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PRODUCTION AND CONSUMPTION OF BLACK COAL AND LIGNITE IN SELECTED EUROPEAN COUNTRIES IN THE CONTEXT OF THE CLIMATE CHANGE POLICY

Summary. Coal continues to be the largest source of electricity generation worldwide, as well as one of the largest sources of carbon dioxide emissions. In most European countries, the level of black coal mining is very low or already non-existent. In the Czech Republic, Germany and Poland, which are the subjects of this study, the high level of lignite mining is maintained, which results from relatively low costs of electricity generation. In the future, energy generated from fossil fuels will be replaced by renewable energy generation.

Keywords: black coal, lignite, renewable energy, global warming, climate change policy.

PRODUKCJA I KONSUMPCJA WĘGLA KAMIENNEGO I BRUNATNEGO W WYBRANYCH KRAJACH EUROPEJSKICH, W KONTEKŚCIE POLITYKI ZMIAN KLIMATYCZNYCH

Streszczenie. Węgiel jest wciąż największym źródłem energii elektrycznej w skali światowej, jak również jednym z największych źródeł emisji dwutlenku węgla. W większości krajów europejskich poziom wydobycia węgla kamiennego jest bardzo niski lub prawie zanikł. W Czechach, Niemczech i Polsce, które są przedmiotem niniejszych badań, utrzymywany jest wysoki poziom eksploatacji węgla brunatnego, co wynika ze względnie niskich kosztów produkcji energii elektrycznej. W przyszłości energia otrzymywana z paliw kopalnych zostanie zastąpiona przez energię odnawialną.

Słowa kluczowe: węgiel kamienny, węgiel brunatny, energia odnawialna, globalne ocieplenie, polityka zmiany klimatycznej.

1. Evolution of black coal and lignite mining in Europe

Since the Industrial Revolution, the economic history of the world has been inextricably linked to coal. Despite the well-known slogan "Control the Oil, Rule the World", in today's economy coal is as significant as crude oil and natural gas, and in the case of electricity generation, this importance is even stronger. In many European countries, lignite and black coal are the most important raw materials in electricity generation. However, the role of black coal in Europe has been decreasing along with the fall and restructuring of West-European mining urban areas, and in a number of European countries its production has ceased completely. Poland is an exception to this rule.

In the course of the 19th century and the first half of the 20th century, black coal mining grew continuously. In 1800, it reached 15 million tonnes, in 1860 – 132 million tonnes and in 1990 – 701 million tonnes. At the end of the 19th century, 5 countries (the United States of America, the United Kingdom, Germany, France and Belgium) mined 95% of the world coal resources and Europe alone extracted 60%[1]. By way of comparison, in 2012 the first ten largest black coal producers by order of extraction were the following countries (extraction in millions of tonnes in brackets): 1. China (3796); 2. The United States of America (938); 3. India (602); 4. Indonesia (488); 5. Australia (383); 6. Russia (304); 7. The Republic of South Africa (286); 8. Kazakhstan (133); 9. Colombia (99); 10. Poland (87). It is worth noticing that this list includes only two European countries, but considering the fact that most of the Russian mining comes from Siberia in Asia (Kuznetsk Basin), the only fully European representative is Poland, which is the last one on the list. Once a "coal continent", in 2012, Europe produced only 3% of the world black coal resources (and this percentage is still decreasing), while China extracted as much as 51% of black coal in the same year.

In Europe, the role of black coal mining is decreasing, which causes industrial restructuring and a decline in the original functions of coal-based industrial regions. This process began in the mid-20th century, but it has not been the same everywhere in Europe. The peak of coal mining in the United Kingdom fell on 1913, in Germany (its modern borders) – on 1956, and in Poland – on 1979. The United Kingdom closed down its last active black coal mines in 2015, and Germany plans to do the same in 2018. As a result of changes in the geography of mining, the black coal currently combusted in thermal power stations in most of the European countries is imported from other continents.

Insofar as the main coal mining regulator in the past was economic stimuli, in today's world these are more and more ecological factors involved. Until the 1990s, the decline in the production of black coal in Europe was triggered by technological transformations and an increase in the cost of production in traditional underground mines. Apart from technological

[1] Ciepielewski J., Kostrowicka I., Landau Z., Tomaszewski Z.: Dzieje gospodarcze świata do 1975 roku. PWE, Warszawa 1977, s. 105-106.

and economic factors, the centrally managed decarbonisation process, associated with finding a relationship between the combustion of fossil fuels and an increase in the average temperature of lower atmosphere, starts to play a key role in the modern world.

The stable, high level of lignite mining, which is almost entirely destined for electricity generation, is a paradox in the light of these processes. This concerns such countries as Germany, Poland, the Czech Republic, Greece, Serbia, Bulgaria, Romania and Hungary. Relatively, role of lignite has increased at the cost of black coal, even though combustion delivers more carbon dioxide to the atmosphere. It is a paradox that despite the current battle against global warming, the role of more harmful lignite is increasing. For comparison, if we take into consideration fossil hydrocarbons used in the production of electrical energy, natural gas, the least harmful of all, has almost entirely replaced petroleum products. The root cause of this process was the growing demand for liquid fuels in transport, where crude oil (previously used for electricity generation) is now being directed, which was hard to satisfy. If we look at individual fuels, 1 MJ (megajoule) of generated energy releases the following average amounts of carbon dioxide in grams: natural gas – 50, aviation petrol – 66, petrol – 67, black coal – 88, lignite – 92[2].

The tendency to prefer lignite over black coal, so clear in many European countries, is a long-lasting indirect result of the decarbonisation process consisting in replacing fossil fuels with renewable energy sources. Due to a lower cost of the production of a unit of electrical energy from lignite than from black coal extracted in Europe, the role of the former has increased accordingly. However, in the long run, especially for environmental reasons, both these coal types are expected to lose their significance in favour of renewable energy sources.

2. Struggle against global warming and the end of the coal age

One of the most frequently cited diagnoses of the modern society is that it is a society of risk. Risk has always accompanied mankind, but its current form differs from the historical one in that it is global and virtually uncontrollable[3]. Most importantly, it involves contemporary environmental threats. The most significant of these threats is global warming, that is the increase in the average temperature of the lower atmosphere (troposphere) triggered by anthropogenic factors, the most important of which is fossil-fuel combustion[4]. This phenomenon is scientifically proven – sociologists of knowledge have ascertained that there is

[2] Voluntary Reporting of Greenhouse Gases Program, http://www.eia.gov/oiaf/1605/coefficients.htm.
[3] Beck U.: Społeczeństwo ryzyka. W drodze do innej nowoczesności. Scholar, Warszawa 2002.
[4] Beck U.: Na ile realna jest katastrofa klimatu?, [w:] Ekologia. Przewodnik Krytyki Politycznej. Krytyka Polityczna, Warszawa 2009, s. 76-117.

a consensus in the matter among professional climatologists[5]. Nonetheless, there is a strong opposition dominated by those who obstinately deny the anthropogenic causes of global warming. It is also a paradox that those "climate denialists" influence public opinion significantly stronger than professional scientists do[6].

Thus, the public opinion on the matter of global warming and other threats to the environment is moulded by pseudoscientists and journalists most, of whom root for the right-wing political provenance. Polish denialists include A. Kołakowska, B. Wildstein, T. Teluk, A. Wielomski, J. Korwin-Mikke, R. Ziemkiewicz, Z. Jaworowski and S. Michalkiewicz. Apart from purely content-related errors in the scope of geophysics, which result from misunderstanding the origin of global warming, their arguments are often peculiar. One example of their faulty reasoning is the position of W. Błasik, who uses terms coined by I. Wallerstein in his world-systems theory to describe the climate change and energy policy of the European Union as a form of pressure exerted by core countries (Central Europe) on semi-periphery countries[7].

The struggle with global warming has become one of the most significant regulators of fossil-fuel extraction and the introduction of new methods of electricity generation. This is because the most important greenhouse gas in the global warming process, albeit not the only and certainly not the most harmful one – is carbon dioxide. Other greenhouse gases include water vapour, methane, nitrous oxide, ozone and freons. Each of those has a slightly different role. Methane has a stronger capability to retain infrared radiation than carbon dioxide, although it is significantly scarcer in the atmosphere. On the other hand, there is much more water vapour, but the increase in the average temperature of the lower atmosphere is caused by the introduction of carbon dioxide (which is not removed by natural processes) as a result of fossil-fuel combustion. The combustion-related origin of this "excess" carbon dioxide found in the atmosphere has been confirmed by means of isotopic analysis. Failure to understand the subtle difference between the role of water vapour and carbon dioxide is one of the most common causes of misconceptions involving the origins of climate change.

Each year, natural sources (volcanic emissions and biological processes) produce 20 times more carbon dioxide than anthropogenic sources (fossil-fuel combustion, manufacture of cement from calcium carbonate, deforestation and farming). The carbon dioxide produced as a result of natural processes is entirely absorbed, whereas its excess amounts, induced by human activity, accumulate in the atmosphere, from where it is removed at a very slow pace. The result is its continuous increase in the air, which enhances the greenhouse effect. Since

[5] Oreskes N.: The scientific consensus on climate change. How do we know we're not wrong?, [in:] DiMento J.F., Doughman P. (eds.): Climate Change. What it means for Us, our Children, and our Grandchildren. Cambridge Mass. MIT Press, 2007, p. 65-99.

[6] Bińczyk E.: Technologia w społeczeństwie ryzyka. Filozofia wobec niepożądanych następstw praktycznego sukcesu nauki. Uniwersytet Mikołaja Kopernika, Toruń 2012, s. 239.

[7] Błasiak W.: Pomiędzy centrum a peryferiami na progu XXI wieku. Geopolityka i ekonomika Polski i Europy Środkowo-Wschodniej w warunkach integracji europejskiej i światowej depresji gospodarczej. Śląsk, Katowice 2013, s. 75-87.

the beginning of the Industrial Revolution, conventionally believed to fall on mid-18th century, the concentration of carbon dioxide has increased by 110 ppm. The consequence of this continuous increase in the concentration of greenhouse gases is an increase in the temperature of the lower atmosphere. It is estimated that compared to the base period of 1850-1900 to the end of the 21st century, this temperature may rise from 1.5 to 2ºC, depending on the scenario[8].

3. Characteristics of coal mining in Poland, the Czech Republic and Germany

The purpose of this paper is to compare the changes in the size of black coal and lignite mining in three Central European countries: the Czech Republic, Germany and Poland. The selection of these countries was not coincidental, as the extraction of both kinds of coal has played an important role in all three.

Some European countries used to "specialise" in the extraction of only one kind of coal, either black or lignite. The first group includes countries concentrated in the Blue Banana, an extensive industrial area in Western Europe, spreading from central England through northern France, the Benelux, and the Rhine, all the way to northern Italy. The Blue Banana used to cover most of the traditional industrial areas formed on black coal deposits. The “black coal countries” were: the United Kingdom, France, Belgium and the Netherlands. Conversely, South-Eastern European countries specialised in lignite production. These include Hungary, Romania, Serbia, Bulgaria, Greece, Slovenia, and outside of Europe – Turkey.

In the Czech Republic, Germany and Poland, both types of coal played a major role. As a result, these countries hold a middle position between the two mentioned groups of “coal states”, also in terms of their geographical location. The West German black coal basins – the Ruhr and the Saar Basin – belong to the Blue Banana, whereas the Lower Rhine Basin is the only large area of lignite extraction within its borders. Let us move on to a brief description of the characteristics of coal mining in these countries, and its share in electricity generation.

In 2012, black coal extraction in the Czech Republic reached 11 million tonnes, in Germany – 12 million tonnes, in Poland – 78 million tonnes and in the whole European Union – 128 million tonnes; the extraction of lignite was 44 million tonnes, 185 million tonnes, 64 million tonnes and 433 million tonnes respectively. In the same year, the import of coal in the Czech Republic amounted to 2 million tonnes, in Germany – 43 million tonnes, in

[8] Zmiana klimatu 2013. Fizyczne podstawy naukowe. Podsumowanie dla decydentów. Międzyrządowy Zespół do spraw Zmiany Klimatu, Warszawa 2015, s. 18.

Poland – 10 million tonnes and in the whole European Union – 211 million tonnes[9]. Such a high coal import into European countries (approximately equal to the maximum yearly extraction in such countries as Poland, the United Kingdom and Germany in the 20th century) proves the fact that black coal mining is decreasing much faster than its utilisation as electrical energy generator. As a consequence, European thermal power stations replace local coal with one that is imported from outside the continent.

3.1. Czech Republic

The Czech Republic became an independent state on 1st January 1993 as a result of the dissolution of Czechoslovakia. Most of the lignite and the entire black coal mined in Czechoslovakia came from the area of the Czech Republic. Today, the size of lignite extraction in Slovakia constitutes 4% of the extraction in the Czech mines. At the beginning of the restructuring process in the early 90s, around 80% of black coal was mined in the Ostrava-Karvina Coal Basin, in the south part of the Upper Silesian Basin. The remaining black coal was extracted on the territory of the following basins: Kladno-Rakovník in the Central Bohemian Region of the Czech Republic, Rosice-Oslavany in the South Moravian Region of the Czech Republic, and Trutnov, which constitutes the south-western extension of the Wałbrzych Basin. Today, it is mined only in the Ostrava-Karvina Coal Basin.

The extraction of lignite is concentrated in three basins in the north-western Czech Republic: Cheb, Sokolov and the Most Basin. Smaller amounts are mined near Hodonin, South Moravia[10]. Today, lignite is the main source of electrical energy generated in the Czech Republic. In 2013, the country produced approximately 80 TWh of electrical energy, of which 20% was generated in nuclear power plants, 8% in black coal-fired power plants and 52% in lignite-fired power plants. It is planned that in 2030 approx. 37% of electrical energy will come from coal and nuclear power plants (altogether, these two sources are to secure three fourths of the supply) and 5% will be generated by gas-fired power plants. The Czech Republic is also a net exporter of electrical energy, and the export oscillates between 11 and 16 TWh a year[11].

Despite relatively advanced technology, the Czech Republic does not produce or develop the production (at least not on a large scale) of electricity from renewable energy sources. This largely results from natural conditions. For geographic reasons, it is impossible to generate electrical energy from the most efficient offshore wind farms. The traditional source of renewable electrical energy in the Czech Republic is small hydroelectric plants dispersed in

[9] Jamrozik A., Sieradzka M., Skrzypczyk D.: Stan wykorzystania i pozyskiwania paliw kopalnych w Polsce i na świecie, [w:] (red.): P. Kwiatkiewicz: Bezpieczeństwo energetyczne: rynki surowców i energii - teraźniejszość i przyszłość, t. II. Fundacja na rzecz Czystej Energii, Poznań 2014, s. 162.
[10] Pešek J., Sivek M.: Uhlonosné pánve a ložiska Erno a hnědého uhlí České republiky. Česká geologická služba, Praha 2012.
[11] Kwinta W.: Rynek energii - Czechy, "Polska energia" 2010/2, wwire.pl/pliki/2/rynenergczecw.chy.pdf.

the country, the most important of which form the Vltava Cascade. In 2012, renewable energy constituted 10% of the overall electricity generation, of which only one fourth came from water power plants[12].

3.2. Germany

Germany with its current borders was formed on 3rd October 1990 by uniting the Federal Republic of Germany, the German Democratic Republic and West Berlin. Both the FRG and GDR were significant coal producers worldwide. There are two black coal basins in the western part of Germany: the Ruhr and the Saar Basin, as well as a great lignite basin in the area of Lower Rhine, located west of Cologne in North Rhine-Westphalia. On the territory of the former GDR, there are two clusters of lignite mines: Central German Basin in Saxony-Anhalt and Lusatian Basin in Brandenburg and Saxony. There also used to be several smaller coal mining centres.

In 2013, the percentage of electrical energy generated from individual energy sources in Germany was as follows: black coal – 19%, lignite – 25%, natural gas and petroleum products – 16%, nuclear energy – 15%, renewable sources – 25%. This reflects the country's great diversity of energy sources as well as a high percentage of the extraction of both types of coal, nearing half of the overall production.

High environmental culture and great technological and financial resources make for rapid development of renewable energy, and Germany belongs to the world leaders when it comes to the increase in its production and its share in the overall electricity generation. The percentage of electrical energy from renewable sources in Germany increased from 6% in 2000 to as much as 30% in 2014. It is estimated that in 2050, 80% of overall electrical energy will be generated from renewable sources. Thus, the age of coal-dominated energy production in Germany is coming to an end.

3.3. Poland

For natural reasons (lack of alternative energy sources), Polish energy is based on coal. Within the restructuring process that took place as a result of the political transformation of the 80s and 90s, there was a radical decrease in black coal mining, although lignite extraction dropped only slightly. In 2014, the overall black coal extraction stood at 50% of its extraction in 1990, while the analogous percentage for lignite was 94%. Therefore, we are facing a similar process to that which can be observed in Germany, namely a relative increase in the importance of lignite in relation to black coal.

[12] International Energy Statistics, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

Poland has one of the richest deposits of lignite in the world. Some examples include the Legnica lignite deposits (Legnica West, Legnica East and Legnica-Ścinawa-Głogów), which are the largest deposits of the kind in Europe, and deposits near Gubin, Trzcianka and Złoczew[13]. However, for environmental reasons, their exploitation is being postponed. It is planned that lignite extraction will be maintained at the current level (of approximately 65 million tonnes) until 2030. In order to achieve this objective, new deposits will have to be exploited. This exploitation will have to commence around 2020, and from 2030, production from these deposits will be dominant[14].

In 2014, 159 TWh of electrical energy was generated. Although Poland is a net importer of electrical energy, the size of this import is rather insignificant (approx. 2 TWh)[15]. In 2013, 50% of electrical energy was obtained from black coal and 35% from lignite. Electrical energy from the latter is cheaper than the energy produced from black coal by 20-30%. Poland does not have nuclear power plants as of yet, and the first one is planned to be commissioned in 2030. Renewable energy constitutes 10% of the overall energy production, and this percentage is expected to increase to 19% by 2030. The share of energy obtained from gas will slightly increase (to 7%)[16].

Despite a similar surface area and natural conditions, the processes of decarbonisation and increasing the share of renewable energy in Poland are much slower than in Germany. It also needs to be pointed out that Polish thermal power stations are technologically obsolete and in need of modernisation. Approximately 56% of capacity is installed in blocks that have been in use for over 30 years[17]. The one-sidedly coal-based character of the Polish energy industry, technological backwardness, lack of nuclear power plants and a small percentage of renewable energy production attest to the underdevelopment of the Polish energy sector.

[13] Złoża węgla brunatnego w Polsce, "Infrastruktura. Środowisko. Energia" dodatek do dziennika "Rzeczpospolita", 9.9.2008, http://www.eko.org.pl/odkrywki.php?dzial=2&kat=13&art=167

[14] Szczerbowski R.: Problemy bezpieczeństwa energetycznego Polski, [w:] (red.): P. Kwiatkiewicz: Bezpieczeństwo energetyczne. Rynki surowców i energii - teraźniejszość i przyszłość, t. II. Fundacja na rzecz Czystej Energii, Poznań 2014.

[15] Rocznik Statystyczny Rzeczpospolitej Polskiej. GUS, Warszawa 2015, s. 516, 520.

[16] Kompendium wiedzy dla inwestorów, Rynek energii elektrycznej;
http://www.rynek-energii elektrycznej.cire.pl

[17] Szczerbowski R.: Problemy bezpieczeństwa energetycznego Polski, [w:] (red.): P. Kwiatkiewicz: Bezpieczeństwo energetyczne. Rynki surowców i energii - teraźniejszość i przyszłość, t. II. Fundacja na rzecz czystej energii, Poznań 2014, s. 33-55.

Table 1

Black coal and lignite production in the Czech Republic, Germany and Poland in the year 1990-2012 compared to global production (in millions of tons). Source: Own elaboration based on the International Energy Statistics[18]

	Czech Republic black coal	Germany black coal	Poland black coal	Czech Republic lignite	Germany lignite	Poland lignite	Global black coal	Global lignite
1990	-	78	147	-	388	68	3739	1109
1991	-	73	140	-	280	69	3570	982
1992	-	72	131	-	242	67	3521	950
1993	18	64	130	67	222	68	3381	968
1994	17	58	133	60	188	67	3493	926
1995	17	59	137	57	193	64	3581	913
1996	17	53	138	60	187	64	3649	929
1997	16	51	137	57	177	63	3678	920
1998	16	45	115	51	166	63	3678	904
1999	14	44	110	45	161	61	3640	876
2000	15	37	103	50	168	60	3763	897
2001	15	31	104	51	175	60	3968	907
2002	14	29	103	49	182	58	4014	910
2003	14	29	102	50	179	61	4349	924
2004	13	29	100	49	182	61	4710	928
2005	13	28	97	49	178	62	5074	945
2006	13	24	94	50	176	61	5359	961
2007	13	24	87	50	180	58	5589	974
2008	13	19	84	48	175	60	5794	983
2009	11	14	77	45	170	57	5932	963
2010	11	13	76	44	169	56	6282	974
2011	11	12	76	46	176	67	6623	1034
2012	11	12	79	44	182	64	6787	1093

Source: own work.

4. Conclusions

The proportions of the shares of individual sources in the production of electrical energy are influenced by a number of factors, the most significant of which are technological transformations and the reduction of greenhouse gas emissions in the effort to combat global warming. However, if we focus on individual countries, we can see that these overall tendencies are modified by other, less significant and local stimuli. Therefore, the

[18] International Energy Statistics, http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm

transformation of the structure of electrical energy sources is complex; it does not always conform to clear-cut norms and it is often unpredictable.

In the case of the three countries studied for the purposes of this paper, the long-lasting strong position of lignite as a fossil fuel is striking. As already mentioned, this is only a transition period which will be followed by the replacement of electrical energy generated in thermal power stations with energy from renewable sources. As opposed to European black coal, lignite is exploited in open-pit mines. As a result, one unit of electricity produced in brown-coal-fired plants is cheaper than in the case of black coal. There is a clash of two factors: economic and environmental, and the latter is slowly starting to outweigh the former. This process is taking a much faster pace in Germany than in Poland and the Czech Republic.

The future of the European and global power industry belongs to renewable energy. It differs from traditional energy not only in the fact that it emits no (or significantly less) greenhouse gasses into the atmosphere, but also in that it is more dispersed. A single wind turbine has the power of 2-3 MW. This means that a single lignite-fired power plant of the size of the one in Bełchatów, Poland, would need to be replaced by 1800-2700 wind turbines. When it comes to electricity generation, this number would have to be even higher.

On the other hand, is it right to unreservedly equate renewable energy with spatial dispersion? Can we not imagine a time when whole regions will produce renewable energy like today's coal basins? There are regions abundant in rivers with significant drops, coasts with large tides, stable and strong winds, significant insolation and the right conditions to produce biomass. Perhaps, irrespectively of the dispersion of electrical energy sources, such regions will also start to function as modern counterparts of the former energy-generating coal basins.

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energetyczne: rynki surowców i energii - teraźniejszość i przyszłość, t. II. Fundacja na rzecz Czystej Energii, Poznań 2014.
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Omówienie

Po rewolucji przemysłowej Europa stała się kontynentem, na którym najważniejszymi źródłami energii stały się węgiel kamienny i, w mniejszym stopniu, brunatny. W czasie, kiedy w Zachodniej Europie (Blue Banana) przeważały regiony produkujące węgiel kamienny, w Europie Południowo-Wschodniej koncentrowano się na wydobyciu węgla brunatnego. Kraje analizowane w niniejszym tekście − Czechy, Niemcy i Polska − są producentami obu rodzajów węgla. Wydobycie węgla kamiennego drastycznie spadło lub całkowicie zanikło we wszystkich krajach członkowskich Unii Europejskiej z wyjątkiem Polski. Węgiel kamienny spalany w europejskich elektrowniach cieplnych w większości pochodzi z innych kontynentów. Znaczenie węgla brunatnego, który pozostaje głównym źródłem produkcji energii elektrycznej w wielu krajach Środkowej i Południowo-Wschodniej Europy, relatywnie wzrosło. Jest to spowodowane przyczynami ekonomicznymi, gdyż produkcja tego typu

energii jest względnie tania. W wyniku globalnej walki ze zmianami klimatu, rola obu rodzajów węgla w produkcji energii elektrycznej maleje. Węgiel jest zastępowany energią odnawialną.