

External costs as a measure of environmental impact in the generation of electricity in Poland

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Abstract. The depletion of natural resources, rising fossil fuel prices and growing environmental awareness, are leading to an increase in the popularity of renewable energy sources. In Poland, the share of energy derived from renewable sources continues to grow and now stands at 12.9% of the country's gross electricity consumption. Energy from renewable sources in Poland is 60€ more expensive per MWh than energy from conventional sources. According to the European Climate and Energy Package, Poland is committed to increasing its share of renewable energy to 15% in 2020, and a further 5% by 2030. It is very important to ensure that the increase in the share of renewable energy will increase the price of energy for the end users. To convince the public of the need to incur greater costs in the purchase of "green" power, we should put forward arguments showing the benefits of its use. The aim of this paper is to demonstrate the viability of support through a system of certification for renewable energy sources and also to estimate the potential increase in energy prices caused by raising RES contribution.

1. Introduction

Widely circulating opinions say that the greenhouse effect is a major threat to our planet. Not many people realize that the rapidly disappearing non-renewable fossil fuels constitute a far greater threat to our civilization [1]-[3]. According to the latest available data, the world's oil reserves will run out by 2047 whilst natural gas by 2068. Coal is in a better situation being exhausted by 2140 and an estimate for uranium is 2144 (Europe's Energy Portal, 2011). Unfortunately, in the now-dominant democracies, there are strong tendencies to favour the present without looking into the future. Successive generations are rarely taken into account because, as they do not exist they have no impact on present decision-making processes. It is vividly seen that the modern world is developing in an unsustainable way. We have seen tremendous growth in the techniques and technologies which are able to transform the modern world and potentially lead to its destruction [4], [5]. Development of human capability to transform the world is beyond the social sciences, and consequently there is no clear criteria for establishing the values to which these changes should serve. Rapid depletion of natural resources requires a new definition of development rules for the modern world even more urgent and necessary [6]-[8].

The "Polish Energy Policy until 2030" project, prepared by the Ministry of Economy provides, in accordance with the guidelines of the European Commission, for increasing the share of renewable energies in the gross electricity consumption to 15% in 2020 and to 20% ten years later. Energy providers are required to provide part of their energy from renewable sources, which will steadily increase in the coming years. Energy production from renewable sources is encouraged by strong economic subsidies. The cost of renewable energy in Poland consists of a basic price for energy and the cost of Renewable Energy Certificates (Green Certificates). Today, one certificate costs 60€/MWh.



Thus, by increasing the proportion of renewable energy in our consumption, this will lead to higher energy costs for the end user. The situation is so serious that, according to a Eurostat report, published in June 2010, the Poles pay the highest price for energy among all EU citizens when revenue per capita is compared.

However, for a comprehensive analysis of the costs and benefits of using energy from renewable sources, compared to the energy from the combustion of fossil fuels, we have to take into account economic, environmental and social aspects. The combination of these issues is consistent with the principles of sustainable development. In order to present these aspects in a quantified manner and compared on a common scale we use ExternE - the methodology for estimating external costs which was proposed by the European Commission. External costs in this methodology include the cost of the health, welfare, environmental damage and moreover, costs associated with the greenhouse effect. These costs are not included in the price of electricity, but are paid by society in an indirect way. Assessing the costs requires taking into account the whole cycle of energy production in accordance with the principles of LCA. The LCA Methodology contains extraction of raw materials, the production phase, decommissioning and waste disposal.

2. The ExternE methodology

Most people believe that the actions taken to increase energy production from renewable sources are caused by the need to avoid the greenhouse effect. Developing renewable energy sources can significantly reduce the greenhouse gas emissions, indicated by the carbon footprint. The carbon footprint shows all the greenhouse gas emissions from the energy production process and allows us to make comparisons using a common scale known as the carbon dioxide equivalent. As a result, we can determine a given process's potential for global warming. The value of carbon footprint for renewable energy sources is significantly lower compared to energy from conventional sources. Electricity derived from coal produces emissions with a value around 1100 gCO₂e/kWh, whilst from renewable energy sources the value is below 100 gCO₂e/kWh [9].

Yet, carbon footprint does not take into account the depletion of fossil fuels. This is also dangerous, because in the long term we will run out of fossil fuels. In addition, it also turns out that the methodology for estimating costs is incomplete because it does not include damage to the environment caused by the various methods of producing energy. However, subsidizing renewable energy under the green certificate system increases the price of energy.

In the 1970s and 1980s, in world literature, many different methods and techniques were described in the assessment of the environment, both in cognitive and practical aspects. The development of these methods was driven by assessments of the environment without which it is impossible to understand the basic laws of nature and man's relationship with the environment [10]. The concept of external costs was introduced in the theory of economy by Pigou at the beginning of the last century [11]. The development of the ExternE methodology started in 1991 and was first planned as a joint venture between the European Commission and the US Department of Energy. The ExternE methodology is a bottom up methodology assessing the whole life cycle and fuel cycle of a specific plant. It employs an impact pathways approach tracing the emissions from the source to the impact. A wide range of impacts is considered ranging from the impact on human life and health through to visual amenities [12]. One impact which the ExternE cost methodology takes into account is climate change. The impact of global climate change is diverse and possibly immense. The interactions between the global climate system, the ecosystem and the socio-economic system are very complex. Intensive research over the past few years has increased our understanding of the various areas and leads to continual improvement in the corresponding models. The ExternE study by the European Commission shows that specifically, the increase in the mortality risk arising from chronic exposure to particulate matter leads to substantial external costs. The current approach of the ExternE study (ExternE Methodology update 2005) is also used to quantify external costs arising from ill-health. Other external factors arising from reduction of agricultural yield and material damage are quantified according to the ExternE method, but these are very small. Up to now there has been no satisfactory means of expressing, in monetary terms, the impact on biodiversity and ecosystems of SO₂ and NO_x emissions

due to acidification and eutrophication [13]. As the external costs are normalized to the electricity output of the power plants, the unit is therefore €/kWh.

This paper attempts to estimate the external cost of electricity production in Poland. It turns out that if they were included in the cost of generating electricity from various sources, the final price would differ significantly from that at present. In other words, the external costs are a measure telling us how much we can change the environment for present and future generations.

3. Energy balance and external costs in Poland

Production of electricity in Poland is mainly based on the combustion of coal and lignite. In 2008, the combustion of coal produced 85,8 TWh, whereas the combustion of lignite produced 53,1 TWh (Table 1), which was over 90% of the overall energy production in Poland. As a result of such a large proportion of coal in comparison to other fuels, the weighted mean external cost of electricity production from coal in Poland reached 52,7 €/MWh (Table 2)

Table 1. Electricity production by fuel type in Poland (TWh)

Fuel Type	Year		
	2006	2007	2008
Coal	93,4	92,8	85,8
Lignite	53,4	51,0	53,1
Gas	4,6	4,5	4,1
RES	5,3	5,4	6,4
Others	5,1	5,1	5,0
Total	161,7	158,8	154,4

External costs, dependent on the type of fuel are presented in Table 2. The table contains in detail pollutant quantities. Note the significant decrease in external costs, which are due to running the desulphurization systems [14]. The costs referring to CO₂ emissions reflect any losses caused by the greenhouse effect. The smallest part of the total external cost of burning coal and lignite in Poland is dust and NMVOC emissions.

Table 2. External cost of electricity production in Poland (€/MWh) [15]

	Coal		Lignite	
	2007	2008	2007	2008
SO ₂	28,59	18,52	47,52	31,94
NO _x	10,69	10,08	9,12	8,45
PM 2,5 - 10	0,11	0,06	0,11	0,10
PM 2,5	1,24	0,67	0,66	0,60
NMVOC	0,06	0,07	0,05	0,05
CO ₂	20,27	20,25	24,48	24,60
Total	60,98	40,67	81,94	65,73

4. Renewable energy sources in Poland

4.1. The potential of renewable energy in Poland

In the development strategy of renewable energy sources in Poland the dominant role is played by biomass [16] whose potential is estimated at 152,8 TWh [17]. It should be emphasized that the

biomass potential has a wide range of values depending on the source mentioned in the literature. Currently, biomass is mainly used for heat production in the generators of low and medium power, and in the combustion process for electricity generation in power stations.

The potential of hydropower is 12 TWh, and its main resources are focused in the Vistula basin 9270 GWh (77.6%), the Oder 2400 GWh (20.1%) and coastal 280 GWh (2,3%). Recently a significant increase in the use of small hydropower plants with a capacity below 2 MW was noted, due to the simpler administrative procedures. But in the longer term the development of the hydropower sector as a whole should be supported, along with power plants with greater capacity [18].

The real economic potential of wind energy in Poland is about 123,3 TWh, of which 107,4 TWh wind power is located on-shore, and 18,6 TWh off-shore [18]. The current pace of development of wind energy should ensure 24% of the entire share of renewable energy sources in 2020 and reduce its production costs.

The potential of solar energy in Poland is about 23 TWh, of which about 0,2% is currently utilized. This will however increase over the coming years. The market potential for solar energy usage in 2020 is estimated at 5,35 TWh, mainly for heating [19].

4.2. External costs of RES compare to fossil fuels

In Poland, the proportion of energy derived from renewable sources continues to grow and now stands at 12.9% of the country's gross electricity production. The greatest dynamics of growth in recent years has been wind power, however the largest share in electricity production, at about 50%, is from biomass. In the overall RES balance, biomass reached up to 85.8% in 2009. The share of renewable energy sources in electricity production is shown in Table 3.

Table 3. Proportion of renewable energy in Poland [20]

Year	2007		2008	
	GWh	%	GWh	%
Hydro Power	2350.9	43.3	2099.6	32.6
Wind Power	521.2	9.6	817.9	12.7
Biomass	2361.8	43.5	3278.2	50.9
Biogas	195,4	3.6	244.7	3.8
Total	5429,3	100	6440,4	100

Such a large proportion of biomass in the gross electricity production indicates the need for greater support for other renewable sources, while it should be noted that biomass burning is characterized by the largest external costs of all RES as shown in the Figure 1. In Europe the primary energy production share of the various sources of renewable energy varies. However, biomass still has the dominant position, but its percentage is smaller at only 65.6% (compare to 85.8% in Poland), whilst that of water is 21.7%, wind 6,6% and geothermal 5,2% [21].

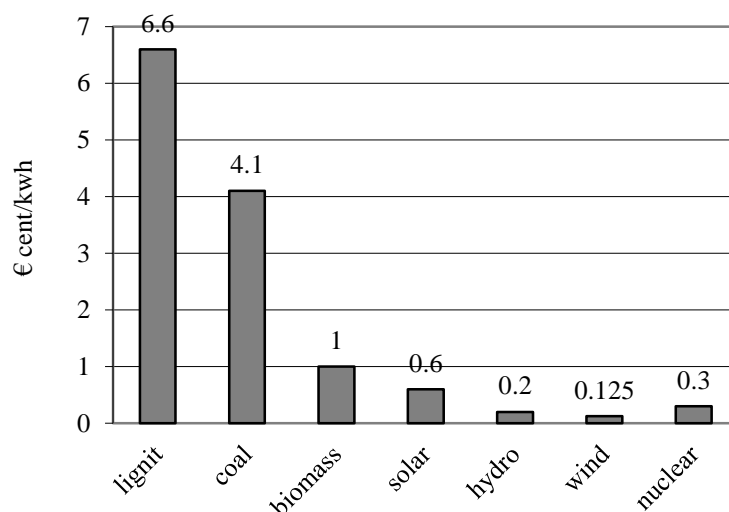


Figure 1. External cost of renewable energy sources and fossil fuels [11], [12], [22]-[24].

4.3. External costs avoided in Poland

The system of green certificates allows for the development of renewable energy sources. In 2008, the annual production of electricity from renewable sources was 6,44 TWh representing 4,1% of the entire electricity production in Poland. Replacing conventional energy with renewable energy sources allows us to avoid environmental losses and as a result leads to economic benefits. Use of renewable sources in 2008 resulted in a saving, in monetary value, of 339,4 million euros in external costs. At the same time the energy from renewable sources, received an additional 386,4 million euros under the green certificate system. Figure 2 demonstrates that the additional price of energy from renewable sources is compensated by a saving of over 87%, in the external costs which should be considered by the final recipient of the energy as a satisfactory level.

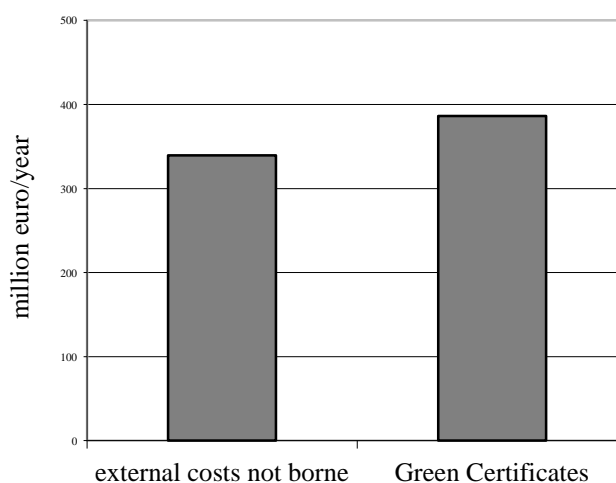


Figure 2. Comparison of Green Certificate amounts with external costs not borne

4.4. Forecast for developing of RES

According to the accepted European Climate and Energy Package, Poland is committed to increasing its share of RES to 15% in 2020. Detailed target forecasts for electricity derived from RES is 10.4% in the years from 2010 to 2012, 12.9% in 2017 and 15% in 2020. Long term forecasts predict a 20% share of RES in 2030 [25]. A new Energy Law was introduced in 2005, which created a support system to assist the development of renewable sources. Under this system, green certificates have been introduced, which subsidize the energy produced from RES.

Table 4. Forecast for the final energy price due to increase of RES share (€/MWh)

Year	2017	2020	2030
Share RES (%)	12.9	15	20
Price of Green Certificates (€)	60	60	60
Amount of increase (€) (share RES x price of Green Certificates)	7.74	9	12
Final energy price (€)	38.25 ^a	40.25	43.25
Percentage increase	–	5,22%	13,07%

^a current price of energy in Poland 38.25 €/MWh

As a result, energy from renewable sources in Poland is 60 €/MWh more expensive compared to energy from conventional sources. It is important to notice that the increased proportion of renewable energy sources in the gross electricity consumption will increase the final cost of energy. Table 4 shows, for a particular RES percentage a corresponding increase in the cost of energy for the end user. It should be also be mentioned that the amount of subsidies is fixed at the same level for all types of renewable energy sources.

5. Conclusion

One of the most frequently repeated opinions regarding energy from renewable sources, is that it is more expensive than energy from conventional sources. In Poland, as a result of the introduction of green certificates, RES energy is 60€/MWh more expensive. However, that increase is offset by a saving of over 87% of external costs, which society would pay indirectly.

One of the priorities of the Polish energy sector is fulfilling its commitments under the European Climate and Energy Package, including an increase in the share of RES in the overall balance of 15% in 2020, this growth will increase the price of electricity to end users, but despite fears, growth will be modest and will be only about 5.22% whilst the share of renewable energy sources will be 15%. According to growth forecasts for RES of up to 20%, the electricity prices will rise by 13.07% for the end user. However, we should not be concerned about increasing support for RES, which causes an increase in the price of energy, as the current level of support for renewable energy in Poland is one of the highest in Europe.

Insufficient rate of development of RES in Poland could therefore be caused by systemic barriers, rather than by not enough support. In order to accelerate the development of renewable energy sources, it should also take into account the diversity of support depending on the type of renewable energy source. The analysis indicates that the external costs of renewable energy sources are characterized by a wide range of costs. Energy derived from biomass and solar power costs more than 3 times in external costs compared to the cost of energy from water or wind. External costs could be one of the factors taken into account for estimating levels of support under green certificates for each RES. This would mean different levels of support for the different RES.

Current projections indicate that Poland will be dominated by lignite-fired and coal-fired power stations for the foreseeable future. Significant development of renewable energy sources in Poland is

expected between 2010-2020. Analysis of external costs in determining the future directions of energy generation in Poland indicates the need to reduce electricity production from lignite. At the same time technology to remove sulphur dioxide should be developed in order to reduce external costs. Constructions in 2008, of the flue gas desulfurization system in Poland, helped to reduce the external cost of the coal and lignite combustion by more than 20% per MWh.

During the analysis of external costs it is also worth considering obtaining energy from nuclear power stations, whose operation involves very low external costs which are comparable with renewable energy sources. However, nuclear power still causes a lot of social fears in Poland. An information campaign is needed to convince the public. In this case, presenting the results of the analysis of external costs could also be very helpful.

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