Original article

The need for verification of the Polish lignite deposits owing to development and nature conservation protection on land at the surface

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ABSTRACT

Poland is a country rich in lignite. The area where the lignite occurs occupies approx. 22% of the total surface area of the country. Geological resources of Polish lignite deposits are estimated at 23.5 billion Mg, but in the majority (69%) the accuracy of their identification is poor. Nevertheless the amount of coal in Polish deposits allows - at least in theory - for mining and energy production at the current level for hundreds of years to come. It is an important raw material for the energy security of the country both currently and in the future. Because the vast majority of Polish and foreign mines use an open pit method for lignite extraction the actual amount of mineral available for the extraction depends not only on the properties of the deposit but to a large extent on the method of development of the surface land above the deposit, as well as on the sensitivity of the environment in the vicinity of any future mines. After careful analysis it can be stated that only a few of the lignite deposits may be subject to cost-effective mining operations. These deposits should be subjected to special protection as a future resource base which will ensure the energy security of the country. Some examples of domestic deposits have been presented where due to the conflict resulting from the development of the area should be deleted from the Balance Sheet of Mineral Deposits because their exploitation is irrational and uneconomic. Keeping such deposits in the Balance Sheet, and the use of large numbers in the context of their resource base leads to an unwarranted sense of wealth which consequently does not encourage the protection of these deposits which may actually be subject to rational exploitation in the near future. In summary there is a need to find a compromise in order to adequately protect all natural resources including mineral deposits.

KEY WORDS: lignite, nature conservation, the balance of resources, protection of deposits

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1. Introduction

Polish deposits of lignite have been subjected to a number of different classifications and rankings in which next to the properties of the deposits themselves the potential for the occurrence of conflicts, resulting from the likely mining operations and the development of areas with a high natural value, was also evaluated. e.g. in KASIŃSKI AT AL. (2006), NIEĆ AT AL. (2015), PIWOCKI & KASIŃSKI (1994), UBERMAN & OSTRĘGA (2008). As a result of these rankings, a list of deposits was established which due to the high value of minerals and the limited degree of the likely occurrence of conflict resulting from potential exploitation are predestined for development. A common feature of all rankings

is a high degree of simplified analysis and consequent generalization. It is understandable that, when dozens of different deposits are evaluated a detailed analysis of all the factors is impossible. An accurate analysis predicting the likely impact of mining operations on the environment is carried out only through the process of an environmental impact assessment when there is a likely development of the deposits.

In this study a contrasting approach is proposed which is based on the knowledge of the boundary of the deposits, the size of these resources, the method of land development above the deposits, and an evaluation of the natural values of these areas. As a result of this analysis a short list of deposits was created, which it is possible and

profitable to exploit today. These deposits should be subjected to special protection as a future resource base which will ensure the energy security of the country. The added value of this work is a realignment of the resource base. It is clear that Poland is only theoretically a country very rich in lignite because today a few dozen of lignite deposits don't represent any value from a mining perspective. Their exploitation from a cost and benefit point of view is unreasonable. Although these deposits – due to their geological nature and location - meet balance sheet criteria, however, they do not meet other economic criteria which result from an assessment of natural value or the intensity of development of the area above the deposits. Their exploitation is often all together impossible for formal reasons, and unprofitable in terms of costs.

The updated published list of mineral deposits, called the Balance Sheet of Mineral Deposits in Poland shows the deposits that meet certain criteria based on geological parameters (BILANS ZASOBÓW..., 2016). Such statements have only book value. To base policy about raw materials on such a balance sheet can lead to misleading conclusions and give rise to a false sense of wealth. This article proposes a realignment of this Balance Sheet of lignite deposits.

This study uses the GEOLOG resource databases of the Polish Geological Institute, and the GEOSERWIS databases of protected natural areas of the General Directorate for Environmental Protection.

2. Polish lignite resources

Lignite in Poland occurs in the Jurassic and Cretaceous, as well as Paleocene and Neocene formations. Today, only coals occurring in the Cenozoic formations represent economic importance as shown by CIUK & PIWOCKI (1990) and WIDERA AT AL. (2016). Coal seams occur in the central lowlands, in the western and central parts of the country. Among the places where this mineral occurs eight coal-bearing areas are recognised. Starting from the west these regions are - Western, North-Western, Legnica, Poznań, Konin-Adamów, Łódź, Bełchatów and Radom. In terms of surface these regions occupy a total of approx. 22% of the country (GEORAPORT, 2013).

Balance Sheet documents resources to a depth of 350 m, a single seam has a thickness of not less than 3 m, the maximum ratio of overburden thickness to seam thickness is 12:1, and the calorific value of coal in the raw state is not less than 6.5 MJ/kg. Given these criteria resources of Polish lignite deposits at the end of 2015 are

estimated at 23.5 billion Mg. In terms of properties and suitability for use, types of Polish lignite in the documented deposits are primarily energy coals, the remaining 0.64 million Mg are bituminous coals (BILANS ZASOBÓW..., 2016).

Currently lignite in Poland is used in the production of electricity in its power plants and also in district heating plants on a much smaller scale. The annual production of lignite is currently at the level of 64 million Mg and is closely related to the demand for this raw material from power plants. Approx. 30% of domestic electricity is produced from lignite. Lignite mines in Poland cover a total area of 17 248 ha which represents 0.055% of the surface area of the country (OCHRONA ŚRODOWISKA, 2015).

3. The accuracy of the recognition of Polish lignite deposits

Among the anticipated economic resources 1.42 billion Mg (6%) are resources in developed deposits in currently operating mines, approx. 5.84 billion Mg (24.8%) are resources of undeveloped deposits identified in detail, and the remaining 16.24 billion Mg (69%) are initially identified resources (BILANS ZASOBÓW..., 2016).

In the case of the majority of Polish unexploited lignite deposits the degree of identification is low. The accuracy of documentation of mineral deposits is well expressed by projected allowable estimation error of the size of resources which in the case of lignite deposits identified in the C₂ category is estimated at 40%, while for deposits identified in the D category the estimation error is above 40%. Approx. 69% of the Polish lignite deposits were identified in the C₂ + D categories, hence caution is recommended during any quantitative interpretation of resources, as well as restraint in formulating economic projections based on these estimates. Aside from this, the amount of lignite resources from domestic deposits makes possible, at least theoretically, exploitation and energy production at the current level for another several hundred years. It is important domestic raw material on which the energy security of the country can be based on.

Because the vast majority of Polish and foreign mines use an open pit method for lignite extraction the actual amount of mineral available for the extraction depends not only on the properties of the deposit but to a large extent on the method of development of the surface land above the deposit, as well as on the sensitivity of the environment in the vicinity of any future mines.

4. Natural environment values, land development in areas lying above the deposits and resulting restrictions for the exploitation of minerals

Over 32.5% of the country is subject to legal protection due to its high natural values (OCHRONA ŚRODOWISKA, 2015). Among the forms of nature protection in Poland the following stand out: National Parks (23) and Landscape Parks (122) along with their buffer zones, Protected Landscape Areas (PLAs) (396) nature reserves (1488), ecological sites (7539), natural monuments (30 258), documentation stations (172), nature and landscape complexes (253). Special form of nature protection include the Natura 2000 areas - special bird protection areas PLB (145) and special habitat protection areas PLH (849) (CRFOP). Bird protection areas cover approx. 15.8% of the country, and habitat protection areas approx. 11.2% (OCHRONA ŚRODOWISKA, 2015). Natura 2000 areas, in many cases, cover existing forms of protection of nature, but often protection is extended to areas previously unprotected, which from a European nature conservation perspective represent a particular value. The boundaries of areas of habitat and bird protection often overlap so it is difficult to assess the total area of the country covered by these forms of protection. Nevertheless, the introduction of the European Natura 2000 nature conservation network, means that the area of the country covered by nature protection legislation goes far beyond the above-mentioned 32.5%.

The ban on mineral exploitation in national parks, landscape parks, and nature reserves does not raise objections, these are areas of outstanding natural value. Within the limits of the protected landscape areas resource exploitation is difficult, although possible under certain conditions. The above forms of protection have been introduced gradually, while the introduction of the boundaries of the Natura 2000 sites was made quickly, in a non-transparent manner and without consultation with existing land users. This process has aroused much controversy. Often Natura 2000 sites were implemented in areas which entrepreneurs were holders of valid licenses for the exploitation of minerals. Although, theoretically mining is possible within Natura 2000 sites, the process of obtaining license for such exploitations, along with implementation of the necessary compensatory measures not only significantly increases the costs of mining activities but mainly causes a significant delay, as shown by UBERMAN & NAWORYTA (2012). It should also be noted that in

the hasty implementation process of the Natura 2000 sites popular habitats with no outstanding natural values were often covered with protection.

In addition to these forms of protection of natural resources we should also mention the protection of groundwater. Poland is not a country rich in water so activities violating the integrity of groundwater reservoirs raise understandable opposition. The occurrence of groundwater that meets certain criteria was identified across the country, and boundaries of the Main Groundwater Reservoirs (MGR) were set for them. Because open pit lignite mining requires dewatering of the deposit it is understood that the occurrence of MGR in the area of a deposit generates a conflict situation and hinders its possible exploitation.

High soil quality classes are also under statutory protection. Legally protected soils of class I-III cover approx. 30% of arable land including land for orchards.

5. Development of land above mineral deposits

The profitability of open pit mining processes depends on many factors among which the land development above the deposit is of considerable importance. In the open pit mining process the entire surface area above the deposit is transformed. Entrepreneurs engaged in mining activities are obliged to purchase the property and compensate lost value as a result of mining activities. Theoretically, mining operations are possible in all conditions. There were even cases where motorways were moved above exploited deposits. In some cases even entire cities lying above valuable deposits are eliminated. The cost-effectiveness of such a procedure is determined by the value, such as uniqueness of minerals, market value, raw materials policy of the state, as well as the amount of minerals justifying incurring large expenses for compensation of lost value after liquidation of the infrastructure/building occupying land above the deposit.

In Poland mineral deposits are the only natural resources which are not subject to legal protection. The actual protection begins after the granting of a license for their exploitation. The boundaries of documented deposits are obligatorily entered into municipal planning documents, however, this action does not provide protection for areas lying above the deposits against development, as stressed by UBERMAN (2011) and NIEĆ ET AL. (2014). The vast majority of Polish lignite deposits have been documented in the 1960s, and their boundaries are well known, yet on the areas lying above the deposits residential development is

progressing, often supra-local road projects such as motorways or highways run across the deposits. Examples of these will be presented later in this article.

6. Examples of deposits of unlikely exploitation

6.1. Deposits with small resources

The Balance Sheet of Resources includes deposits with volumes of resources between a few million to a few billion tons. In the 1980s attempts were made to develop small deposits for the needs of local heating and briquetting plants but the programme was not implemented. Lignite in reservoir conditions contains approx. 50% moisture, and as such is not suitable for transport over long distances. It is also characterized by a low calorific value, hence without processing does not represent an independent and cost-effective source of energy for small heating plants. Therefore, the exploitation of small deposits located far from existing lignite powered plants is irrational in the

current circumstances. It is unlikely that these small deposits will be the subject of future exploitation. The size of these resources is only one factor that suggests that these deposits should be removed from the Balance Sheet of Resources. The area above the majority of them is already developed. Small deposits are summarized in Table 1 along with an indication of their location and resources.

A separate group of small deposits represents residues left after extraction of bigger deposits. These residual deposits exist on the Balance Sheet as independent deposits but from the point of view of the possibility of their development they do not represent any value. Their operations have been discontinued so it is difficult to predict that the small resources left in the deposits will become the subject of future re-exploitation. Table 2 summarizes the resource deposits which remain after the end of previous exploitation. Resources of 30-small deposits listed in Table 1 and 2 represent a total of approx. 113.2 million Mg which is comparable to the average sized deposit.

Table 1. Deposits with small resources representing no value for separate exploitation, based on Bilans zasobów..., 2016

No.	Deposit	County	Anticipated economic resources (thousands of tons)
1	Antoni (Kalno)	świdnicki	2 092
2	Lusina - Udanin pole Płd.	średzki	7 402
3	Lusina - Udanin pole Płn.	średzki	3 085
4	Sadlno	ząbkowicki	95
5	Siedlimowice	świdnicki	1 791
6	Kobielice	radziejowski	6 688
7	Trzydnik	kraśnicki	180
8	Babina - łuska 0 I	żarski	4 381
9	Babina - łuska 0 II	żarski	1 329
10	Babina - łuska 0 III	żarski	5 318
11	Babina - strefa fałdowa f-g	żarski	1 960
12	Maria	nowosolski	72
13	Owadów	radomski	3 038
14	Wola Owadowska	radomski	13 314
15	Łączki	nyski	1 820
16	Polska Nowa Wieś	opolski	747
17	Adamów-soczewka Rogi	turecki	880
18	Dobrów	kolski	17 815
19	Kopalnia Wanda	międzychodzki	47
20	Ochle	kolski	1 229
21	Rumin	koniński	58
	Total amount		73 341

Table 2. The deposits constituting remnants of previously exploited deposits, based on Bilans zasobów..., 2016

No.	Deposit	County	Anticipated economic resources (thousands of tons)
1	Kaławsk-szyb główny	zgorzelecki	639
2	Kopalnia Zapomniana	zgorzelecki	4 142
3	Babina-łuska 0-0A	żarski	4 214
4	Przyjaźń Narodów – szyb Henryk	żarski	280
5	Koźmin	kolski, turecki	11 720
6	Lubstów	koniński	1 859
7	Pątnów III	koniński, słupecki	3 809
8	Władysławów	turecki	1 358
9	Władysławów II	turecki	11 814
Total amount			39 835

6.2. Deposits of medium and large resources

An interesting example illustrating the issue in question is the medium sized Uniejów deposit in the Łódzkie voivodship with resources of 42 million Mg. This deposit is located in the vicinity of the Adamów lignite mine, which is why it was regarded as a potential resource base for the Adamów power plant (600 MW). Currently, in the face of plans to liquidate the Adamów mine due to the age of the power plant the Uniejów deposit has lost its importance as a reserve deposit. However, it is worth taking a closer look due to a long list of non-mining factors preventing its exploitation.

The town of Uniejów is located centrally above the deposit with a population of approx. 3 thousand. The town has many historic buildings including the archbishop's castle and collegiate church which date back to the fourteenth century. The deposit is also criss-crossed by important communication routes - the national road DK 72, and voivodship roads 473 and 469 which are connected to the A2 motorway. The third longest river in the country, the Warta, which reaches its middle course in the vicinity of Uniejów runs right through the middle of the deposit. Among the environmental factors we should mention the Natura 2000 PLB sites of Dolina Środkowej Warty, Nadwarciański and Uniejowski Protected Landscape Area, as well as the Uroczysko Zieleń Nature and Landscape Complex. This is not an unusual case – in fact it is just the opposite. An unusual situation is when there are no protected areas, no major rivers and no dense developments in the vicinity of the deposit. There are very few such deposits. The Uniejów deposit is relatively small in terms of the

size of the resource, therefore, to illustrate the analysed problem it is worth taking a look at deposits with much larger resources.

The deposits of the so called Rów Poznański, i.e. Czempień, Krzywiń, and Gostyń with total resources of 3.69 billion Mg represents approx. 16% of the Polish resources of lignite. In the annually published Balance Sheet of Resources they are treated separately as ones where their eventual exploitation is unlikely due to the wealth of nature conservation land, valuable soil and highly developed agriculture in the region of their occurrence (BILANS..., 2016). Indeed, above this complex of deposits, protected areas were designated among which we should mention: the Generał Dezydery Chłapowski Landscape Park, Krzywińsko-Osiecki Protected Landscape Area and the close proximity of Natura 2000 PLB Zbiornik Wonieść, as well as Natura 2000 PLH Zachodnie Pojezierze Krzywińskie.

In extension of these deposits, to the north is the Mosina deposit (1.495 billion Mg), within the limits of the city of Poznań is the Naramowice deposit (296.3 million Mg), and to the north of Poznań the Szamotuły deposit (746.3 million Mg). The Mosina deposit lies beneath Wielkopolski National Park in the immediate vicinity of the Rogaliński Landscape Park in the area of Natura 2000 Ostoja Rogalińska PLB, PLH Rogalińska Dolina Warty, and PLH Będziewo Bieczyny. In the northern extension the deposit lies beneath the city of Poznań, and the Leszno-Poznań railway line runs along the entire deposit. The Naramowice deposit is located beneath dense developments in the northern districts of Poznań. The River Samica flows above the Szamotuły deposit the course of which is protected by the Natura 2000 PLB Dolina

Samicy. In the northern part the Szamotuły deposit stretches under the River Warta.

Another example is a complex of four deposits in the western region: Rzepin (249.5 million Mg), Torzym (843.9 million Mg), Cybinka (237.5 million Mg), and Sądów (226.5 million Mg). The A2 motorway was built through the Rzepin and Torzym deposits along the old DK 92 road. In parallel, at individual points above the deposits runs the Świebodzin - Słubice railway line. Above the Torzym deposit lies the city of Torzym with a population of approx. 2.5 thousand. Among the protected areas established above the Torzym deposit we should mention: PLH Dolina Ilianki, PLH Dolina Pliszki, and PLA Puszcza nad Pliszką, PLA Dolina Ilianki. The area above the Rzepin deposit is densely wooded and has the protected areas of PLH Dolina Ilianki, PLH Ujście Ilianki, PLH Rynna Jezior Rzepińskich, and PLA Dolina Ilianki.

Cybinka and Sądów deposits can be treated as a single deposit complex because these deposits are adjacent to each other. The DK 29 Krosno - Słubice road runs across it. The deposits are surrounded by Natura 2000 areas and Protected Landscape Areas which are established directly above the deposits - PLH Bory Chrobotkowe near Bytomiec, PLH Diabelski Staw near Radomicko, PLH Torfowisko

Młodno, PLH Krośnieńska Dolina Odry, PLH Lasy Dobrosułowskie, PLH Dolina Pliszki, PLA Puszcza nad Pliszką.

Another deposit called Mosty (175.4 million Mg) in the western region lies almost entirely within the Łuk Murzakowa Landscape Park, partly under the PLB Bory Dolnośląskie, PLH Łęgi nad Nysą Łużycką, and PLH Wilki nad Nysą.

Table 3 lists 16 deposits with exploitations of medium and large resources which due to the developments in their area, and forms of nature conservation above the deposit and within their immediate vicinity are unlikely. Not all deposits were discussed in this article but each case is full of obstacles which prevents profitable exploitation in practice.

As a result of the presented analyses 46 deposits were selected with total resources of 9.29 billion Mg of which 30 are small deposits, or remnants from after the end of exploitation whose total resources are only 113 million Mg. The total presented resources constitute approx. 39.5% of the total resources of Polish lignite deposits. After deducting these there is still approx. 14.2 billion Mg of lignite in Polish deposits of which only 1.418 billion Mg (ca. 10%) are part of currently developed resources.

Table 3. Medium and large lignite deposits exploitation of which due to the development in the area and natural values is unlikely, based on Bilans zasobów..., 2016

No.	Deposit	County	Anticipated economic resources (thousands of tons)
1	Czempiń	kościański	1 034 578
2	Gostyń	gostyński	1 988 830
3	Krzywiń	kościański	666 507
4	Mosina	kościański, poznański, śremski	1 495 412
5	Szamotuły	obornicki, poznański, szamotulski	746 326
6	Naramowice	poznański, m. Poznań	296 324
7	Rzepin	słubicki, sulęciński	249 528
8	Torzym	sulęciński, świebodziński	843 879
9	Cybinka	krośnieński, słubicki	237 487
10	Sądów	krośnieński, słubicki	226 469
11	Trzcianka	czarnkowski, trzcianecki, walecki	300 077
12	Mosty	żarski	175 394
13	Chełmce	inowrocławski	44 348
14	Morzyczyn	koniński	26 113
15	Więcbork	nakielski, pilski, sępoleński	509 113
16	Lubsko	żarski	340 668
	Total amount		9 181 053

7. Deposits constituting a potential resource base for the energy industry

Given the current technological development in the field of electricity generation it can be assumed that energy resources, such as lignite, will be the basis for the production of energy for no longer than another 50 years. Forecasting in a half-century perspective is highly biased, and going beyond this period makes practically no sense. Lignite deposits of 14.2 billion Mg at the current rate of development in the area, and the absence of special nature conservation areas above these deposits are available now for extraction which guarantees the sufficiency of raw materials for at least 200 years, assuming production at today's levels.

The deposits which represent the prospective resource base for the future are mainly: Gubin 2 deposit (1 034 million Mg), Legnica deposits with total resources of 3 426 million Mg, as shown by KASIŃSKI (2010) and NAWORYTA & BADERA (2012), Żłoczew deposit (611.9 million Mg) and some smaller deposits located near the currently operating mines. These above mentioned deposits have been listed in the National Energy Policy to 2030 (POLITYKA ENERGETYCZNA..., 2009), as well as in the National Spatial Development Concept (KPZK, 2012). As a future energy resource base these should be protected against development and careless establishment of additional forms of nature protection considering that well over 32.5% of the country is already covered by different forms of protection, as stressed by NIEĆ & RADWANIEK-BĄK (2010), UBERMAN (2011), NIEĆ ET AL., (2014).

8. Summary

According to popular belief Poland is a country rich in lignite. After inclusion in the Balance Sheet of Deposits the resources of this mineral initially identified (in the D category) have increased by 66.5% from 14 billion Mg in 2008 to 23.5 billion Mg. After this technical procedure, of the total resources approx. 69% constitute deposits identified initially for which resources estimation error is at 40% and higher. Of the 90 documented deposits, 30 are small deposits or remnants after the end of their exploitation and from a mining operations point of view their exploitation is not economically justified.

Many deposits of medium and large resources are located in areas with high nature conservation value which is often legally protected. Introduction of the Natura 2000 European system of nature protection - has impeded access to many

documented deposits. This study lists 16 large and medium-sized deposits that lie in areas of high nature conservation value, or are already developed for housing or road and railway infrastructure. Taking into account a cost and benefit analysis which includes the environmental costs, and the costs of compensation for liquidated development, the exploitation of these lignite deposits is unprofitable.

Within the limits of the deposits listed in Tables 1-3 lies 9.29 billion Mg of lignite. After deducting this amount from the total anticipated economic resources we still have 14.2 billion Mg which will secure raw material for domestic energy for many years to come.

The deposits which are not currently occupied by development and the areas above them that do not constitute areas of outstanding nature conservation value, especially Gubin, Legnica, Żłoczew, should be subject to special protection, and secured against progressive development as an energy resource base for future generations.

Natural resources constitute soils, flora, fauna, underground and surface waters, as well as mineral deposits. Of these resources mentioned only mineral deposits have not been granted statutory protection in Poland. Valuable mineral resources are being irreversibly lost by uncontrolled development in the areas above these deposits, and the careless establishment of restrictive forms of land protection for nature reserves. In accordance with the principles of sustainable development all kinds of natural resources should be protected and their availability for future generations should be taken into account, and in the case of a conflict between different arguments for protection of various resources an adequate compromise should be developed.

Approximately 30% of the Polish national electricity is produced annually from lignite. To produce this electricity lignite mines occupy a total area of 17.2 thousand ha which represents 0.055% of the country's surface area. More than 32.5% of the country is covered by different nature conservation schemes. Given these figures it seems that there is still a lot of room for compromise in the area of the conservation of natural mineral resources.

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