Chances of coal in European power industry

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Abstract: Poland's accession to the European Union has reduced the remnants of import barriers. Moreover, the consolidation and commercialization of the energy sector, the implementation of climate package elements and a whole host of other determinants have caused hard coal mining to begin functioning in a highly competitive market, and its negotiating position, as well as the possibility of survival, depends not only on the level of coal prices in international markets, but also on internal competition.

This paper discusses the position of power coal on international markets and presents some current problems concerning the functioning of particular segments of the hard coal market in the European Union and Poland in terms of opportunities and threats that are a result of climate and energy policy.

1. Coal in the world

Coal (hard and brown) is still the most widely used energy source (figure 1). According to BP data \cite{1, 2} its recoverable resources exceed 826.6 billion tons. The advantage of coal, unlike oil and gas, is the presence of its deposits in more than 70 countries around the world, and a widespread access to this feedstock does not create social and political tensions. Only about 17\% of this feedstock is the subject of international trade. The rest is used for the production of electric power and heat on the spot – in countries that exploit this coal.

![Figure 1. World hard coal reserves (in tons) \cite{1}.](image)

Coal is a safe feedstock for transport and storage, and most of all it is cheap and allows generating electricity and heat at a cost acceptable to individual users and the industry, which thanks to it is competitive [3, 4, 5].

On the other hand, the major disadvantage attributed to this feedstock is carbon dioxide emission—because in the context of today's high-efficiency air protection technologies – this greenhouse gas and water vapour are emitted in the combustion process.

In 2014, world hard coal production exceeded 7.1 billion tons and nearly doubled over the past 20 years. The year 2015 is the first year of coal production decrease – 6.9 billion tons (including 5.8 billion tons of power coal – table 1) – caused by the global recession, which led to a decrease in coal production in China and Indonesia.

The downward trend in coal production continued in 2016, when it fell by 458 million tons, which is the biggest decrease since the highest level recorded in 1971. This decrease was mainly the effect of reducing the production in China due to the process of closing down unprofitable and dangerous production units (-320.7 million tons) and in the USA (-141.9 million tons).

Table 1. Production and consumption of power coal in 2015.

| 2015 [mln Mg] | World | Europe* | Poland* |
|---------------|-------|---------|---------|
| production    | 5811  | 77      | 59      |
| consumption   | 5828  | 228     | 58      |
| import        | 1043  | 176     | 5.6     |
| export        | 1003  | 26      | 6.9     |
| [percentage]  |       |         |         |
| production    | 99.7% | 33.8%   | 101.7%  |
| consumption   | 100.0%| 100.0%  | 100.0%  |
| import        | 17.9% | 77.2%   | 9.7%    |
| exports       | 17.2% | 11.4%   | 11.9%   |

*power coal
Over the last 10 years, coal trade turnover has increased by about 68% – to about 1 260 million tons (including nearly 300 million tons of coking coal), of which approximately 1 billion tons of coal have been transported by sea. The main contributors to the production, trade and consumption of coal are the Pacific Region countries (non-OECD countries – over 4 950 million tons) [6, 7, 8].

In 2016, the trade turnover of all types of coal increased by 1.9% from the level of 1 308 in 2015 to 1 333.5 million tons, as a result of an increase in power coal exports by 14.6 million tons (i.e. by 1.5%) and the increase in coking coal imports by 10.2 million tons (i.e. 3.4%). At the same time it increased by 21.7% compared to 2010, while exports since the year 2000 increased almost twice, i.e. by 105.3%.

Nowadays more than half of world power coal production comes from China. Since 2009 China has also been the largest net importer of power coal (255.6 million tons/year in 2016), ahead of India (200.1 million tons/year in 2016) and Japan (about 189 million tons/year in 2016).

Table 2. Main producers, exporters and importers of hard coal in 2016 [6].

| Main hard coal producers in the world in 2016 (million tons) | Main coal importers in the world in 2016 (million tons) | Main coal exporters in the world in 2016 (million tons) |
|-------------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|
| China 3242.5                                                | China 255.6                                          | Australia 389.3                                      |
| India 707.6                                                 | India 200.1                                          | Indonesia 369.9                                      |
| USA 671.8                                                   | Japan 189.3                                          | Russia 171.1                                         |
| Australia 505.3                                             | Korea 134.5                                          | Columbia 83.3                                        |
| Indonesia 460.5                                            |                                                      |                                                     |
| Russia 365.5                                                |                                                      |                                                     |
| RSA 256.9                                                   |                                                      |                                                     |
| Germany 175.6                                               |                                                      |                                                     |
| Poland 130.9                                                |                                                      |                                                     |

2. Primary energy structure in the European Union and Poland

The structure of primary energy sources in countries of the European Union varies considerably as opposed to Poland, where almost 80% of fuels are solid ones (Figures 3, 4, 5).

![Figure 3. Structure of primary energy sources EU 28 2017.](image-url)
Table 3. Primary energy production volume in the EU, in millions of tons of oil equivalent [Source: EUROSTAT].

| Aggregate production of primary energy 2003 | Nuclear energy | Solid fuels | Natural gas | Crude oil | Renewable energy | Others |
|-------------------------------------------|----------------|-------------|-------------|-----------|-----------------|--------|
| EU-28                                     | 933.8          | 765.5       | 221.02      | 144.9     | 111.1           | 69.1   |
| Poland                                    | 78.8           | 67.3        | 0.0         | 53.6      | 3.7             | 0.9    |

The development of world economy, including the European one, is closely linked to the level of energy consumption. However, there is no doubt that countries having their own primary sources of energy will guarantee themselves a high energy security level and high level of economic independence. On the other hand, EU countries (including Poland) are becoming increasingly dependent on primary energy imports with a distinct decrease in their own production. The dependence on energy feedstocks imports across the EU is around 53%, while Poland with less than 30% dependence situates itself in the top three least dependent European countries – table 4.
The Role of Polish Coal in the National and European Energy Sector

Table 4. Primary energy volume in the EU and Poland in millions of tons of oil equivalent [Source: EUROSTAT].

| Years | 2003 | 2005 | 2007 | 2009 | 2011 | 2013 | 2014 | 2015 |
|-------|------|------|------|------|------|------|------|------|
| EU-28 | 1350 | 1463 | 1467 | 1495 | 1433 | 1441 | 1413 | 1477 |
| Poland | 32.0 | 35.6 | 41.7 | 42.8 | 49.0 | 45.3 | 46.7 | 49.9 |

| Total imports of primary energy |
|--------------------------------|
| EU-28 | 446.7 | 482.5 | 483.7 | 469.8 | 490.2 | 533.4 | 531.0 | 576.0 |
| Poland | 19.9 | 19.7 | 17.0 | 12.8 | 15.3 | 20.1 | 19.6 | 20.9 |

| Total exports of primary energy |
|--------------------------------|
| EU-28 | 937.0 | 903.1 | 861.9 | 821.6 | 802.1 | 790.4 | 773.0 | 765.0 |
| Poland | 78.8 | 77.9 | 71.7 | 66.8 | 67.7 | 70.6 | 66.9 | 67.4 |

| Total production of primary energy |
|-----------------------------------|
| EU-28 | 1840.3 | 1883.6 | 1845.2 | 1847.8 | 1744.9 | 1698.0 | 1607.0 | 1626.0 |
| Poland | 90.9 | 93.8 | 96.4 | 96.8 | 101.4 | 95.8 | 94.3 | 95.4 |

However, for quite some time now, as probably never before on such a scale, we are witnessing a hot and exciting European debate on ‘how much trouble we have with all this coal’. Energy feedstocks are and will be a tool of geopolitics and they have their specificity. The energy policy of the European Union (Energy Roadmap 2050) assumes the complete elimination of fossil fuels – not only coal but also crude oil and natural gas – by 2050. Everything is to be clean and safe – but unfortunately it is not clear yet how to achieve this goal without providing a guarantee of energy security for particular countries. Hope lies in future, clean coal technologies. The position of coal in the European Union is being heavily reduced by the implementation of climate policy, the most recent goals of which have been defined at the Paris Conference on Climate Change. The participants of this conference have set up a very ambitious and, according to them, the only effective goal: to maintain global warming well below 2°C in relation to the average temperature of the pre-industrial period. The subject of discussion were the possible steps of actions, including (EU proposal) – a 40% reduction of CO₂ emission by 2030 (with respect to 1990) and the implementation of “zero emission economy” between 2030 and 2050 (which ultimately means the elimination of all fossil fuels, i.e. carbon, natural gas and petroleum products from economy). However, it is important to underline that not all experts agree in the matter of CO₂ emission impact on global warming. These experts believe that human activity has a minor influence on climate changes, which mainly depend on the activity of the Sun. This is evidenced by periods of warming and cooling in the history of Earth, including glacial periods [9].

Over the last 20 years, a total hard coal output in Europe has decreased by more than 25% – in 2015, hard coal production was 98.6 million tons and brown coal production was less than 400 million tons [10].

In the period from 2012 to 2016, the level of coal imports to the European Union decreased by 22%, from 213.5 million tons to 166.8 million tons. Dynamics of imports in individual EU Member States is shown in the table below (table 5).

Table 5. Imports of hard coal to the EU market in 2012-2016 [9].

| Years | 2012 | 2013 | 2014 | 2015 | 2016 |
|-------|------|------|------|------|------|
| Million tons | 213.5 | 201.6 | 204.9 | 190.7 | 166.8 |
| Price of power coal USD/t | 92.50 | 94.33 | 83.93 | 68.99 | 59.87 |

Average price of coal for energy purposes – free-at-frontier of the EU Countries
The prices quoted in Table 5 are the average prices of coal being sold – free-on-rail/port/land border of the country – importer in the EU. Since 2012 prices have fallen by around 47%. Despite the still high position of coal in the world, its participation in the EU (including Poland) energy policy will depend on the effectiveness of implementation of main climate policy objectives, aimed at reducing the competitiveness of coal by charging it with high costs (including, among others, provision for CO₂ emission prices, subsidizing renewable energy, CCS technology costs, etc.).

3. Polish power coal market

Polish energy sector is based primarily on coal. Its large reserves are located in Poland and account for about 2.2% of global coal reserves. Poland is the largest producer of hard coal in the EU. Hard coal production in Poland accounts for 80% of production in the whole EU.

Poland has a unique structure of energy production in terms of sources, because more than 81% of electric power is produced on the basis of native feedstock, i.e. coal (hard and brown altogether). Such a structure ensures a high level of Poland’s energy independence.

In 2016 the utility hard coal-fired power plants produced 81 348 GWh, which means that their production was lower by 0.65% compared to 2015. At the same time, the utility brown coal-fired power plants generated 51 204 GWh last year, which meant that their production was by 4.41% lower than in 2015. In 2016 wind power plants generated 11 623 GWh of energy, i.e. by 15.76% more than a year earlier. Utility gas sources produced 5 776 GWh last year, i.e. 37.77% more than a year earlier. In the whole 2016 (according to data from the Polish transmission system operator) on the functioning of National Power System electric power production in Poland amounted to 162 626 GWh, which means that it was by 0.53% higher than in 2015. Electric power consumption in Poland in 2016 amounted to 164 625 GWh, and therefore it was by 1.97% higher than in 2015, and the highest since 1988. In 2016 the balance of electric power foreign exchange amounted to plus 1 999 GWh, which means that energy imports were higher than exports.

In the case of Poland, there is no doubt that it is hard coal that will have to be a significant fuel in the energy mix until 2050, even in conditions of low-emission economy forced by the EU. Poland’s economy is heavily dependent on coal. We annually import almost 100% of crude oil and petroleum derivatives, about 70% of natural gas (about 10 billion m³/year) and up to 10 million tons of coal. At current low fuel prices, we spend about 24% of our total revenues from the sum of VAT, CIT and PIT taxes (in the case of fuel prices from the beginning of 2014 it would be over 38%) – and despite that, thanks to coal (Eurostat) Poland occupies a very high 3rd position in the ranking of energy independence. Theoretically we are able to secure 100% of our needs in the area of electricity and network heat production.

Today Poland consumes about 4482.2 PJ (depending on the demand – economic and climatic situation) of hard coal and about 1843.5 tons of brown coal (cumulatively it is an equivalent of about 58 billion m³ of natural gas). According to PSE reports, more than 60% of electric power is produced from hard coal (34-43 million tons/ year) and more than 17% from brown coal [12]. In addition, about 6% of hard coal-based electric power is produced by industrial power plants. The share of hard coal in the structure of fuels used for the production of network heat is over 70%. For climatic reasons Poland, alongside Denmark, Sweden and Germany, has one of the most extensive heating networks in Europe [13].

Estimation of the coal market in Poland is based on many sources of information [13, 14, 15,16, 17, 18, 19, 20, 21, 22]. Over the last 10 years, total power coal sales have decreased by about 18%, while sales of coal to the domestic market have dropped by about 13%. Sales of thick grades have decreased by about 14%. This is mainly due to the gradual decline in output: 102.24 million tons in 2000 and 70.4 million tons in 2016. Inadequate domestic coal supply, especially heating or coking one, does not compensate demand, which generates its imports. According to ARP [19] in 2016 Poland consumed 78.4 million tons of coal, including 60 million tons of power coal. On the other hand the mining sector sold on the domestic market 51.64 million tons, with imports level of approximately 7.9 million tons (10.3 million tons in total) [13].
Table 6. Primary energy consumption in Poland [11].

| Specification                         | 2007   | 2008   | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   |
|---------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Primary energy                        | 4119.9 | 4168.1 | 3941.2 | 4338.3 | 4427.9 | 4387.1 | 4429.4 | 4249.7 | 4322.9 | 4482.2 |
| Hard coal                             | 2015.6 | 1961.0 | 1783.0 | 2007.9 | 1955.6 | 1788.0 | 1861.8 | 1725.7 | 1697.8 | 1843.5 |
| Brown coal                            | 499.6  | 532.7  | 509.8  | 484.7  | 524.4  | 532.1  | 549.9  | 520.3  | 514.1  | 490.1  |
| Crude oil                             | 851.0  | 894.2  | 861.8  | 970.6  | 1027.2 | 1068.9 | 1028.8 | 1025.6 | 1109.6 | 1095.5 |
| Methane-rich natural gas               | 429.2  | 440.5  | 418.5  | 448.0  | 444.5  | 475.4  | 479.0  | 466.6  | 482.4  | 520.6  |
| High-nitrogen natural gas             | 89.0   | 84.8   | 86.5   | 88.1   | 93.0   | 97.3   | 96.1   | 94.7   | 92.2   | 90.4   |
| Water, wind, geothermal and solar energy | 10.8  | 11.3   | 13.3   | 17.4   | 20.9   | 25.6   | 31.8   | 37.1   | 47.3   | 56.2   |
| Firewood                              | 135.7  | 152.6  | 167.2  | 180.3  | 193.1  | 201.5  | 211.5  | 201.4  | 201.4  | 204.5  |
| Refuse derived fuels and other feedstocks | 87.0  | 91.0   | 101.1  | 141.3  | 169.2  | 198.3  | 170.5  | 178.3  | 178.1  | 181.4  |

Since 2013 problems on the domestic coal market have been deepening. It is linked with the gradual decrease in prices of fossil fuels – including coal – on international markets, internal problems and the reduction of electricity production on hard coal as well as the promotion of subsidized renewable energy.

Over 70% of imported power coal is heating coal, distributed through a network of fuel depots in the communal-living sector and other small consumers [19].

3.1. Thermal power industry – electric power production

Thermal power industry, including the production of electricity on the basis of hard coal, brown coal and natural gas, consists of:

- 116 utility power plants and CHP plants, which constitute the national electric power and network heat production base,
- 76 industrial power plants producing about 5% of total electric power,
- Independent CHP plants, producing about 1.5% of total electric power.

Data on the consumption of hard coal in the utility power industry, published among others by the ARP SA (coal sold by the mining sector to the utility power industry) [13] and ARE SA (coal consumed by the utility power industry) [14, 15, 18] are quite divergent as a result of stock levels in power plants and coal imports, which on average accounts for around 3-4% of total hard coal consumption in this sector [19].
Depending on economic and climatic conditions, the utility power industry consumes between 34 and 44 million tons/year of hard power coal fines. Coal stocks kept in piles: from 3.5 to 7 mln tons [13, 14, 15].

By 2020, the consumption in this sector is projected to decrease to 30 million tons/year (increase in brown coal share, subsidized renewable energy, improved efficiency of production, imports of electric power, coal imports, prices of CO₂ emission allowances – EU ETS, IED directives, etc.).

The quality of combusted coal and fuel policy is and will be dependent on the schedule of climate policy implementation:

- mainly coal fine with a low sulfur content <0.6% and a calorific value of 21-24 MJ/kg,
- after 2020, full flue gas desulfurization or high-calorie coal fine (> 27 MJ/kg) with a sulfur content of <0.4%.

It should be emphasized that coal usually adopted as a benchmark in international trade is power hard coal with a calorific value of 6000 kcal/kg (25.121 MJ/kg), sulfur content of 1.0% and grain size of 0-30 (50) mm [23].

In recent years the situation in hard coal mining sector and especially the level of transaction prices in supplies of coal to the power industry have been strongly influenced by the level of electric power prices in BASE futures, which is being set below the costs of electric power generation on hard coal (subsidized renewable energy, both domestic and imported, mainly from Germany and cheaper energy from brown coal is 150-170 PLN/MWh). This results in exerting pressure of the energy sector (with a price fixing nature) on a significant reduction in hard coal prices – up to 30-40% below import parity level and production costs, including signing long-term contracts which guarantee the power industry lowest purchase prices of coal. In the absence of a cheaper coal purchase option, the utility power industry reduces the generation of electric power on hard coal which in turn results in reduced receptions of this feedstock and thus an increase of the piles volume in coal mines, while maintaining stocks in power plants. Such a situation does not allow for pursuing any reasonable pricing policy by the mining sector.

3.2. Heat production

Heat for heating purposes and technological heat is produced by more than 10 688 heat generation sources, 466 of which are licensed heating companies [14, 18].

According to ARE SA this classification includes:

- 145 CHP plants and utility CHP plants,
- 51 industrial CHP plants,
- 10 120 non-utility CHP plants (small and medium sources),
- 372 manufacturing and distribution companies.

According to ARE SA publication [14] the heating sector annually consumes about 14.5 – 17.5 million tons of hard coal. The stock kept on piles is about 2-3 million tons.

According to forecasts of the Polish Chamber of Commerce, in the years 2020-2030 [24] the demand for coal is expected to decrease by up to 7 million tons/year, to 10 million tons/year in the proecological scenario, because of:

| Years | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Total | 15.52 | 155.57| 150.91| 156.34| 163.15| 159.85| 162.50| 156.56| 161.77| 162.62|
| Hard  | 93.13 | 86.55 | 84.27 | 89.21 | 90.81 | 84.49 | 84.57 | 80.82 | 81.88 | 81.34 |
| Brown | 51.14 | 53.80 | 50.79 | 49.60 | 53.62 | 55.59 | 56.96 | 54.21 | 53.56 | 51.20 |

Table 7. Electric power production TWh/year [12].
• reduction of transmission losses – min. 0.5 million tons/year,
• green heat (RES) – up to 10 million tons/year,
• thermal insulation of buildings – up to 4.5 million tons/year,
• waste incineration – up to 1.0 million tons/year,
• cogeneration.

In 2014, domestic heating companies consumed approximately 17.75 million tons of hard coal. The share of coal in the structure of fuels used for heat production is over 75%. These are mainly coals of low sulfur (< 0.6%) and low ash content.

After 2020, heat generation sources have to introduce full flue gas desulfurization (the alternative may be a high-calorie coal fine > 27MJ/kg with sulfur content < 0.4% – IED Directive).

Forecasts provide a significant increase in the share of renewable energy as well as reduction in transmission losses, thermal insulation of heated buildings and increase of heat generation efficiency.

3.3. Small consumer sector – housing, local boiler houses and heat plants, small industries and farms

According to the Central Statistical Office (GUS), this sector consumes around 11.5-12.5 million tons/year (without network heat) [16, 17, 22]. These are mainly thick and medium grade coals, including about 1.25 million tons of qualified fuels (‘eco-pea coals’). This sector is mainly supplied by a network of fuel stores belonging to Authorized Coal Dealers.

It is forecasted that the consumption of coal in this sector will maintain at the current level or decrease by 3-5 million tons per year – in case of radicalization of local governments policy in the field of air protection.

Coal combusted in households and small heat sources (< 1MW) is mainly of high-quality thick and medium grades (about 9 million tons/year) with calorific value of 24 to 31 MJ/kg, sulfur content below 0.6 (0.8) % and ash content less than 10%. However this also includes co-incineration of coal with biomass and municipal waste as well as combustion of low-quality coal fines and coal sludges. Combustion of these fuels, along with road transport, is the main cause of air pollution.

It should be emphasized that the effect of the so-called ‘anti-smog law’ may be – at best – switching to low-emission techniques with efficiency of about 85% (about 25-35% higher) and thus the increase in demand for EKORET and EKOFINS type fuels that meet technological requirements of low-emission coal boilers, and possible forcing-out coarse grades from the market.

Katowice Coal Holding is actively involved in the works of the Low-emission Coal Boiler Manufacturers Platform and the Qualified Solid Fuels, that acts by the Polish Chamber of Ecology. The aim of the Platform is – among other things – the promotion of low emission technologies for combating solid fuels, including hard coal, which until recently were utilized in Regional Low Emission Reduction Programs (PONE) and which, according to audits carried out by the Marshall Office in Katowice, were the most effective techniques in relation: financial expenditures – ecological effect.

4. Poland’s energy policy until 2050

What can replace coal and what will cover our future energy needs, estimated to be equivalent to another 25 million tons/year of hard coal?

According to the project of ‘Poland’s energy policy till the year 2050’ [25] our future energy needs (table 2) – especially in the area of electric power production – will be covered by nuclear and renewable energy (currently it is mainly wind energy). Sources based on natural gas will mainly stabilize the production of energy from renewable sources.

However, the essential energy production till 2050 is to be still based on coal, mainly hard one. This, however, requires replacing of more than 11 500 MW of power from the oldest coal-fired units with power up to 200 and above 200 MW by the year 2030.

Further use of domestic hard coal means a necessity to conclude a major restructuring of the mining sector (deep costs reduction), massive investments to get access to new resources and launch of mining fronts as well as urgent development of energy policy which will not lead to the
marginalization of coal-based energy by heavily subsidized renewable energy and will have mechanisms that allow for a rational financial policy, including taxation, in the mining sector during periods of price booms and boosts. Unfortunately, in extreme boost cases, support for the mining sector could reach the level of at least 1.8 – 2.0 billion PLN/year (about 20 thousand PLN per year per job). Taking into account the EU's ban on public aid for coal, the only option is reduction of mining costs (with estimated coal prices in ARA ports – by at least 26-30 PLN/ton of coal). This option could assure maintaining substantial number of jobs and financial support for the market (consumer spending of workers, services, supplies for mines including: energy, machinery, local and central taxes, etc.). It should be emphasized that coal mining costs, estimated at around 300 PLN/t, include over 100 PLN/t of taxes paid by the mining sector to local and central budget. This should be taken into account when one talks about the competitiveness of coal from Russia, Colombia, and Indonesia. For the money spent on possible coal imports (18-22 billion PLN/year) one could create at least 30 000 new jobs. The argument about extremely harmful effects of coal combustion on our health is important, but it gets more and more outdated. There are practically no power units and larger sources of heat generation that do not have effective air protection installations (smaller sources are successively adapting themselves to the IED Directive). The only gases that are emitted in this case are carbon dioxide and water vapour. Ultimately (CCS) it may be only water vapour.

5. Summary
To promote coal in the EU today one needs a lot of courage, but also a lot of imagination to answer the question WHAT INSTEAD OF COAL?

From the perspective of Polish economy, including energy security, the most rational seems to be the coal option based on low-emission technologies with high efficiency of generation (45% and above), energy from renewable sources, including prosumer energy, supported by energy from gas sources and nuclear power industry. The lack of any element of this production structure (i.e. delay in its implementation) in the forecasted period may mean a significant limitation in production and supply of electric power and heat.

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