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Analysis of the Strategy for the Energy Policy of Poland until 2030 implementation effects in the aspect of environmental protection taking into account the energy security of Poland

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Analysis of the Strategy for the Energy Policy of Poland until 2030 implementation effects in the aspect of environmental protection taking into account the energy security of Poland

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Abstract. The article analyzes whether, after almost 10 years of strategy presented in the Polish energy policy until 2030, implementation effects in terms of the economy impact on the natural environment are visible. The changes in the energy-efficiency index were also taken into account, as well as the possibilities of replacing hard coal in the energy mix by another energy carrier. The article also includes forecasts of the future development of greenhouse-gas emissions in Poland, in order to determine how the implementation of the strategy set by Poland will take place over several years. ARIMA-class models were used for this purpose.

1. Introduction

The Polish energy policy until 2030 was approved by the Council of Ministers on 10.11.2009. It is one of the most important documents that took into account the most significant tasks and challenges that the Polish economy is facing.

The basic directions of Polish energy policy are:

- improving energy efficiency,
- increased security of fuel and energy supply,
- diversification of the structure of electricity generation through the introduction of nuclear energy,
- development of the use of renewable-energy sources, including biofuels,
- development of competitive fuel and energy markets,
- reducing the impact of energy on the environment.

The state's energy policy assumes using coal as the main fuel for energy power in order to guarantee an appropriate level of energy security of the country.

The specific objectives in this area are ensuring the country's energy security by satisfying domestic demand for coal, guaranteeing stable supplies to customers and the required quality parameters. Furthermore, very important is the use of coal applying efficient and low-emission technologies, including coal gasification and processing into liquid or gas fuels. The policy also provides the use of modern technologies in the coal-mining sector to increase competitiveness, work safety, environmental protection and create the basis for technological and scientific development and maximum utilization of methane released when mining coal in mines.



Polish energy security and efficiency

It is defined as "The state of the economy enabling the coverage of the current and long-term demand of consumers for fuels and energy in a technically and economically justified manner, while maintaining environmental protection requirements" [1].

The authors of the publication have been conducting research in the field of energy security in Poland for several years. Their attention has so far focused on the possibility of replacing coal with another carrier in the Polish energy mix. The tests were conducted independently for each of the following factors:

- natural gas,
- crude oil,
- renewable energy sources.

As the figure 1 indicates this is not an easy task due to the level of Polish power industry dependence on both lignite and hard coal.

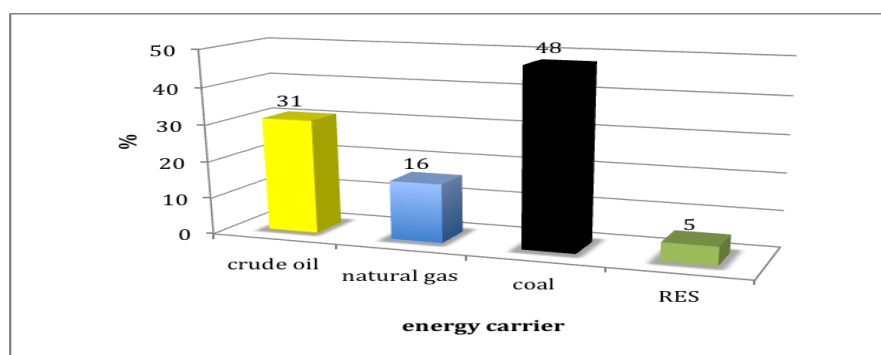


Figure 1. Primary energy consumption in 2017 in Poland, statistical data from [2].

Theoretically, replacing coal is feasible. However, for each of the energy sources, there are major restrictions blocking substitution as of today. They are presented in the table 1 below.

Table 1. Restrictions blocking coal substitution in the energy mix.

| Natural gas | Crude oil | RES |
|---|--|--|
| The majority (70%) of gas used in Poland is obtained on the basis of imports | The majority (95%) of oil used in Poland is obtained on the basis of imports | The cost of the use of renewable energy, which in most cases exceeds the cost of energy production from coal |
| Low level of import source's diversification. Most of the supply comes from Russia | Low level of import source's diversification. Most of the supply comes from Russia | A small share of renewable energy in the energy production structure in Poland |
| An analysis of the gas prices time series from 1985 showed that the price of gas exceeds the coal price twice | An analysis of the gas prices time series from 1985 showed that the price of oil exceeds the coal price three times at least | Long time horizon of building RES energy potential, which would meet the growing energy needs |
| Costs related to the transformation of the Polish energy sector | Costs related to the transformation of the Polish energy sector | |
| The ratio of energy prices based on coal and gas | The ratio of energy prices based on coal and oil | |

Source: own

The presented sources have the main advantage, namely the lower level of emissions of gases generated during their use. In the case of natural gas, the level of CO₂ emission in relation to coal is 50% lower, in the case of crude oil - 20% and RES - 100%. However, this ratio can be changed using CCT. During the combustion of coal in households, heat and power plants harmful substances such as carbon dioxide, nitrogen oxides, sulfur oxides and solid particles are released into the atmosphere. Poland's energy security is based almost 100% on coal. Restrictions and obligations imposed on Poland by the European Union make it necessary to reduce the emission of harmful combustion products. Thus, the energy security of our country may be disturbed. It has been determined that by 2050, energy production from coal should be reduced from 90 to 25 percent. It means that the production level should decrease by around 2% annually in order to reach the set threshold. The other energy carriers used so far in Poland will not be able to replace coal in the energy mix in the near future. In addition, energy efficiency in Poland is about 45% lower than the average of the European Union (figure 2). However, if 2000 is marked as the base year, efficiency in Poland increased by over 150%.

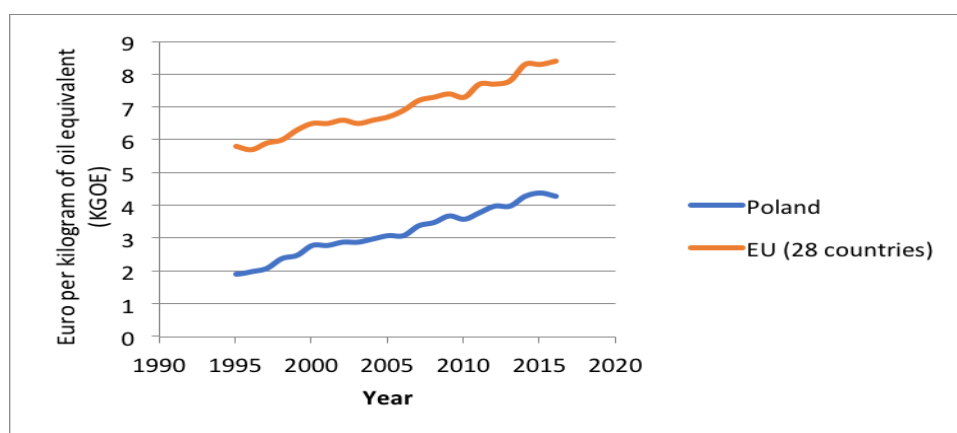


Figure 2. Energy productivity in Poland and EU, statistical data from [3].

The increase in energy efficiency in Europe is mainly related to the introduction of energy-saving devices and technologies, as well as the reduction of the share of energy-intensive industries, increase in electricity prices and a decrease in household consumption [4]. Transformation of coal-based energy requires time, significant financial investments, but above all an alternative energy source that will meet such a challenge. Studies carried out by the authors in the field of energy carriers clearly show that natural gas and crude oil are not a suitable substitute due to the price, and most important uncertain sources of fuel acquisition. Native natural-gas covers only about 30% of the demand, in the case of crude oil it is just about 6%. Renewable-energy sources are energy sources with unlimited access. However, despite the fact that they have so far developed in Poland dynamically, the current rate of their development is not enough to be able to take the place of coal and brown coal within 30 years. This problematic situation forces the search for new technologies enabling coal to remain in the national energy mix. Technologies of this type would allow limiting the emission of gases generated during combustion of coal to an acceptable level. These are so-called Clean Coal Technologies (CCT). Such activities would also ensure the survival of coal companies on the Polish market, which is extremely important considering that they employ about 82,000 people. The term clean coal technologies define all processes and methods that are used to limit the negative impact of coal burning on the natural environment. They can be introduced already at the stage of coal mining, as well as during processing. The aim of the article was to analyze the state of greenhouse-gas emissions in Poland, and the level of technologies classified as CCT development. In addition, the authors presented the CCT technology they are working on and the advantages of using it.

2. Greenhouse-gas emission in Poland

Until 1989, there was a systematic increase in greenhouse-gas production in Poland. Changes in the Polish economy in the early 1990s caused a sharp drop in greenhouse-gas emissions. As a result of intense economic growth in 1995, emissions increased again until 1997. The situation was repeated in 2002–2008. The following years brought a drop in emissions, which was caused by the global economic crisis. After 2010, emission stabilization can be observed at an average of 310 million tons per year. Emission intensity is the ratio of greenhouse-gas emissions to energy consumption. The indicator is calculated as the ratio between greenhouse-gas emissions related to energy production and gross energy consumption in the country. It expresses the number of CO₂ Mg per unit of consumed energy. The rate for Poland slightly (by 2%) exceeds the EU average (figure 3).

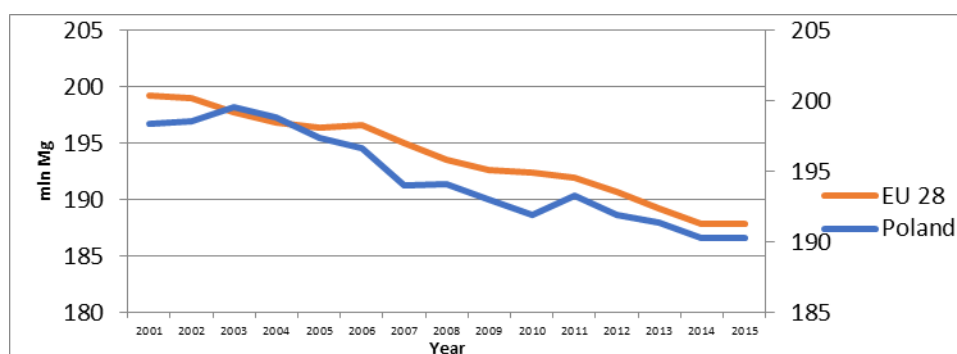


Figure 3. Greenhouse gas emissions intensity of energy consumption, statistical data from [3].

2.1. CO₂ emissions

The dominating greenhouse-gas in Poland is carbon dioxide. CO₂ emissions account for around 80% of all greenhouse-gas emissions in our country. The most CO₂ is generated during the production of electricity, gas, steam and air conditioning supply (57%), by manufacturing industry 22%, transport and storage of goods 7%. In 2017 in Poland CO₂ emissions amounted to 308 million tons. This was over 35% less compared to the base year included in the Kyoto Protocol. The Kyoto Protocol regulates emissions, which expired in December 2012 was extended as part of the so-called Doha Amendment. The new global climate agreement will be in force in the year 2020. In December this year at COP24 in Katowice, the directions of its implementation will be concretised and determined. Poland, ratifying the Doha Amendment, will confirm its commitment to reduce CO₂ emissions by 20% by 2020, in line with the EU climate and energy package. The authors concluded that the analysis of the greenhouse-gas emissions requires knowledge about the evolution of this phenomenon in the coming years. Only then will it be possible to properly plan actions aimed at achieving compliance of emissions with EU requirements. In order to create forecasts contained in article, the authors used the ARIMA model [5, 6, 7]. For each of the forecasts, the models with the lowest value of the information criterion, the smallest error and those whose residues did not show autocorrelation were finally selected for estimation. The estimation was carried out using a Kalman filter and the Gretl software package (figure 4).

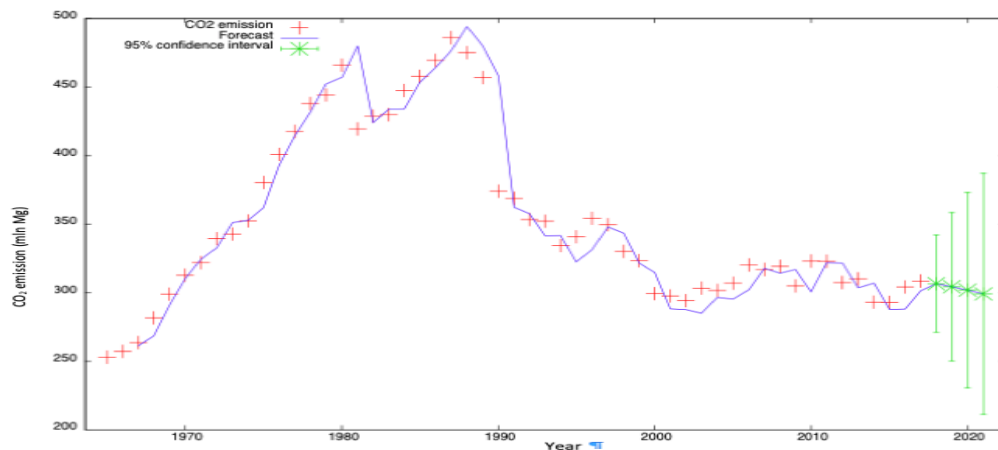


Figure 4. Carbon dioxide emission prognosis.

The authors have forecasted the volume of carbon dioxide emissions by 2020. The forecast has a slight prediction error:

- Mean percentage error MPE = 0.43
- Mean absolute percentage error MAPE = 3.89
- Theil ratio (in percent) = 1.11

The forecast showed that in relation to 1990, with the current rate of decline in CO₂ emissions, Poland will obtain a 20% reduction in 2021. However, there are justified fears that the Doha Amendment may have an adverse effect on coal-based energy, and it should be remembered that 40% of CO₂ production in the world is derived from the production of carbon-based electricity. Figure 5 presents the CO₂ emission related to the production of electricity, gas, steam and the use of air conditioning, which is the most important source of CO₂ emissions in the context of the presented analysis. The forecast for 2019 predicts a 5% decrease in CO₂ emissions compared to the last-known observation. To make the forecast, the ARIMA (1,1,0) was used. The model's MAPE error was less than 3%.

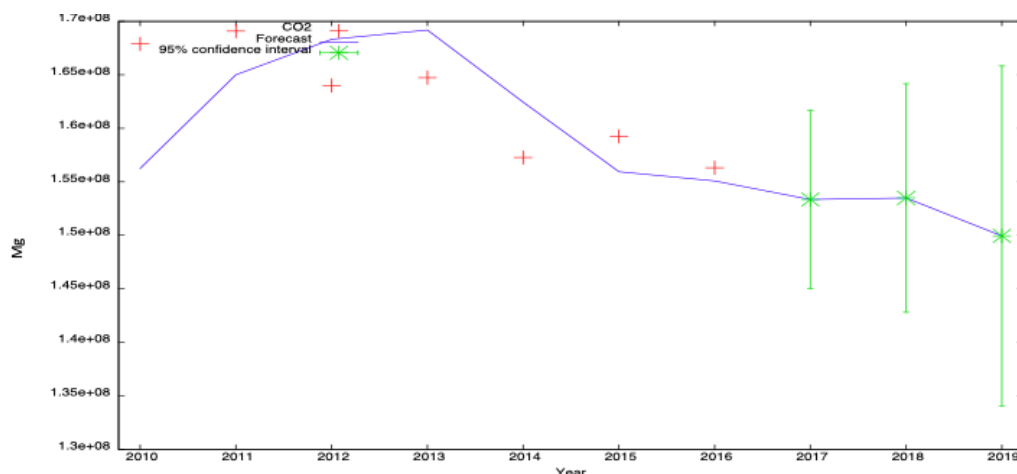


Figure 5. Predicted CO₂ emission in Poland related to production of electricity, gas, steam and air conditioning supply, ARIMA (1,1,0).

Mean percentage error MPE = 0.51
 Mean absolute percentage error MAPE = 2.98
 Theil ratio (in percent) I = 0.99

2.2. NO_x emissions

Human activity introduces only 5% of the global amount of nitrogen oxides to the atmosphere. The main artificial sources of nitrogen oxide emissions are processes carried out in the area of high temperatures or technologies, which result in the formation of nitrogen oxides following appropriate chemical reactions. Furthermore, coal installations emit large amounts of nitrogen oxides (NO_x) - gases that react with water and atmospheric oxygen, transform into nitric acid (HNO_3) causing acid rain, and then into toxic nitrate sprays. These compounds are therefore, a source of secondary particulate matter, irrespective of the emitted fine-grained primary dust (soot particles, i.e. unburned coal, ashes and slags), and contribute to the formation of smog. 29% of NO_x is generated during production of electricity, gas, steam and air conditioning supply and 24% by agriculture, forestry and fishing (figure 6).

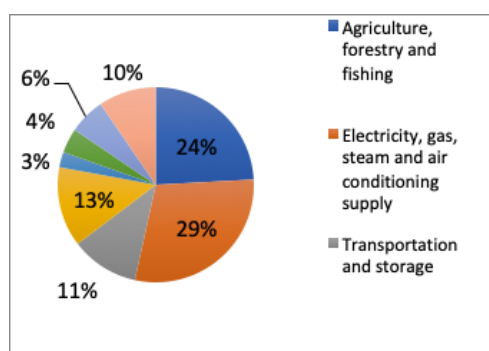


Figure 6. Emissions of the nitrogen oxides by economic activity and households, statistical data from [8].

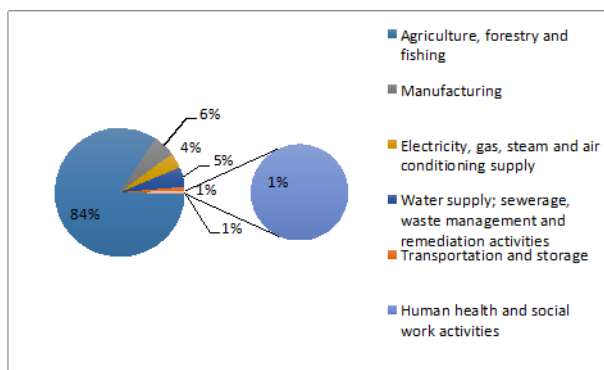


Figure 7. Emissions of the nitrous oxide in Poland in 2016, statistical data from [3].

The characteristics of the dinitrogen oxide (figure 7) as a representative of the NO_x group are also shown below because it has been included in the so-called Kyoto basket. Electricity, gas, steam and air conditioning supply are responsible in Poland for only 4 % of total N_2O emission's production. The N_2O emission in 2017 was 640743 tons. The basic source of this oxide emission in Poland is agriculture (84%) because the main source of global N_2O emissions is soil. Due to the close relationship between the dynamics of changes in the emission of nitrous oxide and the change in the size of mineral fertilization [9, 10]. The level of this fertilization is of key importance for the volume of emissions. In order to predict the amount of NO_x emissions, the ARIMA model (1,1,0) was used (figure 8). MAPE forecast error did not exceed 4%. Both the emission forecast of the entire NO_x and N_2O groups show the same downward trend. From 2008 to 2015, the volume of NO_x emissions decreased in Poland by 24%. According to the forecast made until 2019, it indicates that if we adopt 2015 as the base year, an additional 7% decrease in NO_x emissions can be expected.

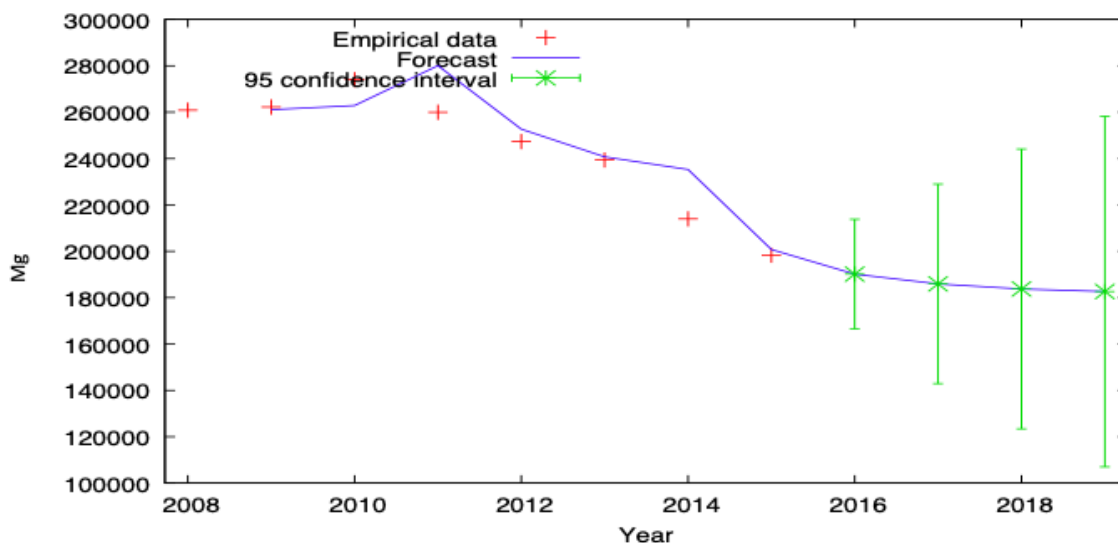


Figure 8. Predicted NO_x emission in Poland, related to production of electricity, gas, steam and air conditioning supply by ARIMA(1,1,0).

Mean percentage error MPE = -2.46

Mean absolute percentage error MAPE = 3.73

Theil ratio (in percent) I = 0.79

2.3. SO_x emissions

The largest source of SO_x emission in Poland are coal-fired power plants. In addition, this has an impact on the generation of suspended particulate matter. Various types of chemical reactions that sulphur dioxide may be subject to cause the formation of sulphate sprays and sulphuric acid inducing acid rain. In 2008-2016, SO_x emission in Poland decreased by 52%, similarly to the average EU value. Sulphur dioxide concentrations are higher in Poland than in most European countries, and similar to those occurring, for example, in the Czech Republic or Slovakia. The main sources of SO₂ emissions in Poland are the fuel and energy industry, the burning of polluted fuels, municipal waste and transport (figure 9).

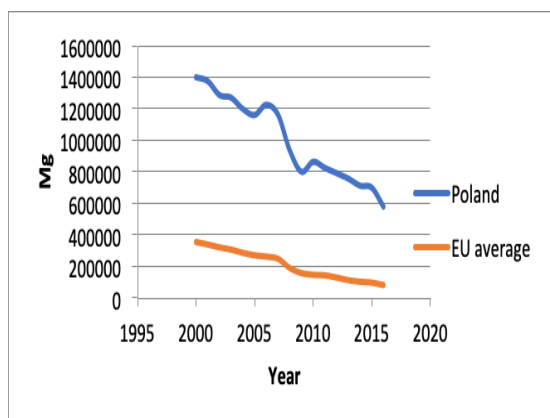


Figure 9. Sulphur oxides air pollutants, statistical data from [3].

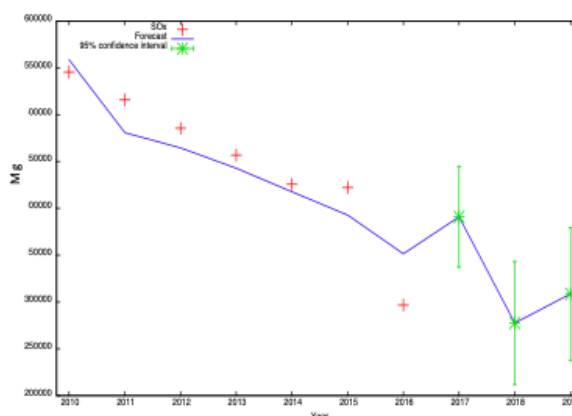


Figure 10. Sulphur oxides energy production and distribution prognosis, ARIMA(1,1,1).

The ARIMA model (1,1,1) of the energy production and distribution time series with a 6% MAPE error indicates that until 2019 a continuation of the downward trend in the time series of SO_x emissions in Poland can be expected (figure 10). Compared to 2015, the forecast indicates a 27% decrease in the volume of emissions until 2019.

Mean percentage error MPE = 0.31

Mean absolute percentage error MAPE = 6.27

Theil ratio (in percent) I = 0.53

3. CCT in Poland

The analysis of the gas emissions in recent years showed a significant decrease in the value of the examined time series. Regarding the division into economic sectors, one of the largest emission reductions can be observed in the energy sector. It is caused mainly by the transformation of the Polish heavy industry, a more rational use of energy and a decrease in coal consumption. In order to meet the requirements of the European Union, and at the same time prevent further elimination of coal from the energy mix in Poland, it is necessary to take action in the field of CCT development. It is inevitable, because the emission of gases and dust in Poland has a negative impact on the lives and health of Poles, as well as the flora and fauna of our country.

The Energy Policy of Poland assumes significant investments aimed at reducing the emission intensity of the energy sector, improving energy efficiency and ensuring a wider use of clean coal technologies. The poor financial outlays on the R & D sphere in Poland and the low inclination to engage industry in this type of activity are characteristic for the area of energy technologies. Support from public funds is very important because high research costs, and uncertainty of the achieved results discouraged private investors from investing in CCT. Clean coal technologies are all technological solutions that are designed to increase the efficiency of coal burning, processing and extraction [11]. One of the technologies that had the greatest opportunity for development in Poland is technology reducing the impact of conventional fuels on the environment, including clean coal technologies and other technologies that affect the reduction of conventional fuels.

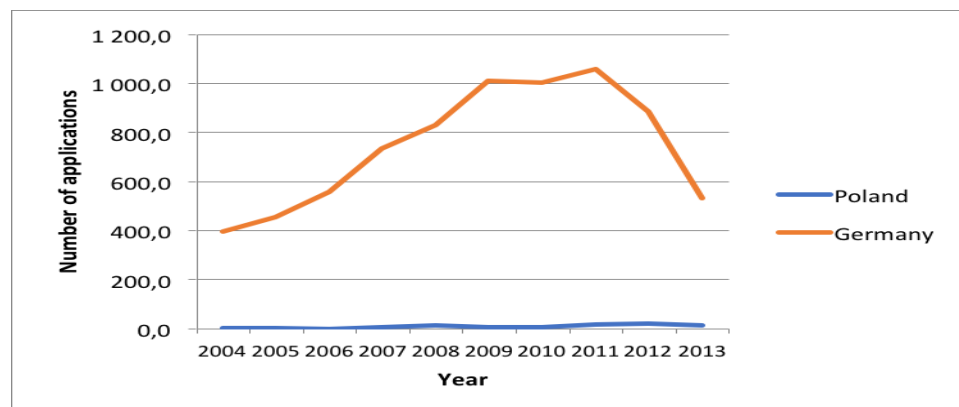


Figure 11. Technologies or applications for mitigation or adaptation against climate change, statistical data from [3]

Figure 11 presents the number of technologies or applications for mitigation or adaptation against climate change, and figure 12 shows the number of applications for capture, storage, sequestration or disposal of greenhouse gases. The graph contains Poland and, for comparison, Germany, which in the European Union leads in this field. In Poland, in 2013, 34 times fewer and 17 times fewer applications than in Germany were reported. Very important in the field of creating CCT technology is the law prevailing in a given country. Public R&D expenditures have a positive impact on the development of CCT technology. On the other hand, the growing share of renewable-energy sources has a negative

impact on it [12]. A strong correlation between emission limitations and the development of innovations in the field of CCT has also been proven. The regulation of CO₂ and NO_x emissions has a positive impact on CCT and AP-CCT in general. The number of applications for capture, storage, sequestration or disposal of greenhouse gases is around 12 higher in Germany.

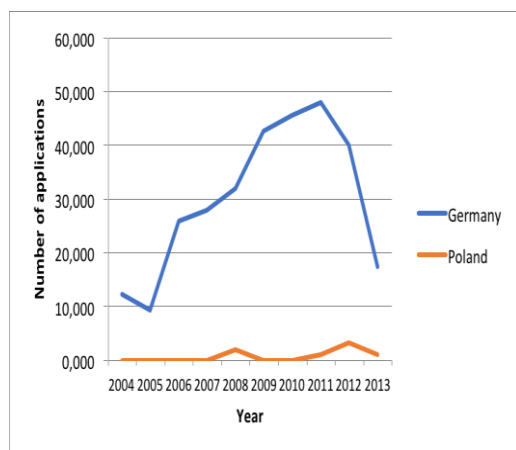


Figure 12. Number of applications for capture, storage, sequestration or disposal of greenhouse gases. statistical data from [3].

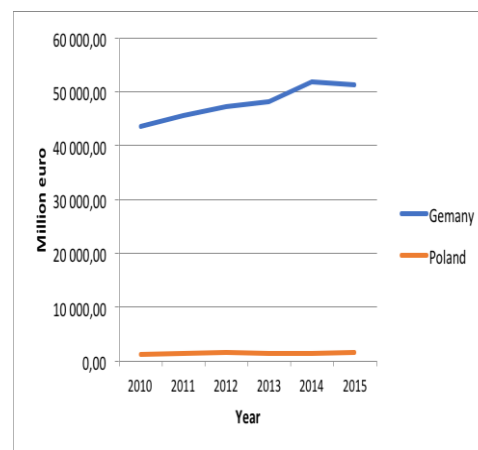


Figure 13. National expenditure on environmental protection by economic characteristics, statistical data from [3].

The sources of pollutant emissions are:

- high emissions - professional power plants,
- low emission - households, local boiler houses.

High emission usually does not cause air pollution in cities, but it contributes to the increase of the general state of air pollution in the country. A major problem in cities, however, is a low emission, especially when using outdated furnaces.

CCT are therefore, all technologies that will help reduce ecological nuisance during the production and use of coal. These technologies can be used and introduced at various stages of coal use:

- during coal burning,
- during flue gas cleaning, which is the area of interest of the authors,
- during coal gasification also underground.

The analysis of the structure of steam coal sales in Poland since 2010 (figure 14) indicates that coal culm accounts for over 80% of coal used in Poland for energy purposes. This is, of course, one of the cheapest fuels, which is its main advantage. Above all, however, in the case of professional power engineering, as well as heating plants, it is often impossible to use better quality coal due to the type of used boilers. For several years in Poland, attempts have been made to eliminate low-quality fuels in the individual provinces. Currently, the energy ministry is preparing a regulation on the quality of coal being an executive act to the Act on the system of monitoring and controlling the quality of fuels. They are designed to introduce quality standards for coal and prohibit the sale of the worst quality fuel.

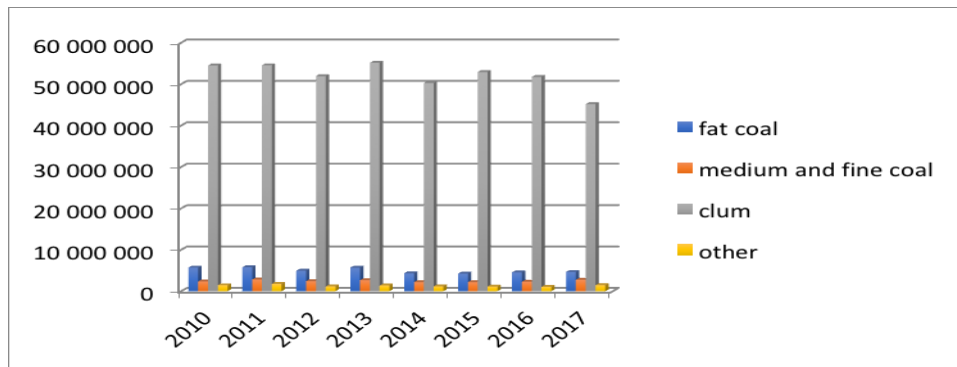


Figure 14. the structure of steam coal sales in Poland, statistical data from [13].

In connection with the above, in order to ensure Poland's energy security based on coal and lignite, appropriate CCT technology should be applied. The authors of the article are working on a technology that will eliminate the negative effects of fuel combustion. Important factors taken into account during its creation were the costs of research, manufacture, versatility of use, ease of use and efficiency of operation. It is a membrane technology to eliminate harmful substances generated during coal combustion. This type of technology can be successfully used in power plants, heating plants and households. In order to facilitate the work on finding the right membrane, the authors created a computer application, which allows optimization of membrane parameters such as permeability and selectivity before it is performed (figure 15) [14, 15, 16].

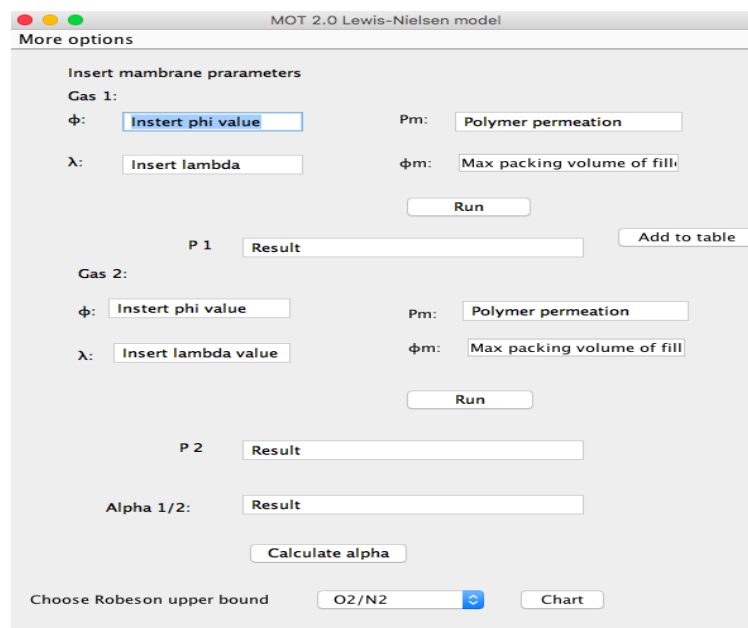


Figure 15. Membrane Optimization Tool main window

The authors assume that the membrane module will consist of a dust separator and a proper membrane. The feed produced as a result of coal combustion will be fed to the module, where the suspended dust will be first removed. The next step is the separation of gases that make up the given mixture, i.e. CO_2 , SO_x , NO_x , N_2 , O_2 . The membrane is intended to separate the naturally occurring in atmospheric air components and greenhouse gases. The gases will be discharged in the form of a permeate or retentate (figure 16). The separated mixture can be further processed and used, for

example, during the production of urea, methanol, or stored. The effectiveness of the used membrane is determined by its parameters, which can be determined using a computer program created by the authors. The programme allows for the design of a membrane with the required permeability and selectivity depending on the used fillers, their size, quantity and organic matrix.

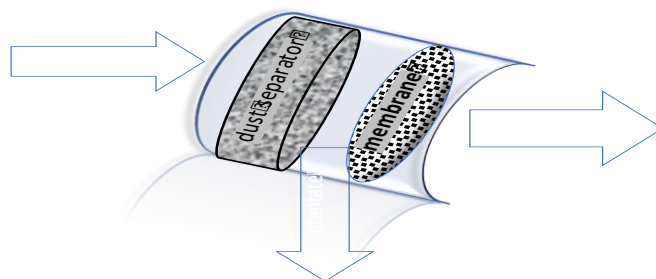


Figure 16. Cross-section of the designed membrane module

4. Summary and conclusions

The basic goal of the article was to examine the state of the strategy included in the Energy Policy of Poland until 2030 implementation. Due to the document's residualness, the authors focused their attention on three aspects:

- energy security of the country and energy efficiency,
- implementation of works aimed at reducing greenhouse-gas emissions.

There is no doubt that in the next years, Polish power industry will continue to produce energy mainly based on coal. The demand for energy in Poland is also constantly growing. It is therefore, necessary to use technologies that allow effective and clean combustion of coal. Because in the next few years, Poland's energy security will be based on hard coal and brown coal, the reduction of greenhouse-gas emissions arising during its burning will be of key importance for Poland. Continued efforts by the European Union to reduce CO₂, NO_x and SO_x emissions pose a challenge for Polish enterprises, including especially coal-fired power plants. These activities from the point of view of environmental protection and the impact of pollution on human health are indisputably necessary. Appropriate, effective and financially beneficial technology that reduces greenhouse-gas emissions is the optimal solution in this case. In Poland, in recent years we have been dealing with a continuous decline in gas emissions, also the forecasts for CO₂, NO_x and SO₂ emissions have been established, indicating that this trend will be maintained. However, it can be difficult to meet the time limits. The analysis of the time series proves that by 2000 the emissivity of the Polish economy was falling very rapidly. However, the year 2001 brought stabilization of the trend, which continues to this day. Further reduction requires the use of appropriate technology. On the other hand, the necessary condition for the creation and, above all, implementations of clean coal technologies are the appropriate financial outlays and state support, which is still lacking at the moment. The high risk of investment failure means that private sector investors are reluctant to engage in such projects. Therefore, it is necessary to undertake efforts to intensify scientific and research works and create facilities for the development of innovative energy technologies.

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