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Stepwise multiple regression method of greenhouse gas emission modeling in the energy sector in Poland

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ABSTRACT

The energy sector in Poland is the source of 81% of greenhouse gas (GHG) emissions. Poland, among other European Union countries, occupies a leading position with regard to coal consumption. Polish energy sector actively participates in efforts to reduce GHG emissions to the atmosphere, through a gradual decrease of the share of coal in the fuel mix and development of renewable energy sources. All evidence which completes the knowledge about issues related to GHG emissions is a valuable source of information. The article presents the results of modeling of GHG emissions which are generated by the energy sector in Poland. For a better understanding of the quantitative relationship between total consumption of primary energy and greenhouse gas emission, multiple stepwise regression model was applied. The modeling results of CO_2 emissions demonstrate a high relationship (0.97) with the hard coal consumption variable. Adjustment coefficient of the model to actual data is high and equal to 95%. The backward step regression model, in the case of CH_4 emission, indicated the presence of hard coal (0.66), peat and fuel wood (0.34), solid waste fuels, as well as other sources (−0.64) as the most important variables. The adjusted coefficient is suitable and equals $R^2 = 0.90$. For N_2O emission modeling the obtained coefficient of determination is low and equal to 43%. A significant variable influencing the amount of N_2O emission is the peat and wood fuel consumption.

Introduction

Access to energy plays a crucial role in growth and development of a country. This is a particularly important aspect in the developing countries. The year 2012 was considered a breakthrough in a scope of a new approach (Sustainable Energy for All—SE4All) and commitments toward achieving a universal energy access by 2030. The world population is continuously growing, which forces governments to ensure access to electricity for the increasing number of earth's inhabitants. The initiative SE4All has a major impact on raising global awareness of fuel poverty and the urgent need to increase access to energy through modern methods of energy production. Yet, electricity production is inevitably accompanied by the greenhouse gas (GHG) emission.

The atmospheric concentration of GHG has increased as a result of human activities stemming from the emergence of agriculture (Kutzbach et al., 2010) and in the past century, due to fuel combustion, which initiated the industrial revolution (Denman et al., 2007). Carbon dioxide (CO_2) emissions are associated not only with consumption but also with production, mining, transportation, gas compression, refining, *etc.* The consequence of fossil fuel combustion, the world's most important energy sources, is an increasing level of anthropogenic CO_2

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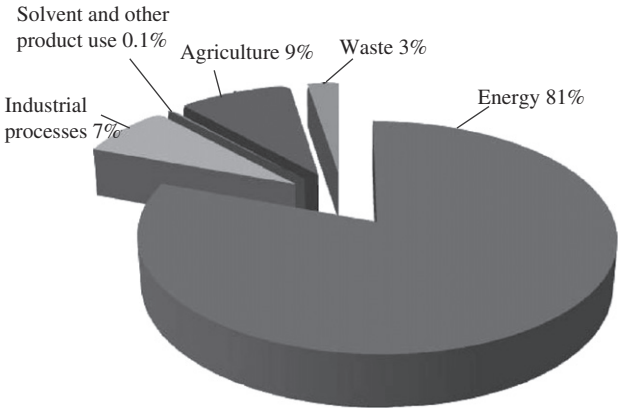

Fig. 1 – Percentage share of individual sectors in greenhouse gas emissions in Poland in 2011.

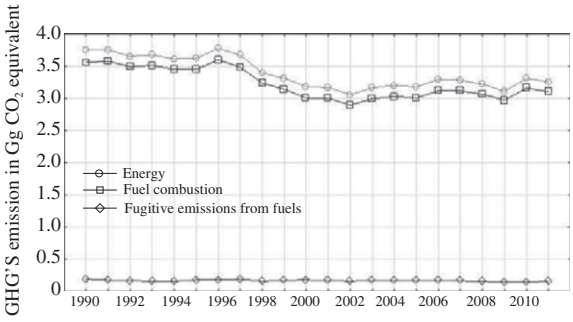

Fig. 3 – Greenhouse gas emissions's total energy emissions for two basic groups in Poland: fuel combustion and fugitive emissions from fuels.

emissions (Stangeland, 2007) and climate change (Andres et al., 2012). Gases such as methane (CH_4) and nitrous oxide (N_2O) play a significant role because of their high potential global impact (IPCC, 2001). The heat absorption coefficient of N_2O is over 300 times more effective and 21-fold in the case of CH_4, compared to CO_2 (Rout et al., 2005; Ullah et al., 2008). Furthermore, gas transportation and distribution result in emissions of CH_4 which occur as an effect of coal mining, natural gas venting and leakages. These indirect emissions differ broadly from source to source, depending on production methods and transportation distance. In 2010, 43% of CO_2 emissions from fuel combustion were produced from coal, 36% from oil and 20% from gas (IEA, 2012). To avoid the consequences connected with production of anthropogenic emissions of GHG, the Intergovernmental Panel on Climate Change (IPCC) concluded that by 2050, CO_2 emissions should be reduced by 50–80% (IPCC, 2001). However, according to the International Energy Agency (IEA), energy efficiency and the use of renewable energy sources do not constitute an adequate potential, which would allow achieving the suggested reduction level (IEA, 2006). Future industrial emissions will depend on diversion in both technology and industrial activities. It is estimated that even with high technological potential to reduce global emissions; the level of industrial emissions of CO_2 in the world will be higher in 2030 compared to the level from 2005. The major reason for it will be the increase in industrial production itself (Akashi et al., 2011). By the year 2035 the demand for electricity will be 70% higher than currently (IEA, 2012).

Poland is the largest hard coal producer in the European Union. About 90% of electricity generated in the country comes from coal. It is one of the very few EU countries which has a low dependence on energy import at the level of 31%, with the EU average of 53% (Ćwiek-Karpowicz et al., 2013). The Polish energy sector actively participates in working toward a reduction of CO_2 emissions by gradually decreasing the amount of coal in the fuel mix and through developing renewable energy resources. The ecological guidelines focused on elimination of harmful environmental activities and efficient energy management, are the basis for sustainable development (Góralczyk, 2003). It is important to increase the share of natural gas in the national structure of primary energy sources and to build the first nuclear power plant in Poland (Frączek et al., 2013). The contribution of renewable energy sources should reach 14% until 2020 (Oniszk-Popławska et al., 2003). Fig. 1 highlights the importance of the energy sector in Poland in the context of government efforts to reduce greenhouse gas emissions.

Fig. 2 presents GHG emissions from production in the energy sector in Poland and other EU countries. In 2011, Poland produced 68.51 Mtoe of energy and its electricity

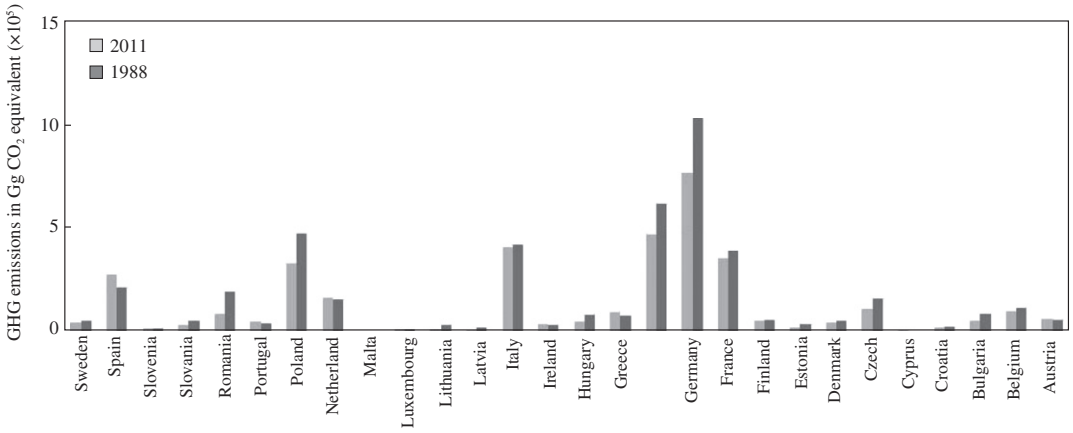

Fig. 2 – EU's greenhouse gas energy emissions in the base year compared to 2011 (IEA).