Anticipating energy intensity of industry using software for creating econometric models

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The article presents the current problems of energetic and the current state of the mining industry and electric industry, as well as indicators of energy intensity projections were compiled using the program GRETL to create econometric models.

1. Introduction

Due to the ever-increasing energy needs of a growing national economy and the large capital- for fuel and energy investments, the primary element in energy policy is to ensure security of supply of cheap energy which has high performance parameters and is produced from green sources. One way to improve national energy security is to reduce the energy intensity of industry, which is the largest purchaser of electricity. Mining of coal and lignite brings energy supplies for the electricity industry, whose product is electricity. It can be concluded, therefore, that those industries are most important from an energy point of view. Prediction of energy consumption indicators in that branches allows for better planning of national development strategies of industry and improvement of energy security.

2. Mining industry

In Poland there are two coal basin: Upper Silesian Coal Basin and Lublin Coal Basin with one active mine. Lower Silesia Coal Basin is now closed. Proven reserves of coal are shown in Table 1.

Table 1. Proven reserves of coal [4]

Specification	Geological resources, mln tones		Industrial resources
	balance	off-balance	
Upper Silesian Coal Basin	36638	22679	7164
Lublin Coal Basin	9262	6918	338
Other resources (Coal Basins in liquidation)	66	3812	-

The adequacy of the resources of this material occurs only for documented deposits in terms of balance. With high probability it can be assumed that the demand for coal in Poland is stable at 75 to 80 million tones per year. There are many papers talking about the adequacy of the resources of coal. Most of them determines that resources, which are documented in active mines, can satisfy the energy needs of the country for 45-50 years. Balance resources of unexploited deposits permitted to extend the mining operations to the next 35 years [5, 6, 8]. Taking into consideration current geological research, we should not expect new discoveries in the Polish coal-producing areas.

Second in terms of quantity used for energy extraction is lignite. Eight areas of reservoir can be named, in which is documented the occurrence of lignite. The richest areas are: Legnica, Wielkopolska, West of the Country and Bełchatów, where is the evidence of almost 1 million tones of lignite. Table 2 shows the proven reserves of lignite.

Table 2. Proven reserves of lignite [4]

Specification	Geological resources, mln tones	
	balance	balance
West of the Country	2854	12602
North-West of the Country	300	952
Legnicki	3803	12726
Wielkopolski	3689	12834
Koniński	780	1036
Łódzki	551	550
Bełchatowski	1862	341
Radomski	92	-

Viability of existing lignite mines is estimated at 30-35 years. The largest prospective reserves are located in the vicinity of Legnica, the real output is 4500 million tones. This quantity provides a mining rate of approximately 55 million tones per year for over 80 years.

World coal production continues to increase, mainly because Asian countries (China, India). However, the fate of coal mining in Western Europe may indicate that the material may be replaced by other energy carriers (renewable energy, nuclear energy). Extractive industry in Poland is the second largest coal producer in Europe and seventh in the world. The annual production of lignite in the country is at 60 million tones per year, which gives in fourth place on the Old Continent and seventh in the world in terms of production volume. However, despite such a high position in the world the export rate is only about 14% of the annual output of coal (11.9 million tones in 2007). Lignite is consumed in its entirety on the domestic production of electricity and heat. It would seem, therefore, that by analogy, the coal mining meets the needs of consumption in power stations as the fuel. However, in 2008 nearly 60% of burned raw material had domestic origin, the rest came from import (Fig. 1). From the significant manufacturer, Poland is becoming a country where others deposit their (export) their coal, and the effect of this is that the annual electricity from imported coal is at the 20% level, which reduces the level of national energy security [1, 4, 6].

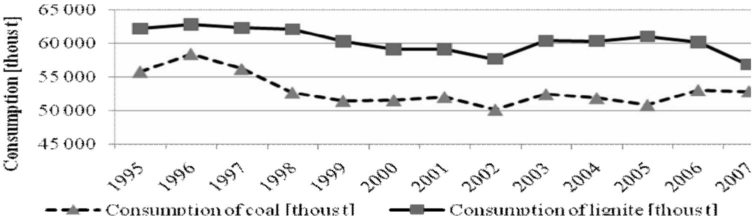

Fig. 1. Consumption of coal and lignite in polish power plants [4]

Despite numerous operations, including employment restructuring, capacity reduction by closing of mines, mining debt reduction, organizational and legal changes to create new structures, the profitability of the mining remains consistently low, and the energy intensity of production sold in 2007 was 27 kWh per 100 PLN production sold. The main reasons for reducing the demand for coal is a relatively high price of Polish coal, resulting, inter alia, from difficult mining conditions, elimination of the capacity of old plants with high production costs and very high environmental installation costs and high costs of rail transport.

3. Electric industry

Electricity industry is highly dependent on coal as the main energy source. In 2008, nearly 92% of the electricity produced in the country was in power plants fired by coal or lignite. This structure does not change over the last decade, which has bad influence of the country's energy security in the absence of diversification of energy sources (Fig. 2).

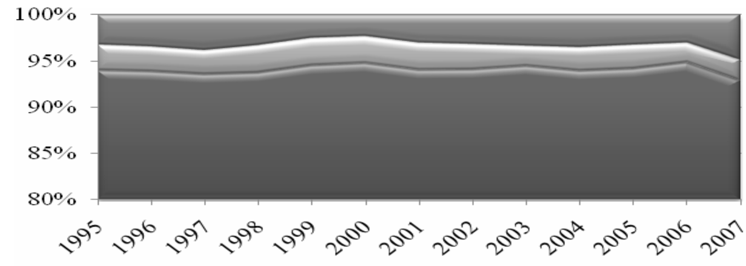

Fig. 2. The Generation of electric energy from national sources [4]

Limitation is increasing with age and technical parameters of power blocks in Poland. The installed capacity of domestic power is 35 000 MW, for comparison, in Spain more than 63 000 MW, although both countries are characterized by a similar number of inhabitants. Unavailability of generating units was in 2008 at around 15%. The reason for this high rate are failures, current repairs and upgrades. Over 80% of power plants in Poland were built before the year 1987 (Fig.3).

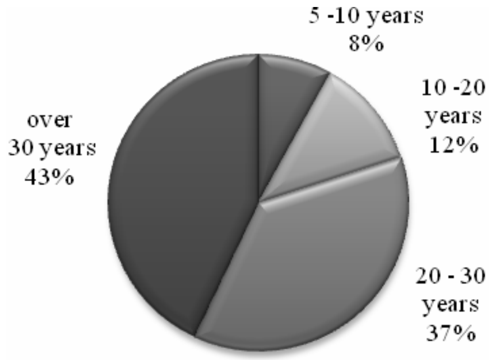

Fig. 3. Polish Power Plant [4]

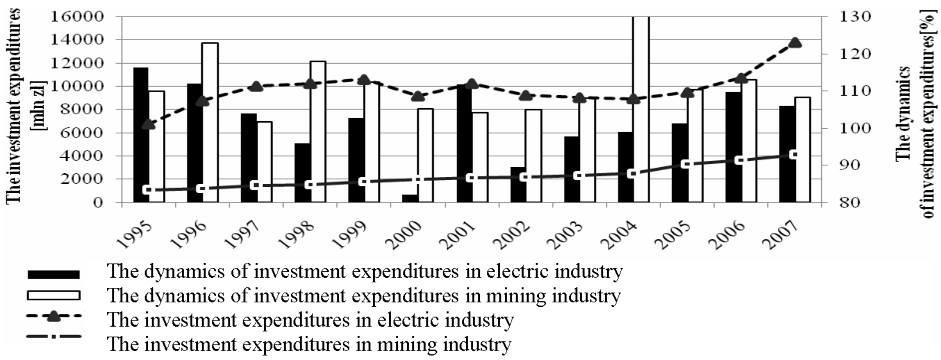

Fig. 4. The investment expenditures and them dynamics in chosen branch of industry [4]

In order to improve the energy security, investments in new electricity generation capacity and modernization of power plants are therefore a necessity. The national electricity industry also faces the problem of insufficient quantity, quality and age of power transmission lines. Over 80% of the 400 kV transmission lines and 99% of the 220 kV lines was built over 20 years ago. Poland is a kind of "energy island". Trans-border merger does not allow for larger flows or on a larger scale of exchange. It is therefore necessary to investment in transmission networks and their modernization. Power losses are estimated at about 12-15% of power, which gives around 5 000 MW per year. Bad law, lack of funding, many protected areas, such as the European Nature 2000 sites and public protests effectively restrict the expansion and modernization of power system [3, 4]. Despite of the steadily increasing investment in developing the power network, the state of energy security does not improve at a satisfactory pace (Fig. 4).

4. Anticipating the energy intensity factors

Commonly used prognostic method is to build predictive models of causes and effects, which is based on relationships between the dependent variable (eg, energy intensity index) and explanatory variables (eg, coal consumption, gross domestic product, expenditure on investment, average employment). These models are called econometric or energometric models depending on the nature of the explanatory variables. Linear econometric model with many explanatory variables is:

$$Y = a_0 + \sum_{k=1}^{K} (a_k X_k) + \varepsilon \tag{1}$$

where: $\boldsymbol{Y}$ – dependent variable, $\boldsymbol{X_k}$ – k -th explanatory variable for $k = 1, 2 \ldots K$, $\boldsymbol{a_0}, \boldsymbol{a_k}$ – struktural parameters of the model for $k = 1, 2 \ldots K$, $\boldsymbol{\varepsilon}$ – random variable.

To determine the various parameters of the econometric model, the classical method of least squares should be used. The next steps in the econometric analysis are presented in Figure 5. To verify the econometric model, the number of statistical tests can be used, which can be done with GRETL software, developed at Wake Forest University in North Carolina. Diagnostics consisted: assessing the coefficient of variation, assessed the relevance of structural parameters (Student's t-test, F-Snedecora test), assessing the degree of fit of the model (R2 determining factor), an assessment of normal distribution (test Jarque'a-Bery), evaluating the linearity of the analytical form of model (White test) and assessing the collinearity of dependent variables [2, 7].

The analysis shows that the energy consumption (understood as the power consumption of 100 PLN production sold) are influenced by many factors. Among these factors are mainly technical and energy, financial, economic, social and ecological ones. The energy-technical factors includes, among others, energy balance of production and distribution of electricity or the balance of power from the perspective of the whole economy. In recent years, the impact of financial-economic factors is growing. Factors such as the price of electricity, investment rate or turnover profit margin have a decisive impact on the finances of enterprises. Econometric model, to truly reflect the reality, must also take into account social factors such as number of employees, salary or outlays on research and development activities. The European Union has paid increasing attention to the protection of the environment, which reinforces the importance of environmental factors (pollution reduction, investment in fixed assets for environmental protection).

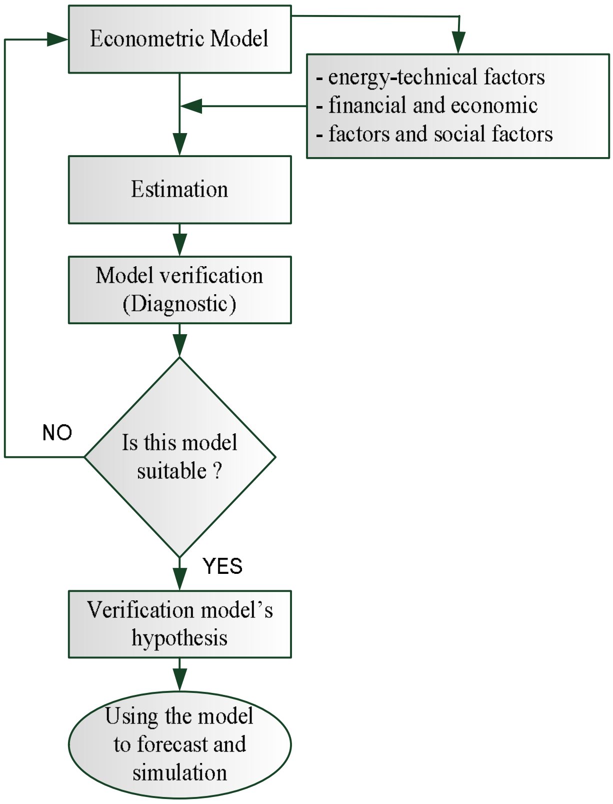

Fig. 5. The Diagram of Econometric analysis

In Tables 3 and 4 there are the structural parameters of models for the industries surveyed. Then, based on the model, indicators of energy intensity projections were developed (Fig. 6), assuming moderate growth in electricity demand. Analysis of statistical data during the period (1995-2007), expert opinions and guidelines laid down by EU directives provide for the designation of dependent variables trends in the coming years [1, 4, 7].

Table 3. The structure parameters of mining industry

Symbol	Value	Description	Unit
a_0	86,7	Constant	-
a_1	-0,8	Investment expenditure	Year 1995=100%
a_2	0,14	Total employment	Thousand of people
a_3	-0,45	Number of branch companies	Unit
a_4	1,15	Electric energy consumption	GWh

Table 4. The structure parameters of electric industry

Symbol	Value	Description	Unit
a_0	143,6	Constant	-
a_1	-10,9	Production of electric energy	TWh
a_2	0,58	Electric energy consumption on 1 employer	MWh/1 employer
a_3	-1,67	Gross national product	Year 1995=100%
a_4	1,15	Price of electric energy	previous year =100%
a_5	0,46	Investment means on environment protection	mln zł count on year1995

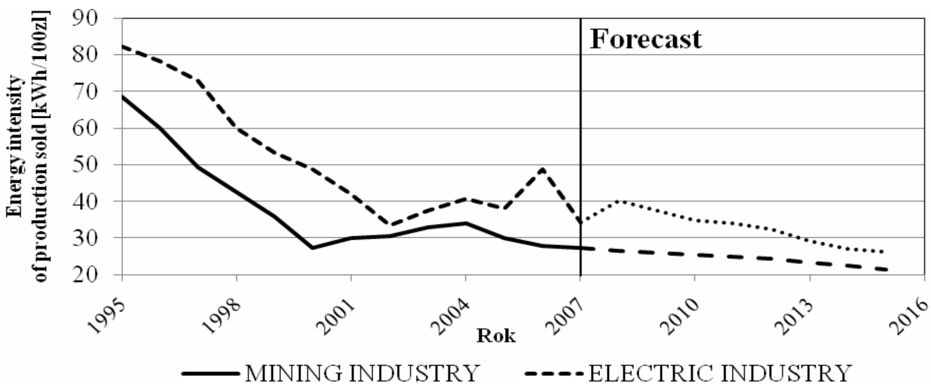

Fig. 6. The energy intensity factors of production sold on horizon 2015

5. Summary

Energy intensity index for mining and electricity during the 15 years declined 3 times. But in recent years, it can be seen a significant slowdown of the process. To maintain economic growth, we should pay special attention to the reported industries, so that they can be a powerhouse of the national economy, and not the main obstacle preventing its development. It is therefore necessary to extend and continue this type of research.

Poland is standing in front of a difficult and costly problem of modernization of the national electricity system (construction of new power plants and transmission lines). The development of ecologically clean energy is associated with reducing greenhouse gas emissions. It is possible that Poland, to meet international obligations related to the problem of warming, will have to make continually postponed decision to build several nuclear power plants. Restructuring and modernization of key industries will allow the realization of country energy policy in accordance with its objectives, mainly zero-energy growth.

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