



Zbigniew GRUDZIŃSKI<sup>1</sup>

## The value of 1 GJ of energy in thermal coals assessed by the international market

**ABSTRACT:** The aim of the paper was to estimate how the value of 1 GJ of energy in coal with a calorific value of 5500 kcal/kg varies on the international coal market compared to 1 GJ of energy in coal with a calorific value of 6000 kcal/kg. The analysis of data from different ports was intended to answer the question of whether the pricing of coals of different producers according to their calorific value is convergent. The best-known price standard for thermal coal is 25.1 MJ/kg coal (6000 kcal/kg) and, until recently, coals with such quality parameters dominated international trade. Currently, coals with parameters other than considered to be standard parameters are traded on the coal market, hence it is necessary to price a unit of energy (e.g. 1 GJ) contained in these coals.

The indices have been selected of the largest exporters of thermal coal for which data was available and referred to the same coal types (grades) determined on the same basis (FOB). Theoretically, the price differential between 6000 kcal/kg and 5000 kcal/kg coal (in USD/ton) should be (at least) as much as the difference in calorific value, i.e. about 9% per USD/ton. In reality, the price differential between these types of coal is greater, though.

The overall conclusion of the analysis is that the price calculated per 1 GJ of energy fluctuated on average by 5.9% over the entire period considered. The analytical results obtained for coal from four countries are quite convergent, so it can be assumed that the calculated relationship between

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the prices of coal with different calorific values (6000 and 5000 kcal/kg) is a good approximation of the observed relationships in the international trade. The calculation results provide a simple formula allowing to estimate the price of coal with a calorific value other than the standard 25.1 MJ/kg (6000 kcal/kg) using the relationships from the international market.

KEYWORDS: international coal market, thermal coal, price indices

## Introduction

Today's global thermal coal trading basically uses price indices, i.e. prices that relate to a certain standardized quality. The need to create price indices resulted both from the development of e-commerce and the increasing use of financial instruments hedging against price risk (Over-the-Counter trading, OTC). The OTC transactions needed the standardization of the product (definition of basic, repeatable features). The subject of these transactions – both physical and financial (so-called paper transactions) – are specific grades of coal for which the price is determined according to price indices (Grudziński 2012, 2018).

Price indices refer to spot transactions. Spot transactions are instant transactions for which a 60–90 day delivery window is assumed (on the coal trading market, since 2015, there have been transactions with a shorter maturity period, i.e. 60, 45, and 25 days). Tenders are one of the variants of spot purchases. Spot transactions are concluded on a one-off basis, specifying the volume, price and delivery terms.

The indices are determined for basic markets; on the exporters' side these are FOB (Free-on-Board) indices at the most important thermal coal export ports, and on the importers' side CIF (Cost, Insurance and Freight) and CFR (Cost and Freight) indices for the most important coal reception points: Western Europe (ARA ports: Amsterdam-Rotterdam-Antwerp) and Asia (Japan and South Korea).

Thermal hard coal traded on international markets accounts for as little as 15–20% of the world's production of this raw material. Although the international coal market has only a small share in the production of this raw material, it plays an important role in shaping coal prices, even in countries which mainly use their own resources (Stala-Szlugaj and Grudziński 2018).

The best-known price standard for thermal coal is coal with a calorific value of 25.1 MJ/kg (6000 kcal/kg) and, until recently, coal with such quality parameters dominated the international trade. This was largely due to transport costs as the transport of high-calorific coal was the most cost-effective. A lower calorific value also usually means a higher ash content and, sometimes, a higher sulphur content, and thus higher environmental costs for a customer who burns such coal (Lorenz et al. 2013, 2016).

The calorific value is the most important quality parameter affecting the price of thermal coal.

The best-known CIF ARA price index (the oldest index since 1991) and FOB Newcastle price index refer to coal with a calorific value of 6000 kcal/kg, sulphur content below 1% and

ash content ranging from 11% to 16%. It should be noted, though, that the most important benchmark index for the entire coal market is the one determined on the FOB Newcastle port prices (Grudziński 2012; Lorenz 2016).

Figure 1 presents a comparison of changes in 6000 kcal/kg thermal coal spot prices between 2015 and 2019 (until June). The comparisons are based only on price indices for which indices for other coal grades were also available. As can be seen, all prices are strongly correlated. Currently, the market is experiencing strong price drops in all markets. Since September 2018, the prices have lost about 40% of their value and are at the level of Q4 2016.

International trade has also always included brands of coals with other quality parameters, and due to the increase in turnover of such coals, price indices have also been developed for

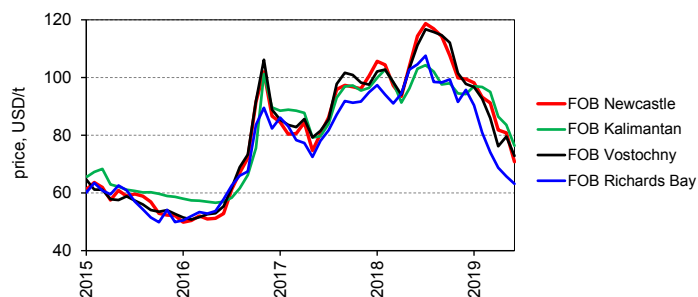


Fig. 1. Comparison of selected FOB thermal coal prices (6000 kcal/kg NAR) [USD/ton]  
Source: Platts, Argus, globaCOAL, World Bank

Rys. 1. Porównanie wybranych cen węgla energetycznych (6000 kcal/kg, NAR) na bazie FOB [USD/tonę]

other quality parameters. These indices are provided by organizations such as Platts, Argus, IHS McCloskey and globaCOAL.

As coals with the same basis (FOB, CIF, CFR) but with a different calorific value have appeared in the quotations, it is possible to calculate the change in price per unit change in calorific value.

The aim of the paper is to estimate how the value of 1 GJ in coal with a calorific value of 5000 kcal/kg varies on the international coal market compared to 1 GJ in coal with a calorific value of 6000 kcal/kg, and whether the pricing of coals of different producers according to its calorific value is convergent (Lorenz 2016; Stala-Szlugaj and Grudziński 2018).

Many coal supply contracts are indexed in relation to spot prices on the international market, and the main indices refer to coal with a calorific value of 6000 kcal/kg, hence the need to price the coal with parameters other than the so-called basic – standard – parameters.

## 1. Analysis of coal price indices for coals with a calorific value of 6000 kcal/kg and 5000 kcal/kg

A comparison of thermal coal spot prices has been carried out for four pairs of FOB coal (i.e. at the exporter's port):

- ◆ FOB Newcastle – Australia,
- ◆ FOB Richards Bay – South Africa,
- ◆ FOB Kalimantan – Indonesia,
- ◆ FOB Vostochny – Russia.

The indices have been selected of the largest exporters of thermal coal for which available data referred to the same grades of coal. These grades of thermal coal were coals with a calorific value of 25.1 MJ/kg (6000 kcal/kg) and 5000 (23 MJ/kg). Quality parameters of the compared coals are NAR (*Net-As-Received*).

The calculations provided cover the period from January 2015 to June 2019. For Russian coal only, data for 5000 kcal/kg coal was available from April 2017. The calculations have been prepared based on monthly averages.

For each pair of coals from a given country, Tables 1 to 4 show the calculated minimum, maximum and average prices as well as the average differential between the prices of the two different coal grades. The analysis was carried out for the period 2015 to 2019 (June) and for the last 12 months. Below the table, the graphs compare price changes for a given pair of coals from a given country. The graphs also show the changes in price differentials between the two grades of coal in question.

The purpose of this analysis was to calculate how the GJ value in coal follows the changes in its calorific value on various markets (in coals of different producers). The adoption of such assumptions has resulted in the same presentation of results for each country.

The results include data in Tables 1 to 4 and graphs in Figures 2 to 9. The graphs show how the actual spot prices of the compared grades of thermal coal develop and how they correlate (together with the linear equation and the coefficient of determination  $R^2$ ).

Graphs showing how the prices of coal (with a calorific value of 6000 and 5000 kcal/kg) changed between 2015 and 2019 in the exports from Australia, South Africa, Indonesia and Russia-Pacific (5000 kcal/kg coal quoted from April 2017 onwards) demonstrate a high consistency of trends, confirmed by graphs and calculated correlations. For four coals, the coefficient of determination  $R^2$  is high – above 0.77 – which means that over 77% of cases describe correctly the equation in the graph. The lowest correlation can be found for coal traded at the ports of Newcastle and Vostochny, and the highest for coal traded at Richards Bay port –  $R^2 = 0.95$ . The presented data shows a high correlation of prices between coal grades at a given port.

Theoretically, the price differential between 6000 kcal/kg and 5000 kcal/kg coal (in USD/ton) should be (at least) as much as the difference in calorific value, i.e. about 9% in USD/ton. In reality, the price differential between these grades of coal is greater, though. The value of 1 GJ of

energy in 5000 kcal/kg coal is less priced than it would result from the very relations between calorific values. Therefore, the next presentation of results shows how much lower the 5000 kcal/kg coal is priced per 1 GJ.

TABLE 1. Comparison of FOB Newcastle 6000 and 5000 kcal/kg coal prices [USD/ton]

TABELA 1. Porównanie cen węgla FOB Newcastle 6000 i 5500 kcal/kg [USD/tonę]

Coal – FOB Newcastle, Australia				
Q kcal/kg	Max.	Min.	Average	Differential
2015 – June 2019				
6000 (NAR)	116.8	49.9	80.3	20.4
5000 (NAR)	86.3	37.9	59.9	
Last 12 months (June 2018 – June 2019)				
6000 (NAR)	116.8	72.5	98.1	36.1
5000 (NAR)	74.8	53.5	62.0	

Source: Platts, Argus, globaCOAL, World Bank.

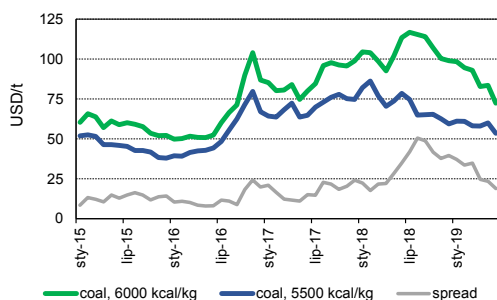


Fig. 2. Comparison of FOB Newcastle 6000 and 5000 kcal/kg coal prices and their differential in exports from Australia in 2015–2019 (June 2019)

Source: Platts, Argus, globaCOAL, World Bank

Rys. 2. Porównanie cen węgla FOB Newcastle (6000 i 5500 kcal/kg) oraz ich różnicy w eksporcie z Australii w latach 2015–2019 (VI 2019)

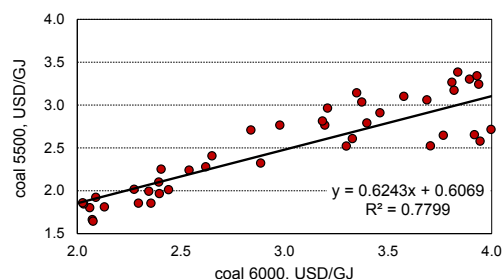


Fig. 3. Correlation results for FOB Newcastle 6000 and 5000 kcal/kg coal prices in 2015–2019 (June 2019)

Source: Author's own study

Rys. 3. Wyniki korelacji cen węgla 6000 i 5500 kcal/kg FOB Newcastle w latach 2015–2019 (VI 2019)

Table 5 summarizes the entire analysis. This summary shows that as far as the entire period 2015 to 2019 (June 2019) is concerned, changing the calorific value from 25.1 MJ/kg (approx. 6000 kcal/kg) to 23 MJ/kg (approx. 5000 kcal/kg) led to a GJ price drop in coal by about 12.3%. On the other hand, the price calculated to 1 GJ of energy fluctuated on average by 5.9%. For the last 12 months, that figure stood at 9%. If the average calculations included coal from the two most important suppliers, i.e. FOB Newcastle coal and FOB RB coal, the values in the whole period would amount to 6.8%, and in the last 12 months to 10.7%.

TABLE 2. Comparison of FOB Richards Bay 6000 and 5000 kcal/kg coal prices [USD/ton]

TABELA 2. Porównanie cen węgla FOB Richards Bay 6000 i 5500 kcal/kg [USD/tonę]

Coal – FOB Richards Bay, RPA				
Q kcal/kg	Max.	Min.	Average	Differential
2015 – June 2019				
6000 (NAR)	107.6	49.8	75.7	14.1
5000 (NAR)	87.8	38.4	61.6	
Last 12 months (June 2018 – June 2019)				
6000 (NAR)	107.6	63.1	86.2	19.1
5000 (NAR)	87.8	51.6	67.1	

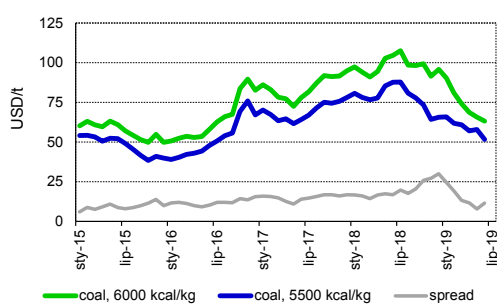


Fig. 4. Comparison of FOB Richards Bay 6000 and 5000 kcal/kg coal prices and their differential in exports from South Africa in 2015–2019 (June 2019)  
Source: Source: Platts, Argus, globaCOAL, World Bank

Rys. 4. Porównanie cen węgla FOB Richards Bay (6000 i 5500 kcal/kg) oraz ich różnicy w eksporcie z RPA w latach 2015–2019 (VI 2019)

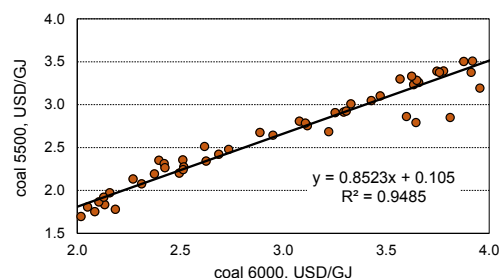


Fig. 5. Correlation results for FOB Richards Bay 6000 and 5000 kcal/kg coal prices in 2015–2019 (June 2019)  
Source: Author’s own study

Rys. 5. Wyniki korelacji cen węgla 6000 i 5500 kcal/kg FOB Richards Bay w latach 2015–2019 (VI 2019)

The results of these calculations could be used for coal supply contract settlements in the case of supplies of varying quality. In coal from countries such as: Russia, South Africa and Indonesia, the pricing of coal with lower calorific value is quite stable in the analyzed period and amount to about 5–7%. The situation is different when it comes to coal from Australia. Price differentials between higher- and lower-grade coal have been systematically increasing and were significantly higher in the last 12 months; the differences in the pricing of 1 GJ in these coals stay at 15%, i.e. they are more than 2.5 times higher than in other coals. However, in the whole period they are very similar to other results.

Over the analyzed period, the actual coal spot prices varied widely, i.e. from USD 38 to 117 per ton. The analysis results obtained for coal from four countries are quite convergent; it can be therefore assumed that the calculated relationship between coal prices with different calorific values (6000 and 5000 kcal/kg) is a good approximation of the observed relationships in the international trade.

TABLE 3. Comparison of FOB Vostochny 6000 and 5000 kcal/kg coal prices [USD/ton]

TABELA 3. Porównanie cen węgla FOB – FOB Vostochny 6000 i 5000 kcal/kg [USD/tonę]

Coal – FOB Vostochny, Russia				
Q kcal/kg	Max.	Min.	Average	Differential
2015 – June 2019				
6000 (NAR)	112.2	72.5	94.0	16.5
5000 (NAR)	90.4	62.0	77.6	
Last 12 months (June 2018 – June 2019)				
6000 (NAR)	112.2	72.5	94.2	18.3
5000 (NAR)	88.3	62.0	75.9	

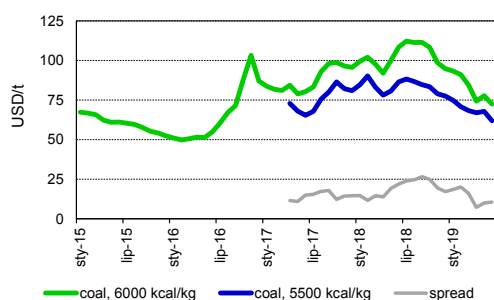


Fig. 6. Comparison of FOB Vostochny 6000 and 5000 kcal/kg coal prices and their differential in exports from Russia in 2015–2019 (June 2019)  
Source: Source: Platts, Argus, globaCOAL, World Bank

Rys. 6. Porównanie cen węgla FOB Vostochny (6000 i 5000 kcal/kg) oraz ich różnicy w eksporcie z Rosji w latach 2015–2019 (VI 2019)

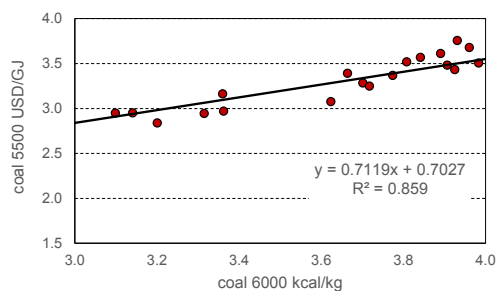


Fig. 7. Correlation results for FOB Vostochny 6000 and 5000 kcal/kg coal prices in 2015–2019 (June 2019)  
Source: Author's own study

Rys. 7. Wyniki korelacji cen węgla 6000 i 5000 kcal/kg FOB Vostochny w latach 2015–2019 (VI 2019)

The comparisons show that a 1 GJ change in calorific value changes the price by about 6%. During the period under review, the actual coal prices fluctuated extensively, i.e. from USD 38 to 117 per ton. The results of these calculations allow for the presentation of a simple formula for estimating the price of coal with a calorific value other than the standard value – 25.1 MJ/kg (6000 kcal/kg) – using the relationships on the international coal market.

The formula for calculating the price of thermal coal with a calorific value other than the standard 6000 kcal/kg – rounded off to 25 MJ/kg – is given below

$$C = C_{baz} \cdot \left( 1 - \frac{Q_{baz} - Q}{M_{baz}} \right)$$

where:

- $C$  – calculated price of coal with calorific value other than base coal,
- $Q_{baz}$  – calorific value in base coal – 25 MJ/kg (6000 kcal/kg),
- $M_{baz}$  – coefficient determining the change in calorific value in relation to base coal. In the current price situation, this coefficient is at the level of approx. 17, i.e. the price varies by about 5.9% per 1GJ/kg compared to the base coal's calorific value. Adopting this coefficient at the level of 20, for instance, leads to a 5% change,
- $C_{baz}$  – coal price (e.g. FOB Newcastle or CIF ARA) with a base calorific value from the international market, USD/GJ (or in another currency converted to GJ).
- $Q$  – the calorific value in MJ/kg of specific coal.

TABLE 4. Comparison of FOB Kalimantan 6000 and 5000 kcal/kg coal prices [USD/ton]

TABELA 4. Porównanie cen węgla OB Kalimantan 6000 i 5500 kcal/kg [USD/tonę]

Coal – FOB Kalimantan, Indonesia				
Q kcal/kg	Max.	Min.	Average	Differential
2015 – June 2019				
6000 (NAR)	104.3	56.6	80.3	15.0
5000 (NAR)	87.3	46.1	65.2	
Last 12 months (June 2018 – June 2019)				
6000 (NAR)	104.3	76.4	93.8	24.3
5000 (NAR)	80.5	64.0	69.5	

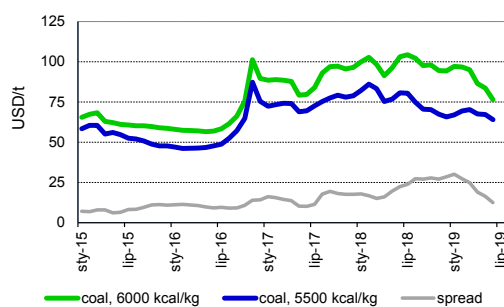


Fig. 8. Comparison of FOB Kalimantan 6000 and 5000 kcal/kg coal prices and their differential in exports from Indonesia in 2015–2019 (June 2019)  
Source: Source: Platts, Argus, globaCOAL, World Bank

Rys. 8. Porównanie cen węgla – FOB Kalimantan (6000 i 5500 kcal/kg) oraz ich różnicy w eksporcie z Indonezji w latach 2015–2019 (VI 2019)

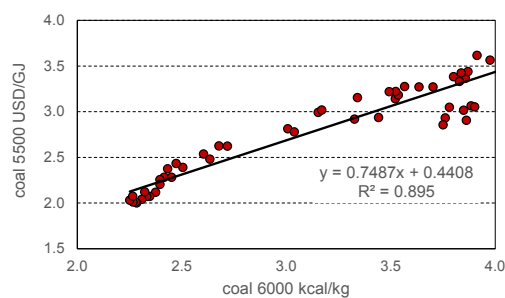


Fig. 9. Correlation results for FOB Kalimantan 6000 and 5000 kcal/kg coal prices in 2015–2019 (June 2019)  
Source: Author's own study

Rys. 9. Wyniki korelacji cen węgla 6000 i 5500 kcal/kg FOB Kalimantan w latach 2015–2019 (VI 2019)



TABLE 5. Results of the analysis of the estimation of 1GJ/kg price change in 5000 kcal/kg coal compared to 1 GJ value in 6000 kcal/kg coal

TABELA 5. Wyniki analizy szacowania zmiany ceny 1GJ/kg w węglu 5500 kcal/kg w porównaniu z wartością 1 GJ/kg w węglu 6000 kcal/kg

FOB Newcastle		FOB Richards Bay	
2015–2019 (VI 2019)		2015–2019 (VI 2019)	
average	-8.3%	average	-5.3%
min.	-18.4%	min.	-12.0%
max.	-2.1%	max.	-0.9%
last 12 months		last 12 months	
average	-14.5%	average	-7.0%
min.	-18.4%	min.	-12.0%
max.	-8.1%	max.	-4.0%
FOB Indonesia		FOB Vostochny	
2015–2019 (VI 2019)		2015 – 2019 (VI 2019)	
average	-5.1%	average	-4.7%
min.	-11.8%	min.	-8.1%
max.	-0.8%	max.	-0.8%
last 12 months		last 12 months	
average	-9.0%	average	-5.5%
min.	-11.8%	min.	-11.8%
max.	-4.8%	max.	-4.8%
Total – average changes – 5.9%/1GJ (2015 – June 2019)			
Total – average changes – 9%/1GJ (last 12 months)			

## Conclusion

The main spot price indices for thermal coal on the international market are determined primarily for standardized quality coal; this makes them easy to convert into units of energy such as 1 GJ. In recent years, as a result of the rapid development of international markets, coals with other calorific values have appeared and price indices are being developed for these coals with reference to other quality parameters; there are also price indices calculated for the same basis (e.g. FOB, CIF, CFR) but with different (than standard) parameters. This situation made it possible to calculate how the price of a given coal grade varies depending on changes in its calorific value. The aim of this article was to analyze those prices and try to standardize the changes. It

has been found that the changes in the prices of coal with a calorific value of 6000 kcal/kg and 5000 kcal/kg at different ports are similar which allows for a standardization of those changes.

These considerations are essential for the analysis of data covering the entire period from 2015 to 2019 (June 2019). In the analysis of data for the last 12 months only, the results for FOB Newcastle coal significantly differ from those for other coals (Richard Bay, Kalimantan, Vostochny). The current high volatility of prices on the Atlantic and Pacific market should stabilize next year and shift to trends observed in previous years.

The analysis of the data allowed to propose a formula for pricing the coal with a different calorific value compared to coal with standardized quality, i.e. 25 MJ/kg (6000 kcal/kg).

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Zbigniew GRUDZIŃSKI

## Wartość 1 GJ energii w węglach energetycznych wycenianych przez rynek międzynarodowy

### Streszczenie

Celem artykułu było oszacowanie, jak zmienia się wartość 1 GJ energii w węglu o wartości opałowej 5500 kcal/kg w stosunku do wartości 1 GJ w węglu 6000 kcal/kg na międzynarodowym rynku węgla. Analiza danych z różnych portów miała odpowiedzieć na pytanie, czy wyceny węgla różnych producentów różnicujących je w zależności od wartości opałowej są zbieżne. Najbardziej znanym standardem cenowym dla węgla energetycznego jest węgiel o wartości opałowej 25,1 MJ/kg (6000 kcal/kg) i jeszcze niedawno węgle o takich parametrach jakościowych dominowały w handlu międzynarodowym. Obecnie na rynku węgla notowane są węgle o innych parametrach uznawanych za standardowe, stąd konieczna jest wycena jednostki energetycznej (np. 1 GJ) zawartej w tych węglach.

Wybrano indeksy największych eksporterów węgla energetycznego, dla których dostępne były dane odnoszące się do takich samych gatunków (klas) węgla i określanych do tej samej bazy (FOB). Teoretycznie, różnica cen między węglem 6000 a 5500 kcal/kg (w USD/tonę) powinna wynosić (minimum) tyle, ile wynika z różnicy kaloryczności, czyli kształtować się na poziomie ok. 9% –w przeliczeniu na USD/tonę. Jednak w rzeczywistości różnica cen między tymi gatunkami węgla jest większa.

Z podsumowania całej analizy wynika, że cena przeliczona na 1 GJ energii średnio zmieniała się o 5,9% w całym badanym okresie. Otrzymane wyniki analiz dla węgla z czterech krajów są dosyć zbieżne, można więc przyjąć, że wyliczona zależność między cenami węgla o różnej kaloryczności (6000 i 5500 kcal/kg) jest dobrym przybliżeniem obserwowanych relacji w handlu na rynku międzynarodowym. Wyniki obliczeń pozwalają na przedstawienie prostej formuły pozwalającej szacować cenę węgla o innej wartości opałowej niż standardowa – 25,1 MJ/kg (6000 kcal/kg) – wykorzystując relacje z rynku międzynarodowego.

SŁOWA KLUCZOWE: międzynarodowy rynek węgla, węgiel energetyczny, indeksy cenowe

