Prospects for development and hard coal economy limitations in the context of ensuring national energy security

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Abstract. The article discusses the changes taking place in the energy sector of Poland and the European Union. Documents that influence the shape of the national energy system - Europe 2020 strategy - have been presented and discussed. The planned paths of energy development were also indicated in accordance with the discussed strategy. The sufficiency of key energy resources was also analysed to ensure further energy security. The article also presents a built theoretical model based on the panel data technique, which takes into account changes in the energy sector. The purpose of this analysis is to build a tool that forecasts the size of coal sales in relation to changes taking place in the energy sector.

1. Introduction
Activities in the framework of the implementation of the Energy Policy of Poland until 2030 were focused primarily on the security of energy supplies, energy efficiency and legislative processes shaping the functioning of the sector. In energy policy the priority is to improve energy efficiency using, among others, national and EU funds. The Ministry of Economy supervises the energy security of the country, which is one of the six strategic priorities of its activity. To secure the country economically, the Ministry of Economy conducts activities that are aimed at:

- changes in the directions and sources of energy carriers and expansion of the country's power grid, among others, due to the increased role of biofuels in the economy,
- development of low-emission technologies, development of electricity transmission systems:
- improvement of energy efficiency, whose activities cover mainly three areas, increasing the efficiency of energy production, energy losses reduction in distribution and industry, and reducing energy consumption,
- increasing the use of energy from renewable sources, including liquid biofuels,
- satisfying the domestic demand for hard coal by increasing the efficiency of coal mining,
- construction of infrastructure for nuclear energy, it is planned to introduce nuclear energy in Poland (2021),
- preparing the economy for wartime and emergency conditions in other words bolstering of national security [1].

In recent years, there has been tremendous progress in energy efficiency, since energy consumption as a proportion of GDP fell by almost 1/3. These achievements became possible thanks to, among others, undertakings of thermo-modernization, which were carried out under the Act on supporting thermo-modernization undertakings, modernization of street lighting and optimization of industrial processes [1].
Still, the energy efficiency of the Polish economy is on average 3 times lower than in European countries, which are the most developed and about 2 times lower than the EU average. In contrast, primary energy consumption in Poland (considering the ratio to the population size is almost 40% lower than in other EU countries), which illustrates the extraordinary potential for energy saving in Poland, and this characteristic is distinctive for a country whose economy is developing intensively.

1.1. Efficient use of resources

The leading initiative on efficient use of resources is one of the seven initiatives set out in the "Europe 2020" strategy for sustainable and smart inclusive growth. That aims at growth of employment and economy. All these institutions cooperate to coordinate activities related to the implementation of necessary structural reforms. The whole initiative aims to create a kind of strategic framework that will support changes leading to the transition to a low-carbon economy based on the effective use of resources. These changes will allow for:

- creating and identifying new opportunities for economic growth and broad investment activities as well as greater competitiveness of the European Union,
- secure supplies of basic resources,
- reducing the impact of resource use on the natural environment and combating climate change,
  reducing the use of resources while improving the economic result [2].

Building a resource-efficient Europe requires the use of technological improvements, changes in the areas of energy, agriculture, transport, industry and changes in the behaviour of consumers and producers. Higher efficiency of resource use controls costs by reducing consumption of energy and materials, which has an impact on increasing competitiveness in the future.

This leading initiative will allow development of a strategic and integrated approach for the implementation of actions set for 2020, which will in turn pave the way for long-term goals planned for 2050. It is important to analyse in this initiative the reasons for ineffective use of certain resources. Such starting point gives the opportunity to effectively use resources in case of higher number of strategies and to develop tools that decision makers should use in order to continue their activities and monitor progress. All of this is to help gain the support and involvement of regional, local and national authorities and citizen stakeholders [2].

The most important goal of this flagship initiative is greater certainty of conducted investment and innovative activity carried out through an agreement concluded on a long-term vision and a balanced consideration of relevant policies in the effective use of resources. All this creates a framework for long-term action in many policy areas that support the schedule of activities related to energy, climate change, fishing, transport, raw materials, industry, agriculture, biodiversity and regional development. All these elements should be properly coordinated, while the main elements of the long-term framework will take the form of a series of coordinated action plans in order to:

- identify the European Union action to develop a low-carbon economy by 2050, limiting carbon dioxide emissions by 80-95% as part of efforts to combat climate change, while ensuring energy security and supporting sustainable growth and job creation,
- to analyse how the European Union can create an energy system by 2050, the main features of which will be low-carbon and efficient use of resources, as well as competitiveness and security, these activities provide assurance to researchers, investors, policy-makers and legislative bodies,
- provide visions to build a secure, competitive, low-carbon, resource-efficient transport system by 2050, seeking to remove obstacles in the internal transport market that promote the use of clean technologies and modernizing transport networks,
- set medium-term and long-term objectives as well as means that lead to their achievement, by striving to decouple economic growth from resource consumption and its impact on the natural environment [3, 4, 5, 6, 7].

The most important environmental issues, i.e. biodiversity, land use, competitiveness, climate change, deforestation, external impact of consumption patterns and production models, access to and
safeguarding of supplies have global scope, hence the European Union has the task of dealing with issues that are related with effective use of resources at the international level and must cooperate closely with key partners, mainly with candidate countries and countries that are located in our neighbourhood.

1.2. Depletion of energy resources
The restructuring of hard coal mining has significantly affected the resource base of the country in terms of black coal resources. It resulted from adapting to the economic and formal-legal requirements of the market economy [8]. The size of the resource base of hard coal, as of 31/12/2016, is a consequence of changes in the assessment of resources in active mines, resulting from the implementation of market economy principles and further restructuring activities. These changes necessitated primarily [8]:

- a different approach to the economic assessment of resources, both in active mines and in the undeveloped deposits,
- liquidation of mines considered to be permanently unprofitable,
- striving to improve the profitability of other mines primarily through increased concentration of production.

Changes in the size of hard coal reserves in Poland in the years 1990-2016 are illustrated in table 1.

| Coal Basin          | As at 31.12.1990 | As at 01.01.2015 |
|---------------------|------------------|------------------|
|                     | Balanced reserves | Industrial reserves | Balanced reserves | Industrial reserves |
| Upper Silesian Total| 57164            | 16568            | 41972            | 3445               |
| Included developed deposits | 29192         | 16168            | 19024            | 3433               |
| Lower Silesian Total| 457              | 248              | 423              | -                  |
| Included developed deposits | 385          | 248              | -                | -                  |
| Lublin Voivodeship Total| 7889           | 476              | 9565             | 319                |
| Included developed deposits | 485           | 194              | 782              | 297                |
| Collectively Total | 65510           | 17292            | 51960            | 3764               |
| Included developed deposits | 30062       | 16610            | 19805            | 3730               |

Recoverable reserves in 2015 amounted to 3,390 million Mg, and in 2016 there was an increase, which resulted from: documenting four new deposits and approval of additives to geological documentation for three deposits. Analysing the current level of output at the level of approx. 70 million Mg annually - this resource will last for about 48 years, i.e. until about 2070, if only the decreasing production in the final phase of coal mining is taken into account.

The geological balance reserves of brown coal are 23,451.13 Mg, of which the majority is energy coal - 23,450.49 million Mg, the remaining 0.64 million Mg are bituminous coals. In the past, briquettes and low-temperature carbonization coal were also documented. At present, all the reserves of briquette and low-temperature carbonization coals are considered as energy coals.

The condition of brown coal reserves, as well as the structure of their identification and the degree of development are presented in the table 2.

With the current output of brown coal in the amount of approx. 70 million Mg, these deposits will be enough for 30 years, i.e. until 2050.

The EU restrictions related to greenhouse gas emissions also have a fundamental impact on the structure of the energy mix. In the case of hard and brown coal, environmental regulations
significantly limit the share of these fuels in the energy mix for RES, natural gas and oil, or nuclear energy [10, 11, 12].

Table 2. Brown coal reserves in Poland [9].

| Reserves          | Total number of deposits | Active plants reserves | Total deposits identified in detail | Pre-identified deposits | Discontinued exploitation |
|------------------|--------------------------|------------------------|-------------------------------------|-------------------------|---------------------------|
| Balanced         | 91                       | 1353.65                | 22081.2                             | 5838.66                 | 16242.5                   | 16.3                     |
| A+B              | 23451.1                  | 1218.66                | 1241                                | -                       | 1241                      | 12.38                    |
| C1               | 3530.84                  | 123.13                 | 3404.43                             | 3404.43                 | -                         | 3.29                     |
| C2               | 12643.1                  | 11.86                  | 12630.6                             | 1193.23                 | 11437.4                   | 0.64                     |
| D                | 4805.14                  |                        | 4805.14                             | -                       | 4805.14                   | -                        |
| Off-balance sheet | 3519.67                 | 45.55                  | 3447.62                             | 872.64                  | 2574.98                   | 26.51                    |
| Industrial reserves | 1064.57                | 1047.74                | 16.83                               | 16.83                   | -                         | -                        |

2. Analysis of the Polish hard coal market

Demand for hard coal is difficult to forecast and plan, especially when economic changes occur and there is a lack of production stability in industrial sectors that consume coal, which are fundamental. The analysis of the Polish hard coal market can be found in many publications by various authors [13, 14, 15, 16, 17, 18]. What is more, one must take into account the changes currently occurring on the world market, and these changes are not favourable for Poland. The price of coal is falling and will continue to decrease. This is directly affected by the drop in the price of coal in the USA and the fact of finding very rich and shallow deposits in Mongolia.

Forecasting sales of hard coal hold great importance to every supplier, producer and seller, because the demand forecasts will decide in the future about the quantity that should be produced and delivered. Mining companies cannot wait for sales - and only then react to it, they should plan and anticipate future demand so that they can respond to customer orders. Companies must act well in advance to plan their investments, launch new products and decide when to withdraw old ones.

It is important to choose the appropriate forecasting method in the planning process, which allows to get information on what will be the absorptive capacity of the coal market if the current strategy of economic development is preserved. In order to create a mining company's development strategy, it seems helpful to use mathematical methods of forecasting.

The basic elements that shape the demand for hard coal are [2]:

- advances in heating technology,
- heating oil and natural gas shares in covering the needs of manufacturing, industry and municipal sector,
- the rate at which economic growth occurs and the shape of industrial production associated with it, in particular the production of heat, electricity and steel,
- climatic conditions,
- coal price
- access to coal substitutes,
- the effects of introducing new technologies to reduce energy consumption in production,
- preferences of individual consumers in the selection of fuel for heating and economic needs.

Internal factors that shape the domestic hard coal market are:

- coal price,
- quality of coal,
costs of coal production and enrichment,
- reported demand for coal,
- level of production capacity and their use in mining,
- costs of transporting coal from the mine to the recipient.

While developing the theoretical model, the focus was on using all technically available technologies for generating electricity from coal, assuming that each of these solutions can be adjusted to reduce CO₂ emissions. It is also related to the preparation of coal with different quality parameters and diversified grain characteristics, adapted to the requirements of a given energy production technology. The following conditions were adopted when building the model:

- coal reserves - Poland has numerous hard coal reserves, which will ensure energy security in the future.
- state policy, which is based on the realization of a long-term program for development of coal-based energy, which will provide all the energy needs of recipients
- state of the environment - the EU has made significant changes in the area of its energy policy, and final conclusions were included in the Green Paper published on March 8, 2006. In addition to the need of ensuring energy security of EU countries and minimization of energy prices (while ensuring conditions for self-financing of the sector), Member States must also minimize harmful environmental consequences of energy technologies. Because it is impossible to develop the global economy only based on energy from renewable sources, one should also look for methods that reduce greenhouse gas emissions. Such methods can be, in other words clean coal technologies, as well as storage of CO₂ resulting from the combustion of fossil fuels.
- modern technologies - rapid progress in construction and the possibility of implementing modern energy technologies, including the development of material and IT technologies.
- domestic market - the main recipient of Polish coal is occupational and industrial power, taking into account the global situation of the oil and gas markets, the price of electricity from coal in the medium term, compared to the price of electricity from other carriers, will still be among the lowest. An analogous situation is the price of heat produced from coal.
- exports - expansion of ports in Gdynia, Gdańsk and Szczecin will allow to increase exports to EU countries. The attractiveness of the Polish market in terms of coal imports will decrease, and properly restructured Polish mining will have a chance to gradually regain the domestic market in those regions where today imported coal is cheaper than Polish.

3. Methodology - mathematical model of research

Taking into account all data for the development of the theoretical model of hard coal sales allows the use of methods such as panel analysis using the least squares method, panel estimates using a panel model with fixed effects and a panel model with variable effects. Panel data contains variables observed in at least two dimensions, e.g. space-time (many objects observed in many periods). Panel data therefore have at the same time characteristics of cross-sectional data (describing the group at a single moment) and characteristics of time series (describing the unit in different periods).

In principle, it is possible to estimate time series for each case or cross-sectional regressions for each time unit by using the expressions (1) and (2) correspondingly [19]:

\[ y_{it} = x_{it}\beta + v_{it} \quad (1) \]
\[ y_{it} = x_{it}\beta + u_{it} + \varepsilon_{it} \quad (2) \]

where:
- \( y_{it} \) - explained variable,
- \( x_{it} \) - explanatory variable (vector of variables),
- \( \beta \) - vector with the N dimension of the structural parameters of the model
- \( v_{it} \) - random error,
- \( u_{it} \) - individual effect,
- \( \varepsilon_{it} \) - pure random error,
where (1) is a model with fixed effects, while 2 is a model with random effects. The importance of panel models is emphasized by articles [20]. Wide range of panel models for econometric analysis is also presented by other articles [21]. They undoubtedly apply in the analysis of economic phenomena.

4. Results of research
The aim of the study is to establish the determinants shaping the sales volume in mining enterprises. To achieve the goal, analyzes were carried out on panel data (balanced panel) and panel models were constructed with generalized method of least squares, a panel model with fixed effects and a panel model with variable effects. The statistics such as: $R^2$ - the standard error of residuals and the sum of residual squares and the F statistics, were used to verify the models.

The assumed level of coal sales was the following explanatory variables: total energy production, production of energy from coal, production of energy from gas, crude oil and renewable energy sources, and emissions of: CO$_2$, CH$_4$, NO$_2$, selected on the basis of substantive knowledge (collection potential explanatory variables), and then they were selected using the Hellwig method.

Table 3 contains the numbers characterizing the results of panel estimation using the least squares method.

| Coefficients | Estimate | Std.Error | t-value | p-value |
|--------------|----------|-----------|---------|---------|
| Intercept    | 1.52 10$^7$ | 9.125 10$^2$ | 1.667 | ***     |
| Solid        | 9.9 10$^{-1}$ | 1.358 10$^{-2}$ | 73.591 | ***     |
| Oil.         | 1.02     | 2.609 10$^{-1}$ | 3.878 | **      |
| Gas          | 5.97 10$^{-4}$ | 3.584 10$^{-1}$ | 1.665 |         |
| OZE          | 1.07     | 3.604 10$^{-2}$ | 29.579 | ***     |
| Multiple $R^2$ | 0.96     |           |         |         |
| Adjusted $R^2$ | 0.95     |           |         |         |
| F-statistic  | 8247     |           |         | ***     |
| Residual standars error | 71.33     |           |         |         |

It was found that the strongest stimulant of the sales volume is the production of primary energy from coal. This phenomenon has its economic justification. A factor closely related to the level of sales was also the level of primary energy production from renewable energy sources and crude oil. Unfortunately, the coefficient of energy production from natural gas in the model is statistically insignificant. Also environmental parameters turned out to be statistically insignificant, as shown in table 4.

Table 4. Panel data model with fixed effects - environmental parameters.

| Coefficients | Estimate | Std.Error | t-value | p-value |
|--------------|----------|-----------|---------|---------|
| Intercept    | 2.72 10$^7$ | 5.026 10$^8$ | 0.541   |         |
| CO2          | -4.655 10$^2$ | 1.132 10$^3$ | -0.411  |         |
| CH4          | 5.188 10$^2$ | 1.250 10$^4$ | 0.041   |         |
| NO2          | -6.439 103 | 1.091 104  | -0.590  |         |
| Multiple $R^2$ | 0.23     |           |         |         |
| Adjusted $R^2$ | 0.21     |           |         |         |
| F-statistic  | 0.8054   |           |         |         |
| Residual standars error | 28030000 |           |         |         |

The same dependences were established by performing panel estimates using a panel model with variable effects, as shown in table 5.
Table 5. Panel data model with variable effects - primary energy production by source.

| Coefficients | Estimate | Std.Error | t-value | p-value |
|--------------|----------|-----------|---------|---------|
| Intercept    | -9.06810 | 1.16410^2 | -0.856  | 0.855   |
| Solid        | 1.011    | 1.97810^-2| 51.145  | ***     |
| Oil.         | 7.29610^-1| 4.19310^-1| 1.740   |         |
| Gas          | 5.95510^-1| 3.64910^-1| 1.632   |         |
| OZE          | 1.004    | 8.00210^-2| 12.549.579| ***  |
| Multiple R^2 | 0.99     |           |         |         |
| Adjusted R^2 | 0.99     |           |         |         |
| F-statistic  | 6368     |           |         | ***     |
| Residual standards error | 72.61 |

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

In this model there are statistically insignificant data related to primary energy production from crude oil and natural gas. The very high statistics of the model, both R^2, adjusted R^2, and F statistics, attract attention. Certainly, the determined factors affect the volume of hard coal sales in a significant way.

5. Discussion

From the conducted analysis, it can be seen that panel data techniques can be used for econometric forecasting, as exemplified by built models predicting demand for hard coal. The problem with building such models is the need to forecast explanatory variables. It generates a forecast burden due to errors created in the forecasting of explanatory variables and additionally, any amount obtained from the theoretical model is burdened with an error resulting from the size of the model's match with real data.

In the case of econometric phenomena analysis there are many factors affecting the analyzed processes. In the case of demand for steam coal - it is: availability of raw material in other countries around the world, price and environmental parameters. The introduction of all this data into the models may result in an increase in the loadability of the models, due to the errors created when forecasting each of the listed parameters.

6. Conclusions

The study shows that:

- panel analyzes are useful for solving problems related to the search for determinants shaping the volume of hard coal sales in mining enterprises,
- the obtained results indicate the advantage of panel models with constant effects on panel models built with estimation using the classic least squares method and panel models with variable effects,
- the factors shaping the sales volume are the production of primary energy from coal, renewable energy and crude oil, where in the case of energy production from coal are stimulants while the others are destimulants, which allows determining the strength and direction of the impact of specified variables on the level of sales,
- environmental factors are not taken into account in the level of sales,
- the increase in the level of variable stimulants positively affects the change in the level of sales,
- in the process of managing finances and shaping sales revenues in the examined enterprises, particular attention should be paid to this group of factors.

The presented method can be use for improvement of hard coal mines management specially on strategic level.

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