Architektury. (2021). *Polityka Energetyczna Polski do 2040 r. (PEP2040)*. <https://www.gov.pl/web/ia/polityka-energetyczna-polski-do-2040-r-pep2040> (in Polish).
- Rybak, A., & Manowska, A. (2018). The future of crude oil and hard coal in the aspect of Poland's energy security. *Polityka Energetyczna – ENERGY POLICY JOURNAL*, 21(4), 141-154. <https://doi.org/10.24425/124505>

- Schreurs, M. A. (2018). EU environmental policy. In H. Heinelt & S. Münch (Eds.), *Handbook of European policies. Interpretative approaches to the EU* (pp. 207-223). Cheltenham: Edward Elgar Publishing.
- Siemek, J., Mokrzycki, E., & Ney, R. (2008). Światowe zasoby surowców energetycznych – wnioski dla Polski. *Rynek Energii*, 6, 409-428. (in Polish).
- Sokołowski, W., & Zięcina, M. (2013). Konfigurowanie łańcuchów dostaw w aspekcie bezpieczeństwa energetycznego. In M. Chrabkowski, C. Tatarczuk & J. Tatarczuk (Eds.), *Bezpieczeństwo w administracji, gospodarce i biznesie. Aksjologia zjawisk kryzysowych w gospodarce, biznesie i logistyce* (pp. 34-49). Gdynia: Wyższa Szkoła Administracji i Biznesu im. E. Kwiatkowskiego. (in Polish).
- Soroka, P. (2015). *Bezpieczeństwo energetyczne: między teorią a praktyką*. Warszawa: Elipsa. (in Polish).
- Stala-Szlugaj, A., & Grudziński, Z. (2019). Rosja na międzynarodowym rynku węgla energetycznego a eksport do Polski. *Zeszyty Naukowe Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk*, 109, 21-38. <https://doi.org/10.24425/znigsm.2019.130172> (in Polish).
- Stańczyk, J. (2019). Istota współczesnego pojmowania bezpieczeństwa – zasadnicze tendencje. *Rocznik Bezpieczeństwa Międzynarodowego*, 5, 15-33. <https://doi.org/10.34862/rbm.2011.2> (in Polish).
- Stavytskyy, A., Kharlamova, G., Giedraitis, V., & Šumskis, V. (2018). Estimating the interrelation between energy security and macroeconomic factors in European countries. *Journal of International Studies*, 11(3), 217-238. <https://doi.org/10.14254/2071-8330.2018/11-3/18>
- Steinhoff, J. (2022). *Polskie magazyny gazu są jednymi z najmniejszych w Europie. Mieszczą 15 procent rocznego zużycia*. <https://tvn24.pl/polska/gaz-ziemny-czy-wystarczy-gazu-na-zime-2022023-ile-polska-ma-gazu-w-magazynach-6126862> (in Polish).
- Szczerbowski, R. (2015). Polityka energetyczna wybranych krajów europejskich a strategia energetyczna Polski. *Energy Policy Journal*, 18(3), 5-14. (in Polish).
- Szurlej, A. (2008). Perspektywiczne segmenty krajowego rynku gazu ziemnego. *Wiertnictwo Nafta Gaz*, 25(2), 349-358. (in Polish).
- Tylec, T. (2013). Uwarunkowania globalne i regionalne bezpieczeństwa energetycznego Polski. *Studia Ekonomiczne*, 139, 93-100. (in Polish).
- Weiner, Cs. (2019). Diversifying away from Russian Gas: The Case of Poland. *Outlines of Global Transformations: Politics, Economics, Law*, 12(2), 138-163. https://www.ogt-journal.com/jour/manager/files/OutlinesofGlobalTransformations_Weiner-1.pdf
- Wojtkowska-Łodej, G. (Ed.). (2020). *Transformacja rynków energii: Gospodarka. Klimat. Technologia. Regulacje*. <https://energia.sgh.waw.pl/sites/energia.sgh.waw.pl/files/inline-files/publikacja%20w%20j%20C4%99zyku%20polskim%20-%20Szkola%20Energii.pdf> (in Polish).
- Zhou, C., Zhu, B., Davis, S. J., Liu, Z., Halff, A., Arous, S. B., Rodrigues, H. A., & Ciais, P. (2023). Natural gas supply from Russia derived from daily pipeline flow data and potential solutions for filling a shortage of Russian supply in the European Union (EU). *Earth System Science Data*, 15(2), 949-961. <https://doi.org/10.5194/essd-15-949-2023>
- Zych, G., Brodnicka, J., Czarnecka, M., Kinelski, G., & Kamiński, J. (2023). The Cost of Using Gas as a Transition Fuel in the Transition to Low-Carbon Energy: The Case Study of Poland and Selected European Countries. *Energies*, 16(2), 994. <https://doi.org/10.3390/en16020994>