IOP Conf. Series: Materials Science and Engineering **268** (2017) 012001 doi:10.1088/1757-899X/268/1/012001

Importance of hard coal in electricity generation in Poland

Franciszek Plewa and Grzegorz Strozik

Faculty of Mining and Geology, Silesian University of Technology, Akademicka 2, 44-100 Gliwice, Poland

grzegorz.strozik@polsl.pl

Abstract. Polish energy sector is facing a number of challenges, in particular as regards the reconstruction of production potential, diversification of energy sources, environmental issues, adequate fuels supplies and other. Mandatory implementation of Europe 2020 strategy in terms of "3x20" targets (20% reduction of greenhouse gases, 20% of energy from renewable sources, and 20% increase of efficiency in energy production) requires fast decision, which have to be coordinated with energetic safety issues, increasing demands for electric energy, and other factors. In Poland almost 80% of power is installed in coal fired power plants and energy from hard coals is relatively less expensive than from other sources, especially renewable. The most of renewable energy sources power plants are unable to generate power in amounts which can be competitive with coal fires power stations and are highly expensive, what leads o high prices of electric energy. Alternatively, new generation of coal fired coal power plants is able to significantly increase efficiency, reduce carbon dioxide emission, and generate less expensive electric power in amounts adequate to the demands of a country.

1. Introduction

First impetus to modernise energy production on global scale gave the Kyoto Protocol (1997), the treaty which has extended United Nations Framework Convention on Climate Change from 1992 and committed state parties to reduce greenhouse gases emissions. European answer for Kyoto Protocol has been European Strategy and Energy Union, which has been formulated at Climatic Conference in Paris 2015, and implemented in Europe 2020 Strategy. The headline targets of EU is reduction greenhouse gas emissions by at least 20% compared to 1990 levels, increase the share of renewable energy in final energy consumption to 20%, and achieve a 20% increase in energy efficiency [1, 2]. These ambitious objectives determine also targets of Polish energetic policy, however not to forgotten is that Polish energy industry is strongly dependent on fossil fuels and discussion about future of Polish energy market must also involve coal mining industry. The exploitation of coal mine deposits in underground mines is becoming increasingly difficult and costly. The fixed and variable costs borne by the coal mines are mostly dependent on the amortization costs of machines and devices, the costs of materials and energy, remunerations, external services, taxes and fees as well as other prime costs [3, 4].

- Costs of electric power include above all costs of energy raw material or – in more general terms – energy sources and costs of its production. A lot of components contribute to costs of electricity production, from which maybe distinguished [5]:
- Investment costs, which means capital required for building power plants, and return of capital,
- Fixed costs of power plants maintaining, which include costs of maintenance of the assets, renovations, fees and taxes, remuneration of Staff and other,

- Variable costs consisting of purchase costs of fuel, its delivery, and emissions allowances costs – in case of fossil fuels fired power plants.

From the point of view of energy recipients, price of energy depends also on costs of electric power grid maintenance, distribution, and energy losses in power energy networks.

Structure of primary energy sources used for production of electric energy (secondary energy) depends on economic indicators (criterion of the lowest prices), national security issues, environmental background, as well factors such as widely understood energy policy (energy development strategy) or use of differentiated primary energy sources for production of electricity.

Within increasing production of electric energy and differentiation of primary energy sources, which in large part can be seen as proportion between fossil fuels and renewable energy sources (RES), assessment of the role of hard coal in the structural transformations in electric energy production is of great importance.

2. Structure of primary energy sources and electricity demand in Poland

Accordingly to data from the end of 2014, slightly more than a half of Polish power engineering is coming from hard coal fired power stations, see table 1.

The projection suggests the electricity demand, at least in the range of dozen or so upcoming years, will be increasing. Upwards trend in consumption of electric energy in Poland will not differ from global economy perspectives.

Increasing demand for electric energy must be accompanied width adequate increase of its supply, what means that new investments in power industry sector are necessary. One can take under consideration that a lot of older power generation units must be gradually over time replaced by new ones due to their obsolescence.

To solve these problems investments in power generation branch will be required both for increase of electricity production and sustaining its current level. Forecasted demands for electric energy and restoration investments presents table 2.

Table 1. Power installed in Polish power plants (state on 31.12.2014) [5, 6].

Type of power plant	Electric power installed (GW)
Total	39 353
Professional heat power stations	31 087
- from which:	
on lignite	9 221
on hard coal	20 291
on natural gas	927
Professional hydropower plants	2 208
- from which pump storage	1 330
Industrial heat and power plants	1 871
Independent RES power plants	4 187
- from which wind power plants	3 866

Table 2. Forecasted increase in consumption of electric energy and investments in power industry [7].

Energy consumption/power capacity	Year			
	2015	2020	2025	2030
Predicted gross consumption of electric energy (TWh)	166.4	177.9	190.3	203.5
Total power capacity (installed) (MW)	38 000	39 500	41 700	44 700
Predicted total power capacity from power plants already existing in 2011 (MW)	34 500	28 700	24 700	17 800
New power capacity required (MW)	3 500	10 800	17 000	26 900

3. Costs of new power generation installation

Development of energy sector could follow different scenarios, accordingly to preferences toward different types of fuels and energy sources as well as factors influencing energy policy. Among them reduction of carbon dioxide to atmosphere will be crucial.

In Poland, where electricity production is based on hard coal and lignite, scenarios of power industry development may include only partial departure from coal as the main energy source. Hence, for all alternative concepts coal as the dominating energy source remains the reference point.

For the purpose of investing in new power plants, from the point of view of energy cost production, such ones should be considered, which will be incurred to obtain required power capacity in the plants. Graph on figure 1 shows estimated cost of acquisition of a unit of electric power for different energy sources.

From the data presented in figure 1 on may conclude that in terms of maximum (installed) power, the lowest expenditures require natural gas power plants, where installation of 1 MW power requires to incur expenditures in the amount of 3.9 million PLN. Second position with investment cost of 6.6 million PLN per megawatt is taken by coal fired and wind power plants. Only by one million PLN greater is the unit cost (PLN/MW) for photovoltaic plants. The highest cost must be incurred for investments in hydropower. It should be pointed out that in rough approximation costs of construction of the off-shore wind facilities are close to nuclear plants and twice higher as on-shore wind power plants and hard coal power stations.

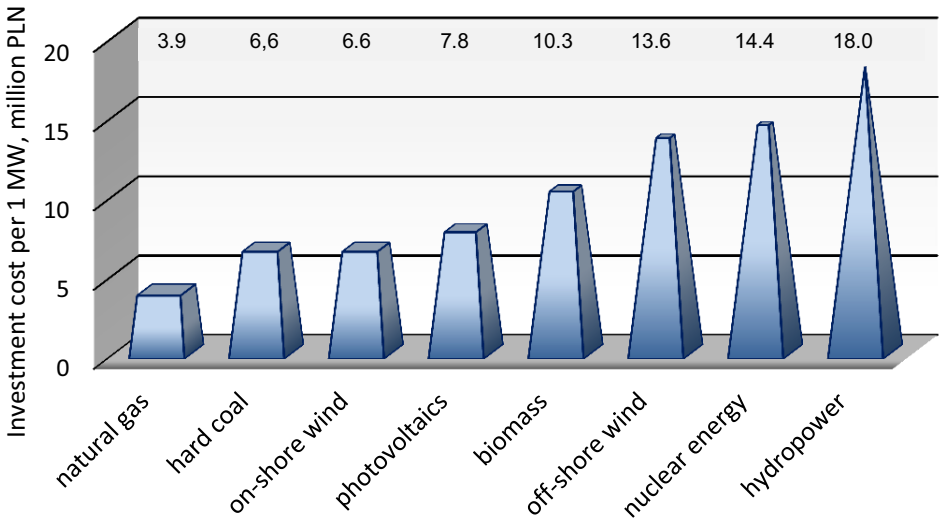

Figure 1. Construction costs of a power plant calculated for maximum power based on 2013 predictions [5, 8].

To asses real cost production of electric energy from different sources, utilisation rate resulting from limited period of time during a year, within power plant produces energy, must be considered. Average power as a statistical parameter is representing a ratio between installed power and number of days during year of power generation This parameter allows to assess actual cost of investment per unit of power for different energy sources.

Duration of work of generators depends on necessary maintenance breaks (e.g. renovations, exchange of fuel in nuclear plants) and – as it is the case for the most of RES – interruptions resulting from variability of meteorological conditions [5, 6]. The longest work time during a year characterizes power plants based on fossil fuels and nuclear energy, which are reduced only by periodical maintenance and replacement of nuclear fuel respectively [9].

Although large investments in development of nuclear energetics would provide relatively inexpensive electric energy in large amounts, this direction of power industry development seems to be unrealistic

both due to existing policy of power generation development and negative social perception of nuclear plants construction. Building of nuclear power plants still remains in doubt and in predictable future it would be hardly to expect a point of turning, especially considering a global trend to get out of this kind of energy source. Advantageous feature of nuclear power implementation is long life time of a plants, which is about 60 years long in contrary to 40 years of exploitation of an coal fired plant [9].

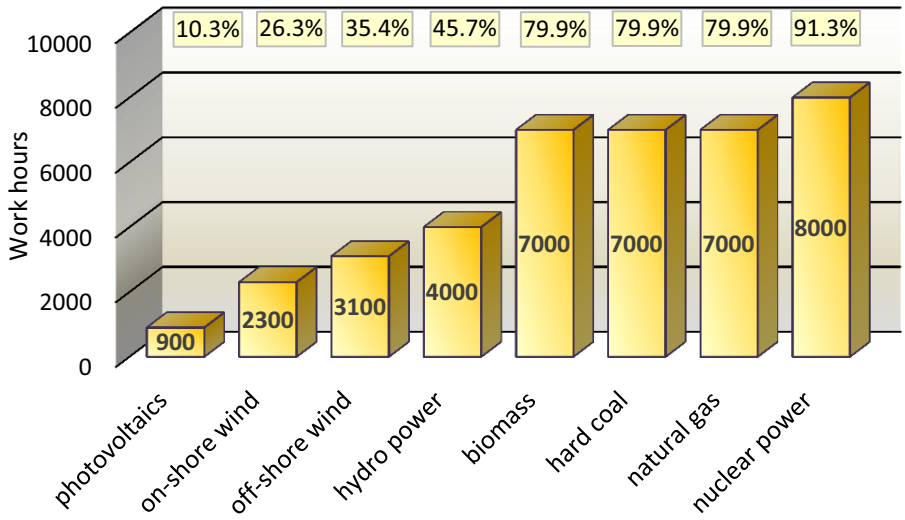

Figure 2. Time of use of the power installed in different types of power stations [5, 6].

Weather conditions in Poland (variability of meteorological conditions, relative small number of sunny and windy days) are disadvantageous enough, to use full capacity of installed power only in about 10% of a time yearly for solar energy and 23% - 35% for wind based generators. Absence of guaranteed deliveries of energy from providers operating in area of RES forces national energy system to keep running certain amount of power installed in coal fired power stations, for the purpose of compensation of energy losses generated by RES based facilities. This is especially important while the most available RES in Poland is energy of wind [10].

The lowest investment costs to produce 1 MW of power gain natural gas power plants (3.9 million PLN/MW), then hard coal fired power plants and on-shore wind plants with the cost of 6.6 million PLN/MW. Only little higher expenditures are required by photovoltaics, where installation of 1 MW costs 7.8 million PLN/MW. Usage of other energy sources is much more capital-intensive.

From the point of view of costs of electric energy, low investment cost of power station construction is fading its significance in the face of high natural gas prices and exposing the country to a risk of dependence on import of this fuel.

Comparing data shown in figures 1 and 3 one can see that the lowest investment cost, in relation to obtained average power, still relates to natural gas (4.9 million PLN/MW). However, one should keep in mind that increasing consumption of natural gas must be in 100% covered by its importing.

The second lowest cost of acquisition of average power represents hard coal (8.3 million PLN/MW), on the other hand the most expensive average power being is the one being generated from RES. Within this group of resources especially expensive venture is instalment of photovoltaic cells, which are able to generate power only by 900 hours yearly, thereby their average power is 11 times smaller than installed [5].

Also inviable seem to be investments in hydropower, which represents the second highest cost of average power acquisition. It should be also mentioned, that water dams are in use mainly for the purposes of flood protection and power plants accompanying them are of less importance.

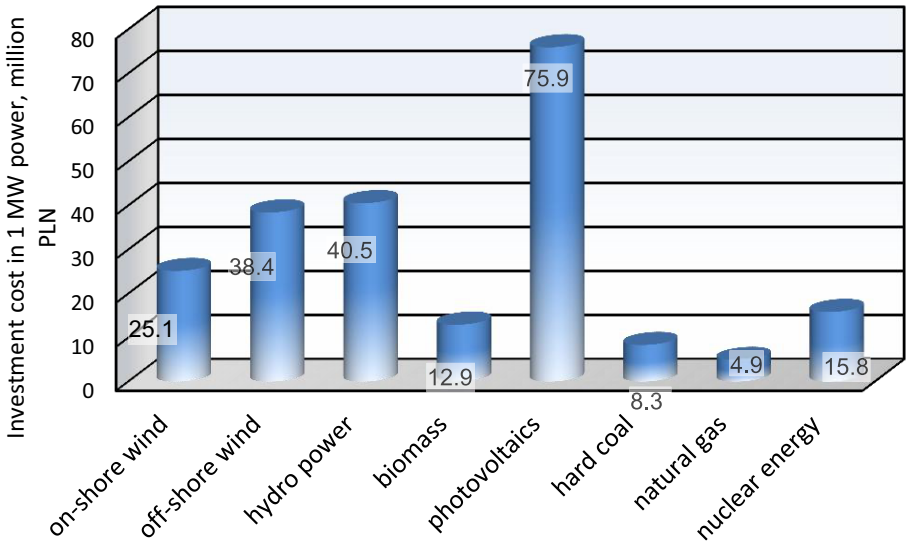

Figure 3. Investment costs in RES calculated as million PLN/MW of average power accordingly 2013 prices.

On the basis of investments values and operational costs (including purchase of fuels), rough costs of energy unit may be assessed. Table 3 presents production costs of 1 MWh of electric energy in Poland for selected methods of its generation.

Definitely most expensive energy source is undoubtedly photovoltaics with production cost of 1091 PLN/MWh. High investment costs are accompanied by high operational costs (maintenance), which amount about 10% - 15% of investment value for small installations of less than 1.5 kW power, down to 1% - 2% for installations between 100 kW and 1 MW [11].

Table 3. Production costs of electric energy in Poland from different sources [8, 6, 12].

Energy source	Production cost (PLN/MWh)	Energy source	Production cost (PLN/MWh)
On-shore wind	466	Photovoltaics	1091
Off-shore wind	713	Hard coal	282
Hydropower	484	Natural gas	314
Biomass	784	Lignite	171
Nuclear power	313		

Nowadays as well as in near future, electric power from hard coal combustion still is and will be the least expensive one. Even by increasing cost of its production resulted from emission allowance fees, which will make it closer to other energy sources, it will remain the most cost-effective [13].

Currently the percentage of different kinds of RES in production of electric energy in Poland amounts respectively: 10.7% hydropower 43.1% wind, 41.0% biomass, 0.2% photovoltaics, and 5% other sources [4]. In previous years wind turbines became much less expensive (by 25% in period 2008 – 2014), but it cannot be expected further decreasing of their prices, which could reduce costs of their instalment and energy [5].

By such comparisons one should keep in mind that each energy source is characterized by different scale of power, which it is able to provide to the total energy balance at the level of demands of the whole

country. In this approach all kinds of RES may be consider as useful on a local level, where no gross consumer occur. Dispersion of power plants powered by RES (mainly small wind turbines) is advantageous in this context on rural areas, where delivery of electric energy from large power stations is connected with high energy losses by its supply. Average electric losses in supply reach up to 9% of energy generated.

Wind power plants, frequently in a form of single turbines, are built in areas, which ensure possibly highest number of windy days. Additionally, differentiation of meteorological conditions over the country should allow continuous delivery of energy from at least a certain part of them, however even these factors do not guarantee stable level of power coming from wind. For instance in July of 2015 a critical situation occurred in national power balance, when due to still air weather over the whole country, wind power stations generated only 430 MW from 4178 MW of power standing potentially for disposition. Considering recent legislation changes it is hardly to count on further development of on-shore wind power stations. However, an idea of construction the first off-shore wind farm has appeared, which is targeted to possess 600 MW of installed power by expenditures of about 10 billion PLN that means almost 17 million PLN per megawatt of power installed [10].

4. Production costs of electric energy in other countries

Production costs of electric energy from hard coal in Poland, Germany, and U.S. are similar and amount 282 PLN/MWh, 280 PLN/MWh, and 300 PLN/MWh respectively. Cost of production of energy from on-shore wind generators in Poland with 466 PLN/MWh is significantly higher than in Germany and U.S., where these costs are similar and amount 280 PLN/MWh and 260 PLN/MWh respectively [14, 15, 16].

On the example of data from United States, the influence of technology applied in hard coal fired power plants on energy production costs can be demonstrated. Accordingly data collected in Table 4, the least expensive energy comes from power plants equipped with steam-gas turbines (round 66 – 67 USD/kWh), though cost of carbon dioxide capture and storage are estimated at the level of 12.5 – 27.8 USD/kWh. Accordingly presented data, energy from nuclear power plants may be less expensive than from hard coal fired power stations, what is also probable in Poland, while the production cost of 1 MWh energy from hard coal provided by table 3 does not consider differentiation of power generation technologies.

Table 4. Estimated production costs of energy in coal fired power plants commissioned after 2018 in U.S. (USD/MWh) [15].

Type of technology	Time of work (%)	Return of investment	Fixed operational costs	Variable operational costs	Energy transfer costs	Energy production cost
Coal – ordinary	85	65,7	4.1	29.2	1.2	100.1
Coal – advanced	85	84.4	6.8	30.7	1.2	123.0
Coal – Advanced + CCS*)	85	88.4	8.8	37.2	1.2	135.5
Gas – ordinary SGT**)	87.8	15.8	1.7	48.4	1.2	67.1
Gas – advanced SGT	87	17.4	2.0	45.0	1.2	65.6
Gas – advanced SGT and CCS	87	34.0	4.1	54.1	1.2	93.4
Nuclear	90	83.4	11.6	12.3	1.1	108.4

*) CO_2 capture and storage, **) Steam-gas turbine

In terms of RES in American conditions, the least expensive and additionally the most competitive in regard to hard coal fired power plants are on-shore wind power plants, what can arguable resulted from climatic conditions [15].

On the background of data presented in table 5, the most expensive sources of electric energy are off-shore wind power plants and photovoltaics (similarly as in Poland). Especially expensive is production of electricity from solar thermal energy, which is still at the level of a few pilot plants worldwide.

In turn, production costs of energy in Germany have been collected in figure 4. They stay in general proportion do energy production costs in Poland, except photovoltaics, for which electric energy production cost is comparable with natural gas and on-shore wind plants.

Table 5. Estimated production costs of electric energy from RES after 2018 in U.S. (USD/MWh) [15].

Type of RES	Time of work (%)	Return of investment	Fixed operational costs	Variable operational costs	Energy transfer costs	Energy production cost
Wind – on-shore	34	70.3	13.1	0.0	3.2	86.6
Wind – off-shore	37	193.4	22.4	0.0	5.7	221.5
Photovoltaic	25	130.4	9.9	0.0	4.0	144.3
Thermal solar	20	214.2	41.4	0.0	5.9	261.5
Hydropower	52	78.1	4.1	0.0	2.0	90.3
Biomass	83	53.2	14.3	6.1	1.2	111.0
Geothermics	92	76.2	12.0	42.3	1.4	89.6

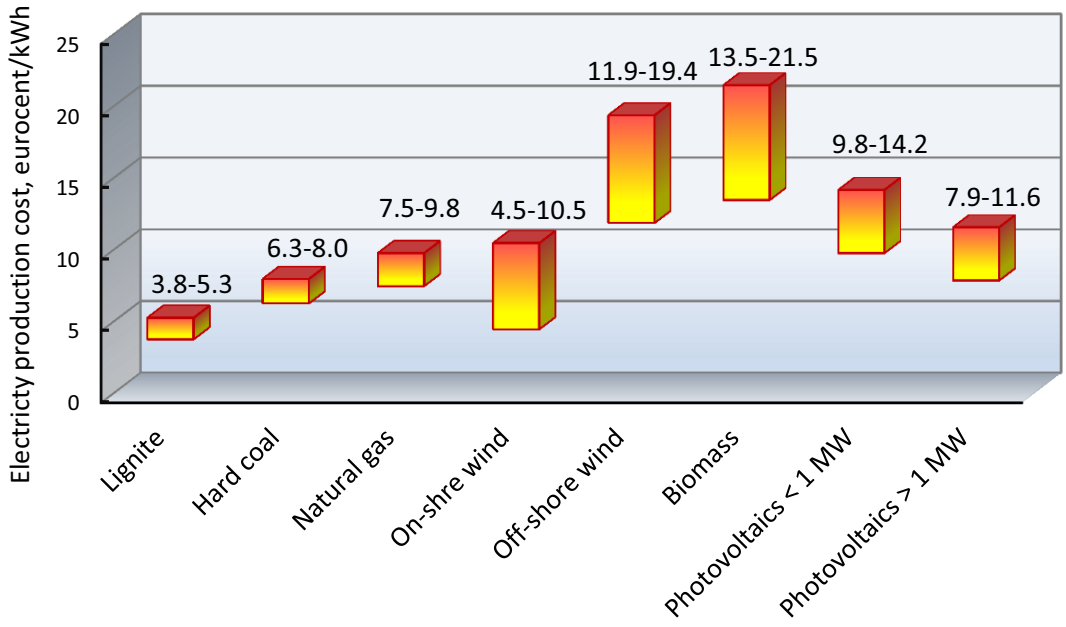

Figure 4. Electric Energy production costs in Germany in 2013 [16].

5. Global trends in share of hard coal in production of electric energy

Share of coal (both hard coal and lignite) in global production of electric energy is not dominating and amounts round 39.5% [7]. However for many world leading economies it is primary or having high share source of energy for production of electricity. Share of coal in production of electric energy in selected countries illustrates the chart in figure 5. Coal remains an important source of energy production in all countries, which are its largest producers. However, most of these countries decreased production of electric energy. Between 1995 and 2015 Poland's share of coal as a source of electricity decreased only from 97.5% to 80.9%, while in U.K. from 81.1 to 22.9%, or in USA. from 53.9% to 34.3% [19]

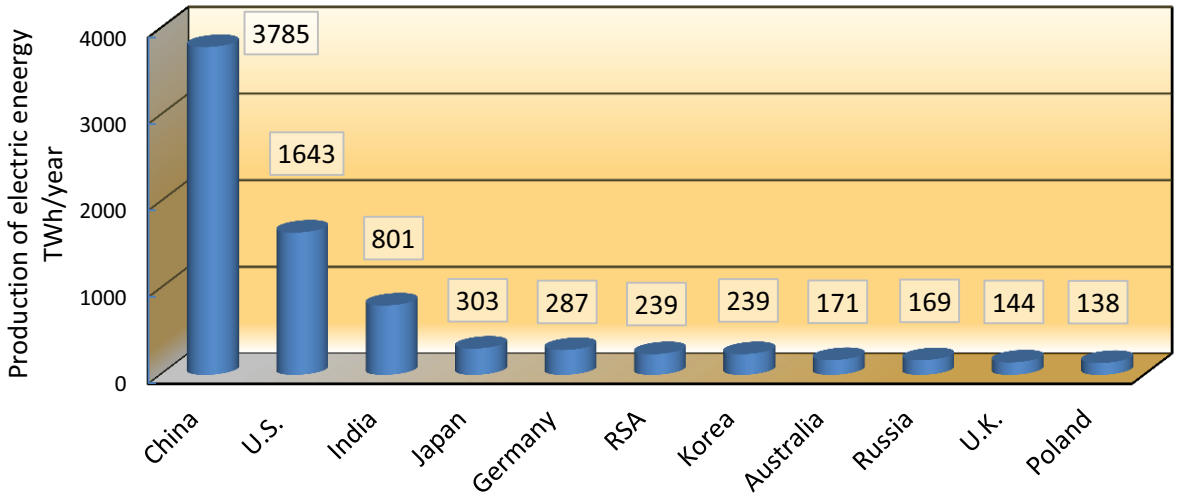

Figure 5. Shares of coal in energy production by selected countries [10].

Share of coal as well as other fuels and energy sources in production of electricity undergoes long-term trends resulting from changes of prices (e.g. oil), technical development (e.g. nuclear power and RES), or environmental policies (e.g. coal and RES). In the whole period taken under analysis in figure 5, decreasing trend in use of oil can be observed since decade of 70's of 20th Century, leading to marginal share of oil consumption for electric energy production. Use of natural gas since last years is almost constant and should not change significantly until 2035 [17]. Also nuclear power after a period of increased interest, will keep constant share in production of electric energy. In turn, hydropower demonstrates constant share over the whole considered period, what could suggest lack of development opportunities, due to high investment costs and objections from the communities, which resist building of hydropower stations, due to huge social and environmental implications of creating large artificial water reservoirs.

Accordingly the forecast of shares structure of electric energy sources shown in figure 6, RES are representing relatively new source of energy, which development within time span up to 2035 is limited and may achieve about 12% of share in total energy production in relation to current share of only 5%.

Consumption of hard coal in global scale has been significantly increased since 2000 and this trend will last up to about 2020 (figure 7). Increased demand for hard coal is an implication of sudden and significant economic progress in China. Also economy of India indicates strongly growing demand for hard coal. In case of Europe demand for hard coal will decrease by 50% in perspective until 2035 [18]. However the forecast shows clearly that in global scale demand for hard coal will be increasing, mainly due to countries, which are expected to step into progress phase slightly later.

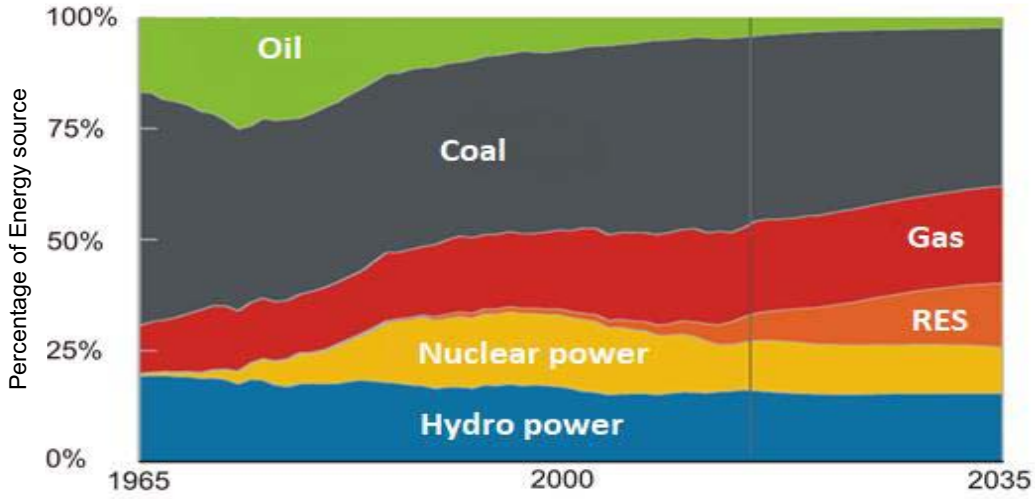

Figure. 6. Global shares of electric energy sources [19].

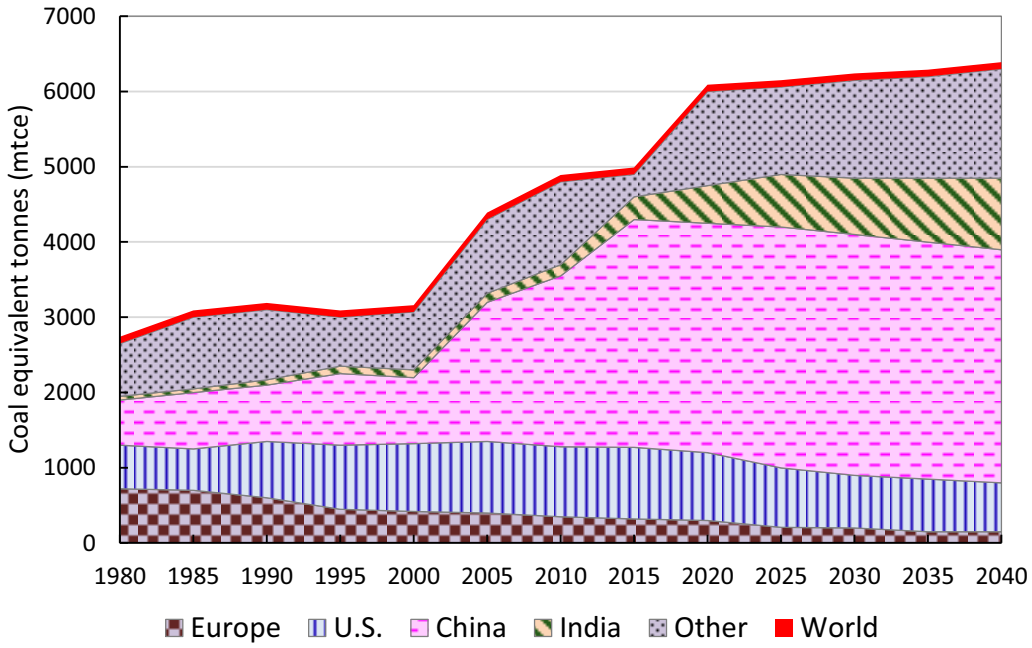

Figure 7. Forecast of demands for hard coal by world regions [19].
[coal equivalent: mass of coal, which combustion generates 29.39 GJ (8.14MWh) of energy]

6. Production of electric Energy in Poland at the background of EU

A suitable example illustrating possible changes in energetic economy in Poland might be Germany, where similarly as in Poland production of electric energy is based on hard coal and lignite. Simultaneously Germany create broad field for observation of RES problematics.

In 2016 Germany produced total amount of 648 million kWh of electric energy. From that 338 million kWh (52%) came from fossil fuels, and 30% (191 million kWh) from RES (figure 8). Source of 40% of produced electric energy was hard coal and lignite. Between RES the most important energy source is wind with 12.3% share in total production of electric energy [3, 4].

In the same year in Poland has been produced 164 million kWh of electric energy, from which 22 million kWh came from RES, making 13,43% of total electric energy produced [19]. Thereby, share of RES in Polish electricity production doubled since 2010.

Prices of electric energy in Poland belong to medium between EU member countries and in 2016 amounted 3.52 cent/kWh for households and 7.1 cent/kWh for gross consumers [22]. The most expensive is the electric energy in Denmark and Germany, where its price for households amounted 30.84 cent/kWh and 29.77 cent/kWh respectively [20]. At the same time in these countries share of RES in production of electric energy is the highest among EU member countries with 30.0% and 51.3% respectively, what seems to be a non-accidental correlation, particularly in view of the fact that total amounts of electricity production in those countries are incomparable, while Denmark produces 17 times less electricity than Germany [3].

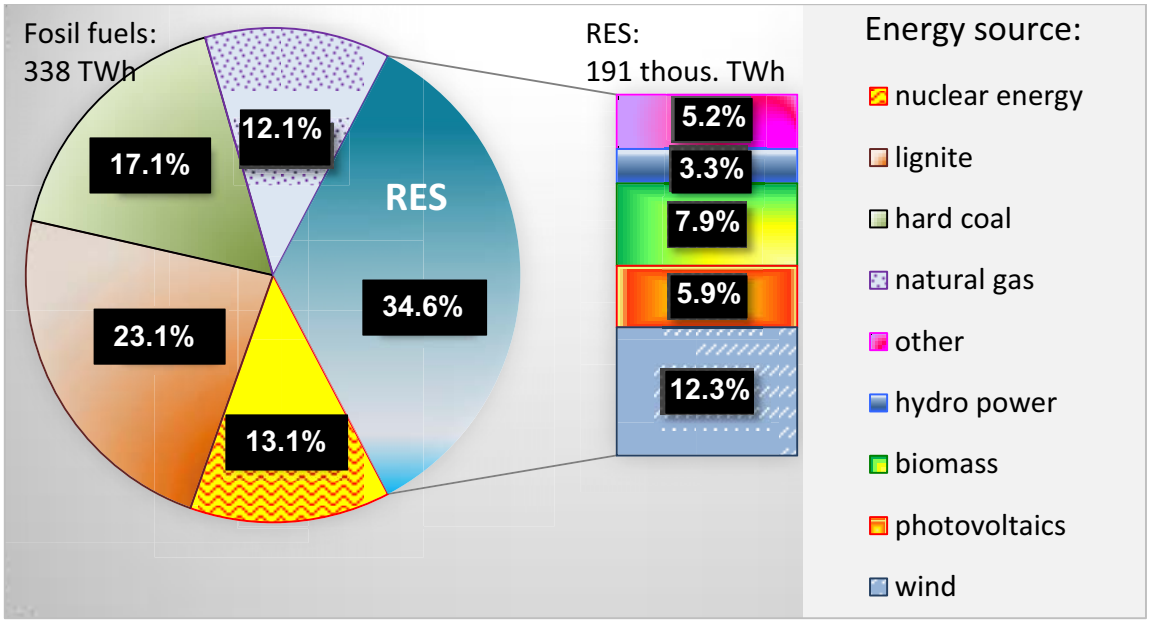

Figure 8. Share of particular electric energy sources in Germany at the end of 2016 [3].

Pursuant to the EU guidelines, until 2020, 20% of electric energy being produced in Poland should come from RES. Thereby share of RES must increase from 13.43% in 2015 up to 20% in 2020 [4] at the expense of non-renewable sources, mainly hard coal and lignite, which share should be limited by about 6% [21].

However taking under consideration forecasted general increase of electric energy demand, estimated as 7% between 2015 and 2020, demand for energetic coal might stay at the same level. In such a way influence of increasing percentage of electricity from RES on the demand for hard coal and lignite in longer perspective should be at least partially compensated.

7. Emission of carbon dioxide in coal based power generation

Figure 9 shows carbon dioxide emissions to the atmosphere in Poland and Germany in years 2005 - 2014. Before 2010 mass of CO_2 emitted to the atmosphere was decreasing and during further years followed constant level of round 820 million tonnes in Germany and 325 million tonnes in Poland per year [7].

Because of the size of the economies in Poland and Germany this difference is not surprizing, although interesting could be calculation of CO_2 emission per capita (table 6). In such an approach, emission of carbon dioxide amounted in considered years round 10.3 tonnes in Germany and 8.4 tonnes in Poland per inhabitant.

Accordingly Eurostat [3] indicator of greenhouse gases emission calculated as energy being produced with emission of CO_2 to the total amount of produced energy on 2000 basis (100%), took in 2014 value of 95.8% in Germany and 90,1% in Poland by average for EU members countries 89.1%. From the point of view of these data, climate doctrine of German environment protection policy should be more concentrated on giving a positive example rather than pressure on Poland and other EU member countries to reduce CO_2 emissions.

Implementation of the carbon dioxide emissions charges and building of CO_2 capture and storage plants will be reflected in higher production cost of electric energy. For instance, in case of lignite fired power plant, implementation of CO_2 capture and storage facility will increase production cost of 1 MWh energy up to round 280 ÷ 300 PLN.

In turn, by predicted increase of carbon dioxide emission cost up to 25 ÷ 30 EUR/tonne, production cost of electric energy from lignite would reach a level of about 270 ÷ 290 PLN/MWh and 380 ÷ 400 PLN/MWh for hard coal. Besides higher energy prices, increased production costs would give an impulse to reduce CO_2 emission as result of its capture and storage and creation of better environment for development of RES based energetics [8].

Table 6. Carbon dioxide emissions in Poland (PL) and Germany (D) from 2010 to 2014 [7]

CO_2 emission	2010		2011		2012		2013		2014	
	PL	D	PL	D	PL	D	PL	D	PL	D
million t/year	828.2	324.5	802.3	337.0	815.0	326.0	842.0	321.1	798.6	316.8
t/year per capita	9.32	7.99	9.9	9.1	10.0	8.5	12.7	8.3	9.8	8.2

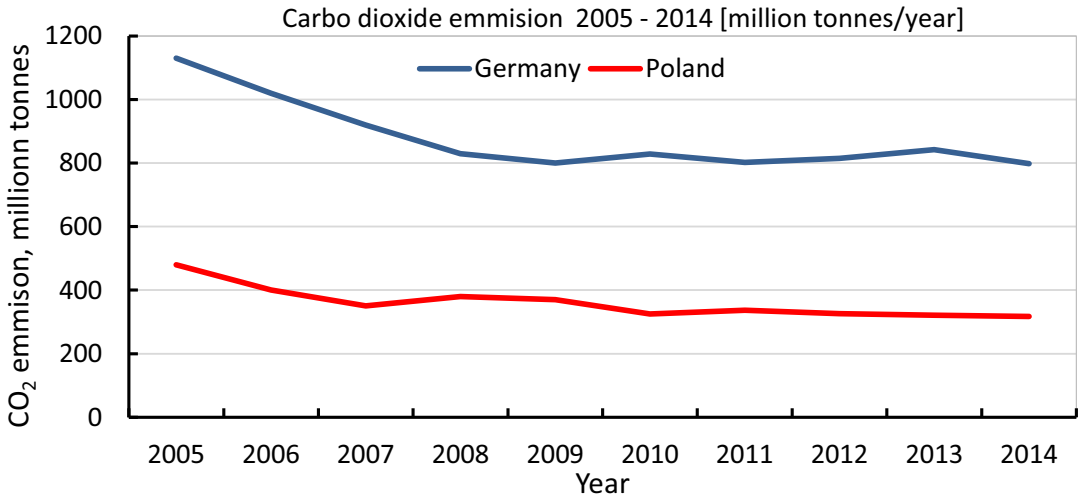

Figure 9. Carbon dioxide emission in Poland Germany in period 2010 – 2014 [7].

8. New coal fired power plants in Poland

In the framework of restoration and energy potential development investments in power industry new power plants are built as well as old power units are replaced with new ones. These new installations ensure much higher efficiency and smaller carbon dioxide emission, which is reflected in lower coal consumption and smaller CO_2 emission per unit of energy [22].

Hard coal fired power stations with conventional energy units are working on sub-critical parameters with performance of about 37%, however efficiency of older, exploited units is much smaller. For instance, efficiency of power units 1 – 4 in power plant Rybnik is about 34% ÷ 35%, while the

performance of new units for sub-critical parameters reaches 38% ÷ 42% and in the latest units operating on super-critical parameters reaches 44 ÷ 46% [13]. These units will also have significantly reduced emissions of CO_2. The largest investments in new power units have been characterized in table 7.

Projects, which have been described in table 7 present only a selection from a plan of maintaining and development of electric energy production in Poland presented graphically in Figure 10. Power units and stations presented on the map contain objects of differentiated importance for national balance of energy production and probability of their implementation (at least in near future). Nevertheless one can expect that the majority of electric energy will be generated by power units of high output, fired with hard coal.

Table 7. Selected new investments in power units in Poland [7]

Power plant	Operator	Power, efficiency, start of building	Fuel
Power plant Turów (unit 11)	PGE	Power: 430 - 450 MW Efficiency 43.4% Start of building 06.2016.	Lignite
Power plant Opole (units 5 and 6)	PGE	Power: 2 x 900 MW Efficiency 45.5% Start: 2017/18	Hard coal
Power plant Jaworzno	Tauron	Power: 910 MW Efficiency: 45.9% Start: 0.6.2019.	Hard coal
Power plant Kozienice	Enea	Power: 900 - 1000 MW Efficiency 45.6% Start: 12.2017.	Hard coal

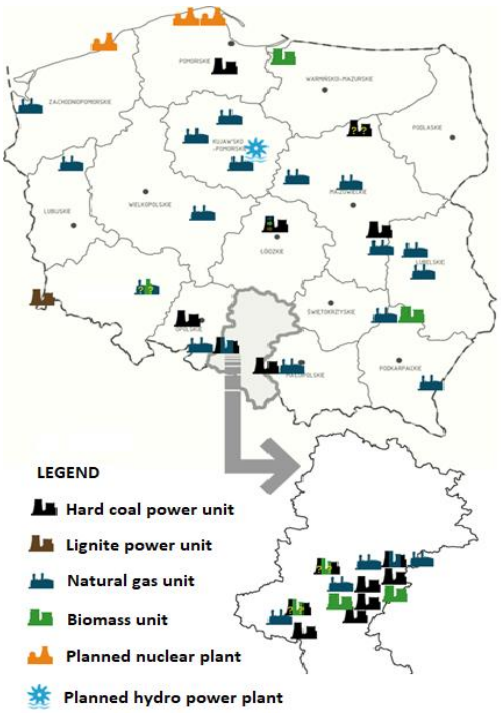

Figure 10. Investments in new power units and power stations in Poland [7].

The picture of evolution of Polish electric energy branch may be compared with current state and forecasts for power generation industry in Germany.

Despite declared concentration on RES, German energy industry concentrates first of all on coal as a fuel for new power plants intended to replace old plants and cover increasing demand for electric energy.

In the period of years 2014 – 2108 almost 12 GW of power from non-renewable sources will be shut down. Slightly more than a half of this power will be replaced by new power unit and power plants operating on fossil fuels (figures 11 and 12). Analysing structures of energy sources in deactivated and starting power stations one can see no change in amount of power generated in lignite fired power plants, which produce almost a quarter of total electric energy in Germany.

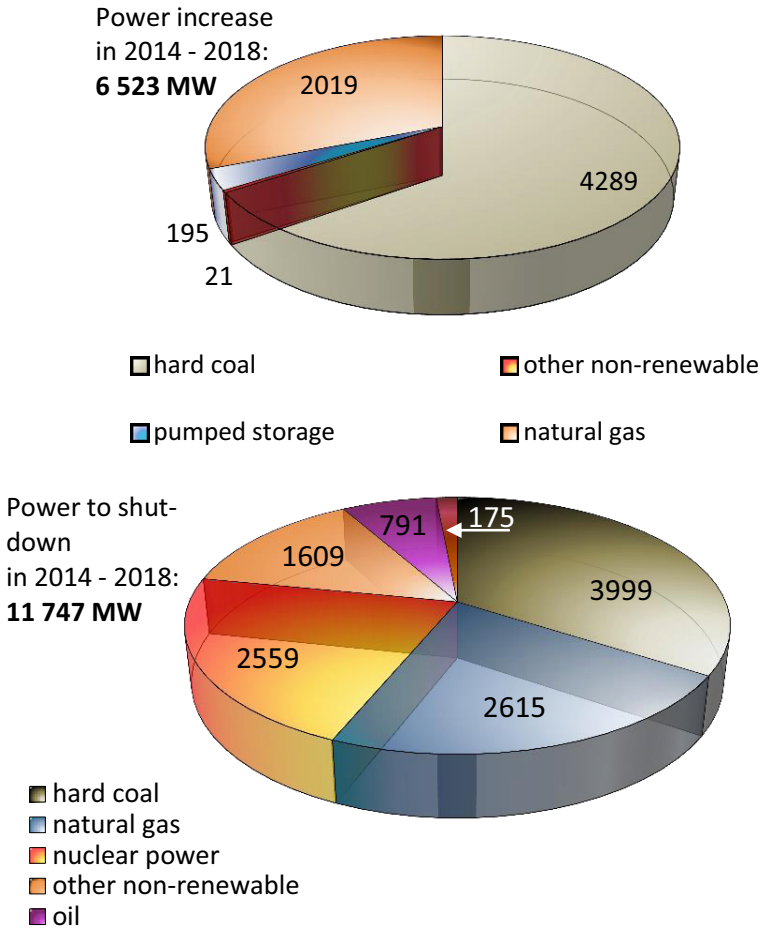

Figure 11. Plans of start-up and withdrawal of electric energy generation power in Germany [20].

In case of hard coal fired power plants, between 2014 and 2018, share of hard coal in production of energy will increase by 7%, taking finally share of 19% between all electric energy sources. Therefore, progress in RES based energy production had been used mainly in aim to replace production of energy from most expensive and import-dependent sources like oil and natural gas, as well as to make possible shut-down of negatively perceived nuclear power plants.

It should be emphasized that data from electricity production in Germany have been elaborated in years 2013 – 2015 and cover a perspective up to 2018, therefore the most of described tasks are already completed. In turn large number of coal fired power units designed to start in longer time perspective, what is illustrated in figure 11, indicates that reduction of coal consumption of electric power generation does look unrealistic

In first place on power generation efficiency with performance of 61,5% are gas-steam turbines. However they must be powered with coal and natural gas [21]. In future should be available such units powered only hard coal with use of coal gasification process for generation of gaseous fuel [22].

Figure 12. Planned new coal fired power plants in Germany [23].

9. Comments on development of coal production for inland electricity production in Poland

Although demands for energetic coal in perspective up to 20 years will not be a subject of significant decrease, economic condition of Polish hard coal industry is getting worse. In the most pessimistic scenario of changes in energy sources, is possible that hard coal would not be ousted by competition, but just replaced necessarily by other fuels and energy sources, including imported hard coal.

Restructuring of old mines in terms of ownership and accessing new not yet mined coal beds does not give guarantee the maintaining necessary level of coal production and particularly solid, long term competitiveness of prices.

On the areas of Uppers Silesia and Lublin coals basins exist favourable located, yet not mined reach resources. There is a need to build new mines on such areas, which activity from exploration, through building up to equipment and environment production should be achieved completely through Polish companies. A great asset in development of modern coal mining shall be undoubtedly high level of Polish mining technologies and know-how.

Not without significance for building of new coal mines are such factors as:

- Possibility to locate the mines in advantageous mining-geological conditions,
- Design of mine structure and access to the coal beds from the point of view of application of modern technical and organizational solutions,
- Best conditions to minimize impacts on the environment,

which influence heavily final price of energy fuel offered on the market.

10. Conclusion

Both global as well as European trends in source structure changes in power industry, despite gradual increase of RES participation, does not exhibit drastic decrease of demands for energetic hard coal.
Growing demand for electric energy and necessity of old power units replacement, require significant investments in the power industry.

Examples of Poland and Germany shows that serious losses of power resulted from closure of old power stations may be compensated only by new coal fired power plants.

New power units are characterized by slightly higher efficiency and will be significantly more environmental friendly.

Production costs of electric energy will be influenced by buying of emission allowances and implementation of carbon dioxide capture and storage systems, however increased electric energy prices might be, at least in a part, compensated by achievement lower level of hard coal prices resulted from launching of new coal mines

References

[1] EUROPE 2020 - A strategy for smart, sustainable and inclusive growth (Annex 1 – Europe 2020: an Overview). EUR-Lex. European Commission. Retrieved 25 September 2015
[2] Raines T nad Tomlinson S 2016 Europe's Energy Union. Foreign Policy Implications for Energy Security, Climate, and Competitiveness, Europe Programme/Energy, Environment and Resources, Gatham House
[3] http://ec.europa.eu/eurostat/web/products-datasets/-/med_eg30
[4] http://ec.europa.eu/eurostat/web/energy/data/shares
[5] http://ncbj.edu.pl/niezalezna-ocena-kosztow-produkcji-energii-elektrycznej#podsumowanie
[6] Kwartalnik Agencji Rynku Energii *Sytuacja w energetyce* http://www.rynek-energi-elektrycznej.cire.pl
[7] http://euracoal.eu
[8] http://info.wyborcza.biz/szukaj/gospodarka/cena+za+tonę+emisji+co2
[9] Michalak J 2012 Analiza porównawcza opłacalności inwestycji węglowych i jądrowych *Polityka energetyczna* **15/4** pp 187-99
[10] https://data.worldbank.org/indicator/EG.ELC.COAL.ZS
[11] http://solaris18.blogspot.com/2012/09/koszty-montazu-i-eksploatacji.html
[12] Zaporowski B 2008 Analiza kosztów wytwarzania energii elektrycznej *Polityka energetyczna* **11/1** pp 531-42
[13] Zaporowski B 2011 Efektywność energetyczna i ekonomiczna elektrowni i elektrociepłowni dużej i średniej mocy *Polityka energetyczna* **14/2** pp 455-68
[14] https://de.wikipedia.org/wiki/Stromgestehungskoste
[15] Levelized Cost of New Generation Resources in the Annual Energy Outlook. U.S. Energy Information Administration, April 2017
[16] Stromgestehungskosten Erneubare Energien. Fraunhofer-Institut für Solare Energiesysteme ISE, November 2013
[17] Katzer J (ed.) 2007 The Future of Coal, Massachusetts Institute of Technology
[18] Finkelman R B and Shifenk D Coal as promising source of critical elements. Progress and future prospects *International Journal of Coal Geology Elsevier* Available online 19 June 2017
[19] BP Energy Outlook 2017 Edition
[20] Data on energy price trends. Long-Time Series from January 2000 to March 2017. Statistisches Bundesamt 2017
[21] Heberg A 2015 Europe'/s energy security – od the Energy Union the answer, European Policy Centre
[22] Ministerstwo Skarbu Państwa 2017 Przyszłość polskiego węgla jako surowca energetycznego
[23] Friends of the Earth: http://www.foeeurope.org/search/foee/new%20coal-fired%20power%20stations?page=1