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Green Paper – challenges to RES development in Poland

***Abstract**. The EU regulations in the field of energy-environmental policy and Green Paper, published in 2013, have influenced the operation of the power sector, especially power generation sources. Special attention is focused on RES in power generation because one of the most effective manners of reducing carbon dioxide emissions is increasing the consumption of renewable energy. The development of RES in Poland is constrained by limited grounds for biomass production and lack of biomass infrastructure. The potential of wind, hydropower and solar energy is relatively low. The paper presents the analysis of effectiveness of selected investment in RES.*

***Streszczenie.** Regulacje WE w zakresie polityki energetyczno-środowiskowej i Zielona Księga, opublikowana w roku 2013, wpływają na system elektroenergetyczny, a szczególnie na źródła wytwarzania energii elektrycznej. Szczególną uwagę należy skierować na OZE w generacji energii elektrycznej, ponieważ jest to najskuteczniejszy sposób ograniczenia emisji ditlenku węgla. Postęp w wykorzystaniu OZE w Polsce jest ograniczony z powodu niedostatecznych areałów gruntów do produkcji biomasy i braku odpowiedniej infrastruktury. Możliwości wykorzystania wiatru, energii wodnej i solarnej są stosunkowo niewielkie. Artykuł prezentuje analizę efektywności wybranych inwestycji w OZE. (**Zielona Księga – wyzwania dla rozwoju OZE w Polsce**).*

Keywords: renewable energy sources, energy policy, environment.
Słowa kluczowe: odnawialne źródła energii, polityka energetyczna, środowisko.

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Introduction

Combating climate change is one of the most important objectives of the European energy policy. It seems that the climate conference to be held in Paris in 2015 will be of crucial importance and chances are that a global agreement will be reached by all countries in the world, especially those with high share in emissions. It is rational to assume that the targets of particular countries should match their economic abilities, considering all the financial consequences.

The European Commission document *Green Paper. A 2030 framework for climate and energy policies* [1], affects the power system and the energy market in Poland. At present, there is an ongoing debate in the EU on the new aims of the reduction of carbon dioxide emission and the share of energy from renewable sources until 2030. The consultations are expected to end by June 19th, 2013.

Energy-environment policy for Europe

Mitigating the climate change, limiting the import of natural gas and crude oil, and providing secure energy to consumers are the most important objectives of the European energy-environment policy formulated in the document of the Commission of European Communities *An Energy Policy for Europe*, COM (2007) [2]. The achievement of the energy policy goals requires the control of European energy consumption, the increased use of energy from renewable sources, energy savings and increased energy efficiency.

The EU countries develop common projects for controlling climate changes, concentrating mostly on carbon dioxide emissions reduction, as due to fossil fuel burning, these emissions are considered to be one of the main causes of the greenhouse effect. Reducing greenhouse gas emissions seems to be an essential factor in the mitigation of the global warming.

In the document of the Commission of European Communities [2] the main assumption of energy policy is formulated: "*Energy accounts for 80% of all greenhouse gas (GHG) emission in the EU; it is at the root of climate change and most air pollution. The EU is committed to addressing this – by reducing EU and worldwide greenhouse gas emissions at a global level to a level that would limit the global temperature increase to 2°C compared to pre-industrial levels."* [2]. So the strategic objective of Europe's energy policy is at least a 20% reduction of greenhouse gases by 2020 compared to 1990.

The Directive 2009/28/EC on renewable energy sets ambitious targets for all EU countries. The EU will reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy in the transport sector. The development of specific type of the RES varies considerably depending on the country, for example geothermal heat in Sweden and Hungary and solar thermal energy in Germany and Greece. Each country should establish a national renewable energy action plan.

One of the most important paths to achieving the mitigation of CO_2 emissions is reducing global primary energy use by 20% by 2020 (compared to 2006). It will require not only significant investment but also some efforts in terms of behavioural changes. Another proposition of the Commission [2] is: "increasing the level of renewable energy in the EU's overall mix from less than 7% today to 20% by 2020". The 20% target is very ambitious and will be rather not attainable in many countries, e.g. in Poland, where the potential of renewable sources (wind, hydropower, solar energy, biomass and biofuels) is relatively low.

Environment requirements are repeated in the document *A Roadmap for moving to a competitive low carbon economy in 2050* [3] and formulated also for 2030. The discussion of updated energy-environment policy is proposed in the document *Green Paper* [1].

The most important objective of the Roadmap is reducing GHG emissions by 80 to 95% by 2050 compared to 1990 levels in developed countries. The scenarios in the Roadmap assume the following key findings [1]:

- By 2030 GHG emissions would need to be reduced by 40% in the EU to achieve a GHG reduction of between 80-95% by 2050, and to limit atmospheric warming to below 2°C.
- Transforming the EU's energy system to reach higher shares of renewable energy (a share of around 30% in 2030), to improve energy efficiency and to built better and smarter energy infrastructure.
- Significant investments are needed to modernize the energy system with the impact to the energy prices in the period up to 2030.

The EU has clear regulations in the subject of energy and climate policies up to 2020. Now the EU should propose a new 2030 framework for climate and energy policies. The investors should be prepared for changes in the policy because of long investment cycles of power infrastructure.

A reduction in carbon dioxide emissions in power sector could be realized by electricity savings, technology changes and increase of efficiency of power generation, as well as CO_2 sequestration (if commercially available).

The aims of the Green Paper

New policies for 2030 have to confirm that the EU is able to meet energy and climate objectives formulated in the energy Roadmap 2050 [3]. But the situation in EU countries is now quite different in comparison to the previous years. The most important changes are following:

- the financial and economic crisis,
- the lack of funds for long term investments,
- the consolidation of global energy markets,
- the development of distributed and dispersed power sources,
- and the various attitude of international partners to reducing GHG emissions.

The aim of the Green Paper is to consult some proposition of energy-environment policies of the EU countries. The most important issues of discussion have been focused to targets, other policy instruments, competitiveness and the different capacity of Member States to act [1]. The 2030 requirements should take into account the evolution of technology over time but also security of supply and competitiveness. Additionally, there are some interactions between the targets for GHG reduction, the share of RES and energy savings.

The EU countries should meet the 2020 target of 20% share of renewable energy in gross final energy consumption. In the period 1995-2000 the share of renewable energy grew by 1.9% a year, in the period 2001-2010 by 4.5% a year. In the period 2011-2020 the growth should be about 6.3% per year to meet the 2020 target. If we consider a share of around 30% in 2030 then the growth should be even more rapid. But higher shares of RES will not ensure greater security of supply. The 30% share of RES in 2030 without increasing of the cost of electricity will be a challenge, especially in Poland.

Analysis of future structure of electricity sources

The report "Power Choices"

In 2010 Union of the Electricity Industry – EURELECTRIC – A.I.S.B.L. presented the report „Power Choices" [4]. Presented in Table 1 and 2, the results of electricity costs analysis forecast a discount rate equal to 9%. Power engineering is now undergoing transformation in terms of the supply structure as well as demand. The use of RES is the most important option of carbon dioxide mitigation in power generation processes because of Directive 28/2009/EU and ETS regulations. The operating power capacity (Fig.1) in the EU is 1 318 GW in 2050 due to increase of RES (55%). The peak loads in UE equal to 587 GW in 2030 and 678 GW in 2050 could be supplied by coal, natural gas, nuclear and hydro power plants together. Fossil fuel power plants constitute power reserve for RES. Many computer programs are able to optimize the structure of power generation sources in supplying consumer demand, eg. [5].

Table 1. Levelized costs of electricity in RES (source [4])

Years	Wind power plant	Off-shore wind power plant	PV power plant	Solar power plant	Tidal power plant	Biomass generation plant
-	€'05/(MW·h)	€'05/(MW·h)	€'05/(MW·h)	€'05/(MW·h)	€'05/(MW·h)	€'05/(MW·h)
2010	68	94	448	453	208	112
2020	68	93	435	343	158	108
2030	67	89	316	282	137	101
2050	66	84	273	240	121	97

Table 2. Cost of electricity in power plants in €/(MW·h) (source [4])

Years	Coal power plant	Coal power plant with CCS	Natural gas combined cycle power plant	Nuclear power plant
0 €'08/t CO_2				
2020	49	82	57	45
2030	47	65	55	45
2050	43	58	52	44
30 €'08/t CO_2				
2020	76	86	68	45
2030	69	69	65	45
2050	64	61	62	44

Energy policy of Poland till 2030

The development of RES in Poland is constrained by limited grounds for biomass production and lack of biomass infrastructure [6]. However, the forecast for Poland [7] is very optimistic (see Table 3) and the share of the RES power plants in 2030 is equal to 20,4% (most of them in wind power plants).

Comparison the cost of electricity in large power plants and RES

The comparison of emission data in Tables 1, 2 and 4 indicates advantages of nuclear, biomass and natural gas as fuels of electricity generation. Nuclear energy is one of the cheapest sources of energy with low emission. Electricity production in these power plants has also relatively stable costs. The next generation of nuclear reactors should even reduce production costs. New nuclear power plants could produce electricity at 4,5 € cents per kWh. The fourth generation fission nuclear reactors and future fusion technology improve the competitiveness, safety and security of nuclear electricity, as well as reduce the level of waste [2].

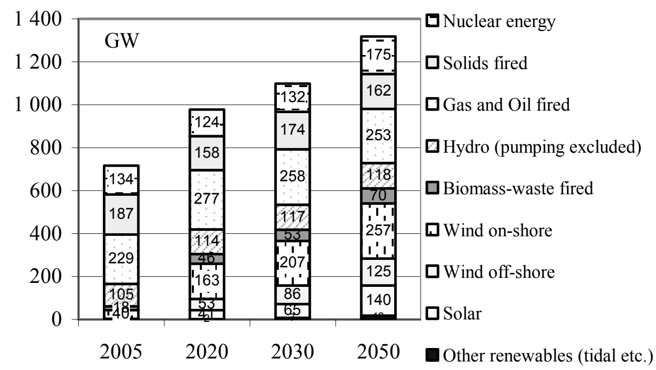

Fig. 1. Forecast structure of power plants in the EU in GW (source: [4])

Table 3. Forecast of power plants capacity in Poland in MW (source: on the basis of [8])

	Years			
Technology	2015	2020	2025	2030
Coal power plants	24 697	23 196	21 704	21 587
Cogeneration coal power plants	6 204	6 531	6 799	6 897
Cogeneration natural gas power plants	422	672	1 177	2 518
Hydro power plants	1 045	1 135	1 151	1 151
Pumping hydro power plants	1 406	1 406	1 406	1 406
Nuclear power plants	0	1 600	3 200	4 800
Industrial cogeneration power plants	2 313	2 408	2 495	2 557
RES power plants	3 920	7 516	9 831	10 496
Total	**40 007**	**44 464**	**47 763**	**51 412**

The interesting analysis of cost of electricity is presented in [9] (Table 5). According to that analysis, the cost of electricity generated by RES is higher in comparison to conventional and nuclear power plants.

The carbon dioxide emissions from power plants can be reduced in several ways: by changing the electricity production technology from conventional, fossil fuel technology to technologies employing non-emission or low CO_2 emission energy sources, such as nuclear, or renewable sources, by increasing the efficiency of electricity production, and by CO_2 sequestering. At present the main lines of development of the CO_2 emissions reduction technology are methods of capturing CO_2 from exhaust gases and oxygen combustion. The majority of experts believe that the implementation of these technologies will be possible after 2025 [10].

Table 4. Basic data of power plants (source [2])

Energy sources	Technology	Cost of electricity in 2005 (source IEA)	Projected cost of electricity in 2030 with €20÷30/t CO_2 (source IEA)	GHG emissions	Efficiency
-	-	€/(MW·h)	€/(MW·h)	kg CO_2/(MW·h)	%
Natural gas	Open cycle Gas Turbine (GT)	45-70	55-85	440	40
	Natural Gas Combined Cycle (NGCC)	35-45	40-55	400	50
Coal	Pulverised Fuel with flue gas desuphurisation (PF)	30-40	45-60	800	40-45
	Circulating Fluidised Bed Combustion (CFBC)	35-45	50-65	800	40-45
	Integrated Gasification Combined Cycle (IGCC)	40-50	55-70	750	48
Nuclear	Light Water Reactor (LWR)	40-45	40-45	15	33
Biomass	Biomass Generation Plant (BGP)	25-85	25-75	30	30-60

Table 5. Cost of electricity of selected power plants (Source: on the basis [9], currency rate 4,3 PLN/€)

Power plant	Investment cost	Time of use of installed power per year	Cost of electricity (2011)
-	10^6 €/MW	h/a	€/(MW·h)
Gas turbine PP	0,91	7000	73
Coal PP	1,53	7000	66
Wind PP	1,53	2300	108
PVPP	1,81	900	254
Biomass Generation Plant	2,40	7000	113
Wind PP (off shore)	3,16	3100	166
Nuclear PP	3,35	8000	73
Hydro PP	4,30	4000	113

Renewable energy sources

Wind power plant (WPP) – case study

The *NPV* coefficient is applied to evaluate the efficiency of power plant investment [11]. *NPV* indicator, if the liquidation value of the investment is disregarded, is equal to the discounted cash flows minus the investment cost *I* born during the time N_b of building the power plant and discounted at the time of launching the operation.

$$NPV = V - I = \sum_{t=0}^{N_e} \frac{\pi(t)}{(1+r)^t} - I \qquad (1)$$

The discounted investment cost is described by the following formula

$$I = \sum_{t=-N_b}^{t=0} \frac{I_t}{(1+r)^t} = \sum_{t=-N_b}^{t=0} I_t (1+r)^{|t|} \qquad (2)$$

where: r – the discount rate, N_e – the operation period, $\pi(t)$ – the yearly net balance of revenue in consecutive years t, i.e. the difference between the actual revenue $P(t)$ and cost $C(t)$.

The total cost incurred in a year $C(t)$ includes fuel and energy cost, pay cost, environmental fees, repair cost, sales cost, and insurance. It was assumed that the operation generates the cost C. In real economy the cash flows in power industry investments depend, among others, on the production level, production cost, and energy price, all of which are influenced by the competition of energy producers.

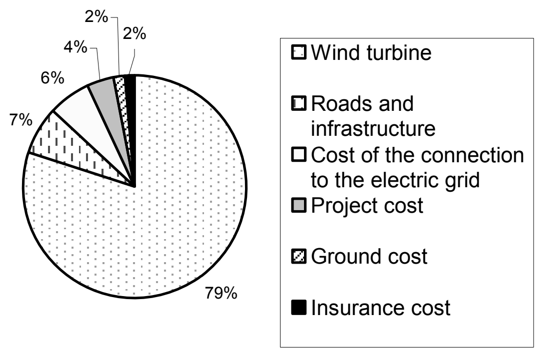

Fig. 2. Shares of categories of investment cost in total cost

The development of wind power plants in Poland is constrained by limited availability of areas with good wind conditions. The economic efficiency of wind power plants depends on many variables. The categories of WPP investment cost and their shares in total cost are presented in Fig.2.

The investment cost of a Enercon wind turbine (2,0 MW type E 82) is equal to 2,4 million EUR, so the total investment cost is about 3 million EUR. The operation cost could be estimated on the level of 30 000 €/(MW·a). The life time of WPP is assumed as 25 years and discount rate 6 %. The electricity price for producers on the energy market is about 45 €/(MW·h) and additional price of "green certificates" is about 60 €/(MW·h). Taking into account these data, the positive values of NPV are obtained for the time of use of installed power greater than 1400 hours per year for discount rate r = 6 % and 1850 hours per year for discount rate r = 10 %. But if the support system ("green certificates") is neglected then the time of use of installed power, that motivates WPP investment, should be about 3230 hours per year for discount rate r=6% and about 4305 hours per year for discount rate r=10%. In Poland it is rather difficult to achieve the time of use of installed power greater than 2000 hours per year. Mean cost of electricity calculated for turbine Enercon type E 82 (Table 6) is higher than electricity price on the power market.

Table 6. Cost of electricity in WPP (turbine Enercon type E 82)

Time of use of installed power	Discount rate	Cost of electricity
h/a	%	EUR/(MW·h)
2000	6	74
2000	10	98
1500	6	98
1500	10	130

The energy from RES power plants must be stored in order to make it reliable. The main reason to store energy is to balance the supply and demand of energy. Because of the unpredictable wind speed some form of storage is necessary to compensate for calm periods. Solar energy is not available on cloudy days and during nights. The storage methods that could be applied in the future are batteries, supercapacitors, pumped-storage hydroelectricity, compressed air energy storage (CAES) and flywheel energy storage. The development of storage systems will support the increase of energy generation in wind power plants and others RES power plants (solar and photovoltaic).

Photovoltaics power plants (PVPP)

The global power of the PV installations is about 101 GW in the world (source: European Photovoltaic Industry Association EPIA). New photovoltaics of power over 30 GW (17 GW in Europe) were installed in 2012 (23 GW in 2011). The PV power plants will generate about 140 TWh of electricity, which means about 53 million tons of avoided CO2 emissions. More accurate data will be published in the EPIA report „Global Market Outlook for Photovoltaics 2013-2017". The greatest European markets of photovoltaics in 2012 were Germany (7.6 GW), Italy (3.3 GW) and France (1.2 GW), whereas the greatest world potentates of photovoltaics are China (3.5-4.5 GW), USA (3.2 GW) and Japan (2.5 GW).

One of the greatest investment project in Poland is the future construction of 4 photovoltaics farms with the power of 4 MW in the eastern part of the country (area 9 ha). The future PV power plant "Podlasie Solar Park" will operate from 2014 year. The investment cost is estimated as about 10 million USD. Now in Poland only one PV power plant (1 MW) is installed whereas 32000 MW in photovoltaics operate in Germany and 3000 MW in photovoltaics in Belgium.

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Conclusions

The proposals of *Green Paper* [1] are some inspiration to the discussion about long-term energy-environment policy of the EU. But now, after the Kyoto protocol, there is no agreement on new GHG reduction of all countries in the world. The uncertainty of future climate convention results doesn't help in formulation of the EU targets. The future EC policy should be oriented towards market regulation, safety of energy supply [12] and stability of power engineering investment.

Subsidies of RES and high price of the ETS allowances could lead to increase of electricity price for consumers. High price of electricity means low competitiveness of the economy of EU countries [13].

In the case of new investments, the decision on the choice of electricity generation technology, which would ensure the safety of energy supply for the nearest few tens of years (a power plant life is about 40-60 years), is to be made within a few years from now. Some issues have to be solved. For RES it is necessary to determine their increase in the total amount of energy generated, to find resources which could be used in decentralized energy generation and to estimate real cost of energy obtained from them.

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