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Polish lignite resources, mining and energy industries – what is next?

Introduction

The Polish energy industry (as well as the entire national economy) have developed intensively since the Second World War on the basis of rich lignite resources. This required geological exploration, mining and the construction of lignite-fired power plants. Geological exploration required thousands of boreholes to be drilled to depths ranging from several dozens to several hundred meters. As a result, more than 150 lignite occurrences were identified, of which nearly 100 can be called deposits (Kasiński 2010; Kasiński et al. 2006; Mazurek and Tymiński 2023; Widera 2016, 2021).

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In this study, the management of lignite deposits, mining and the lignite-based energy industry after 1989 (i.e. since the collapse of communism in Poland) were subjected to a detailed analysis. In this time interval, 25–35% of Polish electricity was generated from lignite (e.g. PSE 2023; Widera et al. 2016) and its role in the national energy mix is set to remain significant for at least two more decades (e.g. EPP2040 2022; Kasztelewicz at al. 2018; Naworyta 2022, 2023; PEP2040 2021; Project… 2014; Tajduś et al. 2014). Between 1990 and 2022, at least a dozen opencast lignite mines operated, of which only five remained by the end of 2023. The opening and closing of subsequent opencasts caused social, economic, environmental and climatic conflicts (e.g. Badera and Kocoń 2014; Brauers and Oei 2020; Naworyta and Badera 2012; Uberman and Naworyta 2012). The impact of Covid-19 and the war in Ukraine has had a clearly visible impact on the Polish mining and lignite-based energy industries (BP 2023; Hebda 2023; Naworyta 2023).

In the context of the current EU climate policy, domestic policy and geopolitical situation, the protection of Polish lignite deposits takes on a different meaning than before. Thus, the main goals of this study are as follows:

1) outline the position of the Polish mining and energy industry in a European and global context;
2) present the lignite resources and deposits in Poland;
3) characterize mining and lignite-based electricity production in Poland;
4) discuss the future of Polish lignite resources, including new proposals for the legal protection of its deposits.

1. The background of global and European lignite mining and lignite-fired energy

1.1. Production and consumption of lignite

Global production and consumption of lignite are almost equal, thus, according to the latest available data (Table 1; BRG 2022), they will be characterized together. In 2020, Poland ranked sixth in the world, with 56.0 Mt of lignite extraction. In the European rankings, it is the fourth largest producer after Germany, Russia and Turkey (with annual lignite productions of 107.4 Mt, 73.3 Mt and 71.2 Mt, respectively). In the EU, but also among Euracoal members, Poland is second after Germany (Table 1; Euracoal 2021).

Data from 2015 and 2022 (included in Table 1) clearly show two opposite trends in lignite mining. In most European countries, especially those belonging to the EU, there has been a clear decline in production, for example, in the comparable years, 178.1 and 107.4 Mt of lignite were extracted in Germany, and 63.1 and 46.0 Mt were extracted in Poland. This means a decrease in lignite mining between 2015 and 2020 by 40.0 and 27.1%, respectively. By contrast, in non-EU countries such as China and Turkey, lignite production significantly increased in these years (Table 1).

Table 1. Top twenty countries with the largest lignite production in the world in 2015 and 2020

Tabela 1. Czołowe 20 krajów z największą produkcją węgla brunatnego na świecie w latach 2015 i 2020

No.	Country/region	Production in 2015 (Mt)	Production in 2020 (Mt)
1.	China	206.0	260.0
2.	Germany	178.1	107.4
3.	Russia	73.2	73.3
4.	Turkey	56.1	71.2
5.	Indonesia	60.0	60.0
6.	**Poland**	**63.1**	**46.0**
7.	USA	64.3	44.8
8.	Australia	61.0	40.4
9.	Serbia	37.7	39.7
10.	India	43.8	36.6
11.	Czechia	38.1	29.5
12.	Bulgaria	35.9	28.0
13.	Romania	25.5	15.0
14.	Laos	4.5	15.3
15.	Greece	46.2	13.9
16.	B & H[1]	12.2	13.6
17.	Thailand	15.2	14.1
18.	Mongolia	5.8	9.8
19.	Kosovo	8.2	8.5
20.	Canada	9.2	7.2
	European Union	401.2	244.3
	Europe	523.4	384.3
	World	1,089.0	965.9

BGR 2022; Euracoal 2021.
[1] B & H – Bosnia and Herzegovina; Poland is marked in bold.

1.2. Role of lignite in electricity generation

The share of different sources of electricity varies greatly depending on the country, its own fossil fuel base and its geographical location, i.e. its climatic zone. Thus, hard coal, renewables and gas dominate global electricity production (85% in total). The remaining

15% comes from nuclear power, oil and lignite – 3%. Renewable energy sources predominate in the EU (40%), followed by nuclear energy (22%) and gas (20%). In the EU-27 countries, a total of 16% of electricity is produced from coal (8% from hard coal and 8% from lignite), while the remaining 3% comes from oil (Figure 1).

Unfortunately, Poland still has a very unfavorable energy mix structure, which it inherited from the twentieth century. In 2022, 50% of electricity was generated from hard coal and 27% from lignite. The third position is taken by renewables (17%) and the fourth by

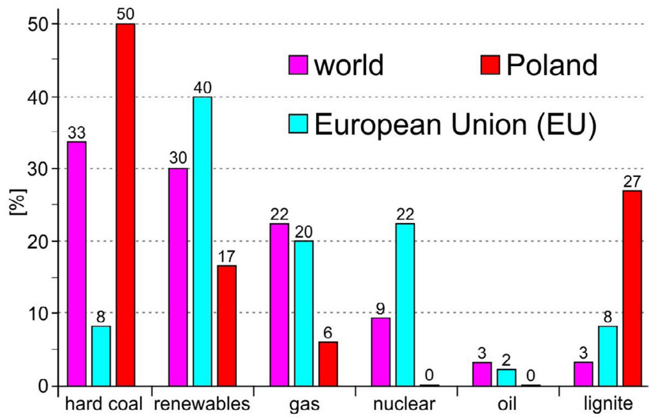

Fig. 1. Structure of electricity generation from various sources, including lignite, in 2022
(EMBER 2023; Energy-Charts 2023; IEA 2023; PSE 2023)

Rys. 1. Struktura produkcji energii elektrycznej z różnych źródeł, w tym z węgla brunatnego, w 2022 roku

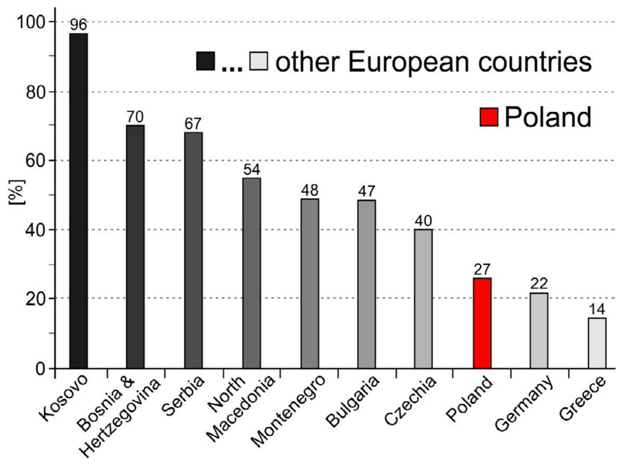

Fig. 2. Top ten countries with the largest share of lignite in national electricity production in 2022
(EMBER 2023; Energy-Charts 2023; PSE 2023)

Rys. 2. Czołowe 10 krajów z największym udziałem węgla brunatnego w krajowej produkcji energii elektrycznej w 2022 roku gas (6%). It should be noted that in Poland, electricity is produced from oil in trace amounts (<0.5%) and is not yet produced from nuclear sources (Figure 1). However, there are seven countries in Europe where lignite plays a greater role in the energy mix than in Poland (e.g. Ediger et al. 2014; Jovančić et al. 2011; Kavouridis 2008; Sivek et al. 2020). In four countries

Table 2. Top twenty countries with the largest lignite resources and reserves around the world at the end of 2020

Tabela 2. Czołowe 20 krajów z największymi zasobami i rezerwami węgla brunatnego na świecie na koniec 2020 roku

No.	Country/region	Resources (Gt)	Country/region	Reserves (Gt)
1.	USA	1,368.1	Russia	90.5
2.	Russia	541.4	Australia	73.9
3.	Australia	403.7	Germany	35.7
4.	China	323.8	USA	29.9
5.	**Poland**	**322.4**	Indonesia	14.7
6.	Viet Nam	199.9	Turkey	11.0
7.	Pakistan	176.7	China	8.3
8.	Mongolia	119.4	Serbia	7.1
9.	Canada	118.3	NZ[1]	6.8
10.	India	40.0	**Poland**	**5.8**
11.	Indonesia	37.0	Brazil	5.0
12.	Germany	36.5	India	5.0
13.	Serbia	13.1	Greece	2.9
14.	Brazil	12.6	Pakistan	2.9
15.	Romania	9.6	Hungary	2.6
16.	Kosovo	9.3	Czechia	2.5
17.	Argentina	7.3	Ukraine	2.3
18.	Czechia	7.1	B & H[2]	2.3
19.	Ukraine	5.5	Canada	2.2
20.	Turkey	5.3	Bulgaria	2.2
	European Union	287.1	EU	52.7
	Europe	318.2	Europe	75.5
	World	3,681.5	World	320.5

BGR 2022.
[1] NZ – New Zealand;
[2] B & H – Bosnia and Herzegovina; Poland is marked in bold.

(Kosovo, Bosnia and Herzegovina, Serbia, and North Macedonia), more than 50% of the electricity comes from burning lignite. Kosovo leads in this ranking, where as much as 96% of domestic electricity is still generated in lignite-fired power plants (Figure 2; Di Bella and Thaci 2023; EMBER 2023).

1.3. Lignite resources and reserves

International classifications of deposits, including lignite, differ from those from Poland in terms of terminology and meaning (compare JORC 2012; Nieć et al. 2014; Sobczyk and Nieć 2017; Thomas 2023). Therefore, data compiled by the Federal Institute for Geosciences and Natural Resources (BGR 2022) is presented first, which can be easily compared (Table 2). The largest lignite resources (inferred resources) in the world are held by the USA, Russia and Australia, while the leaders, in terms of reserves (proved reserves), are Russia, Australia and Germany. In the global ranking of lignite reserves, apart from Russia, Germany and Poland, there are two more European countries, namely Turkey and Serbia. It should be noted that Europe has less than a tenth of the global resources and a quarter of the world's reserves of this raw mineral (Table 2).

Poland ranks fifth in the world, with total geological lignite resources (inferred resources) being estimated at 322.4 Gt. Its reserves (well-documented economic, balanced resources – proved reserves) were calculated at 5.8 Gt, which gives Poland tenth place (Table 2). In contrast to the international classification discussed here, the national classification of lignite resources and reserves in Poland is characterized below.

2. Resources and deposits of lignite in Poland

2.1. Measured resources

The main source of information for Polish lignite resources are two cyclical reports, specifically *Mineral Resources of Poland* (e.g. Tymiński and Mazurek 2022) and *The balance of mineral resources deposits in Poland* (e.g. Mazurek and Tymiński 2023). The largest part of the geological resources, in ninety-one deposits, is referred to as 'anticipated economic resources' in the studies mentioned. Their amount was estimated at 23.1 Gt at the end of 2022 (Mazurek and Tymiński 2023). Using the international classification, they are closest to measured resources (Nieć et al. 2014; Sobczyk and Nieć 2017). It is worth noting that the rapid increase in lignite resources was from ~13.5 Gt to ~23.5 Gt in the 2009–2011 period (Figure 3). This resulted from the inclusion of measured resources (reserves) in some poorly explored deposits in the balance, i.e. category D, according to the Polish classification (Naworyta 2016; Tymiński and Mazurek 2022).

2.2. Proved reserves

The measured ('anticipated economic') resources discussed above (Figure 3) include those that were initially documented and those that were documented in detail. In the latter case, these are both mined deposits (~1.0 Gt) and unmined deposits containing ~5.8 Gt of lignite (Mazurek and Tymiński 2023). The ~5.8 Gt of lignite can be described as a strategic reserve (i.e. it should be subject to legal protection) and the deposits in which it occurs as proven reserves in the international classification (JORC 2012; Thomas 2023), or simply 'reserves' (see Table 2).

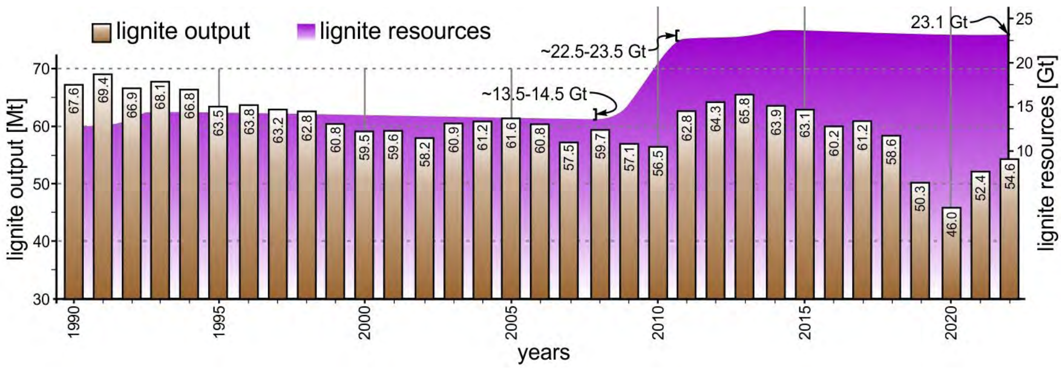

Fig. 3. Changes in lignite mining and geological (measured, 'anticipated economic') resources in Poland in the years 1990–2022 (Mazurek and Tymiński 2023; Tymiński and Mazurek 2022)

Rys. 3. Zmiany w wydobyciu i zasobach geologicznych węgla brunatnego w Polsce w latach 1990–2022

2.3. Lignite deposits

The majority of Polish lignite deposits cover an area of ~70,000 km^2 in central-western Poland. Out of >150 identified occurrences, sixty-nine of the most important deposits that meet the balance criteria are characterized in this study (Figure 4). These criteria include three geological and mining parameters (thickness of lignite layer >3 m, depth of the deposit floor <350 m, and overburden ratio <12), as well as one chemical and technological parameter (net calorific value >6.5 MJ/kg) (Table 3; Kasztelewicz 2004; Mazurek and Tymiński 2023; Tymiński and Mazurek 2022; Widera 2021).

Table 3. Basic geological and mining parameters and genetic types of the main lignite deposits in Poland

Tabela 3. Podstawowe parametry geologiczno-górnicze i typy genetyczne głównych złóż węgla brunatnego w Polsce

Deposit number	Deposit name	Amount of geological resources (Mt)	Average seam or seams thickness (m)	Overburden ratio	Average depth of seam (m)	Genetic deposit type
1	Rogi–Rudnica	76.5	5.4	11.3	66.4	epeirogenic
2	**Sieniawa 1, Sieniawa 2**	**17.6**	**10.2–19.0**	**3.0**	**37.2–39.6**	**glaciotectonic. epeirogenic**
3	Rzepin	249.5	12.2	7.9	97.3	epeirogenic
4	Torzym	1005.5	21.4	7.9	180.8	epeirogenic. tectonic
5	Cybinka–Sądów	295.5	8.3–13.5	9.1	136.6	epeirogenic. tectonic
6	Gubin–Zasieki–Brody	1934.3	18.8	7.2	162.9	epeirogenic. tectonic
7	Mosty	381.1	9.1	8.0	82.7	glaciotectonic. epeirogenic
8	Parowa–Ruszów–Węgliniec	36.1	8.6	6.8	67.5	epeirogenic
9	Radomierzyce	503.7	18.0	4.3	95.3	tectonic
10	**Turów**	**290.1**	**34.0**	**2.1**	**95.0**	**tectonic**
11	Radojewice	63.2	6.3	10.0	69.5	epeirogenic. tectonic
12	Chełmce	44.3	6.1	9.2	59.7	epeirogenic. tectonic
13	Radziejów	52.4	6.1	8.3	56.4	epeirogenic. tectonic
14	Włocławek	43.2	4.2	10.3	47.4	tectonic. epeirogenic
15	Piotrków Kujawski	22.5	7.7	7.9	57.5	epeirogenic. tectonic
16	Pątnów V	50.5	9.2	8.7	54.5	epeirogenic. tectonic
17	Morzyczyn	26.1	5.7	8.4	53.9	tectonic. epeirogenic
18	**Tomisławice**	**39.9**	**6.5**	**6.9**	**46.1**	**epeirogenic. tectonic**

Deposit number	Deposit name	Amount of geological resources (Mt)	Average seam or seams thickness (m)	Overburden ratio	Average depth of seam (m)	Genetic deposit type
19	Mąkoszyn–Grochowiska	50.2	5.9	8.8	55.0	epeirogenic. tectonic
20	Pątnów IV	closed	–	–	–	tectonic. epeirogenic
21	Lubstów	closed	–	–	–	tectonic
22	Pątnów I–III	closed	–	–		tectonic. epeirogenic
23	Dęby Szlacheckie–Izbica Kujawska	112.6	8.0	8.5	80.3	epeirogenic. tectonic
24	Niesłusz–Gosławice	closed	–	–	–	tectonic. epeirogenic
25	Morzysław	closed	–	–	–	tectonic. epeirogenic
26	Drzewce	closed	–	–	–	tectonic. epeirogenic
27	Rumin	3.2	2.6	1.2	5.8	epeirogenic
28	Ochle	0.4	4.3	1.2	9.3	epeirogenic
29	Piaski	103.6	6.1	7.3	48.5	tectonic. epeirogenic
30	Władysławów	closed	–	–	–	tectonic. epeirogenic
31	Koźmin	closed	–	–	–	tectonic. epeirogenic
32	Siąszyce–Grochowy	50.3	6.3	8.4	56.6	tectonic. epeirogenic
33	Adamów	closed	–	–	–	tectonic. epeirogenic
34	Uniejów	41.9	3.8	6.7	28.2	epeirogenic
35	Rogóźno	419.1	35.6	4.3	189.5	karstic
36	Złoczew	612.0	51.4	5.0	266,6	tectonic. karstic
37	Wieruszów	117.6	7.5	9.1	75.8	tectonic. epeirogenic
38	**Szczerców**	**595.5**	**50.3**	**2.3**	**171.0**	**tectonic. karstic**

Deposit number	Deposit name	Amount of geological resources (Mt)	Average seam or seams thickness (m)	Overburden ratio	Average depth of seam (m)	Genetic deposit type
39	**Bełchatów**	**44.7**	**52.4**	**3.3**	**186.1**	**tectonic. karstic**
40	Kamieńsk	132.4	18.1	9.2	184.6	tectonic. karstic
41	Szamotuły	229.2	23.1	7.6	179.6	tectonic. epeirogenic
42	Naramowice	212.4	28.0	6.9	212.5	tectonic. epeirogenic
43	Poznań Town	652.1	19.0	8.8	186.1	tectonic. epeirogenic
44	Mosina	1580.5	33.6	5.8	227.5	tectonic. epeirogenic
45	Środa Wlkp.	249.6	10.4	8.9	103.0	epeirogenic
46	Cykowo–Sepno–Racot	110.6	12.8	11.6	161.9	epeirogenic
47	Czempiń Town	361.1	29.5	6.4	219.5	tectonic. epeirogenic
48	Czempiń	1034.6	33.4	7.6	231.9	tectonic. epeirogenic
49	Krzywiń	666.5	33.3	7.1	249.9	tectonic. epeirogenic
50	Góra	818.4	24.8	7.9	220.9	epeirogenic. tectonic
51	Pogorzela	142.6	29.7	6.8	233.2	tectonic. epeirogenic
52	Poniec–Krobia	1749.7	14.7	9.2	204.3	epeirogenic
53	Gostyń	1988.8	33.7	6.3	245.4	tectonic. epeirogenic
54	Oczkowice	996.3	12.8	9.7	133.4	epeirogenic. tectonic. glaciotectonic
55	Sulmierzyce	89.9	19.3	8.9	172.0	tectonic. epeirogenic
56	Ścinawa–Głogów	9949.2	28.5	7.5	243.3	epeirogenic
57	Ścinawa	1568.6	22.6	9.1	214.6	epeirogenic
58	Legnica North	1465.4	23.0	8.1	209.1	epeirogenic

Deposit number	Deposit name	Amount of geological resources (Mt)	Average seam or seams thickness (m)	Overburden ratio	Average depth of seam (m)	Genetic deposit type
59	Legnica West	863.6	21.0	6.6	158.8	tectonic. epeirogenic
60	Legnica East	839.3	18.1	7.6	155.4	tectonic. epeirogenic
61	Ruja	305.1	16.8	8.0	140.4	tectonic. epeirogenic
62	Więcbork	509.1	20.0	9.0	200.1	tectonic
63	Trzcianka	610.2	4.6	9.0	46.4	epeirogenic
64	Nakło	245.3	18.5	7.3	149.5	tectonic
65	Wąbrzeźno	34.6	6.7	5.9	46.0	epeirogenic
66	Drezdenko	141.4	8.3	10.7	97.2	epeirogenic
67	Głowaczów	76.3	4.8	6.5	37.1	epeirogenic
68	Wola Owadowska	13.3	4.8	2.9	18.8	epeirogenic
69	Owadów	3.0	4.0	4.4	21.8	epeirogenic

Bielowicz and Kasiński 2014; Kasiński et al. 2006, 2019; Kasiński and Urbański 2022; Mazurek and Tymiński 2023; Urbański and Widera 2016; Widera 2016.

The resources of the Poniec–Krobia deposit highlighted in red contain most of the resources that were included in the geological resources of the Oczkowice deposit in the latest documentation; deposits exploited at the end of 2023 are marked in bold.

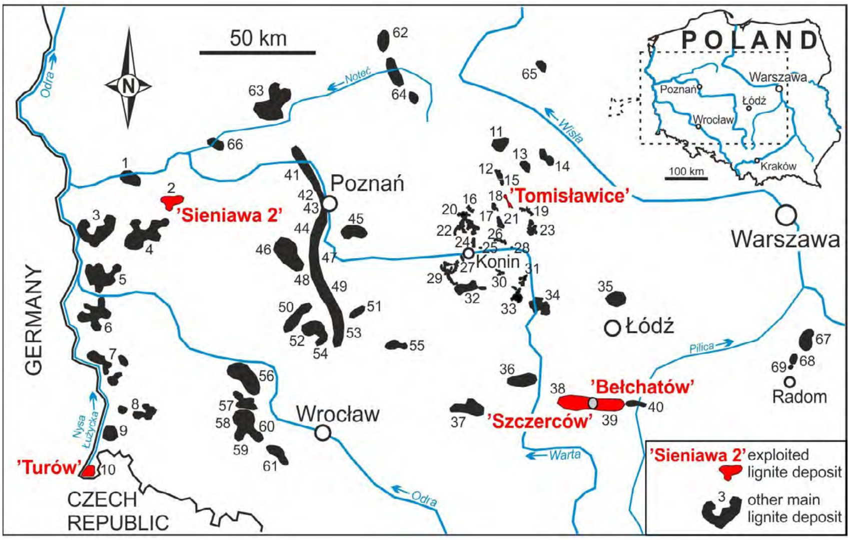

Fig. 4. Main lignite deposits in Poland with those marked as being mined at the end of 2023.
For more details, see Table 3

Rys. 4. Główne złoża węgla brunatnego w Polsce z zaznaczonymi, eksploatowanymi na koniec 2023 roku

3. Lignite mining in Poland

3.1. Brief historical overview

Within the current administrative borders of Poland, lignite began to be mined in its southwestern parts as early as 1740. Over the next century, it was mainly exploited underground, but ground surface (opencast) mining also occurred on a local scale. In 1873, the *Glückauf* mine was opened and in 1904, this was followed by the *Herkules* mine which still operate today as the Sieniawa Lignite Mine and the Turów Lignite Mine, respectively. The latter was already large-scale industrial mining and, in 1937, >5 Mt of lignite was extracted there (Kasztelewicz 2004; Widera 2021).

A breakthrough in Polish lignite mining occurred during and immediately after World War II. Lignite extraction had already begun near Konin in 1942 (later called the Konin Lignite Mine) and, in 1964, near Turek (Adamów Lignite Mine). In 1980, the first tons of lignite were extracted from the (at that time largest) Bełchatów Lignite Mine. This led to a record output of 73.5 Mt in 1988, which was the largest in the entire history of Polish lignite mining (Kasztelewicz 2004; Tajduś et al. 2014). Finally, lignite extraction in the Adamów Lignite Mine ended in 2021 (Widera 2021; Widera et al. 2022).

3.2. Currently operating mines, opencasts and geology of some deposits

In recent years, the Bełchatów, Turów, Konin and Sieniawa lignite mines have been operating in Poland:. At the end of 2023, lignite was extracted from only five deposits: the Szczerców and Bełchatów (Bełchatów Lignite Mine), Turów (Turów Lignite Mine), Tomisławice (Konin Lignite Mine) and Sieniawa 2 (Sieniawa Lignite Mine) (Figure 4). In all cases, lignite exploitation currently takes place exclusively in opencast (surface) mines. It is worth mentioning the Gubin deposit near the border with Germany and the Złoczew deposit near the Bełchatów Lignite Mine (numbers 6 and 36 in Figure 4 and Table 3, respectively), which are prepared to start mining activity (Widera 2021). So far, lignite mining from both of these deposits has not started, mainly due to changes in the energy policy of Poland and the EU in recent years – this will be discussed in Section 5.

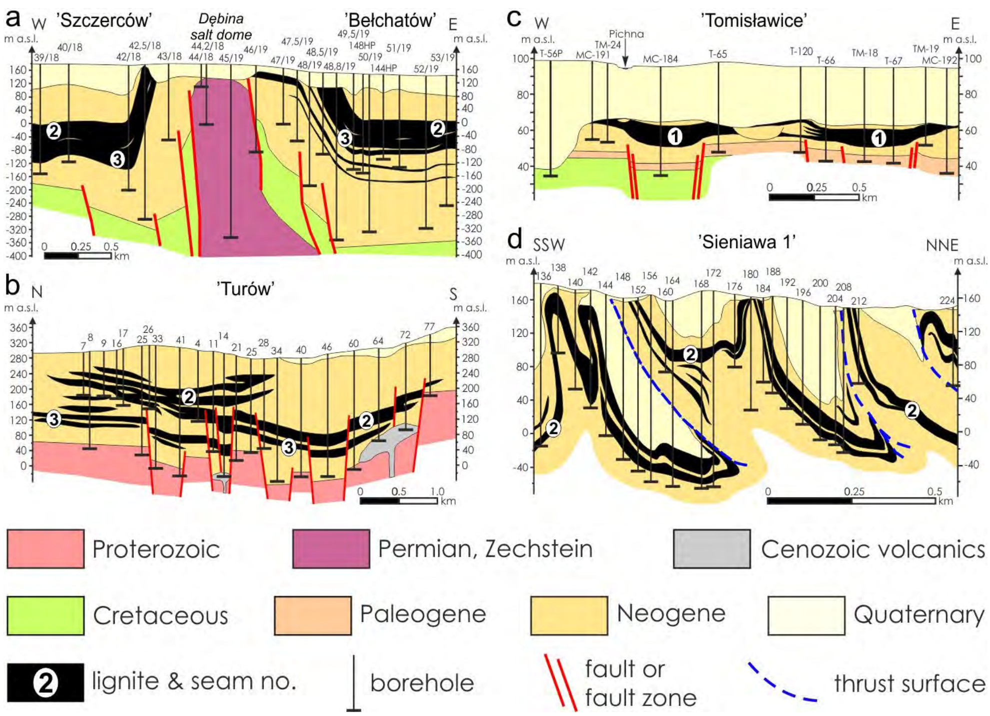

Fig. 5. Simplified geological cross-sections through the main exploited lignite deposits in Poland representing various genetic types
a – Gotowała and Hałuszczak 2002; Widera and Hałuszczak 2011; b – Kasiński 2000; Kasiński et al. 2019; c – Widera 2021; d – Kot and Widera 2018.
See Figure 4 for location and the text for lignite seam names

Rys. 5. Uproszczone przekroje geologiczne przez główne eksploatowane złoża węgla brunatnego w Polsce reprezentujące różne typy genetyczne

The geology of Polish lignite deposits in this study is briefly characterized in the currently exploited deposits. In general, they are divided into four genetic types: epeirogenic, tectonic, karstic and glaciotectonic (Widera 2016). Most of these represent the tectonic and/or epeirogenic type, from which >98% of lignite production comes. The remaining <2% is extracted from the Sieniawa 2 deposit, which is of the glaciotectonic type (Figures 4, 5; Table 3). It is worth noting that knowledge about the genetic type of lignite deposits influences their geological and mining parameters and, as a result, is useful when planning lignite exploitation in surface opencast mines.

The majority of Polish lignite deposits that have economic value, including those currently being mined, are of Early and Mid-Miocene age. The lignite mined from these belongs to three stratigraphically different seams. These are the third Ścinawa lignite seam – 3, the second Lusatian lignite seam – 2, and the first Mid-Polish lignite seam – 1 (Figure 5). The Szczerców and Bełchatów deposits, as well as the Turów deposit, fill tectonic grabens and are characterized by the thickest lignite seams with a maximum thickness of ~250 m and ~70 m, respectively (Figure 5a, 5b). By contrast, the 'Tomisławice' deposit, which covers a weakly expressed tectonic depression, has the thinnest lignite seam, with a maximum thickness of <12 m (Figure 5c). The 'Sieniawa 2' deposit is one of the best-developed glaciotectonic lignite deposits in the world. In this case, the mined lignite seam is strongly folded and faulted, in the form of numerous thrusts. Despite the large resources, the lignite from the Sieniawa 2 deposit is only exploited on a relatively small scale due to the complex geology (Figure 5c; Table 3). For more detailed information on the geology of other Polish lignite deposits, the interested reader is directed to the following publications and the literature cited therein: Kasztelewicz 2004; Kasiński 2010; Bielowicz and Kasiński 2014; Tajduś et al. 2014; Kasiński et al 2019; Widera 2016, 2021; Kasiński and Urbański 2022).

4. Lignite-fired electricity in Poland

4.1. Lignite-fired power plants

Almost all of the lignite mined in Poland is burned in power plants to generate electricity. In recent years, only three of these have been operational, namely the Bełchatów, Turów and Pątnów (Pątnów I and Pątnów II) power plants (Figure 6), which are fired with lignite and their total capacity is 8,201 MW. The largest power plant in Poland (and Europe) is Bełchatów (5,102 MW). The Turów and Konin power plants have an installed capacity of 1,981 MW and 1,118 MW, respectively. Unfortunately, most of the currently operating units in the above-mentioned lignite-fired power plants are outdated and have an efficiency below 44% (Naworyta 2022).

At this point, at least three facts should be noted. Firstly, lignite is usually burned in power plants located close to opencast mines. Secondly, an exception to this is the Sieniawa

Lignite Mine, where there is no large lignite-fired power plant nearby. Thirdly, lignite from this mine, approximately 0.5 Mt in 2022 and ~1 Mt in 2023, is transported and burned in the Pątnów power plant, which is over 230 km away (Figure 6).

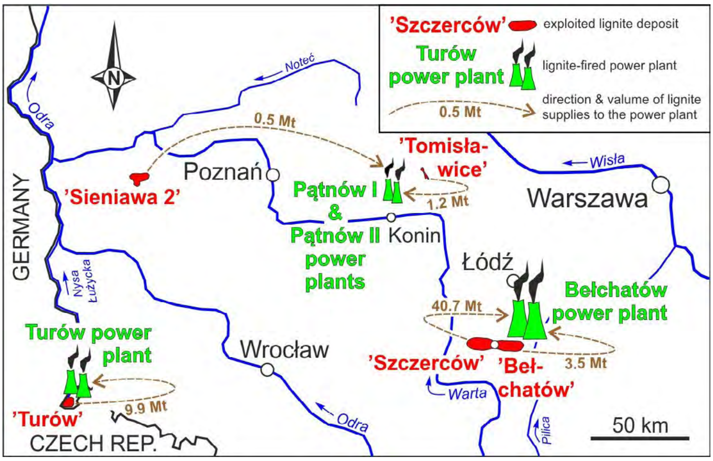

Fig. 6. Approximate amounts of lignite delivered from deposits to lignite-fired power plants in Poland in 2022 (Mazurek and Tymiński 2023; other data obtained from lignite mines). Compare with Figure 4

Rys. 6. Przybliżone ilości węgla brunatnego dostarczonego ze złóż do elektrowni opalanych węglem brunatnym w Polsce w 2022 roku

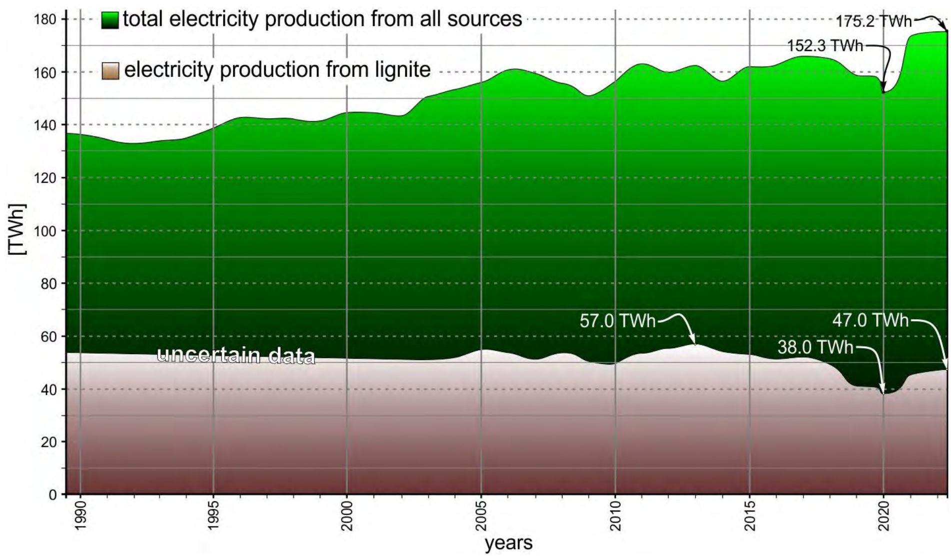

Fig. 7. Total of Poland's electricity generation versus electricity generated from lignite in the years 1990–2022 (PSE 2023)

Rys. 7. Całkowita produkcja energii elektrycznej w Polsce na tle energii elektrycznej wytworzonej z węgla brunatnego w latach 1990–2022

4.2. The role of lignite in electricity generation

In 2022, ~27% of electricity was produced from lignite, which represents the second most important source in the Polish energy mix after hard coal. In the years 1990–2022, however, the share of electricity from lignite in the Polish energy mix fluctuated from 25% to over 35%. In this time interval, the total electricity production in Poland was ~130–175 TWh, of which ~38–57 TWh came from lignite (Figure 7).

After 1989, there is a clear upward trend in the generation and consumption of electricity in Poland. The opposite, slightly downward trend, is visible in the mining and production of electricity from lignite (compare Figures 3, 7). Nevertheless, the biggest collapse, in both cases, relates to the Covid-19 pandemic in 2020 (Figure 7; Naworyta 2022, 2023).

5. What is next with lignite in Poland?

5.1. The mining and energy industry

The future of the energy industry and therefore lignite mining in Poland is contained in two fundamental documents. These are the *Energy Policy of Poland until 2040* (PEP2040 2021) and the *Principles for the update of the Energy Policy of Poland until 2040* (EPP2040 2022). The second document is a supplement to PEP2040 (2021) which was required due to the Covid-19 pandemic and the war in Ukraine.

According to the above documents, lignite active exploitation is expected until 2040. This contradicts the validity of the mining concession that the Bełchatów Lignite Mine holds until 2038, but the Turów Lignite Mine holds it until 2044 and the Sieniawa Lignite Mine has until 2063 (Widera 2021). Either way, lignite and electricity production from it will continue to decline in the coming years. According to the latest information from the Konin Lignite Mine, it will end operations at the end of 2024. In this situation, the old units in the Pątnów I power plant will be turned off and the Pątnów II power plant will remain, with a new unit with a capacity of 474 MW. In the following years, the power units will be turned off successively, from the oldest to the newest, and they are expected to generate electricity until 2038 and 2044 in the Bełchatów and Turów lignite-fired power plants, respectively (see Figure 6; Naworyta 2023).

5.2. Alternative methods of using lignite

In addition to the traditional use of lignite to produce 'dirty' electricity by burning it in power plants, there are other, so-called 'unconventional' methods of its utilization. These methods can be divided into three groups. In the first and second cases, lignite is gasified underground (*in situ*), i.e. in the deposit, or it is extracted from the deposit and gasified on the surface (*ex situ*), respectively (e.g. Hajdo et al. 2012; Bhutto et al. 2013; Mao 2016; Memon et al. 2016; Sobczyk et al. 2017). The third case involves biochemical processes in which appropriate species of bacteria or fungi are used for lignite gasification both *ex situ* and *in situ* (e.g. Ritter et al. 2015).

Unfortunately, the alternative, unconventional methods of using lignite for 'clean' electricity purposes have not yet been applied on an industrial scale in Poland, but they are used, among other places, in Russia, Tajikistan and the USA, as reported by Hajdo et al. (2012). This does not mean that there was and is no interest in the gasification of Polish lignite. Among the lignite deposits mentioned in this study (compare Figure 4 and Table 3), only five deposits (Ścinawa-Głogów, Torzym, Krzywiń, Gostyń, and Kamieńsk) indicate that they would be suitable for underground gasification (Bielowicz and Kasiński 2014). However, the Złoczew deposit was proposed as a site for launching the first underground lignite gasification installation in Poland, both pilot and commercial (Urbański and Widera 2020). However, numerous studies on the biogasification of Polish lignites have been intensively conducted in the last decade (e.g. Bucha et al. 2018; Detman et al. 2018; Szafranek-Nakonieczna et al. 2018; Pytlak et al. 2021).

5.3. The legal protection of lignite deposits

In Poland, the most important laws regarding the management and protection of mineral deposits are the *Geological and Mining Law* (GML 2011), the *Protection of Agricultural and Forestry Land Law* (PAFLL 1995) and the *Planning and Spatial Development Law* (PSDL 2003). Thus, the protection of lignite deposits, at the exploration and extraction stages, is subject to the same legal regulations as other mineral deposits (GML 2011). However, the rational management of them and their optimal use must also take into account environmental protection and local development plans (PAFLL 1995; PSDL 2003). These legal issues have been repeatedly discussed in case studies performed by a large group of Polish researchers (e.g. geologists, urban planners, and lawyers), including some of the authors of this paper (e.g. Kostka 2014; Lipiński 2015; Mikosz 2015; Mazurek et al. 2022; Mazurek and Szamałek 2022; Naworyta 2016; Nieć et al. 2014; Nieć and Radwanek-Bąk 2011; Szamałek et al. 2021; Uberman and Naworyta 2012).

Mineral extraction requires taking into account land management. This particularly applies to opencast (surface) mining, especially lignite mining, as it involves excluding large areas from agricultural or forestry production for many years. In accordance with the listed Polish regulations, the exploitation of any mineral (e.g. lignite) must be approved by the local authorities and included in the local spatial development plans of the community area (PAFLL 1995; PSDL 2003; GML 2011). It should be noted that the public administration, as well as the geological administration and mining supervision, are involved in the process of planning mining activities. In practice, however, there is a significant difference in their approaches to cooperation. We should also not forget about the emerging social and environmental conflicts mentioned in the initial sections of this study (e.g. Badera and Kocoń 2014; Kasiński et al. 2006; Naworyta and Badera 2012; Uberman and Naworyta 2012).

Conclusions

As shown above, lignite has played a fundamental critical role in the Polish mining and energy industries for decades. However, in light of the EU's energy policy, its role in generation in lignite-fired power plants will come to an end within the next twenty years. However, Poland still has huge well recognized and documented resources and reserves of lignite, distributed in numerous and genetically diverse deposits, the futures of which are unclear. Therefore, it seems justified to summarize the existing legal standards, and the practice of their application, and propose their changes in the following ways:

1. Documented but undeveloped (unmined) mineral deposits, including lignite do not have the same protection as exploited deposits in Poland. In the case of undeveloped deposits, the municipal authority only seeks non-binding opinions from the geological administration in the spatial planning process, while binding mining supervision arrangements are required for exploited deposits.
2. All undeveloped deposits, regardless of the amount of the resources and their economic value, are equally poorly and insufficiently protected in light of the current legal regulations. In the case of strategic deposits, they require particular protection against investments on the ground surface such as: housing, railways, and road construction, etc. Thus, this gap in the law must be filled as soon as possible.
3. The lack of a list of strategic deposits under special protection does not protect resources of significant importance for the Polish economy. However, on 28th October 2023, the *Geological and Mining Law* (GML 2011) was amended. This change is aimed at introducing the protection of deposits considered to be strategic by the Chief National Geologist. It is intended to protect selected deposits from industrial, road, railway and residential development.
4. The mentioned list of strategic deposits is not yet known, but lignite deposits are not expected to be included on it. Therefore, we suggest that up to a dozen lignite deposits that generate the least social and environmental conflicts should be covered by legal protection. The lignite contained in them can be used in the future (e.g. in unfavorable geopolitical conditions caused by war or pandemics) for chemical or biochemical processing to produce, among other benefits, 'clean' electricity. Thus, everything must be performed in accordance with the principle of sustainable development so as not to deprive future generations of opportunities for energy security.

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POLISH LIGNITE RESOURCES, MINING AND ENERGY INDUSTRIES – WHAT IS NEXT?

Keywords

lignite deposits, energy transition, lignite exploitation,
lignite power generation, deposits protection

Abstract

Poland is among the top ten countries in the world in terms of lignite resources (including reserves). With respect to lignite mining, its position is even higher at sixth in the world, fourth in Europe and second in the European Union (EU). The role of lignite in the Polish energy mix is crucial because ~27% of electricity was generated in lignite-fired power plants in 2022. However, there are countries in Europe where the dependence on lignite is much greater and currently in the range of 40–96%. Both the national and EU climate energy policy assumes the abandonment of lignite as a source of 'dirty' electricity within the next two decades. This ambitious goal is achievable but it may be threatened by the geopolitical situation. However, after 2040–2044, a large number of lignite deposits will remain in Poland. The deposits are well recognized and the detailed geology is well documented, with the estimated reserves intended for exploitation amounting to 5.8 Gt. These deposits, like the five which are currently mined, are stratigraphically diverse and characterized by a complex geology, representing different genetic types. In the context of a coal-free energy policy in the EU, the problem of the legal protection of lignite deposits remains. Thus, the question arises of what is next for Polish lignite deposits. They may be managed in the coming decades by using improved unconventional methods, such as *in situ* or *ex situ* gasification. Lignite deposits will constitute a strategic reserve in the event of a deep energy crisis caused by an unstable geopolitical situation. Finally, we suggest the urgent introduction of more precise legal changes that would protect at least part of the lignite resources in Poland for future generations.

POLSKIE ZASOBY WĘGLA BRUNATNEGO, GÓRNICTWO I ENERGETYKA – CO DALEJ?

Słowa kluczowe

złoża węgla brunatnego, eksploatacja węgla brunatnego, wytwarzanie energii z węgla brunatnego,
transformacja energetyczna, ochrona złóż

Streszczenie

Polska znajduje się w pierwszej dziesiątce krajów na świecie pod względem zasobów i rezerw węgla brunatnego. Pod względem wydobycia węgla brunatnego jej pozycja jest jeszcze wyższa, tj. szósta na świecie, czwarta w Europie i druga w Unii Europejskiej (UE). Rola węgla brunatnego w polskim miksie energetycznym jest kluczowa, gdyż w 2022 roku w elektrowniach nim opalanych

wytworzono ~27% energii elektrycznej. Zarówno krajowa, jak i unijna polityka klimatyczno-energetyczna zakłada w ciągu najbliższych dwóch dekad odejście od węgla brunatnego jako źródła „brudnej" energii elektrycznej. Ten ambitny cel jest możliwy do osiągnięcia, jednak może mu zagrozić sytuacja geopolityczna. Z drugiej strony, po latach 2040–2044, w Polsce pozostanie duża liczba złóż węgla brunatnego. Złoża są dobrze rozpoznane, szczegółowa budowa geologiczna dobrze udokumentowana, a szacowane zasoby przeznaczone do eksploatacji wynoszą 5,8 Gt. Złoża te, podobnie jak pięć obecnie eksploatowanych, są zróżnicowane stratygraficznie, charakteryzują się złożoną geologią oraz reprezentującą różne typy genetyczne. W kontekście bezwęglowej polityki energetycznej w UE pozostaje problem prawnej ochrony złóż węgla brunatnego. Rodzi się zatem pytanie: co dalej z polskimi złożami węgla brunatnego? Można je w nadchodzących dziesięcioleciach zagospodarować, stosując udoskonalone metody niekonwencjonalne, takie jak zgazowanie *in situ* lub *ex situ*. Złoża węgla brunatnego będą stanowić rezerwę strategiczną na wypadek głębokiego kryzysu energetycznego spowodowanego np. niestabilną sytuacją geopolityczną. Zatem sugerujemy pilne wprowadzenie bardziej precyzyjnych zmian prawnych, które chroniłyby przynajmniej część zasobów węgla brunatnego w Polsce dla przyszłych pokoleń.