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Polish energy sector's dependence on lignite mining: The process of transition

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Abstract

This opinion study is devoted to the role of lignite in the Polish energy sector in recent decades, i.e., after the collapse of communism in 1989. Lignite is the primary source of electricity in Poland, second only to hard coal. More than 25–35% of Polish electricity was generated by lignite-fired power plants in 1990–2022. To meet the needs of the energy industry, 46–70 Mt of lignite was mined annually in that period. Hence, Poland was, and still is, one of the world leaders in lignite production. Despite the ongoing transition of the Polish energy sector, changes occur very slowly due to political, economic, environmental and social reasons. In the years 2021–2022, the downward trend in lignite mining, influenced mainly by the COVID-19 pandemic, was reversed by the war in Ukraine. Fortunately, there is now a great opportunity to accelerate the energy transition in Poland because of domestic political changes at the end of 2023. Nevertheless, complete independence from coal, including lignite, will not take place within the next 10–25 years, i.e., before nuclear power plants are built and the share of renewables in Poland's energy mix increases by at least several times.

Keywords

Energy industry, lignite production, energy transition, mining transition, Poland

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Abstract

This opinion study is devoted to the role of lignite in the Polish energy sector in recent decades, i.e., after the collapse of communism in 1989. Lignite is the primary source of electricity in Poland, second only to hard coal. More than 25–35% of Polish electricity was generated by lignite-fired power plants in 1990–2022. To meet the needs of the energy industry, 46–70 Mt of lignite was mined annually in that period. Hence, Poland was, and still is, one of the world leaders in lignite production. Despite the ongoing transition of the Polish energy sector, changes occur very slowly due to political, economic, environmental and social reasons. In the years 2021–2022, the downward trend in lignite mining, influenced mainly by the COVID-19 pandemic, was reversed by the war in Ukraine. Fortunately, there is now a great opportunity to accelerate the energy transition in Poland because of domestic political changes at the end of 2023. Nevertheless, complete independence from coal, including lignite, will not take place within the next 10–25 years, i.e., before nuclear power plants are built and the share of renewables in Poland's energy mix increases by at least several times.

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1. Introduction

The share of lignite as the basis for electricity production around the world, in the European Union (EU) and in Poland, varies greatly. For example, in 2018, it was only approx. 3% in the world and approx. 9% in the EU [1,2]. In the same year, approx. 30% of electricity came from burning lignite in Poland [3]. With the extraction of 58.6 Mt of lignite in 2018, Poland took sixth place in the world, after Indonesia but before the USA [4]. Despite such high values, in other countries the role of lignite in their domestic energy mix is significantly greater than in Poland [5–9]. The above-mentioned approx. 9% of electricity in the EU was obtained from the combustion of approx. 90% of extracted lignite. The remaining approx. 10% was mainly consumed by the chemical industry, local heating and agriculture. However, the use of lignite for electricity production was uneven, ranging from approx. 87% in Bulgaria to over 99% in Poland, Romania and Slovakia, and 100% in Greece. Regardless of the volume of production, the energy sector in some European countries is dependent on lignite. In 2018, for example, 55–97% of electricity was generated in lignite-fired power plants in the following countries: Kosovo, Bosnia and Herzegovina, Serbia and North Macedonia. In other countries, such as Bulgaria, Greece, Poland and Germany, it was 43%, 34%, 30% and 22% of the total energy mix, respectively [3,10]. The sudden abandonment of lignite as a source of electricity would cause the breakdown of energy systems in the countries listed, including Poland.

Therefore, the main aim of this study is to show that, in the coming years, as in the past decades, without lignite the Polish energy sector will not meet the needs of its economy and inhabitants. Firstly, this will be achieved by briefly describing the energy and mining industries, and explaining

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the causes of fluctuations in lignite mining and electricity production from it. Secondly, lignite production and its share in Poland's electricity generation will be discussed. Finally, the authors' latest forecasts regarding the reduction of lignite mining in Poland in the coming 20 years are presented.

2. Materials and methods

The main source of data used in this paper are annual statistical reports published by Polish Grid Company. Supplementary information on global and European electricity production comes from Enerdata and Eurostat reports, respectively. In turn, the geology of Polish lignite deposits and the production of electricity from it is described on the basis of the authors' previous contributions.

The above-mentioned materials are used to present them in graphical and tabular form. The figures show, among other things, the volume of total electricity production and consumption in Poland and the extraction and production of electricity from lignite in the years 1990–2022. The tables contain numerical data on the basis of which the figures are prepared. Moreover, when describing the geology of lignite deposits and lignite extraction from them, in addition to the authors' own materials and current information from Polish lignite mines is used.

To summarise the methodological section, it can be said that methods typical of opinion research are applied. Therefore, to achieve the aims of this paper, an analysis of the political, economic and social consequences accompanying the exploitation and combustion of lignite is carried out. Finally, the authors' forecast of their changes in the context of the transformation process of the Polish energy and mining industries based on lignite is presented. Due to the rapidly occurring changes, not only published materials are used, but also the most up-to-date opinions of national scientific and decision-making bodies, to which the authors of this paper belong.

3. Brief review of previous research

The energy system in Poland has been the subject of various studies. In the Polish literature there are many annual reports prepared by the Polish Grid Company [2,11,12]. These reports contain both the volume of electricity production and consumption divided into different sources, such as: hard coal, lignite, gas, hydro and renewables (wind, solar PV, biomass), and so on. On the other hand, Poland's long-term energy policy has been described in extensive contributions that, paradoxically, change every few years [13–15]. In turn, the Polish energy sector is most often discussed in the world's statistical studies [1,10,16–22]. The role of lignite in the Polish energy industry increased significantly after World War II. Hence, the number of publications on this subject is huge. They can be divided into comprehensive studies [3,23,24] and case studies [9,25–29]. The mentioned publications describe both the history of the lignite-based energy industry and present various scenarios for its development, none of which have come true.

Many scientific geological documents, maps and atlases have been devoted to geology and lignite mining in Poland. The first group comprises those studies that focused mainly on the geology of lignite-bearing areas [3,30–36]. The second group of studies was devoted mainly to lignite mining, including, above all, the annual "Balances of Resources of Mineral Deposits in Poland" prepared by the Polish Geological Institute – National Research Institute [37], the industry magazine called "Węgiel Brunatny" (i.e., "Lignite"), and books by Kasztelewicz [23] and Tajduś et al. [24]. It is worth noting at this point that the issues of lignite mining are also partially discussed in other publications listed in this section. Opencast (surface) lignite mining is, of course, inextricably linked to environmental-climatic and socio-economic conflicts. These issues were described in both Polish [38–46] and world literature [47–54]. Nevertheless, in the last 3–5 years, the impact on the Polish energy industry, including the one based on lignite, has also been exerted by COVID-19 and the war in Ukraine. Their importance has already been analysed and discussed in a relatively large number of studies [17,28,55–57].

4. Outline of energy sector in Poland

After the fall of communism in Poland in 1989, both the production and consumption of electricity increased, but in waves. This general upward trend is evident, as is its periodic reversal over several years. In the analysed time interval (i.e., 1990–2022), the amount of electricity production was usually greater than its consumption. However, the exceptions were 2014 and the years 2016–2021 (Fig. 1). Poland's electricity production in 1990 amounted to 136.3 TWh, while in 2022 it was 175.2 TWh. This means that the average annual increase in electricity production was approx. 1.2 TWh/year. There was a similar upward trend in electricity consumption in the years 1990–2022, i.e., approx. 1.2 TWh/year (Table 1).

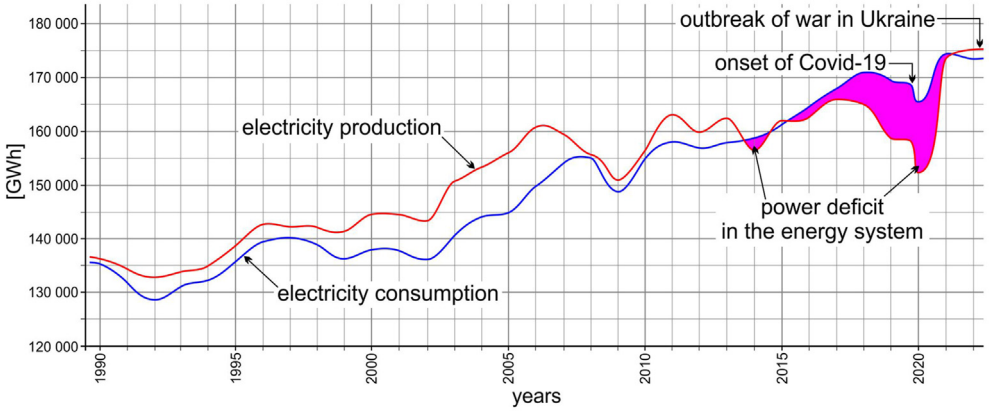

Fig. 1. Production and consumption of Poland's electricity in 1990–2022 (data source: [12,18]).

During the dominant part of this period, electricity production was higher than its consumption and the power reserve ranged from 0.6 TWh in 2008 to 11.3 TWh in 2005. Unfortunately, in the years listed above (2014, 2016–2021), the electricity deficit in the Polish Energy Grid reached as much as 0.8–13.3 TWh (Table 1; [12]). Of course, the biggest deficit in the energy system was undoubtedly related to the rapid development of the COVID-19 epidemic in 2020 (Fig. 1). In the most recently analysed year (2022), there was a small surplus in Poland's energy balance, which was obtained by increased electricity generation from all energy sources, including lignite.

In 2022, Poland was still over three-quarters dependent on coal, of which over one-half was hard coal and over one-quarter was lignite. Less than one-quarter of the total electricity production was obtained from other sources, such as renewables (hydro, wind, solar, etc.) and gas. It is worth noting

Table 1. Data used to construct Figures 2 and 3 (data source: [12,18]).

Year	Total electricity production [TWh]	Total electricity consumption [TWh]	Electricity production from lignite [TWh]
1990	136.3	135.3	d.u.
1991	134.6	139.1	d.u.
1992	132.8	128.8	d.u.
1993	133.7	131.3	d.u.
1994	134.9	132.2	d.u.
1995	138.7	135.9	d.u.
1996	142.7	139.6	d.u.
1997	142.4	140.2	d.u.
1998	142.2	138.8	d.u.
1999	141.3	136.4	d.u.
2000	144.4	138.0	d.u.
2001	144.6	137.8	d.u.
2002	143.2	136.2	d.u.
2003	150.8	140.6	51.5
2004	153.4	144.1	52.1
2005	156.0	144.8	54.9
2006	160.8	149.8	53.5
2007	159.5	154.2	51.1
2008	155.6	155.0	53.8
2009	150.9	148.7	50.8
2010	156.3	155.0	49.5
2011	163.2	157.9	53.6
2012	159.9	157.0	55.6
2013	162.5	158.0	57.0
2014	156.6	158.7	54.2
2015	161.8	161.4	53.6
2016	162.6	164.6	51.2
2017	165.9	168.1	52.0
2018	165.2	170.9	49.1
2019	158.8	169.4	41.5
2020	152.3	165.5	38.0
2021	173.6	174.4	45.4
2022	175.2	173.5	47.0

d.u. – data uncertain.

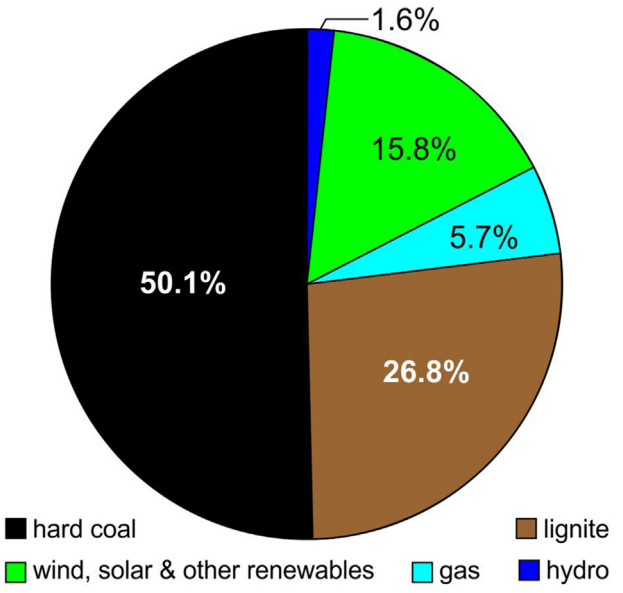

Fig. 2. Percentage share of energy sources in Poland's electricity production in 2022 (data source: [12]).

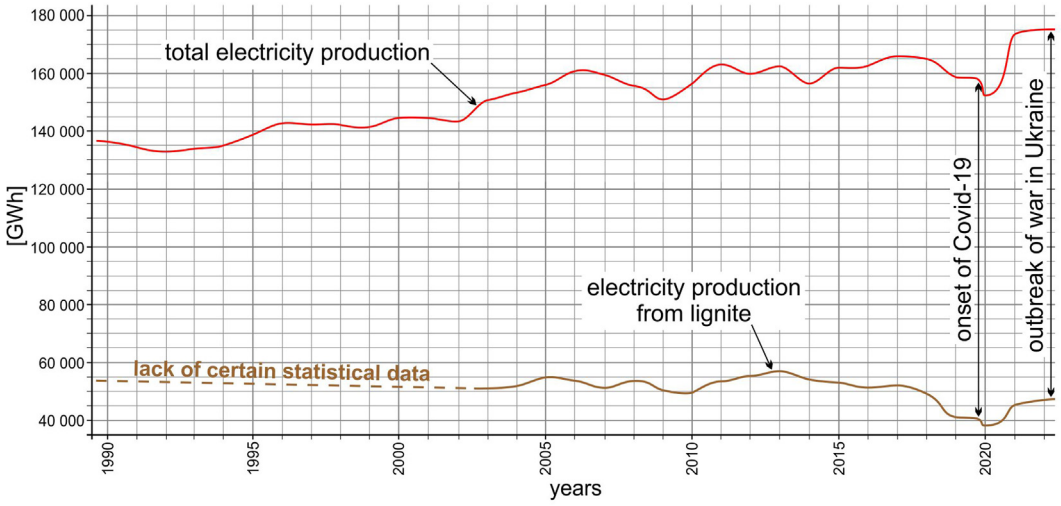

Fig. 3. Comparison of Poland's total electricity production and that obtained from lignite in 1990–2022 (data source: [12,18]).

that a total of 17.4% of electricity in Poland was recently obtained from renewable sources (Fig. 2). It can be claimed with certainty that, until 2017 (except for 2010), electricity production from lignite was in the range of 50.8–57.0 TWh (Fig. 3; Table 1). This constituted approximately one-third of Poland's energy mix. However, in relation to total electricity production, at least two facts must be noted. Firstly, in the years 1990–2022, domestic electricity production showed a general upward trend, while electricity generation from lignite had a slightly decreasing trend. Secondly, the amount of electricity produced as a whole and that from lignite are closely correlated (Fig. 3).

5. Lignite mining in Poland

To be able to generate such relatively large amounts of electricity from lignite as presented above (Figs. 2 and 3), it must first be found, extracted and delivered to the power plants. Therefore, more than 150 small and large lignite deposits have been documented in central and southwestern Poland (Fig. 4; [30,32–34]). Several dozens of them are

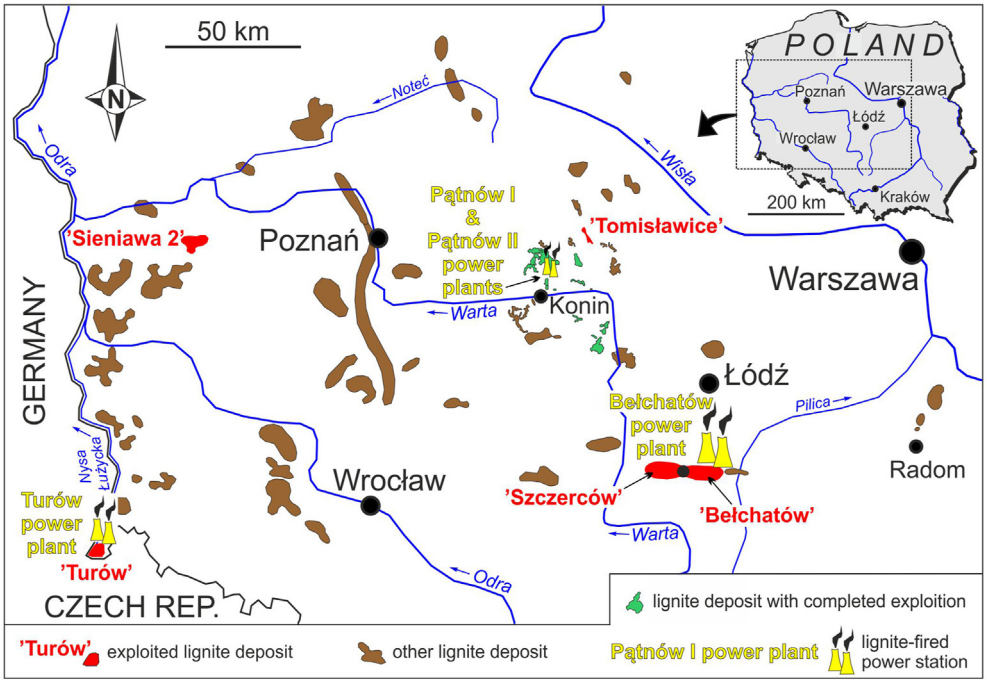

Fig. 4. Location of main Polish lignite deposits, opencasts and lignite-fired power plants in mid-2024 (data source: [3,9]).

suitable for opencast mining [3,31,36] and only a few for underground gasification [46,48]. Ninety-one Polish lignite deposits were balanced at the end of 2022. Their total proven recoverable resources (geological resources) were calculated at approx. 23.1 Gt. However, for the deposits exploited at that time (economic resources), the resources recovered amounted to approx. 0.92 Gt and constituted 4.26% of the proven recoverable resources [37].

Currently, in mid-2024, lignite is being mined in four mines (Bełchatów, Turów, Konin and Sieniawa) from the following five deposits: "Szczerców", "Bełchatów", "Turów", "Tomisławice" and "Sieniawa 2" (Fig. 4). In 2022, lignite output from individual deposits amounted to: 40.7 Mt – "Szczerców" and 3.5 Mt – "Bełchatów" (Bełchatów Lignite Mine), 9.9 Mt – "Turów" (Turów Lignite Mine), 3.5 Mt – "Tomisławice" (Konin Lignite Mine) and 0.53 Mt – "Sieniawa 2" (Sieniawa Lignite Mine). The remaining 1.8 Mt came from the already-closed Drzewce ("Drzewce" deposit) and Jóźwin IIB ("Pątnów IV" deposit) opencasts managed by the Konin Lignite Mine [37]. There are three lignite-fired power plants near these mines, i.e., Bełchatów, Turów and Pątnów (Pątnów I and Pątnów II), respectively. In the case of lignite from the Sieniawa Lignite Mine, a large part of it (approx. 0.5 Mt in 2022 and approx. 0.9 Mt in 2023) is transported and burned by the Pątnów power plant located over 230 km away (Fig. 4). The total installed capacity in the lignite-fired power plants is 8201 MW: 1118 MW at Pątnów (644 MW in Pątnów I, 474 MW in Pątnów II), 1981 MW at Turów and 5102 MW at Bełchatów [27]. It should be noted that the Bełchatów power plant was the largest coal-fired power plant, in general, and the largest polluter in the EU and the whole of Europe, emitting more than 35 Mt of CO_2 in 2022 [22].

The data depicted above clearly show that, in the years 1990–2022, lignite played the most significant role, after hard coal, in the Polish energy sector (Figs. 1–4). In this time interval, from 25% to over 35% of electricity was produced from lignite. Apart from short-term fluctuations in the range of 30–35% in the years 2003–2012, since 2013 there has been a clear downward trend in the share of electricity from lignite in Poland's energy mix. This is consistent with the decline in lignite output at that time (Fig. 5; Table 2). The reason for this should be attributed to the depletion of deposits near Konin [53], the renovation of power units at the Turów

Table 2. Data used to construct Figures 2 and 3 (data source: [20]).

Year	Lignite production [Mt]	Share of electricity from lignite [%]
1990	67.6	d.u.
1991	69.4	d.u.
1992	66.9	d.u.
1993	68.1	d.u.
1994	66.8	d.u.
1995	63.5	d.u.
1996	63.8	d.u.
1997	63.2	d.u.
1998	62.8	d.u.
1999	60.8	d.u.
2000	59.5	d.u.
2001	59.6	d.u.
2002	58.2	d.u.
2003	60.9	34.2
2004	61.2	34.0
2005	61.6	35.2
2006	60.8	33.3
2007	57.5	32.0
2008	59.7	34.6
2009	57.1	33.4
2010	56.5	31.7
2011	62.8	32.8
2012	64.3	34.8
2013	65.8	35.1
2014	63.9	34.6
2015	63.1	33.1
2016	60.2	31.5
2017	61.2	31.3
2018	58.6	29.7
2019	50.3	26.1
2020	46.0	25.0
2021	52.4	26.2
2022	54.6	26.8

d.u. – data uncertain.

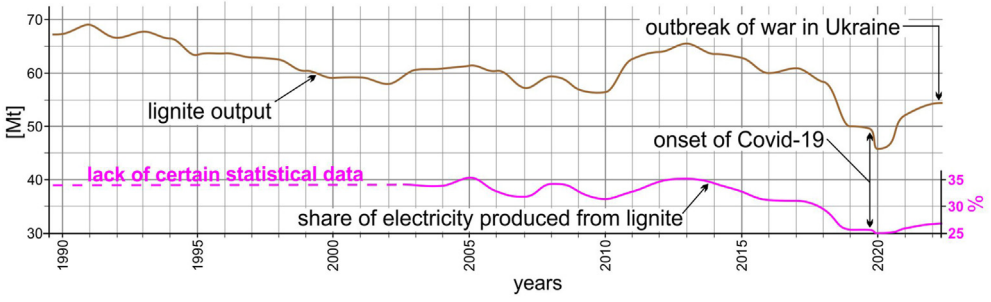

Fig. 5. Lignite output and its share in Poland's electricity generation (data source: [20]; compare Tables 1 and 2).

power plant and, finally, the COVID-19 pandemic [27,28]. Therefore, the lowest share of lignite in electricity production (25.0%) coincides with its lowest output (46.0 Mt) in 2020 (Fig. 5).

6. Fluctuations in lignite-based electricity production

Results protection of the natural environment (the creation of "wounds" in the Earth, lowering of the groundwater levels, emission of greenhouse gases, excessive noise, etc.), the acceptance of or opposition to the construction of new mines (resettlement of the rural population), as well as the possibility of enriching local communities and the population, have always accompanied the mining and energy industry based on lignite. These problems are still current in Poland [24,25,27,38,39,41,42,50,51,58] and other European countries where a significant part of the electricity is generated from lignite [5–8,59–61]. The perturbations in the development of Polish lignite mining are due to four main reasons. Firstly, numerous lignite deposits that are being exploited or could be mined are located in legally protected and environmentally valuable areas. Secondly, the rural population may, or may not, agree with the building of a new lignite mine in a referendum. Thirdly, protests by pro-ecology organisations may make the extraction of lignite and the production of electricity from it very difficult or even impossible. Fourthly, mining and the lignite-based energy sector quite accurately reflect long and short-term trends in the Polish economy [40,43,45,47]. The closing of successively exploited opencast mines and the temporary shutdown of power units due to their modernisation have a significant impact on reducing lignite output and the generation of electricity. For example, the beginning of the slight downward trend in 2013 was due to increasingly lower efficiency, especially in the renovation of old power units in the Turów power plant [9]. In turn, production in the Adamów Lignite Mine was drastically reduced in 2017, and at the beginning of 2018 the Adamów lignite-fired power plant was closed [3,27]. This resulted in a deepening of the analysed downward trend. Nevertheless, the largest decline in lignite mining to 46 Mt and electricity production from it to 25% of total Polish electricity production occurred in 2020 (cf. Fig. 5 and Table 2). This is obviously a consequence of the development of the COVID-19 pandemic and the significant economic slowdown [27,28].

It should be recalled that, in communist times (before 1990), the environmental, social and economic issues characterised above were subordinate to state policy. This means that environmental protection and, for example, resettlement of the rural population from areas for planned lignite mines and lignite-fired power plants were not taken into account by the communist governments. This changed after 1989 when democracy commenced, and the centrally controlled economy began to gradually transform into an increasingly liberal economy. However, real changes came in 2004, i.e., after Poland's accession to the EU [3,24]. Since 2004, subsequent democratic governments in Poland have had to take into account both social protests, including pro-ecological organisations, and the climate and energy policy of the EU [50]. Over the last 20 years, Poland has contributed new plans related to energy and climate policy for the coming decades. In 2021, a document entitled "Energy Policy of Poland until 2040" was created [14]. It replaced the documents "Energy Policy of Poland until 2030" and "Energy Security and Environment – perspective until 2020" [3]. However, the geopolitical situation (COVID-19, the war in Ukraine) has forced a new approach to energy security, as well as to the diversification of energy sources and energy independence. Hence, it was already necessary to modify PEP2040 [14] in 2022. These modifications are included in the "Principles for the update of the Energy Policy of Poland until 2040" [13]. The downward trend in lignite mining and electricity production described above reached its minimum in 2020 when the global economy was locked down due to COVID-19 pandemic. In turn, the reversal of the trend in 2021–2022 was closely related to post-pandemic economic rebound and Russia's aggression against Ukraine (cf. Fig. 5 and Table 2; [17,20,21,28,55–58]). A significant increase in electricity production, and therefore lignite mining, was facilitated by the commissioning of a new power unit (496 MW) at the Turów power plant in 2021 [27,28].

The current Polish energy policy is inextricably linked with the national climate policy and the climate and energy policy of the EU. In the latter case, it is assumed that the EU will achieve climate neutrality by 2050. It should be added that the European Council approved the updated EU climate goals in 2020. They are as follows: 1) reduction of net emissions of greenhouse gases (GHG) by at least 55% by 2030, compared to the level in 1990; 2) over 32% share of renewable sources in gross final energy consumption; 3) increase in energy efficiency by 32.5%; and 4) completion of the EU internal energy market [14]. In EPP2040 [13] it is stated, in relation to PEP2040 [14], that Poland's energy sector will be based on the following four pillars:

- energy sovereignty;
- just energy transition;
- zero-emission energy system;
- good air quality [13].

The above-mentioned pillars of Poland's future energy policy include the following main changes in PEP2040 [14]:

- increasing technological diversification and extension of capacity based on national energy sources;
- further development of renewable energy sources;
- improving energy efficiency;
- further diversification of supplies and providing alternatives for hydrocarbons;
- adjustment of investment decisions related to gas production capacity to fuel availability;
- maintaining the readiness of coal/lignite units to operate in accordance with their technical lifetime;
- implementation of nuclear energy (large or small modular reactors);
- grid and energy storage development (high level of cybersecurity);
- negotiations regarding the reform of the EU's climate policy [13].

7. Polish lignite-based energy and mining sectors – future predictions

The Polish energy sector was over 75% dependent on coal, including over 25% on lignite in 2022 (see Fig. 2). The economic crisis caused by the COVID-19 pandemic has shown the weakness of the hard coal industry compared to the lignite industry [28]. In other words, a decline in hard coal output (for the first time in history, less hard coal than lignite was mined in 2022; [20]) was balanced by increased lignite extraction. As a result, the role of lignite in Poland's energy industry increased in 2021–2022 (cf. Figs. 2 and 5 and Tables 1 and 2). Regardless of external geopolitical conditions, the transition of the Polish energy sector was progressing too slowly in the period 2015–2023. At that time, the populist governments of right-wing parties almost completely stopped the development of onshore wind energy [52]. In this case, it was the "Distance Act" of 2016, which introduced a provision prohibiting the construction of wind farms at a distance from residential buildings, i.e., less than 10 times the height of the wind turbines: the so-called "Rule 10H". According to various estimates, this rule excluded as much as 99.5% of Polish territory from wind investments. Fortunately, this may change soon because the last elections in Poland (October 2023) were won by democratic parties. Their electoral programs included a drastic reduction in the role of coal/lignite in Poland's energy mix in the coming years. It should be noted, however, that, unlike wind energy, solar energy is developing very quickly. This is confirmed by over a hundred-fold increase in installed capacity in photovoltaics (PV) in 2016–2022 (from 0.11 to approx. 12.00 GW) ([52]; supplemented).

Unfortunately, the authors of this paper have to express their scepticism in achieving the above-mentioned goals of these very ambitious plans by 2030, 2040 or 2050 [13,14,21]. Our opinion has both historical and factual justification. In the case of lignite, in the 33 years since the fall of communism, the share of lignite in electricity production has decreased from approx. 35% to approx. 25%. If average electricity consumption in Poland grows at its constant current rate (1.2 TWh/year; see Section 4), then, by 2050 electricity production must be at least 30–40% higher than today. This means that it is not enough to replace approx. 25% of electricity from lignite (e.g., with nuclear, gas or renewable energy), but it will be necessary to supplement the estimated missing 30–40%. Thus, the total gap in the energy system may exceed 100–120 TWh in 2050. Finally, it should be stated that it is possible to limit or even end the generation of electricity from lignite. On the contrary, however, in light of the data presented, complete independence of the Polish energy sector from hard coal by 2050 is unlikely. In unpublished opinions, both scientific and decision-making bodies, including those of the authors of this paper, plans to reduce the production of electricity from coal (hard coal and lignite together) to 37.5% by 2030 and to 11% by 2040 are completely unrealistic [14].

8. Discussion

Poland has huge proven recoverable (geological) resources of coal, including lignite. In the latter case, with current extraction, there would be enough for 400–500 years. Nevertheless, both Polish citizens and subsequent Polish governments have realised that the dominance of coal (> 75% in 2022) in the energy sector is coming to an end. This general direction is consistent with the EU's energy and climate policy but the differences are in the pace of transition of the Polish energy sector. Of course, this transition offers great opportunities to reduce GHG emissions. Nevertheless, Poland is moving too slowly away from coal (hard coal and lignite), on which it is still very dependent.

The complete abandonment of coal in Poland's energy sector seems superficially simple. This is due to historical (in recent decades, even > 98% of electricity came from coal), social (tens of thousands of Poles still work in mining and the coal-based energy industry) and political/geopolitical reasons. In national politics, successive governments were afraid of conflict with the mining and energy industries, as well as protests by local communities, for example, against the development of nuclear power plants or onshore wind farms. In turn, geopolitical factors, such as the COVID-19 pandemic or the war in Ukraine, have assured opponents of rapid energy transition that national reserves of hard coal and lignite are able to ensure Poland's energy security. As shown in this paper, the COVID-19 pandemic caused the largest decline in the demand for electricity in the analysed time period (1990–2022) than since the collapse of communism in Poland in 1989. On the other hand, the post-pandemic energy rebound was mainly due to a strong increase in electricity generation from lignite. This contributed to a reduction in import and a slight surplus of production over electricity consumption in 2022 (cf. Fig. 1 and Table 1).

Poland's fundamental aim is to reduce GHG emissions, leading to improved air quality, initially through a significant reduction and then elimination of coal in electricity production. On a local scale, it is also important to move away from coal, both in heating individual buildings and municipal heating. Therefore, it is currently assumed that Poland's energy industry will become independent from coal because of the development of renewables and nuclear and gas energy in the next 10–25 years. This is mainly to be achieved through the introduction and popularisation of offshore wind energy, small-scale PV and nuclear energy. The construction of the first nuclear reactors, both large and modular, is at the planning stage, so their quick integration into the energy system is uncertain. According to the current, optimistic plans of Poland's energy policy [13,14], it is assumed that 16% of electricity will come from nuclear power plants in 2040. On the other hand, solar PV and wind energy (adding gas energy) cannot ensure energy stability in unfavourable Polish climatic conditions. Currently, less than 30% of the power capacity installed in renewable energy sources is effectively used.

In light of the presented facts, the plans of the Polish energy policy and, to the best of the authors' knowledge, it must be stated that complete independence from coal by 2050 will be very difficult, expensive or even impossible. Most likely, by the end of 2025 (oral information from the Konin Lignite Mine), lignite will be exploited in the Tomisławice opencast, and electricity from it will be produced at the Pątnów power plant (see Fig. 4). This means a loss of capacity installed in lignite-fired power plants by over 1.1 GW (three old Pątnów I units and one new unit in Pątnów II) in the coming months. In the following years (in the authors' opinion), old power units in the two remaining lignite-fired power plants (i.e., Bełchatów and Turów) with an efficiency below 44% should be turned off first. This is justified by the fact that they are the most harmful to the environment. The last power units to be turned off, probably in 2038 and 2044, will be the most modern units in the Bełchatów and Turów power plants, respectively. This will be tantamount to the end of lignite mining in Poland after 150 years of its history. However, to ensure Poland's energy security, the reserve of stable power obtained from hard coal will most likely have to remain in the energy system for longer.

9. Conclusions

This opinion study provides a concise overview of the transition process of the Polish lignite-based energy and mining industries over the last 40 years. Despite huge lignite resources in Poland, the end of its mining and combustion in power plants to produce electricity seems certain. This is in line with both domestic and EU climate policies.

The process of transforming the Polish energy sector will have to overcome at least several difficulties in the coming years. Firstly, thousands of people employed in lignite-fired power plants and lignite mines will lose their jobs. Secondly, in an uncertain geopolitical situation (e.g., pandemic or war), electricity produced from domestic fossil fuels seems to be a good basis for the entire Polish energy system. And thirdly, excluding hard coal and lignite, Poland currently has underdeveloped other energy sources such as renewables and nuclear energy.

To sum up, we should appeal to Polish decision-making bodies to accelerate the transition of the Polish energy sector, including the one based on lignite. This can be achieved through the intensive development of renewable energy (mainly wind and solar) and the construction of at least several units in nuclear power plants. After completing the above-mentioned projects, it is possible to end the production of electricity from lignite in Poland by the mid-2040s.

Ethical statement

The authors state that the research was conducted according to ethical standards.

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Conflicts of interest

The authors declare no conflict of interest.

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