Hard coal for energetic purposes: price – quality relationships; international coal market observations and Polish practice

Abstract

Coal is the most abundant and commonly used energy carrier in the world. In coal-producing countries, coal is often the cheapest fuel for electricity and heat production. Prices of steam coals offered by exporters on international markets reflect current economic and market conditions and are also related to the prices of other fossil fuels like crude oil and natural gas. International coal market observations and analyses lead to the conclusion that steam coal prices depend only on heating value. In Polish practice, steam coal prices are calculated using price formula in which coal price is a function of three quality parameters: net calorific value, ash content and sulphur content, and a price of ‘basic’ or ‘reference’ coal (which means: coal of defined quality).

This paper presents the results of international coal market analyses of relationships between coal price and quality and describes the Polish coal pricing system. A new solution, relevant to domestic coal mines and power plants, is presented to improve and simplify the conditions of bilateral settlements of coal deliveries.

Key words: Coal market, Coal prices, Price-quality relationships

1. Introduction

In the last 30 years, the energy crises shocked the global economy. Peoples and governments realised how important energy is for economic and civilisation development and for human beings. Rapid increase of prices of primary energy carriers – first of all hydrocarbon fuels – forced the introduction of energy conservation programmes and the efficient use of all kinds of energy, and the reduction of energy-consumption in the economy.

These events also showed that there are many factors influencing the prices of energy carriers, e.g. political situation in the regions of fossil fuels production (armed conflicts, strikes) or weather anomalies.

Crude oil is the most ‘political’ fossil fuel: the reserves are distributed non-uniformly, with the largest deposits in the Middle East - a region of permanent conflict. Crude oil is a raw material designed first of all for motor fuels and lubricants production and is limitedly used in electricity generation, but in some regions – popular for heating. Crude oil production quotas and prices are controlled by OPEC [1, 6].

The largest natural gas reserves are located in former Soviet Union countries and also in the Middle East. Natural gas is a competitive fuel for electricity and heat production comparing to other
fossils. Its competitiveness arises from elasticity in use, and depends on availability and prices in particular markets.

With this background, coal seems to be a stable fuel: its abundance, regular distribution of the reserves in the world, and large amount of coal producers, can guarantee easy access to the supplies [2].

2. International coal markets

Hard coal production in the world amounts about 3.5 milliard (3.5 x 10^9) tons annually. Over 85% of global demand for coal is supplied by domestic production - it means that only 15% of total world production is internationally traded [2].

Coal is a heterogeneous raw material, which can be described and characterised by a range of quality parameters, factors and indices. Heterogeneity of coal results from its genesis, location of deposits, geological conditions of coal formation, etc. The quality requirements of coal consumers differ depending on the equipment they have. There are reasons for which the quality standard for steam coal does not exist. The lack of quality standard is a peculiarity of coal as a market commodity.

There is neither a single world market for coal, nor a single world coal price. Also the coal stock exchange does not function (as for crude oil or metals) although first tests have been carried out.

However, we can divide international coal markets into two fundamental regions related to geographic position of coal deposits (suppliers) and place, where the coal importing countries are located.

Usually the two markets are named from the oceans (Pacific and Atlantic), that the coal transporting ships have to pass from coal producers to consumers [2, 3].

In the Pacific market the main coal suppliers (exporters) are Australia, Indonesia and China and the main consumers (importers) – Japan, South Korea and Taiwan.

West European and Mediterranean Basin countries are the dominant coal importers in the Atlantic market where South Africa, Colombia, Poland and the USA are the main suppliers.

The key quality parameter of coal for energetic purposes is the heating (or calorific) value as it determines directly the amount of heat released during combustion. Other important factors for electricity and heat generators are: ash content and composition, sulphur content as well as moisture and volatile matter content.

In coal statistics, the data on coal production and consumption are expressed in natural units or in tons of coal (or oil) equivalent – tce or toe. Coal prices are related to metric tons or to equivalent fuel to make them better comparable to other energy carriers.

3. Steam coal prices on the international markets

Coal prices depend on many factors like: coal supply-demand ratio in a given period, relation to the prices of other energy carriers, costs of coal production in coal-producing and exporting countries, the level of state aid (subsidies) to the coal industry as well as tax and tariff regulations in coal-producing and importing countries, electricity market deregulation, liberalisation of international trade, transportation costs (inland and maritime), etc.
Fig. 1
Steam coal prices in particular markets (coal: 6000 kcal/kg basis, sulphur cont. less than 1%)
Data sources: Australia, USA [4, 5], Europe, Asia [7]

Fig. 1 shows the comparison between coal prices related to different coal markets: Australian, US, European and Asian. To make the comparison easier – all prices have been converted to the same heating value (net calorific value, NCV = 6000 kcal/kg = 25.12 MJ/kg). According to data sources – in all coals the sulphur content was less than 1%.

The prices are fob (free on board, at piers of main ports) for Australia and US – the coal exporters [4, 5], and cif (cost, insurance, freight) for European and Asian importing markets [7].

An increase or decrease of prices reflects current economic and market conditions and depends on geographical region. It can be stated that the trends are very similar in each analysed market, only US coal prices strayed a little in tendencies from others recently.

Fig. 2
Comparison of coal, crude oil and natural gas prices in West European markets
Data sources: coal [7], crude oil, natural gas [4, 5]

Fig. 2 presents how coal prices were related to the prices of other fossil fuels like crude oil and natural gas in the period of 1994 - 2001. For the presentation, the annual average prices on West European markets have been chosen [4, 5, 7]. Original data have been expressed in current US dollars per GJ (giga joule). The figure shows that, in Europe, coal and natural gas prices have shown similar
tendencies. The changes of crude oil prices reflect the conditions of oil markets as well as some out–of–market factors, which influence the prices but are difficult to predict (e.g. political situation).

In the long term, one can observe that the coal prices follow the changes of crude oil prices with about 1 year delay (based on annual averages) [2, 4, 8-11].

4. Coal price – quality relationships

In internationally traded coals, the calorific value usually ranges from about 24 to 28 MJ/kg (with the highest values for US coals). The ash content is relatively low and amounts from 8 to 16 % [2, 3]. These two parameters are directly connected together: the higher the calorific value of coal, the lower the ash content.

Not only the percentage of ash is important but also ash composition and characteristic, and its behaviour during combustion. Even if ash content is low, the specific ash characteristic can cause problems in boilers or heat exchangers.

Sulphur content in coal is an important quality parameter because it influences the sulphur oxides emissions. Burning low-sulphur coals seems to be the simplest and often the cheapest method to decrease the national SO₂ emission, but it is difficult to evaluate how much low sulphur coals are available on the market. Most of coals on international markets have rather low sulphur content – less than 1%: however more detailed data on sulphur content in coals produced are published only very rarely.

As high sulphur coals are more burdensome for environment (during combustion) than low sulphur coals, one could think that such coals should be much cheaper. However the observations of coal prices on international markets do not prove this directly.

The relationships between coal price and basic quality parameters of steam coals have been investigated by the authors and analysed using multiple regression method. Analysis has been based on the data published in [3] where the prices of several dozen of coal classes (each described by three parameters: heating value Q, ash A and sulphur S content) were quoted. For the analysis, the authors have chosen the coals from four countries (South Africa, Colombia, Australia and US) which are the main exporters of coal into the EU market. The data (prices and parameters) concerned the 4 years, 1997-2000.

The results of analysis lead to the following conclusions:

until the end of 1998 [9]:
- very strong dependence on calorific value
- weak impact of sulphur content
- no relations between price and ash content

since 1999:
- distinctive dependence on calorific value
- no relations between price and sulphur nor ash content
- what is more – taking into consideration the ash and sulphur content worsens the results of regression analyses.

Statistically better results were obtained for more distant years and the worst – for last year of analysis (2000).
Conclusion: according to international coal market trends and observations, the prices of coal for energetic purposes are clearly dependent only on the heating value.

5. Polish coal pricing system

In Polish hard coal mining, the specific pricing system is used. It was introduced in 1990 year and was for application in the transition period of domestic economy (from centrally planned to the free market) [8]. In this system, the coal prices have been determined by two separate formulas for steam and for coking coal. Eq. (1) describes the formula for steam coal fines (designed for power and CHP plants) in which the price is a function of three quality parameters of coal:

\[
C = W_c \cdot C_{ref} \left( \frac{Q'_i}{25.12} - \frac{S'_i - 1}{10} - \frac{A' - 12}{100} \right)
\]

where:
- \(C\) - price of coal fines
- \(C_{ref}\) - price of ‘reference’ coal
- \(Q'_i\) - net calorific value (NCV) of coal, in MJ/kg
- \(S'_i\) - total sulphur content, in %
- \(A'\) - ash content, in %
- \(W_c\) - factor decreasing the price for coals of high ash content.

All quality parameters are measured at ‘as received’ basis.

The so-called ‘reference’ coal is the coal of NCV = 25.12 MJ/kg (6000 kcal/kg), sulphur content of 1% and ash content of 12%. The price \(C_{ref}\) refers to the ‘reference’ coal.

The formula was derived from the dependencies between quality and price observed (existed) in the international coal trade in the 1980s and introduced the similar relationships: the change of 1% in ash content results in 1% change of coal price and respectively 0.1% change in sulphur content results in 1% change of coal price. Changes of the coal quality are measured in relation to the pattern (or standard) which is the ‘reference’ coal.

Initially – three intervals of ash content were applied: I - from 0 to 12% A (\(W_c = 1\)); II - from 12.1 to 21% A and III - for coals of ash content above 21% (for third interval \(W_c = 0.8\) which means the coal prices were 20% lower for coals with high ash content). The division into three intervals of ash content was introduced to promote coal washing by making it profitable. For coals of second interval 1% decrease in ash content resulted in 2% improvement in price. The increase in price should compensate the loss of coal mass to tailings during coal washing and the costs of washing.

The steam coal price formula was the one valid in Poland from May, 1990 until the end of 1993. After that date, no formula for coal pricing is obligatory but the Eq. (1) is still commonly used by coal mines and energy generators in bilateral settlements for coal deliveries to evaluate the deviations from contract parameters of coal. Since 1994, the simplified formula has been used where \(W_c = 0.8\) for entire range of ash content.

After a few years of the formula application, some disadvantages were revealed. First one arose from high inflation level in Poland in the early 1990s that resulted in fast coal prices increase and that caused too big a price growth for higher-quality coals and in consequence a decreasing demand for better coals. Therefore the main target of the system application has been missed.
6. New solution of hard-coal pricing for energetic purposes

Some solutions to improve the existing pricing system have been proposed in the meantime, but they have not been accepted. The newest one has been presented recently. It was elaborated – likewise the previous system from 1990 - in the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Krakow [11].

The proposed pricing system has been based on the following assumptions:

1. Coal price is proportional to the calorific value.
2. The impact of sulphur and ash on the coal price is treated as a correction to the price.
3. Coal quality parameters – according to the proposal – should be given at ‘dry basis’ to avoid discrepancies in laboratory analyses made both by coal buyer and supplier.

The moisture content in coal fines is one of the most disputable (controversial) parameter because it influences the total weight of the coal and therefore it impacts on other quality parameters because they are determined at ‘weight’ basis. In the Polish Standard, the quality parameters of steam coal are expressed at ‘as received’ basis, however a modification of the standard is planned at present, intending to change the quality parameters into ‘dry basis’.

The proposed new reference coal parameters are the average parameters of steam coal used in Polish power generating industry. They are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Dry basis</th>
<th>As received basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>calorific value</td>
<td>[MJ/kg]</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>ash content</td>
<td>[%]</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>sulphur content</td>
<td>[%]</td>
<td>1</td>
<td>0.9</td>
</tr>
<tr>
<td>moisture content</td>
<td>[%]</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

The new coal pricing formula is described by the Eq. (2):

\[
C_{we} = C_{baz} \cdot \frac{Q_i^d}{24} \cdot \left(1 - \frac{W_{r}}{100} \right) - w_S \cdot (S_i^d - 1) - w_A \cdot (A^d - 24)
\]  

where:

- \(C_{we}\) – calculated price of steam coal, [PLN/Mg],
- \(C_{baz}\) – basic price of coal, [PLN/Mg],
- \(Q_i^d\) – calorific value of coal (at dry basis), [MJ/kg],
- \(A^d\) – ash content (at dry basis), [%],
- \(S_i^d\) – total sulphur content (at dry basis), [%],
- \(W_{r}\) – total moisture content, [%],
- \(w_S\) – factor correcting the price regarding the sulphur content, [PLN/Mg]
The term:
\[
\frac{Q^d}{24} \left( 1 - \frac{W'_r - 10}{100} \right)
\]
causes direct proportionality of price to calorific value. As the calorific value is to be measured at ‘dry basis’ – a total moisture content has to be taken into account. The idea of the formula is that only the moisture content above 10% influences the price – by decreasing it by 1% on each 1% of moisture. The moisture content below 10% does not influence the price.

Second term:
\[
w_s \cdot (S^d - 1)
\]
corrects the price regarding sulphur content and expresses the value of the correction in PLN (Polish zloty) per ton of coal.

The third term:
\[
w_A \cdot (A^d - 24)
\]
corrects the price regarding ash content and – as for sulphur - expresses the value of the correction in PLN per ton of coal.

The ‘basic price of coal’ \( C_{bas} \) is a very important element of the system – both in presently used and in proposed new formula. This price is a subject of negotiation between coal producers and the biggest coal consumers (power and CHP plants). It refers to the coal of the quality specified in the formula (2).

International coal markets observations do not prove the relationships between coal prices and ash and sulphur content. Usually they have lower calorific value, so more coal is needed to achieve the same thermal effect. It increases also the transportation costs. The higher sulphur content, the more sulphur dioxide creates and can incur additional costs for flue gas desulphurisation. These are only few examples that sulphur and ash in coal are arduous for both energy generators and environment.

The assessment of how the sulphur and ash content should influence the coal price is difficult, because it depends on many factors and it can be evaluated in different ways by particular coal users.

In the new formula, the valuation of the sulphur and ash impact is proposed to be made according to the obligatory fees (in Polish environmental regulations) for the emissions of \( \text{SO}_2 \) and \( \text{PM} \), and for solid wastes storage (fly and bottom ashes). The level of these corrections is still under discussion.

One can ask: is the pricing system for coal necessary? We can answer: maybe it is not necessary but it is useful because it simplifies the settlements between coal producers and consumers, and allows one to calculate a difference of coal price in case the quality of coal delivered to the buyer differs from that in the contract.

7. Conclusions

– Prices of steam coals on international markets reflect current economic and market conditions and are also related to the prices of other fossil fuels like crude oil and natural gas.

– The most important quality parameter of coal for energetic purposes is the heating (or calorific) value as it determines directly the amount of heat released during combustion.
International coal market observations and analysis lead to the conclusion that steam coal prices depend only on a heating value.

In Polish practice, steam coal prices are calculated using a price formula in which coal price is a function of three quality parameters: net calorific value, ash content and sulphur content, and a price of ‘basic’ or ‘reference’ coal (which means: coal of defined quality).

A new solution, proposed for domestic coal mines and power plants, is intended to improve and simplify the conditions of bilateral settlements of coal deliveries.

References