Trends in coal use – global, EU and Poland

Wojciech Suwala, Artur Wyrwa and Tadeusz Olkuski

AGH University of Science and Technology, the Faculty of Energy and Fuels, Mickiewicza 30, 30-619 Kraków, Poland

olkuski@agh.edu.pl

Abstract That aim of this paper is to compare trends in global, European use of coal with tendencies in Poland, one of heavy coal dependent countries. Polish power generation is unique among OECD countries, the share of both hard coal and lignite in power generation reaches 81% [1]. Climate policy of European Union is to phase out intensive greenhouse gases sectors, thus to transform Polish power generation into less carbon intensive. Although such policy is generally accepted in Poland, the past and practically proposed regulation that excludes coal generation from capacity mechanisms, is considered as threat to energy security. Coal is the base for generation for one simple reason, abundant in European scale hard coal reserves and significant capacities in lignite. Natural gas reserves allow to supply about 1/3 of consumption, but prices and supplies dependent hitherto on contracts with GAZPROM did not allow to develop significant generation capacities. Renewable resources are limited, there is not much possibilities for hydro, wind and solar. Poland is also one of the countries of poor air quality, traditional coal based space heating systems plus obsolete car fleet generate vast emissions, especially during the winter. Only recently this became top priority of environmental authorities. This situation is subject to transformation, government, managers are aware that the role of coal needs to be decreased, but there are two main questions, the paste of transformation and the future energy mix. The paper attempts to answer the question whether the expected changes in Polish energy mix are comparable or differ from the global and European tendencies.

1. Global view

The major force that determines use of coal is the climate change which was identified and is observed in recent decades, and Intergovernmental Panel on Climate Change declares: “It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century” [2]. On the other hand climate on earth was never stable and is continuously changing.

Carbon dioxide is greenhouse gas which concentration rises since the beginning of the industrial era thus claimed to be the main reason for growing earth temperature contributing to climate change. The main sector responsible for greenhouse gases emissions is energy, mainly electricity and heat production and other energy processes (figure 1) and their share is estimated at about 35% of total.
China is the country of largest carbon emissions, overcoming twice next on the list – USA (Table 1). Poland with emissions of 78Mt or less than 0.9% is ranked as 21st.

Table 1. Ranking of the selected countries by 2014 total CO2 emissions (expressed in thousand metric tons of carbon) [4]

| Rank | Country                                | Carbon emissions | Percent  |
|------|----------------------------------------|------------------|----------|
| 1    | CHINA (MAINLAND)                       | 2806634          | 30.16%   |
| 2    | UNITED STATES OF AMERICA               | 1432855          | 15.40%   |
| 3    | INDIA                                  | 610411           | 6.56%    |
| 4    | RUSSIAN FEDERATION                     | 465052           | 5.00%    |
| 5    | JAPAN                                  | 331074           | 3.56%    |
| 6    | GERMANY                                | 196314           | 2.11%    |
| 15   | UNITED KINGDOM                         | 114486           | 1.23%    |
| 17   | TURKEY                                 | 94350            | 1.01%    |
| 18   | ITALY (INCLUD. SAN MARINO)              | 87377            | 0.94%    |
| 19   | THAILAND                               | 86232            | 0.93%    |
| 20   | FRANCE (INCLUDING MONACO)              | 82704            | 0.89%    |
| 21   | POLAND                                 | 77922            | 0.84%    |
| 22   | TAIWAN                                 | 72013            | 0.77%    |
| 23   | KAZAKHSTAN                             | 67716            | 0.73%    |
|      | Total                                  | 9306200          | 100.00%  |
Following pictures present global perspectives on GHG emissions and power generation, from World Energy Outlook prepared by International Energy Agency in three scenarios: CP - Current Policies, NP - New Policies, and 450 Scenario. The latter assumes radical climate policy not to exceed 450 ppm of carbon dioxide. The New Policies Scenario assumes that countries follow their Nationally Determined Contributions, as declared after COP21 in Paris. However, today this scenario seems not to be attainable due to the declaration of abandoning commitments by USA administration. It is expected that the energy related carbon dioxide emissions in growing economies will increase due to the economy progress while slightly decreasing in OECD countries (figure 2).

![Figure 2](image)

**Figure 2.** Energy-related CO₂ emissions by region in the New Policies Scenario [5]. (NDC CO2 target - Nationally Determined Contributions related to the COP21 Paris Agreement)

In the NP and CP scenarios energy consumption should rise from present 24 thousands of TWh to by some 25% to 2025 and 65% to 2040 in NP scenario while in CP 30% and 80% respectively (figure 3).

![Figure 3](image)

**Figure 3.** Global electricity production and structure, TWh (based on [5]). (scenarios: CP Current Policies, NP New Policies)
2. Comparing European and Polish trends and prospects

Present generation of electricity in Poland is dominated by coal both hard and lignite, what was inherited from the previous less environment aware periods and limited access to other fuels. On the other hand such structure guarantees supply security, given experiences even with hard winters. This structure started to change, other sources gradually gain significant share (figure 4).

Figure 4. Poland power generation 1973-2015 [TWh] [1].

Later discussion will present prospects of the alternation of this tendency to accelerate GHG emissions abatement.

Trends in GHG emissions in European Union and Poland (data based on [6]) (figure 5) show that the pace for the period 1990 – 2014 was comparable, both EU and Poland reduced emissions by 20-30%. However, Polish emissions decreased significantly in the period 1990 – 2000, being practically at the same level thereafter. Recent 10 years for EU present significant acceleration in emissions reduction, as well as Polish emissions in 5 recent years. The latter should be verified in the next periods.

Figure 5. Trends in GHG emissions EU28 and Poland (based on [6]).
(EU 10Y represents last 10 years for EU28, PL5Y last 5 years for Poland)
2.1. Reference energy mix for Poland

In 2016 the European Commission published the latest reference scenario for Poland prepared with the use of the PRIMES model. This has created an opportunity to compare the results presented therein with the results of the TIMES-PL model. PRIMES is an energy-economic model developed by E3MLab of the Polytechnic University in Athens. It covers all EU countries [7]. TIMES-PL is a model of the Polish power system developed at the AGH University of Science and Technology [8]. It belongs to a family of national models developed using the TIMES generator. Both PRIMES and TIMES-PL are used for modeling the development of the power system in the medium and long term. It should be noted that the results of both models are not forecasts of the most probable state of the system in the future, but rather explore possible system development trends for certain determinants and assumptions. This type of research makes it possible to analyze the impact, especially of the various environmental and energy policy instruments, on the development of the energy system. A similar comparative analysis was made for the 2013 EETT2050 Reference Scenario [9]. Nevertheless, since then there has been some changes, especially in regards to the European emissions trading system, for which higher prices of CO₂ emission allowances are foreseen. Another significant change is a greater pessimism towards the commercial use of carbon capture and storage technology due to slow development of this technology even under public support of the European Economic Recovery Program (EEPR). Consequently, CCS technology is only being used since 2040 and to a much lesser extent than it was presented in the previous EETT report. Prices of emission allowances, main energy carriers and electricity demand forecasts used in the Reference Scenario in both models are presented in table 2. The technical and economic parameters characterizing the energy technologies are presented respectively in EETT 2016 for PRIMES and in GIPH [10] for TIMES-PL.

| Table 2. Major assumptions on prices in the Reference Scenario for European Union (PRIMES) and Poland (TIMES-PL). |
|---------------------------------------------------------------|
| **EUA €/Mg CO₂** | 2015 | 2020 | 2030 | 2040 | 2050 |
| Gas $/1000 m³    | 290  | 390  | 445  | 480  | 500  |
| Coal in import to EU $/Mg | 77   | 95   | 102  | 119  | 77   |
| Gross Electricity generation [TWh] | 162.4 | 176.2 | 203.2 | 219.2 | 245.3 |
| **TIMES-PL:** |
| Gas $/1000 m³    | 308  | 300  | 287  | 274  | 268  |
| Coal $/Mg        | 84   | 89   | 102  | 118  | 137  |
| Gross Electricity generation [TWh] | 163.7 | 175.5 | 197.4 | 223.6 | 240.5 |

Figure 6 shows the fuel structure of electricity generation according to the PRIMES model for all 28 EU Member States. As anticipated, more ambitious CO₂ reduction targets under the current EU climate policy are raising the prices of CO₂ allowances and result in gradual displacement of fossil fuels from the EU's energy mix and their substitution by renewable energy sources, mainly wind turbines and solar power plants. Figure 7 shows Poland power generation capacities and its structure.
Figure 6. EU28 power generation [TWh] and structure (based on EU Reference ...).

PRIMES results for Poland show a similar trend. Significant decreases in the use of hard coal and lignite. Power units which are planned to be decommissioned in the period after 2030 are not renewed using coal technologies but rather in technologies using natural gas, renewables and nuclear.

Figure 7. Poland power generation capacities [GW] and structure (based on EU Reference ...).

In case of the TIMES-PL model the assumption about the CCS potential seems to be crucial. With the assumptions that CCS technology will be available after 2035 and that there will be social accept ance for the opening of new coal mines, both hard coal and lignite remain the main fuels used to produce electricity. Nevertheless, the share of solid fuels in electricity production is decreasing to 48% in 2050 (figure 8).
The situation is different with the assumption (which is similar to the one in the EETT scenario) that there will be a delay in the possibility of CCS use in the power industry. Figure 9 depicts the TIMES-PL results concerning the fuel structure for electricity generation for the case when electricity production in CCS-equipped power plants is reduced to the values provided in the EETT report.

It is clear that with such high prices of CO₂ emission allowances and with limitations for the application of CCS technology, the use of coal for power generation becomes unprofitable. Similarly to the EETT scenario, coal power plants are displaced by gas, renewable and nuclear power plants.

3. Conclusions
The paper tried to answer the question whether the tendency to maintain high share of coal generating in Poland is contradictory to general trends and whether it would contribute relevantly to climate change. The answer for the latter is negative, Polish share in emissions is less than 0.9% thus irrelevant in global scale.

The trend in GHG emissions in Poland is changing, there was a decrease between 1990 and 2000, then the level of emissions was variable but did not present decreasing trend. Only recent five years show decrease, but it is too short to derive any relevant conclusions. In contrary EU28 presents decreasing trend especially in last ten years.
The Polish power generation mix once monopolised by coal, both hard and lignite is gradually changing. Coal will be dominating till 2030 when it is expected to be replaced by nuclear, gas and wind generation.

The quality of air in Poland needs improvement thus low or zero emissions technologies should be applied, also in energy sector.

Acknowledgments
The paper is an effect of the statutory project no. 11.11.210.375

References
[1] IEA Poland 2016 – Energy Policies of IEA Countries – Poland 2016 Review, OECD/IEA, 2017
[2] IPCC 2013, Climate Change 2013 The Physical Science Basis, http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf
[3] IPCC 2014: https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf
[4] http://cdiac.ornl.gov/trends/emis/top2014.tot
[5] World Energy Outlook, 2016, IEA Paris
[6] http://ec.europa.eu/eurostat/data/database
[7] Capros P, Paroussos L, Fragkos P, Tsani S, Boitier B, Wagner F, Busch S, Resch G, Blesl M and Bollen J 2014 Description of models and scenarios used to assess european decarbonisation pathways Energy Strategy Reviews 2 pp 220–30
[8] Wyrwa A, Pluta M, Skoneczny S, Mirowski T 2014 Modelling the long-term development of an energy system with the use of a technology explicit partial equilibrium model Vol 8500 of Lecture notes in computer science, Springer International Publishing pp 489–503
[9] Wyrwa A, Szurlej A, Gawlik L and Suwała W 2015 Energy scenarios for Poland - a comparison of PRIMES and TIMES-PL modeling results Journal of Power Technologies (Polish Energy Mix) 95 pp 100-6
[10] Gawlik L (ed) 2013 Coal for Polish energy sector in 2050 perspective - scenario analyses. Mining Chamber of Industry and Commerce (Katowice: Wydawnictwo Instytutu Gospodarki Surowcami Mineralnymi i Energi PAN)