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Impact of the CO_2 Emission Rights Price and Planning Horizon on the Selection of Emission Reduction Technologies for a Set of Power Plants

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Abstract

The goal of the work is to determine how the process of allocation of emission reduction technologies to emission sources is dependent on varying CO_2 emission rights price and on the length of the planning horizon as well, for a given set of power plants based on coal and lignite. Allocation of emission reduction technologies to emission sources is made in such a way that the total cost of the allocation (consisting of both the investment cost and the operational cost) in the given time horizon is minimal. Each technology can be used only if its cost is less than the price of CO_2 emission rights. Technologies with higher investment costs can be used only in a longer time horizon, since this cost can be spread over a greater number of years. The calculations were tested on the set of 20 major power plants in Poland.

1. Introduction

In recent years one can observe increasing activities in the developed countries, especially in the richest countries of the European Union, aimed at creating a so-called "emission-free" economy in the long-term horizon. More and more countries have developed policies of greenhouse gasses emissions reduction. As a result of Kyoto conference and a number of lesser-known conferences and international agreements, as well as the internal arrangements which came into force in the European Union (e.g. the European Union 20-20-20 goals), Poland has committed to a large reduction in greenhouse gas emissions, mainly CO_2 in the coming years. This will entail the need to spend huge sums on investments in new equipment and technologies, especially in the power generation industry due to the generation of nearly 90% electricity in coal based power plants. It is worth noting that the European Union is the only region in the world, which has reduced its greenhouse gas emissions (by 18.5%). Union effort in this area unfortunately has a little significance, since it corresponds only for 11% of global CO_2 emissions related to human activity (Poland for approximately 1%). Most of the reduction of greenhouse gas emissions in the EU has been achieved in countries in transition, including Poland (by approx. 35%).The main issuers in the world are China (29%) and the U.S. (16%).

Among EU countries, the Polish situation in the area of greenhouse gas emissions is relatively very difficult and is the result of long-term negligence in the implementation of modern energy technologies (including nuclear power plants), omissions in terms of reducing emissions, and the huge importance of heavy industry, particularly steel, cement and energy plants, based mainly on the use of coal and lignite. Because of the relationship between economic growth and increase emissions of greenhouse gases, it is important what kind of energy resources and technologies for energy generation will receive political and financial support.

The economic situation in the world is now radically different from that of the late twentieth century, when costly policies to stop anthropogenic climate change through sustainable economic development and the reduction of greenhouse gas emissions were supported by scientist bodies and governments. However, in the last years due to the financial crisis climate policy began to interfere with economic development. It is still believed that the reduction of greenhouse gas emissions will not only improve the quality of the environment, but also will help to achieve a higher level of economic development. Decisions undertaken now on climate and energy policies, especially on the introduction of new energy production technologies will determine the possibility of reducing greenhouse gas emissions for decades. The basic problem for Poland is how to fulfill the commitments on reducing emissions without decreasing the economic growth.

Due to the importance of the problem of emissions reduction, there is urgent need to develop methods that enable the efficient use of financial means, mainly state-owned, intended to reduce emissions. Even a slight reducing in spending, due to the huge scale of the problem, gives significant savings. The method referred to later in this paper is not developed to determine the optimal plan for reducing CO_2 emissions, but can be a tool to compare the effects and the costs of different scenarios of greenhouse emissions reduction. One of the important problems with the practical application of quantitative methods in this area is the lack of reliable data concerning the costs and conditions for purchasing CO_2 emission rights, which in this case can be explained by the fact that these rights will be a subject of international trade, and the market price will be heavily dependent on supply and demand, as well as the world's economic activity. Another, although a lesser problem is that the prices of energy carriers (gas, coal) are subject to rapid change, even within a few months. Also, the costs of installing and operating of CCS (Carbon Capture and Storage) are not yet known, because no such system has been implemented on an industrial scale.

Useful, although simplified, tools to assess the economic effectiveness of policies of reducing greenhouse gas emissions, in particular CO_2, are the curves of marginal abatement cost (MAC). These curves are developed to illustrate the economics of climate change mitigation and are often used in decision making in the field of climate policy. MAC curves are used in many countries, including Poland to find a cost-effective solution. MAC curves not only have the advantage of indicating the marginal cost of abatement for different technologies of emission reductions, but also allow for the calculation of the total abatement costs and average costs. MAC curves can vary in regard to the geographic scope, the time horizon, the sectors of economy considered and the method used for their generation. According to the method of their generation MAC curves can be divided into on expert-based curves and mathematical models derived curves.

Approaches based on expert knowledge rely on assumptions for the emission reduction potential and the corresponding cost of different abatement technologies and represent their costs. The main advantage of expert -based MAC curves is that they are easily understood by decision makers. Considered technologies are ranked from the cheapest one to the most expensive one in order to represent the costs of achieving given levels of emissions reduction. The main disadvantage is that this approach does not take into account the interdependence of technologies. Model-based MAC curves derive the costs and potential for emissions reduction from mathematical model runs. They are more accurate, but much more difficult to generate.

An example of model-derived MAC curves obtained for the UK transport system, based on using an energy system model MARKAL, developed by International Energy Agency is shown in Figure 1-1, while an example of expert-based MAC curves shown in Figure 1-2.

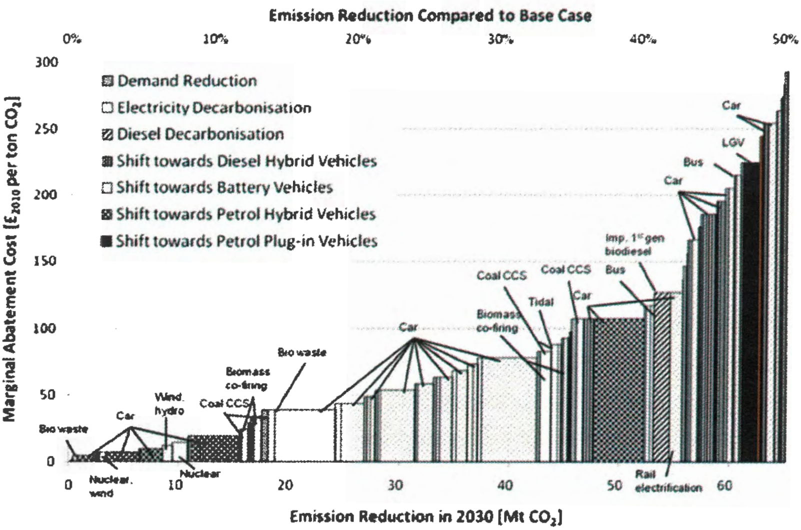

Figure 1-1: An example of model-derived MAC curves for the UK transport sector in 2030, (Kesicki 2013)

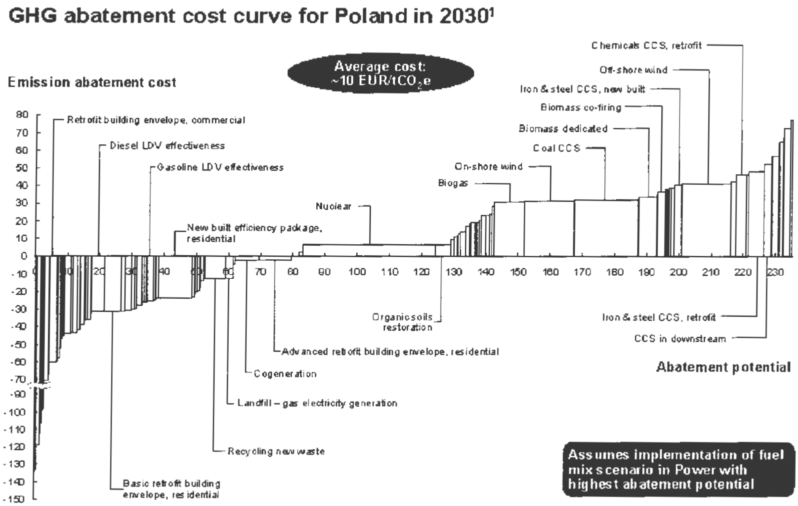

Figure 1-2: An example of expert-based MAC curves for Poland in 2030 (Poświata, Bogdan 2009)

2. Statement of the problem

The goal of the research is the evaluation of the impact of the price of CO_2 emission rights and the length of the planning horizon as well, on the selection of emission reduction technologies in a set of emission sources. This goal can be achieved using the method described in Kaluszko (2011). The method was developed to solve the problem how to efficiently allocate financial means for the emissions reduction technology for a number of considered sources in order to achieve the desired level of CO_2 emissions in a given period at the lowest cost. The problem consists in minimizing the total cost that must be incurred to reduce CO_2 emissions to a given level in a set of sources. The total cost is divided into individual costs of implementation of a selected reduction technology in each emission source. The cost of implementation of a technology consists of both the investment cost and the operational cost. Since there are only a number of available abatement technologies, the problem belongs to the class of integer programming problems. The full enumeration of all possible allocations of technologies to emission sources cannot be implemented due to the huge number of variables. The developed method is a heuristic method, based on dynamic programming. In addition to the primary objective of the method it can be also used to determine the unit cost of reducing CO_2 emissions i.e. to give the same results as MAC curves. Section 3 shows the effects of applying the method on a practical example.

3. Numerical example

The calculations were carried out on the practical example of the set of 20 major power plants in Poland, based on coal and lignite. Annual emissions of CO_2 are given in Table 3-1. Table 3-2 shows efficiencies and costs of various CO_2 emission reduction technologies.

Table 3-1: CO_2 annual emissions for 20 major power plants in Poland

Name	Fuel	Power in MW	CO_2 emission in million t/year
Bełchatów	Lignite	4320	35,3
Kozienice	Coal	2880	20,7
Turów	Lignite	1900	15,6
Połaniec	Coal	1800	13,0
Rybnik	Coal	1775	12,8
Dolna Odra	Coal	1740	12,6
Jaworzno III	Coal	1635	11,8
Opole	Coal	1530	11,0

Pątnów	Lignite	1200	9,8
Łaziska	Coal	1155	8,3
Siersza	Coal	810	5,8
Ostrołęka	Coal	720	5,2
Łagisza	Coal	710	5,1
Ostrołęka	Coal	650	4,7
Siekierki	Coal	620	4,5
Adamów	Lignite	600	4,9
Skawina	Coal	490	3,5
Konin	Lignite	490	4,0
Stalowa Wola	Coal	350	2,5
Żerań	Coal	350	2,5

Table 3-2: Efficiencies and costs of CO_2 emission reduction technologies

Technology	Efficiency	Investment cost	Operational cost
biomass	15%	100 €/kW	10 €/kW
new installation (coal)	10%	1500 €/kW	-23.5 €/kW*
new installation (gas)	40%	700 €/kW	440 €/kW
CCS	100%	600 €/kW	30 €/ton of CO_2
new installation (coal) + CCS	100%	2040 €/kW	27 €/ton of CO_2 -23.5 €/kW
new installation (gas) + CCS	100%	1060 €/kW	27 €/ton of CO_2 +440 €/kW

*Note: the value is negative, due to burning less coal, compared to current installation

The computations for a certain level of emission reduction give the solution in the form of a set of reduction technologies for each source. This allows for the calculation of the price of reduction of one ton of CO_2 for each technology used in each source. This price varies depending on the investment costs and operational costs of the technology. Operational costs do not depend on the duration of use of the technology as opposed to investment costs, which are spread on different number of years. Figure 3-1 shows the price of reduction of one ton of CO_2 for each source. Each calculated price must be compared with the price of CO_2 emission rights. The technologies with higher costs than the price of CO_2 emission rights (above the short dashed line) must be abandoned and replaced with the purchase of CO_2 emission rights. After this shift, one gets the average price of reduction of one ton of CO_2, as shown in Figure 3-2. In order to evaluate the impact of the price of CO_2 emission rights on the average price of CO_2 emission reduction the calculations must be repeated for different price levels of CO_2 emission rights. Figure 3-3 shows the average price of reducing CO_2 emissions by one ton as a function of CO_2 emission rights price.

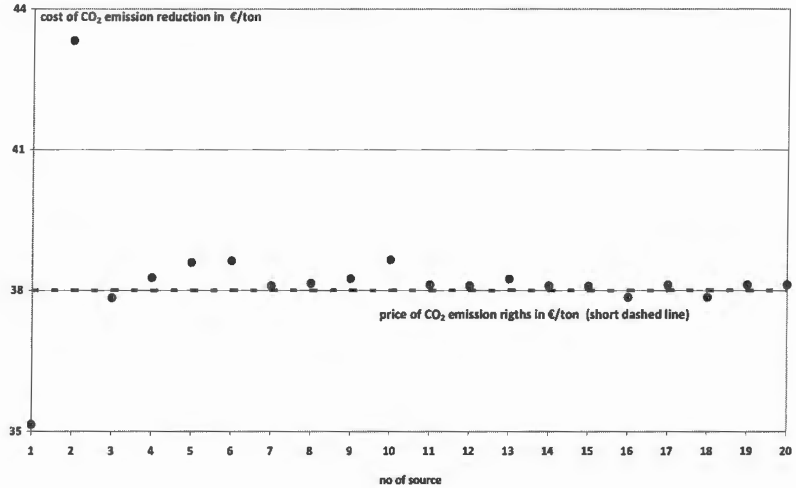

Figure 3-1: Costs of CO_2 emission reduction compared to price of CO2 emission rights

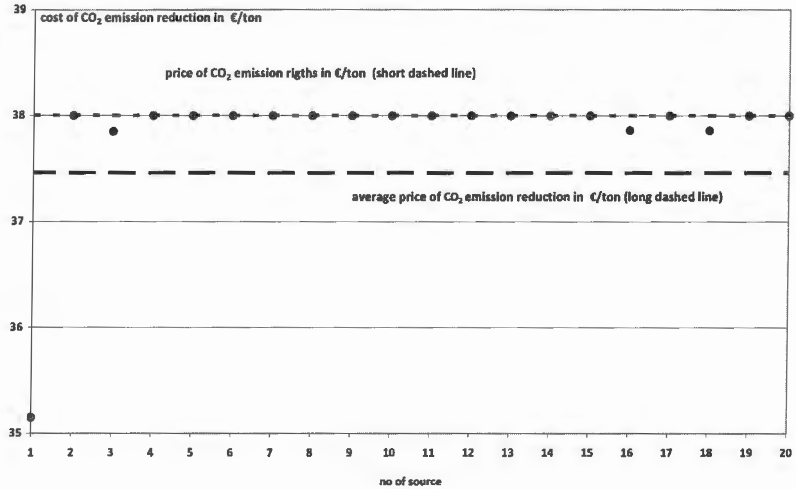

Figure 3-2: Average cost of CO_2 emission reduction

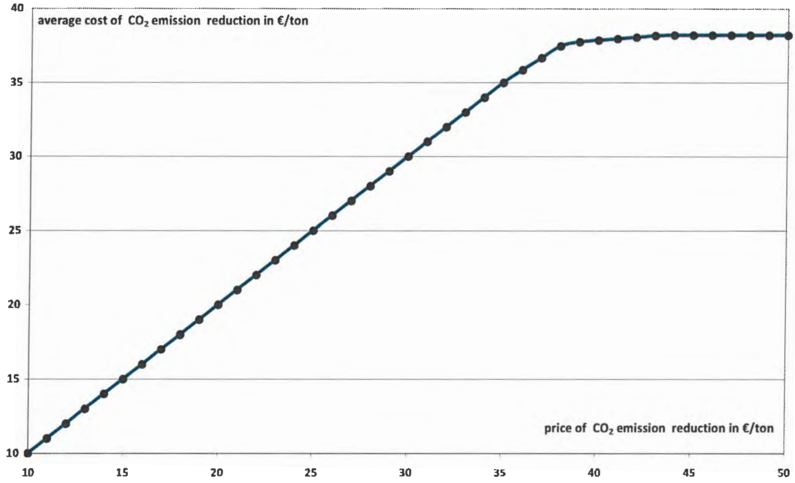

Figure 3-3: Average cost of CO_2 emission reduction as a function of price of CO_2 emission rights

As noted earlier the price of reduction of emissions of one ton of CO_2 for each technology and each source also depends on how long the technology is used, and this in turn depends on the length of the planning horizon. One can expect that a longer planning horizon allows for the implementation of technologies characterized by higher investment costs. Calculations carried out for different time horizons confirm this hypothesis. Figures 3-4 and 3-5 show how the selection of emission reduction technologies in the sources no. 1 and no. 18 respectively, changes depending on the length of the planning horizon. As one can see from the data in Table 3-2 source no. 1 has high emissions, while the source of 18 small. For source no. 1 one can observe a tendency to use more expensive technologies at longer planning horizons, while in the source no. 18 no relation to the length of the planning horizon can be observed. This can be explained by the fact that for small sources, such as source no.18, financial means are assigned after assigning them to large sources, such as source no. 1, since emissions from large sources have much greater impact on the entire emissions than those from small ones.

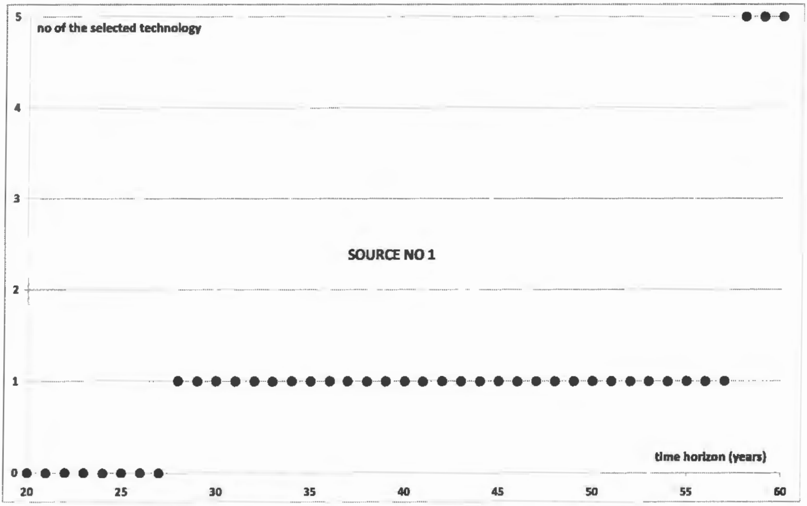

Figure 3-4: Technology selection for source no 1

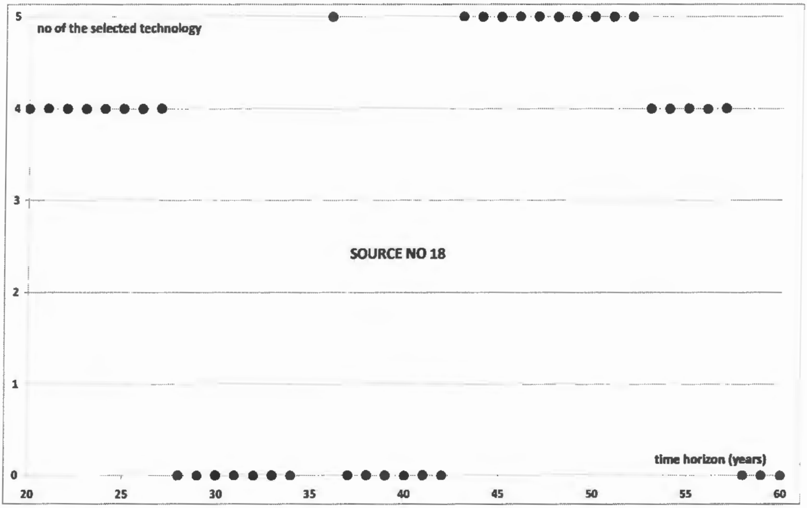

Figure 3-5: Technology selection for source no 18

4. Summary

On the basis of presented results of calculations it can be concluded that the method used for the evaluation of the impact of the price of CO_2 emission rights and the impact of the length of the planning horizon on the selection of emission reduction technologies can be a useful tool for decision makers. Since the decisions made regarding the energy and climate policy have impact on the economy for decades, they must be taken very carefully after a detailed analysis of many aspects of such policy. Effective reduction of greenhouse gases emissions involves a long, costly investment process in new technologies and new equipment. Despite of the fact that nowadays MAC curves remains the main tool for analysis the proposed method of analysis presented in this paper can also be helpful.

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