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Domestic hard coal supplies to the energy sector: the impact of global coal prices

Introduction

A significant increase in Poland's coal imports has been observed, in recent years. While in 2016 Polish consumers imported 6.2 million Mg of coal (of which 4.2 million Mg was steam coal), and in 2017 roughly 10.1 million Mg of coal (of which 7.4 million Mg was steam coal), Poland's coal imports amounted to 10.6 million Mg just between January and September of 2018 (of which 8.8 million Mg was steam coal). It is estimated that by the end of the year coal imports will exceed 15 million Mg, of which steam coal will amount to approx. 12 million Mg. Although the Polish power sector and the district heating sector are not dominant consumers of imported steam coal, yet an increase in the share of imported coal is expected in the upcoming years.

The increase in Poland's coal imports is the result of various factors, out of which three are worth mentioning:

- limited production capacity of domestic coal mines,
- quality parameters of imported coal (higher calorific value, low Sulphur and ash content),
- lower prices of imported coal.

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The first factor is directly related to the specificity of the investment process in hard coal mining. Changes planned in the mining capacity should be based on robust analyses of coal demand, which should later be used for adjustments in the investment strategies of mining enterprises.

The second factor is related to the requested quality parameters of coal consumers. For most power plants or Combined Heat and Power (CHP) plants, the quality of coal must meet specific requirements. In consequence, as a minimum, the calorific value, Sulphur content, and ash content have to be within specific ranges.

The third factor is related to the coal market conditions, hence to the relation between domestic and global coal prices. While correlations between global and domestic coal prices have been observed, Figure 1 shows that they are not directly linked. Evidently, a lower price of imported coal, when compared to the price of domestic coal, leads to a higher volume of imports. In this context, a key research question is: how would possible changes in the price relation between domestic and imported coal affect the total volume of Poland's coal imports?

The problem of hard coal imports to Poland has been widely discussed in the literature. Thus, the following papers should be mentioned (Gawlik et al. 2016; Gawlik and Mokrzycki 2017; Grudziński 2014; Lorenz 2015; Malec et al. 2015; Stala-Szlugaj and Grudziński 2018; Stala-Szlugaj 2013, 2014; Szurlej et al. 2014).

In light of the abovementioned conditions, this paper aims to analyze the impact of potential changes in the price relation between domestic and imported coal on the volume of

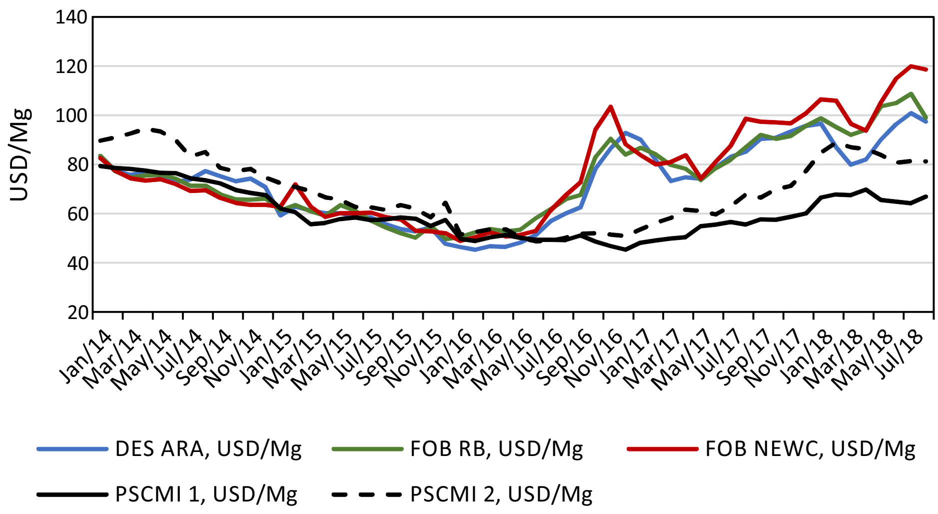

Fig. 1. Steam coal price indices comparison – global (DES ARA, FOB RB, FOB NEWC) vs. Poland (PSCMI 1, PSCMI 2)
Source: ARP 2018a, ARP 2018b and NBP 2014–2018

Rys. 1. Porównanie indeksów cen węgla energetycznego – światowe (DES ARA, FOB RB, FOB NEWC) vs. krajowe (PSCMI 1, PSCMI 2) coal imported to Poland. The study was carried out with the application of a computable model developed for the Polish energy system. The model reflects the fundamental relations between coal suppliers (mines, importers), power plants, and CHPs.

The remainder of this paper is organized as follows: the methodology of the paper is presented in section 2. Section 3 outlines the key assumptions and describes multiple scenarios. The results are discussed and analyzed in section 4. The paper ends with conclusions and main findings (section 5).

1. Methodology

The mathematical model developed to address the research problem stated in the introduction is formulated to represent the domestic hard coal mining sector, including the most important relations in the power generation and heat producing sectors. In that regard, all coal mines operating in Poland are reflected, on the supply side of the model, i.e. Polska Grupa Górnicza SA, Jastrzębska Spółka Węglowa SA, Lubelski Węgiel Bogdanka SA, TAURON Wydobycie SA, Przedsiębiorstwo Górnicze Silesia Sp. z o.o., WĘGLOKOKS KRAJ Sp. z o.o., Zakład Górniczy Siltech Sp. z o.o., Eko-Plus Sp. z o.o., Karbonia SA and Spółka Restrukturyzacji Kopalń SA. Moreover, the coal producers are implemented in the model as individual coal mines, which are characterized by the quantity and quality characteristics of their produced coal. Furthermore, the maximum level of domestic coal supply is limited by the production capacity of the mines.

Due to the research problem studied in this paper, coal importers are also taken into account and hence assigned to the supply side. It is assumed that coal transshipment terminals such as railway border crossings, and seaports represent coal importers/suppliers (Fig. 2).

Fig. 2. Main coal transshipment terminal locations in Poland

Rys. 2. Główne lokalizacje terminalów przeładunkowych węgla w Polsce

The quantity of imported coal is limited by the maximum capacity of railway border crossings and seaports.

Due to the heterogeneity of hard coal, the model includes a classification of coal according to type and quality classes. Polish standard PN-82/G-97002 is assumed as the coal quality standard. Aside from the assignment of produced/imported coal to the appropriate range, type and class, each coal is also described by detailed qualitative parameters (including calorific value, ash content and Sulphur content).

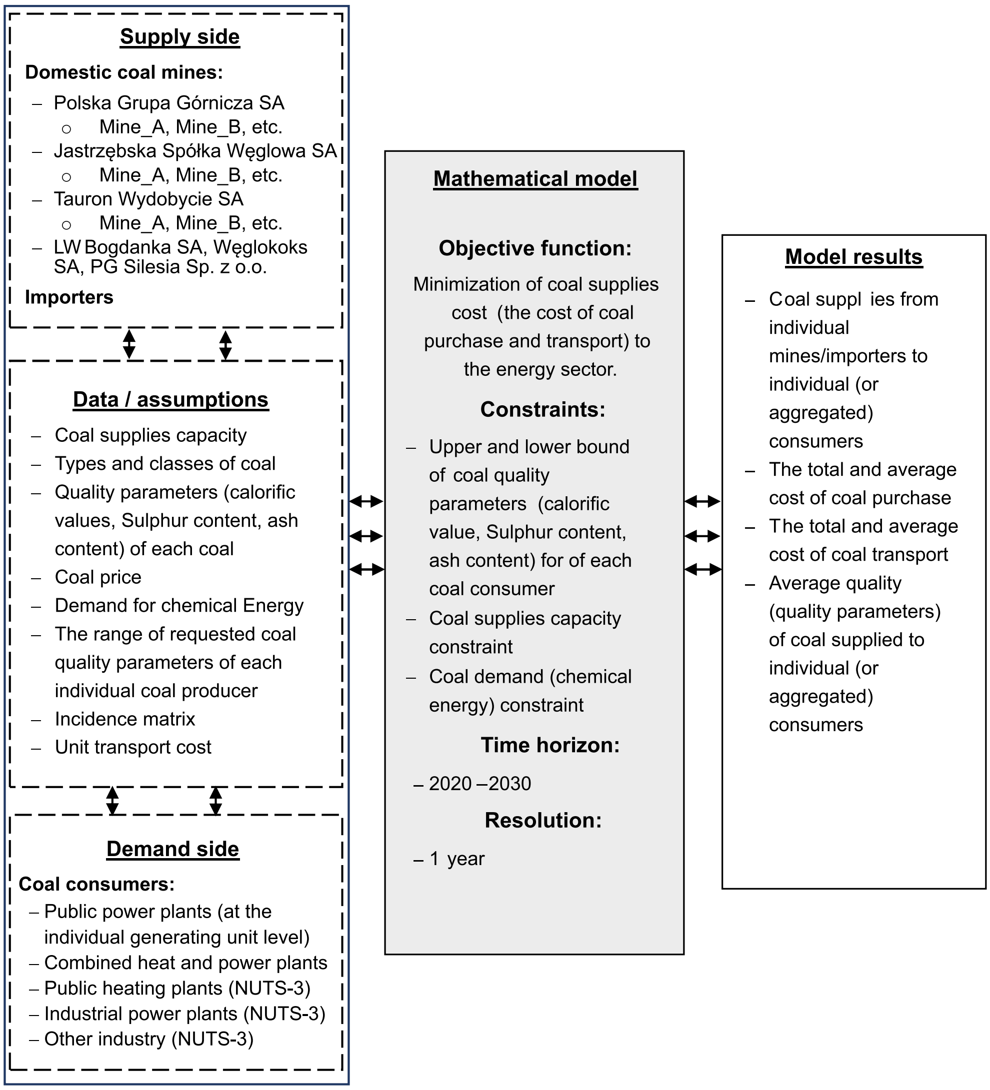

Fig. 3. Simplified conceptual model

Rys. 3. Uproszczony model konceptualny

On the demand side, key coal consumers are reflected individually (i.e. public power plants and combined heat and power plants as well as industrial and public heating plants). The range of quality parameters is set individually for each coal consumer (i.e. lower and upper limit of calorific value, Sulphur and ash content). This mirrors the real requirements from coal consumers, which are characterized by specific requirements concerning quality parameters.

The aim of the model is to minimize the total coal supplies cost (volumes of coal of specific quality) while meeting the demand for chemical energy of each individual coal consumer and taking quality requirements into account. The objective function of the model includes two main elements, namely:

- coal-purchasing costs,
- transportation costs.

The assumed time horizon of the model is 2020–2030 with a yearly resolution. The model is developed in GAMS (General Algebraic Modelling System) (Brook et al. 1992), formulated as a Linear Programming (LP) problem and solved with the use of the CPLEX solver (GAMS 2010). In addition, the formulation of the model is in line with the general methodology of computable models presented in: (Kamiński 2010, 2011; Sierksma 2002; Sioshansi and Conejo 2017; Winston 2004). A simplified conceptual model is presented in Figure 3.

Table 1 presents the sets of the model. Table 2 describes the parameters and Table 3 the variables of the model. Table 4 describes the constraints and balances (equations and inequalities) of the model.

Table 1. Sets of the mathematical model

Tabela 1. Zbiory modelu

Name	Description
m	Coal suppliers (mines and importers), $m \in M$
t	Coal quality classes and types, $t \in T$
s	Coal consumers (public power plants (at the individual generating unit level), combined heat and power plants, public heating plants (NUTS-3), industrial power plants (NUTS-3), other industry (NUTS-3), $s \in S$
y	Years, $y \in Y$

Table 2. Parameters of the mathematical model

Tabela 2. Parametry modelu

Name	Unit	Description
$MT_{m,t}$	–	Incidence matrix: 1 – if mine/importer *m* is a potential supplier of coal *t*, 0 – otherwise
$Demand_{s,y}$	GJ	Demand for coal of consumer *s* in year *y*
$NCV_{m,t,y}$	GJ/Mg	Average calorific value of coal *t* offered by mine/importer *m* in year *y*
$MinNCV_{s,y}$	GJ/Mg	Lower bound of calorific value accordingly quality requirements of consumer *s* in year *y*
$MaxNCV_{s,y}$	GJ/Mg	Upper bound of calorific value accordingly quality requirements of consumer *s* in year *y*
$AshContent_{m,t,y}$	%	Average ash content of coal *t* offered by mine/importer *m* in year *y*
$MinAshContent_{s,y}$	%	Lower bound of ash content accordingly quality requirements of consumer s in year *y*
$MaxAshContent_{s,y}$	%	Upper bound of ash content accordingly quality requirements of consumer *s* in year *y*
$SulphurContent_{m,t,y}$	%	Average Sulphur content of coal *t* offered by mine/importer *m* in year *y*
$MinSulphurContent_{s,y}$	%	Lower bound of Sulphur content accordingly quality requirements of consumer *s* in year *y*
$MaxSulphurContent_{s,y}$	%	Upper bound of Sulphur content accordingly quality requirements of consumer *s* in year *y*
$CoalSuppliesCapacity_{m,t,y}$	Mg	Coal production/import capacity of coal *t* offered by mine/importer *m* in year *y*
$CoalPrice_{m,t,y}$	PLN/Mg	Price of coal *t* offered by mine/importer *m* in year *y*
$Distance_{m,s}$	km	Distance from coal mine/importer *m* to consumer *s*
$TransportCost_{m,s,y}$	PLN/km·Mg	Unit transport cost from mine/importer *m* to consumer *s* in year *y*

Table 3. Variables of the mathematical model

Tabela 3. Zmienne modelu

Name	Unit	Description
Positive variable		
$CoalSupplies_{m,t,s,y}$	Mg	Supplies of coal *t* from supplier (mine/importer) *m* to consumer *s* in year *y*
Free variable		
TotalCoalSuppliesCosts	PLN	Total coal supplies costs (coal purchase and coal transport cost)

Table 4. Constraints and balances (equations and inequalities) of the model

Tabela 4. Ograniczenia i bilanse modelu

Name	Unit	Description
$EQU\_CoalDemand_{s,y}$	GJ	Balance of production and demand for coal from consumer *s* in year *y*
$EQU\_MinNCV_{s,y}$	GJ/Mg	Lower bound of calorific value requested by consumer *s* in year *y*
$EQU\_MaxNCV_{s,y}$	GJ/Mg	Upper bound of calorific value requested by consumer *s* in year *y*
$EQU\_MinAsh_{s,y}$	%	Lower bound of ash content requested by consumer *s* in year *y*
$EQU\_MaxAsh_{s,y}$	%	Upper bound of ash content requested by consumer *s* in year *y*
$EQU\_MinSulphur_{s,y}$	%	Lower bound of Sulphur content requested by consumer *s* in year *y*
$EQU\_MaxSulphur_{s,y}$	%	Upper bound of Sulphur content requested by consumer *s* in year *y*
$EQU\_CoalCapacity_{m,t,y}$	Mg	Production/importing capacity of coal *t* offered by mine/importer *m* in year *y*
EQU_TotalCoalCosts	PLN	Total costs of coal supplies (coal purchase and transport cost) – the objective function

The mathematical representation of model is given below:

- ***EQU_CoalDemand*** $_{s,y}$

$$\underset{s\in S}{\forall}\ \underset{y\in Y}{\forall}\ \sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot NCV_{m,t,y}\cdot MT_{m,t}\right)\geq$$
$$\geq Demand_{s,y}$$

- ***EQU_MinNCV*** $_{s,y}$

$$\underset{s\in S}{\forall}\ \underset{y\in Y}{\forall}\ \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot NCV_{m,t,y}\cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot MT_{m,t}\right)}\geq$$
$$\geq MinNCV_{s,y}$$

- ***EQU_MaxNCV*** $_{s,y}$

$$\underset{s\in S}{\forall}\ \underset{y\in Y}{\forall}\ \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot NCV_{m,t,y}\cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot MT_{m,t}\right)}\leq$$
$$\leq MaxNCV_{s,y}$$

- ***EQU_MinAsh*** $_{s,y}$

$$\underset{s\in S}{\forall}\ \underset{y\in Y}{\forall}\ \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot AshContent_{m,t,y}\cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot MT_{m,t}\right)}\geq$$
$$\geq MinAshContent_{s,y}$$

- ***EQU_MaxAsh*** $_{s,y}$

$$\underset{s\in S}{\forall}\ \underset{y\in Y}{\forall}\ \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot AshContent_{m,t,y}\cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y}\cdot MT_{m,t}\right)}\leq$$
$$\leq MaxAshContent_{s,y}$$

- ***EQU_MinSulphur$_{s,y}$***

$$\underset{s \in S}{\forall} \underset{y \in Y}{\forall} \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y} \cdot SulphurContent_{m,t,y} \cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y} \cdot MT_{m,t}\right)} \geq$$
$$\geq MinSulphurContent_{s,y}$$

- ***EQU_MaxSulphur$_{s,y}$***

$$\underset{s \in S}{\forall} \underset{y \in Y}{\forall} \frac{\sum_{m,t}\left(CoalSupplies_{m,t,s,y} \cdot SulphurContent_{m,t,y} \cdot MT_{m,t}\right)}{\sum_{m,t}\left(CoalSupplies_{m,t,s,y} \cdot MT_{m,t}\right)} \leq$$
$$\leq MaxSulphurContent_{s,y}$$

- ***EQU_CoalCapacity$_{m,t,y}$***

$$\underset{m \in M}{\forall} \underset{t \in T}{\forall} \underset{y \in Y}{\forall} \sum_{s}\left(CoalSupplies_{m,t,s,y} \cdot MT_{m,t}\right) \leq$$
$$\leq CoalSuppliesCapacity_{m,t,y}$$

- ***EQU_TotalCoalCost***

$$TotalCoalCosts = \sum_{m,t,s,y}\left(CoalSupplies_{m,t,s,y} \cdot MT_{m,t} \cdot CoalPrice_{m,t,y}\right) +$$
$$+ \sum_{m,t,s,y}\left(CoalSupplies_{m,t,s,y} \cdot Distance_{m,s} \cdot TransportCost_{m,s,y}\right)$$

2. Key assumptions and scenarios

As mentioned in the methodology section, all key fine coal consumers were reflected in the model, on the demand side. The assumed demand for the years 2020–2030 of chemical energy from public power plants, public combined heat and power plants, public and non-public heating plants as well as industrial power plants and other large industrial plants are presented in Table 5 and Figure 4.

Table 5. Model assumptions – fine coal demand (TJ)

Tabela 5. Założenia do modelu – zapotrzebowanie na miały energetyczne (TJ)

TJ	2020	2025	2030
Public power plants	592,677	639,012	559,442
Public combined heat and power plants	249,435	232,435	220,414
Public and non-public heating plants	97,957	95,679	81,685
Industrial power plants and other large industrial plants	112,971	104,344	97,566
Total demand	1,053,041	1,071,470	959,108

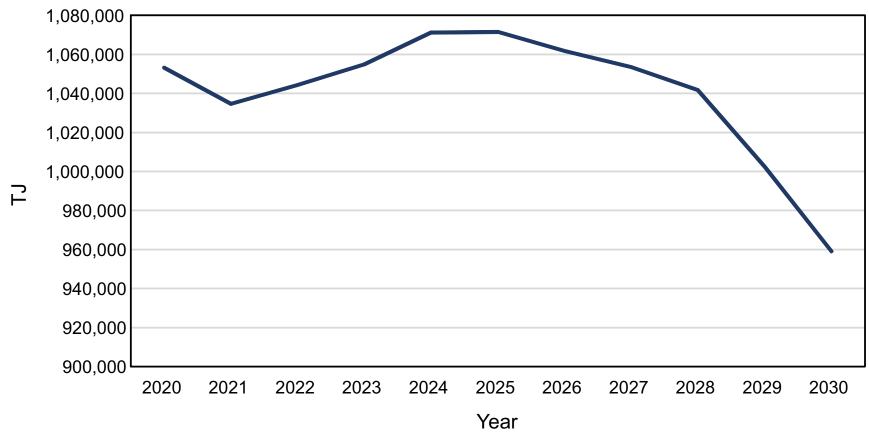

Fig. 4. Model assumption – total fine coal demand (TJ)

Rys. 4. Założenia do modelu – całkowite zapotrzebowanie na miały energetyczne (TJ)

In addition, apart form the annual fine coal demand, upper and lower bounds of specific quality parameters required by each power generation unit (and in some cases aggregated power plants) were assumed. For this study, the following quality parameters were considered: Net calorific value (NCV) (Fig. 5), ash content (Fig. 6) and sulphur content (Fig. 7).

One of the key assumptions in this work is that domestic coal is characterized by the calorific value of 21 MJ/kg, and imported coal by the value of 25 MJ/kg. Thirteen scenarios were formulated in order to carry out the analysis. A key factor differentiating each scenario was the relation of imported coal prices (coal price at the railway crossing or seaport) versus the prices of coal offered by domestic coal producers. Although the reference coals are characterized by different calorific value, in this work prices are differentiated in PLN/GJ so that the key parameter for coal consumers is adequately treated.

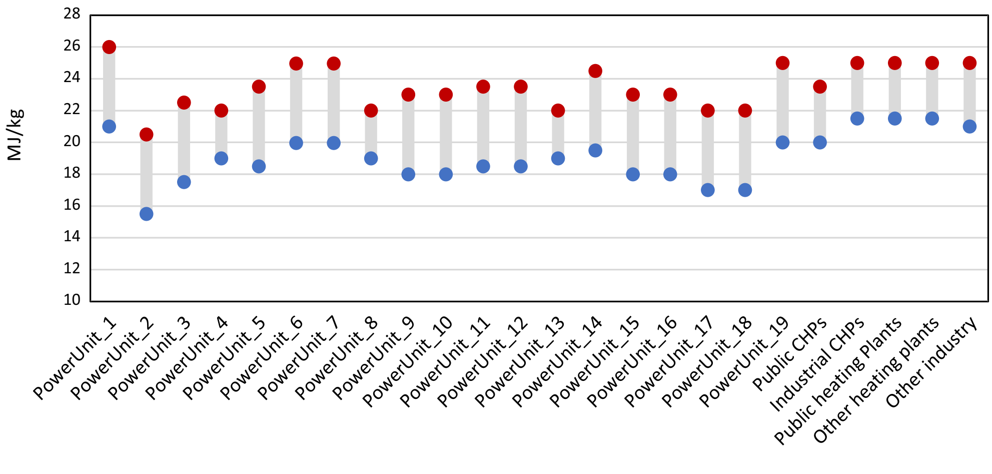

Fig. 5. Minimal and maximal NCV of fine coal required by demand units (MJ/kg)

Rys. 5. Minimalna i maksymalna wartość opałowa
wymagana przez odbiorców miałów energetycznych (MJ/kg)

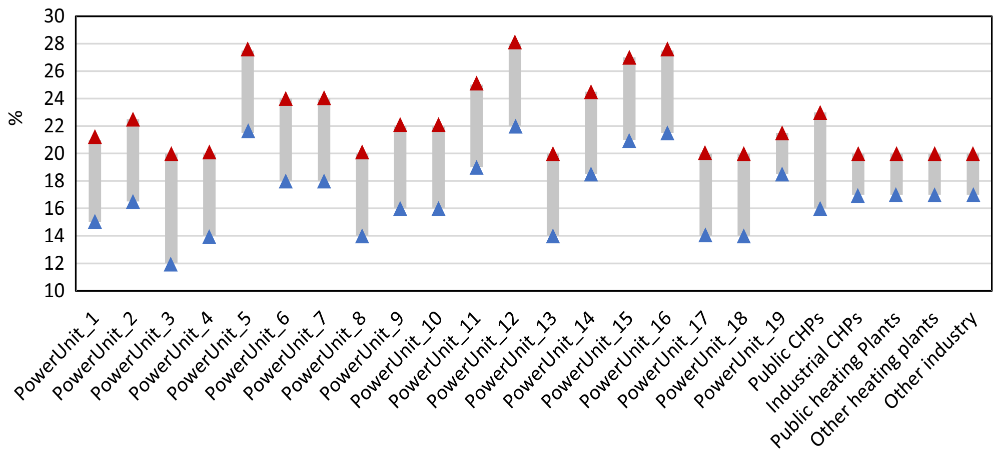

Fig. 6. Minimal and maximal ash content in fine coal required by demand units (%)

Rys. 6. Minimalna i maksymalna zawartość popiołu
wymagana przez odbiorców miałów energetycznych (%)

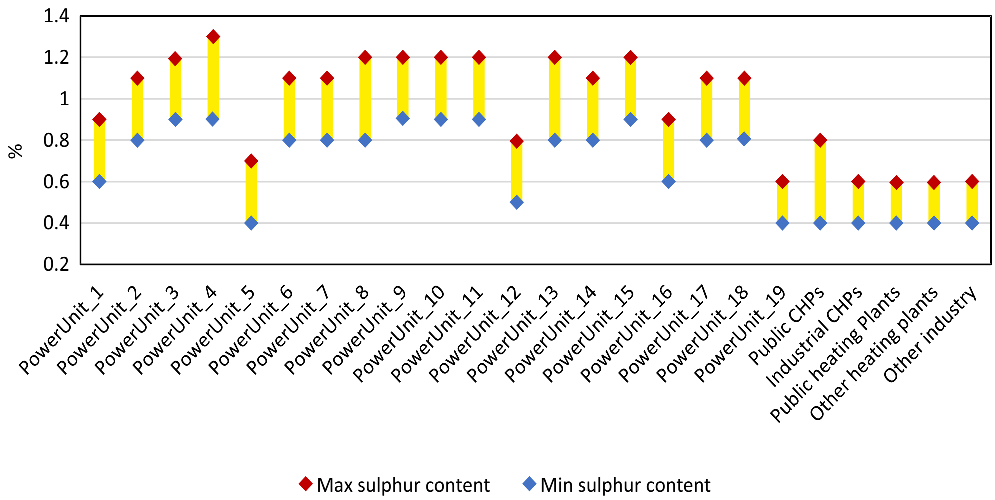

Fig. 7. Minimal and maximal sulphur content in fine coal required by demand units (%)

Rys. 7. Minimalna i maksymalna zawartość siarki wymagana przez odbiorców miałów energetycznych (%)

Table 6. Comparison of scenarios

Tabela 6. Porównanie scenariuszy badawczych

Scenario	Imported fine coal price change in relation to domestic coal price
Scenario –30%	30% lower imported coal price
Scenario –25%	25% lower imported coal price
Scenario –20%	20% lower imported coal price
Scenario –15%	15% lower imported coal price
Scenario –10%	10% lower imported coal price
Scenario –5%	5% lower imported coal price
Reference scenario Scenario 0%: both coal prices are of the same value	
Scenario +5%	5% higher imported coal price
Scenario +10%	10% higher imported coal price
Scenario +15%	15% higher imported coal price
Scenario +20%	20% higher imported coal price
Scenario +25%	25% higher imported coal price
Scenario +30%	30% higher imported coal price

In the reference scenario, **Scenario 0%,** the reference prices of domestic fine coals and the reference prices of imported coals (at transshipment terminals) are of the same value. Under the other twelve scenarios, the price difference ranges from –30% to +30% (Table 6).

The maximum level of coal supplies from domestic mines is limited by their production capacity. However, the demand for fine coal exceeds the production capacity. As a result of the insufficient quantity of coal mined in domestic mines (characterized by quality parameters requested by consumers), an imbalance between estimated domestic production and consumption is observed. Due to the estimated shortage of coal, a minimum level of fine coal imports is required in order to meet the demand forecasted for 2020–2030 (Fig. 8).

The decline in the volume of coal imports after 2024 is linked to the expected reduction in demand from power plants and CHP plants, as well as other industrial sectors that consume fine coal.

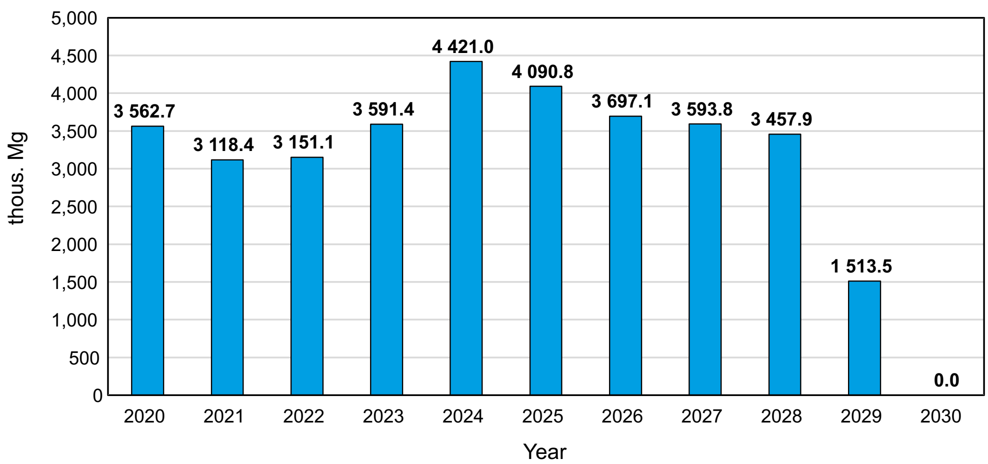

Fig. 8. Assumed imbalance between domestic fine coal production capacity and demand (thousand Mg)

Rys. 8. Założona różnica pomiędzy krajowymi zdolnościami produkcyjnymi a zapotrzebowaniem na miały energetyczne (tys. Mg)

3. Results and discussion

The results of this study estimate the volume of coal imports between 2020 and 2030. Figure 9 presents the results for the years 2020, 2025 and 2030. In the **0% scenario**, coal imports are estimated to be in the range of 8.3–11.5 million Mg. The lowest value of coal imports is observed in 2030, due to a decrease in demand for coal from key consumers, while the highest value of coal imports is observed in 2025. In addition, in Figure 9 it can be

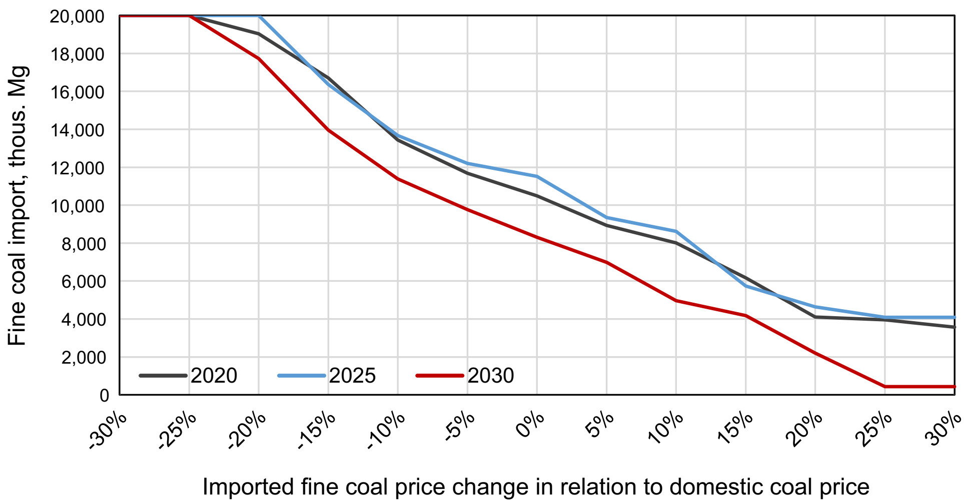

Fig. 9. Total imported fine coal supplies under the analyzed scenarios (2020, 2025 and 2030) (thousand Mg)

Rys. 9. Całkowity import miałów energetycznych dla analizowanych scenariuszy (2020, 2025 i 2030) (tys. Mg)

observed that in the scenarios in which there is an increase in imported coal prices (with respect to the domestic coal prices) there is a decrease in fine coal imports (0.4–4.1 million Mg). In these scenarios, the lowest value is observed in 2030, and the highest is observed in 2025.

In the scenarios in which the reference prices of imported fine coal (ex-border) take lower values than domestic coal prices, an increase in the volume of imported coal is observed. The maximum supply of coal imported to Poland is limited by the maximum transshipment capacity of railway border crossings and seaports, amounting to the total value of 20 million Mg. In 2020, the maximum values are observed when the prices of imported coal are lower than the prices of domestic coal by at least 20%. In turn, in 2025 and 2030 the maximum values are reached when prices are lower by at least 25%.

When the results of all the scenarios are compared with the reference scenario, the differences in import volumes for higher prices of imported coal ranges from 7.2 to 7.9 million Mg and the difference ranges between 9.5–11.7 million Mg for imported coal prices lower than the domestic coal prices (Fig. 10). Furthermore, the results presented in Figure 10 show the change in the volume of imported steam coal with the change in imported coal prices (with respect to domestic steam coal).

Based on the results of the model, it is also possible to analyze the share of imported coal in the total coal consumption of Polish fine coal consumers. Figure 11 presents how a change in imported/domestic steam coal price relations would affect the share of imported coal in fine coal consumption over the analyzed 11-year time horizon (2020–2030). Evidently, the lowest volume of imported coal is seen when its price is 30% higher than the domestic one.

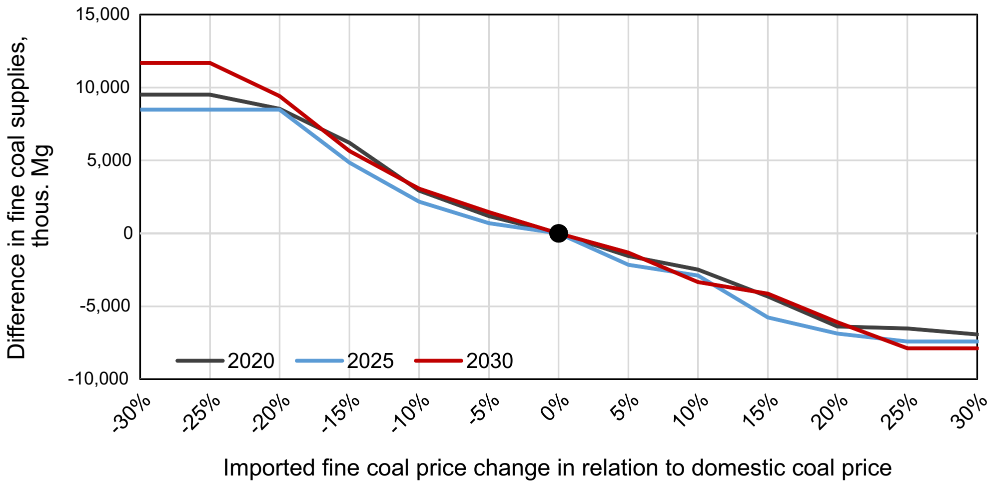

Fig. 10. Imported fine coal supplies differences under the analyzed scenarios (2020, 2025 and 2030) (thousand Mg)

Rys. 10. Import miałów energetycznych w zależności od analizowanego scenariusza (2020, 2025 i 2030) (tys. Mg)

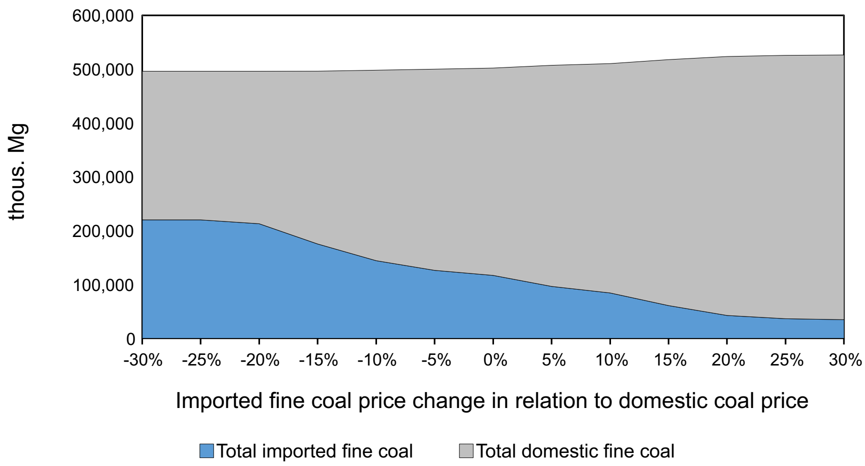

Fig. 11. Total imported and domestic fine coal supplies in years 2020–2030 (thousand Mg)

Rys. 11. Całkowite dostawy miałów energetycznych (import i dostawy krajowe) w latach 2020–2030 (tys. Mg)

The results of the sensitivity analysis on the changes of the relation between domestic and imported coal prices are presented in Figure 12. For instance, a 30% increase in imported coal prices leads to a simultaneous decrease in coal imports of about 70% (with respect to the level of the reference scenario volume) and an increase in supplies from domestic mines

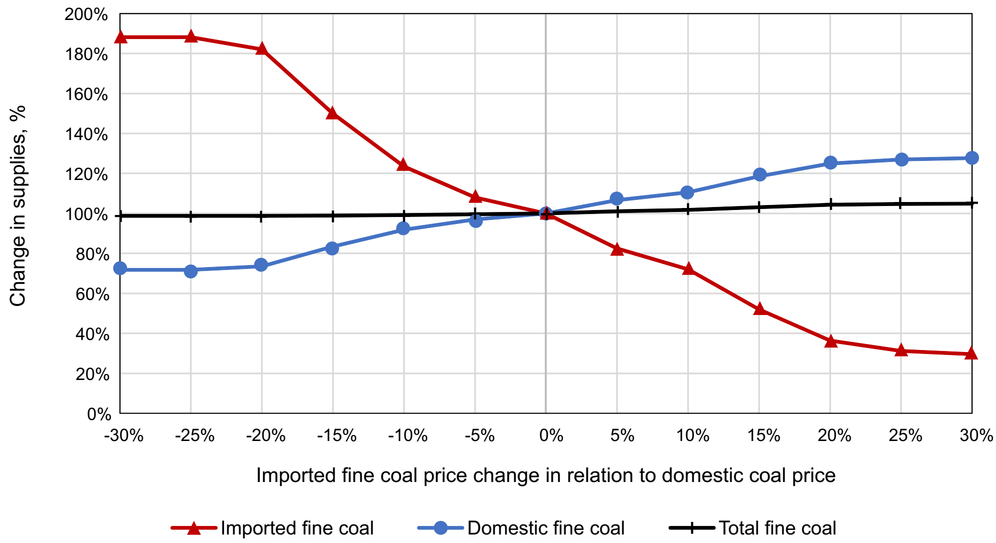

Fig. 12. Total coal supplies change with respect to the relation
of imported vs domestic steam coal price change (%)

Rys. 12. Zmienność dostaw węgla w zależności od relacji ceny węgla importowanego do krajowego (%)

by approximately 28% (with respect to the level of the reference scenario volume). The lower level of imported coal supplies prompts an increase in the share of domestic coal (domestic coal supply increases). This is also due to the fact that imported coal has a higher calorific value when compared to the coal produced in Poland.

With a decrease in the price of imported coal, there is a gradual increase in the supply coal imports. For the **–30% scenario**, the level of imported coal almost doubles (180%), while the supply from domestic mines is reduced by around 28% when compared to the levels observed in the reference scenario.

The sensitivity analysis was also carried out for the cumulative supply of fine coals for the years 2020, 2025 and 2030. The results are presented in Figure 13–15.

Figure 16–20 show Poland's territory broken down into 73 statistical regions at the NUTS-3 level. The figures also depict the regions in which there is a surplus of coal supplies in a given direction. Coal supplies to the energy sector and other demand sectors were aggregated regionally at the NUTS-3 level. For each region, the difference between coal supplies from domestic mines and imports were calculated. As a result, values above zero indicate that there is a surplus of supplies from domestic mines, while values lower than zero indicate a surplus of imported coal in a given region. The intensity of the color on the cartograms expresses the surplus, in absolute terms (also dependent on the total, aggregated level of demand for coal in a given region).

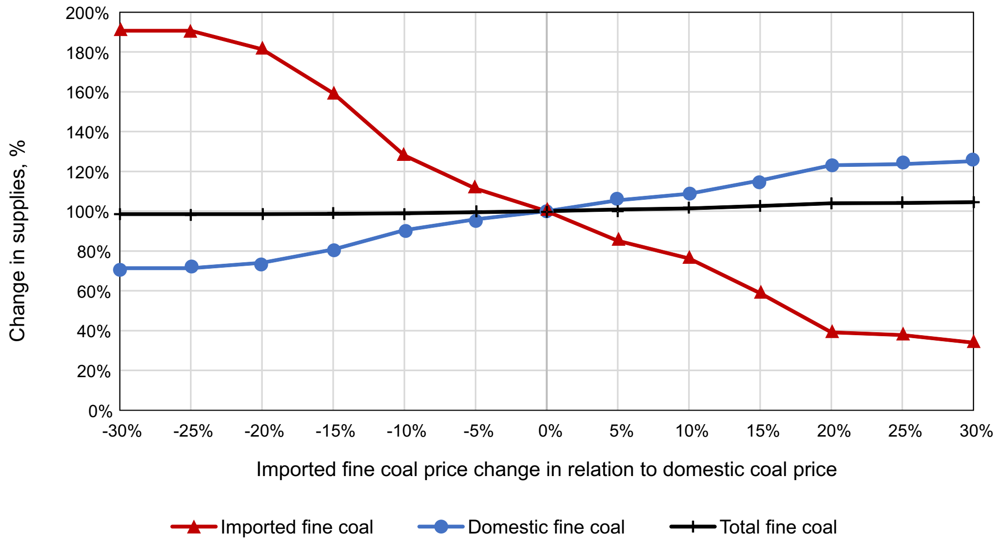

Fig. 13. Variation in coal supplies with respect to the relation
of imported vs domestic steam coal price change in 2020 (%)

Rys. 13. Zmienność dostaw węgla w zależności od relacji ceny węgla
importowanego do krajowego w 2020 roku (%)

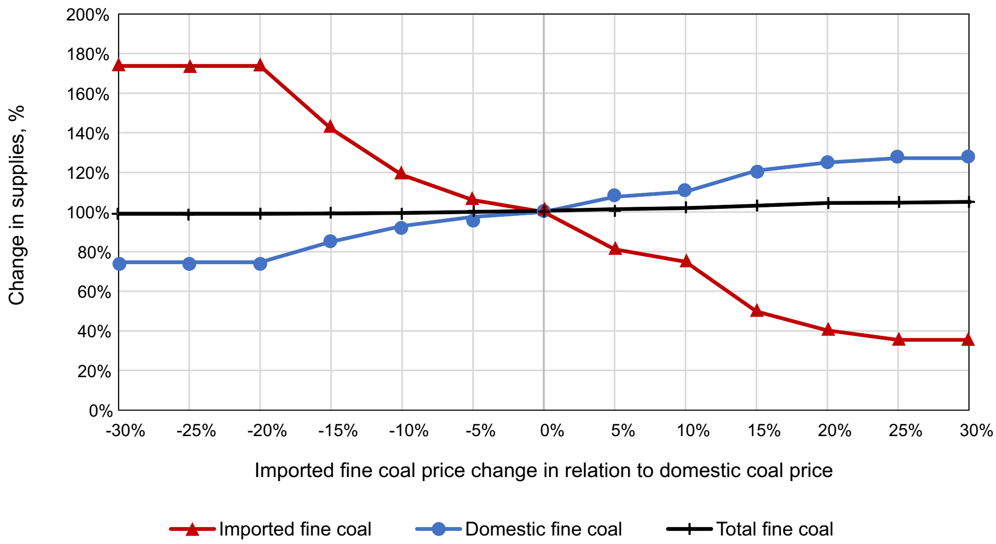

Fig. 14. Variation in coal supplies with respect to the relation
of imported vs domestic steam coal price change in 2025 (%)

Rys. 14. Zmienność dostaw węgla w zależności od relacji ceny węgla
importowanego do krajowego w 2025 roku (%)

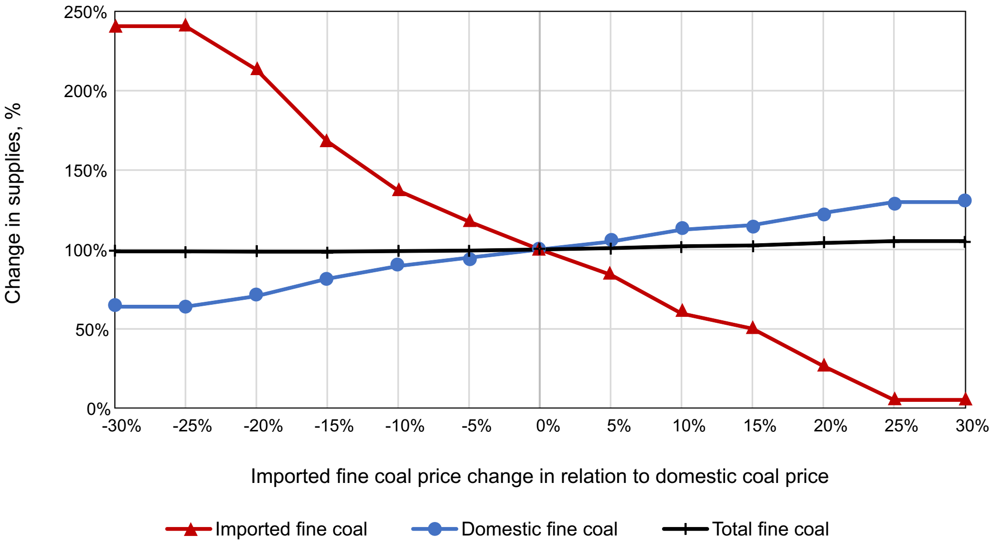

Fig. 15. Variation in coal supplies with respect to the relation
of imported vs domestic steam coal price change in 2030 (%)

Rys. 15. . Zmienność dostaw węgla energetycznego w zależności
od relacji ceny węgla importowanego do krajowego w 2030 roku (%)

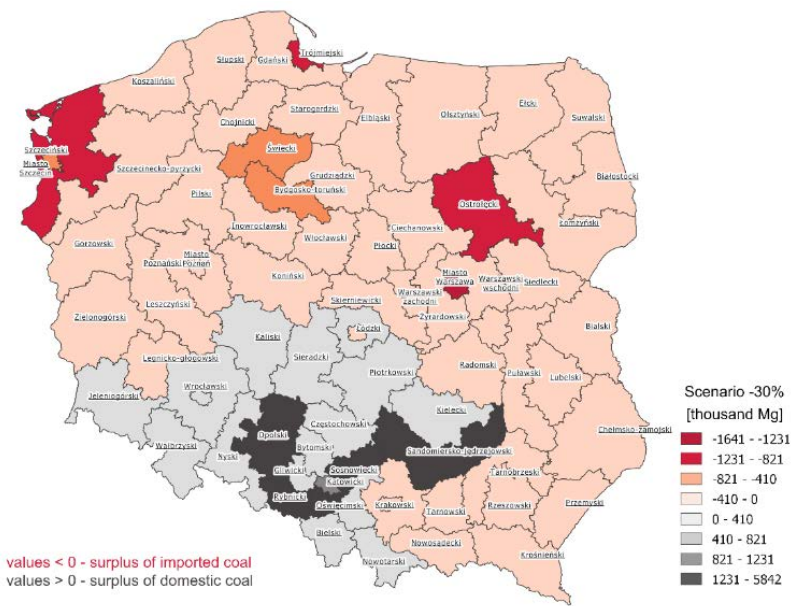

Fig. 16. Fine coal supplies in 2020 under Scenario –30%

Rys. 16. Dostawy miałów energetycznych w 2020 roku dla scenariusza –30%

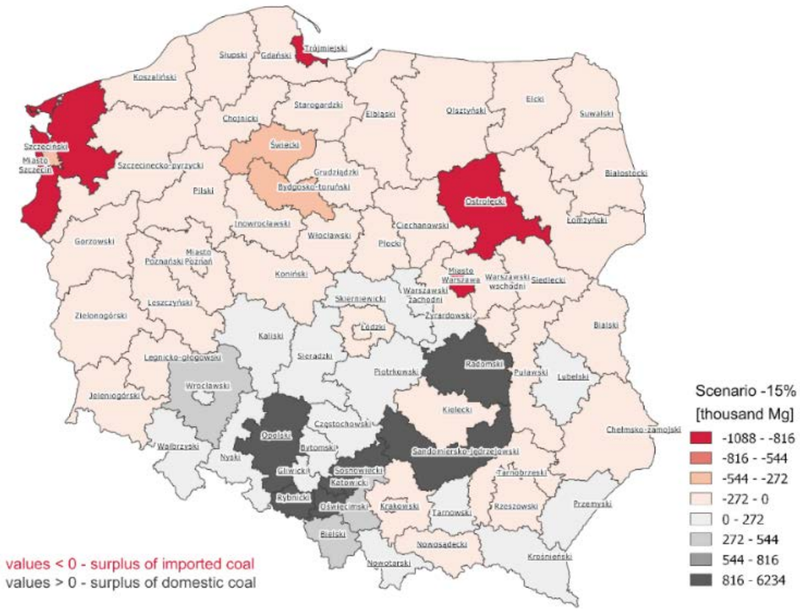

Fig. 17. Fine coal supplies in 2020 under Scenario –15%

Rys. 17. Dostawy miałów energetycznych w 2020 roku dla scenariusza –15%

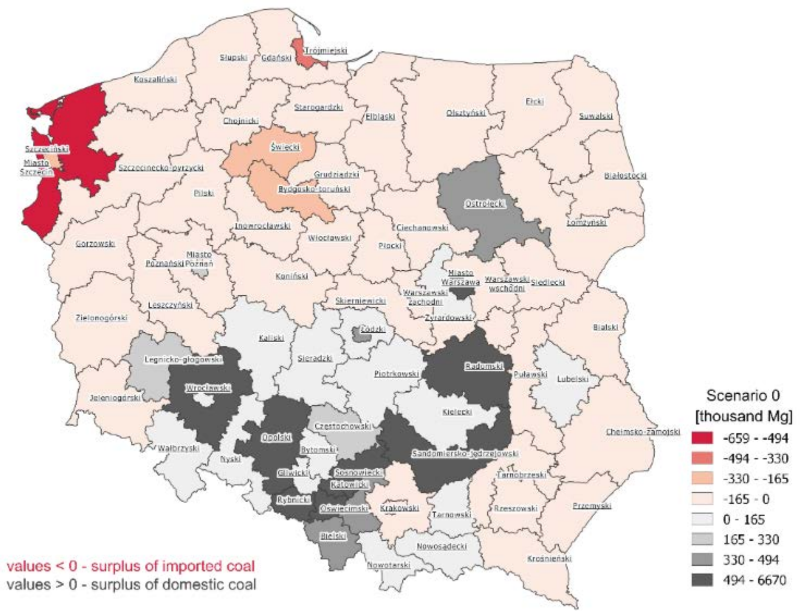

Fig. 18. Fine coal supplies in 2020 under Scenario 0%

Rys. 18. Dostawy miałów energetycznych w 2020 roku dla scenariusza 0%

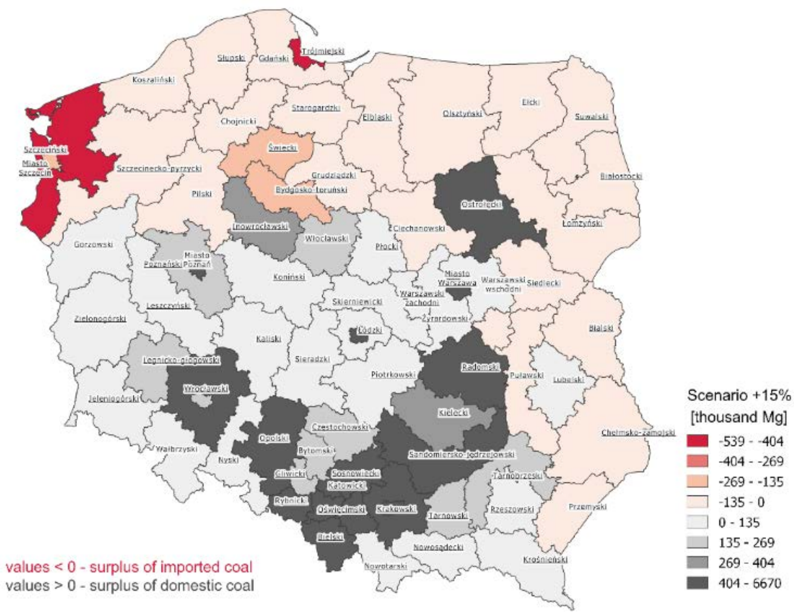

Fig. 19. Fine coal supplies in 2020 under Scenario +15%

Rys. 19. Dostawy miałów energetycznych w 2020 roku dla scenariusza +15%

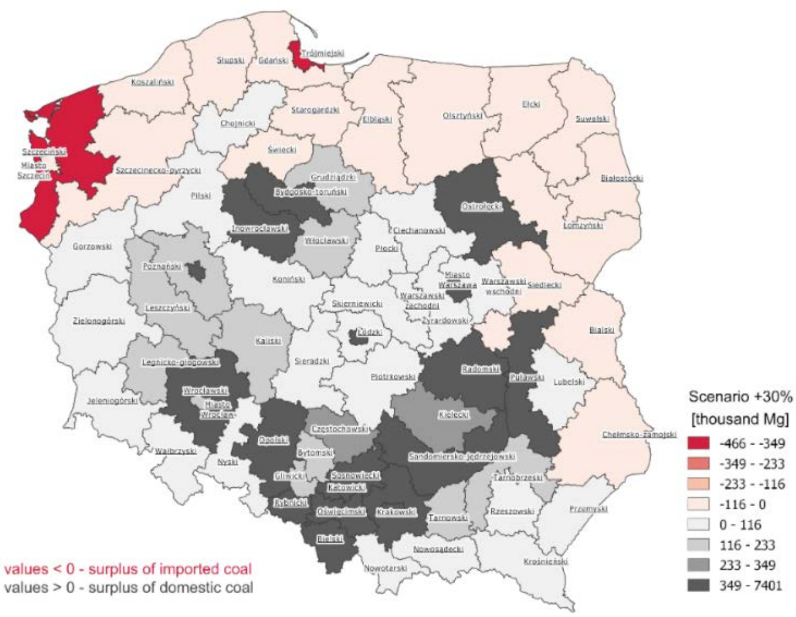

Fig. 20. Fine coal supplies in 2020 under Scenario +30%

Rys. 20. Dostawy miałów energetycznych w 2020 roku dla scenariusza +30%

The aforementioned cartograms were prepared for 2020, under five scenarios, i.e. **scenario –30%** (Fig. 16), **scenario –15%** (Fig. 17), **scenario 0%** (Fig. 18), **scenario 15%** (Fig. 19) and **scenario 30%** (Fig. 20).

The cartograms illustrate how the geographical range of profitability of fine coal import changes with different price relations between domestic coal and imported coal. In two extreme cases, there is a definite advantage of one of the directions over the other. In the **–30% scenario**, the supply in the central and south-western regions is dominated by domestic coal, due to the significant distance (farthest) to seaports (Gdynia, Gdańsk, Szczecin, Świnoujście) and railway crossings (border) with Russia, Belarus and Ukraine (Fig. 16). In the scenario where the prices of imported coal are 30% higher than the prices of domestic coal (**30% scenario**), the surplus of supplies of imported coal is observed only in regions located relatively close to the seaports and railway border crossings (Fig. 20).

Conclusions

The article aimed to analyze the impact of potential changes in the price relation between domestic and imported coal and its influence on the volume of coal imported to Poland. The study was carried out using a mathematical model developed for this purpose. The model reflects the relations between coal suppliers (domestic coal mines, importers) and key coal consumers (power plants, combined heat and power plants, heat plants, industrial power plants). The model was run under thirteen scenarios, differentiated by the ratio of the imported coal price versus domestic coal price for 2020–2030.

The results of the scenario in which the prices of imported and domestic coal, expressed in PLN/GJ, are equal, indicate that the volume of supplies of imported coal is in the range of 8.3–11.5 million Mg (depending on the year). In the case of an increase in prices of imported coal with respect to domestic coal one, the supplies of imported coal are at the level of 0.4–4.1 million Mg (depending on the year). However, even when the prices of imported coal are higher by 30% than domestic coal prices, in 2030, when there is no absolute need to import coal, a certain quantity of coal is imported to Poland.

Furthermore, with a decrease in the price of imported coal, there is a gradual increase in the supply of coal imports. For the scenario in which a 30% lower imported coal price is assumed, the level of imported coal almost doubles (180%), while the supply from domestic mines is reduced by around 28%, when compared to the levels observed in the reference scenario.

The obtained results also allow for developing an analysis of the range of coal imports depending on domestic versus imported coal price relations in the form of cartograms. In the two extreme cases, a definite advantage of one of the directions over the other is observed. In the scenario –30%, domestic coal supplies prevail in the south-western and central regions of Poland. In the case of the +30% scenario, the surplus of imported coal supplies is only found in regions close to the seaports and railway border crossings.

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DOMESTIC HARD COAL SUPPLIES TO THE ENERGY SECTOR: THE IMPACT OF GLOBAL COAL PRICES

Keywords

optimization, energy, coal mining industry, fuel and energy sector, coal imports

Abstract

The paper analyzes the impact of potential changes in the price relation between domestic and imported coal and its influence on the volume of coal imported to Poland. The study is carried out with the application of a computable model of the Polish energy system. The model reflects fundamental relations between coal suppliers (domestic coal mines, importers) and key coal consumers (power plants, combined heat and power plants, heat plants, industrial power plants). The model is run under thirteen scenarios, differentiated by the ratio of the imported coal price versus the domestic coal price for 2020–2030. The results of the scenario in which the prices of imported and domestic coal, expressed in PLN/GJ, are equal, indicate that the volume of supplies of imported coal is in the range of 8.3–11.5 million Mg (depending on the year). In the case of an increase in prices of imported coal with respect to the domestic one, supplies of imported coal are at the level of 0.4–4.1 million Mg (depending on the year). With a decrease in the price of imported coal, there is a gradual increase in the supply of coal imports. For the scenario in which a 30% lower imported coal price is assumed, the level of imported coal almost doubles (180%), while the supply from domestic mines is reduced by around 28%, when compared to the levels observed in the reference scenario. The obtained results also allow for the development of an analysis of the range of coal imports depending on domestic versus imported coal price relations in the form of cartograms.

DOSTAWY WĘGLA KAMIENNEGO DLA ENERGETYKI: WPŁYW ŚWIATOWYCH CEN WĘGLA

Słowa kluczowe

optymalizacja, górnictwo węgla kamiennego, energia, import węgla, sektor paliwowo-energetyczny

Streszczenie

Celem artykułu jest analiza wpływu potencjalnych zmian relacji cen węgla krajowego do importowanego na poziom importu węgla do Polski. Obliczenia zostały wykonane z wykorzystaniem matematycznego modelu polskiego sektora paliwowo-energetycznego, w którym zamodelowano najważniejsze zależności występujące w systemie rzeczywistym. Odzwierciedlone zostały kluczowe relacje pomiędzy dostawcami węgla (krajowe spółki węglowe, kopalnie oraz importerzy) a jego kluczowymi odbiorcami (elektrownie, elektrociepłownie, ciepłownie, elektrownie przemysłowe). Model został rozwiązany numerycznie dla trzynastu scenariuszy badawczych zróżnicowanych względem relacji

cen węgla importowanego do krajowego, dla lat 2020–2030. Wyniki uzyskane dla scenariusza, w którym założono ceny węgla importowanego i krajowego (wyrażone w zł/GJ) są równe, wskazują, że poziom dostaw węgla importowanego mieści się w przedziale 8,3–11,5 mln Mg (w zależności od roku). W przypadku wzrostu cen węgla importowanego w stosunku do krajowego, dostawy węgla z importu kształtują się na poziomie 0,4–4,1 mln Mg. Wraz ze spadkiem wartości cen węgla importowanego następuje stopniowy wzrost importu węgla. W scenariuszu, w którym założono o 30% niższą cenę węgla importowanego, jego wolumen jest prawie dwukrotnie większy (180%), podczas gdy dostawy z kopalń krajowych zostają ograniczone o około 28%, w porównaniu do poziomów obserwowanych w scenariuszu referencyjnym. Uzyskane wyniki umożliwiają również analizę zasięgu geograficznego importu węgla do Polski w zależności od relacji cen węgla krajowego do importowanego.