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The Potential of GHG Emissions Reduction in Macedonia by Renewable Electricity

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The energy sector in Macedonia is the main emitter of greenhouses gases (GHG) with share of about 70 % in the total annual emissions (12 – 14.5 Mt CO_2-eq). Furthermore, within the energy sector, 70-75 % of emissions are associated with the electricity generation due to the predominant role of the lignite fuelled power plants. This makes the electricity sector the most significant key source and, at the same time, the main target for GHG emissions reduction. The main goal of this paper is to assess the potential for GHG emissions reduction by increasing the use of renewable energy sources (RES) for electricity generation. For this purpose a RES scenario for the power system expansion is developed by making use of EnergyPLAN model. The maximal penetration of wind and solar energy results in reduction of the GHG emissions from the reference scenario for 8.26 %. Total investment needed for realization of this option is estimated to 800 M€. Furthermore, the RES technologies are analyzed from economic aspect and combined in a form of emission reduction cost curve, displaying the total marginal cost of the GHG emissions reduction by renewable electricity.

1. Introduction

At the moment, the most critical issues in European energy sector are security of supply and GHG emissions. One of the most promising solutions for alleviation of energy import and diversification of the energy resources, which at the same time reduce the GHG emissions are renewable energy sources. Hence, the common goal of the European Union is to increase the share of RES into final energy consumption to 20 % in 2020 and to reduce GHG emissions by 20 % until 2020 in comparison to their levels in 1990 and by 30 % until 2030 if the other developed countries undertake similar steps. The main problem of RES, except biomass, is their intermittent nature, so in order to use them effectively it is necessary to have energy storage in the system (Krajačić et al. 2009). Because of the high investment cost in the storage systems usage of the RES is becoming even more expensive (Krajačić et al. 2010).
In the case of Macedonia, energy production is based mainly on the low-quality domestic lignite, biomass, mainly for space heating and hydro. The share of other than hydro and biomass RES is very low. In recent years, the increasing electricity demand

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has been covered by import which has even rising trends (Taseska et al. 2010). In short, the most important problems the energy sector faces are unfavorable energy mix with high prevalence of lignite, strong dependence on energy import, poor condition of the energy systems and high degree of inefficiency in energy production and use (Markovska at al. 2009). All this makes the energy the most important national target sector for implementation of GHG emissions reduction measures (Markovska et al., 2008).

This paper presents analysis conducted in the energy planning program for the Macedonian energy sector in order to identify the GHG emissions reduction potential of renewable electricity - wind and solar photovoltaic (PV), as well as the costs of the GHG emissions reduction realized with these technologies.

2. Methodology

2.1 The EnergyPLAN model

In order to reduce GHG emissions, ensure security of supply, decrease import of the electricity and fossil fuels, renewable energy has become of key interest within energy planning (Connolly et al. 2010). In order to conduct technical analysis of high penetration of the renewables in the energy system of Macedonia, EnergyPLAN model has been used (Aalborg University, n.d.). EnergyPLAN model is input/output model that performs annual analysis in steps of one hour. Typical input data are demands, fuel consumption and different regulation strategies while the output data are annual production from different energy sources, fuel consumption, CO_2 emissions. EnergyPLAN model is specialized in the large scale integration of the renewables in the energy system (Lund, 2005), optimal combinations of the renewables (Lund, 2006), implementation of the combined heat and power (CHP) plants in the energy systems (Lund and Andersen, 2005) and simulation of the 100 % renewable energy systems (Krajačić et al. 2011).

2.2 Input data

Energy system of Macedonia for 2008 has been reconstructed in EnergyPLAN model. Basic data about power producing units have been obtained from Macedonian Energy Company (ELEM, n.d.) and from (Taseska et al., 2010). Energy consumption and supply data have been taken from (IEA, n.d.) while hourly wind power production was calculated by making use of hourly wind speed provided by METEONORM program (METEONORM, n.d.) for the year 2008. Hourly production data for hydro power plants have been obtained from Electricity Transmission System Operator of Macedonia (MEPSO, n.d.) for year 2009 while hourly load data for Macedonian power system have been provided by UCTE (ENTSO-E, n.d.). Load curve for hourly district heating demand has been calculated by using degree-day and temperature obtained from (METEONORM, n.d.).

3. Results

The potential of GHG reduction is analyzed by integration of the wind and PV into the reference system. Also, the new gas CHP plant, built in 2010, has been included in the analysis. The installed wind capacity is varied from 50 MW to 400 MW and PV capacity is varied from 2 MW to 50 MW, which is in accordance with the Macedonian RES strategy (Ministry of Economy, 2010). The total electricity demand is 7.79 TWh/y and demand for electric heating of households is 1.96 TWh/y (Pešut et al., 2009). The minimal capacity of power plant in the Macedonian system is limited to 410 MW. The new gas CHP plant with the capacity of 227 MWe and 160 MWt during periods with low heat demand is included in the group together with the lignite power plants. Analysis of the energy system is conducted for one year period taking into consideration RES production and demand on hourly base. Results of the conducted analysis for the potential GHG emissions reduction for different installed wind power (WP) and PV capacity is presented in Fig. 1. GHG emissions vary between 8.7 and 9.4 Mt CO_2 depending on the level of penetration of wind and solar energy. The maximal penetration of wind and solar energy (400 MW WP and 50 MW PV) results in reduction of the GHG emissions from the reference scenario for 8.26 %. As shown in Fig. 2., total investment needed for realization of this option is estimated to 800 M€.

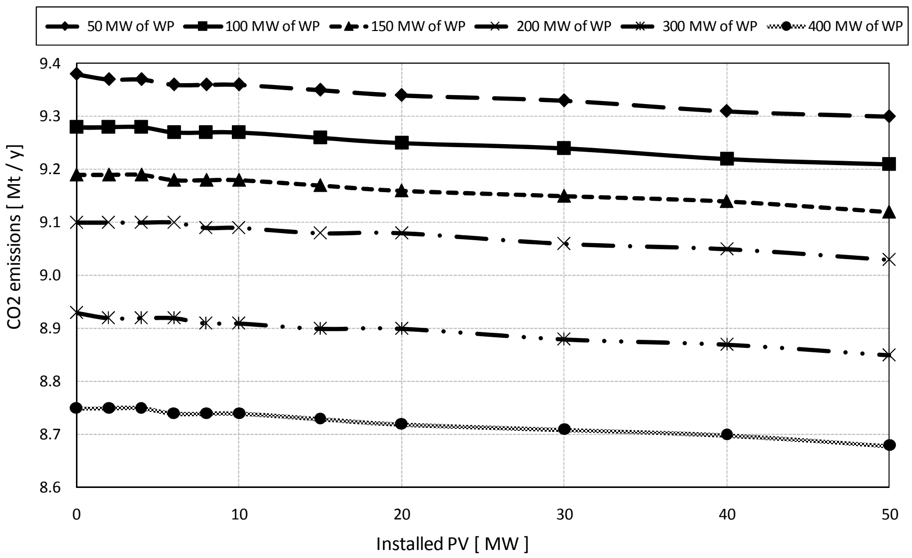

Fig. 1:. CO_2 emissions in the reference and closed energy system with the installed gas CHP plant and for different installed wind and PV capacity

The combined representation of reduction/cost indicators is shown by marginal cost mitigation curve (Fig. 3), with the achievable GHG emissions reduction in the horizontal axis and the specific cost of the mitigation options in the vertical axis.

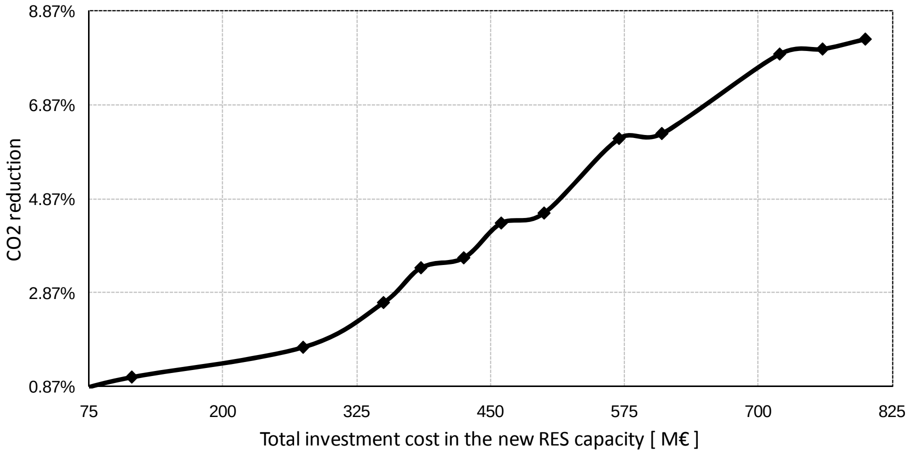

Fig. 2: Investment cost of the CO_2 reduction by wind and solar electricity

The total achievable reduction (case of maximal penetration of wind and solar energy) is estimated to 0.76 Mt CO2, of which 0.7 Mt can be reduced by wind capacities at price of 40 €/t CO2. The remaining part (0.06 Mt CO2) can be reduced by PV capacities at much higher price (150 €/t CO2).

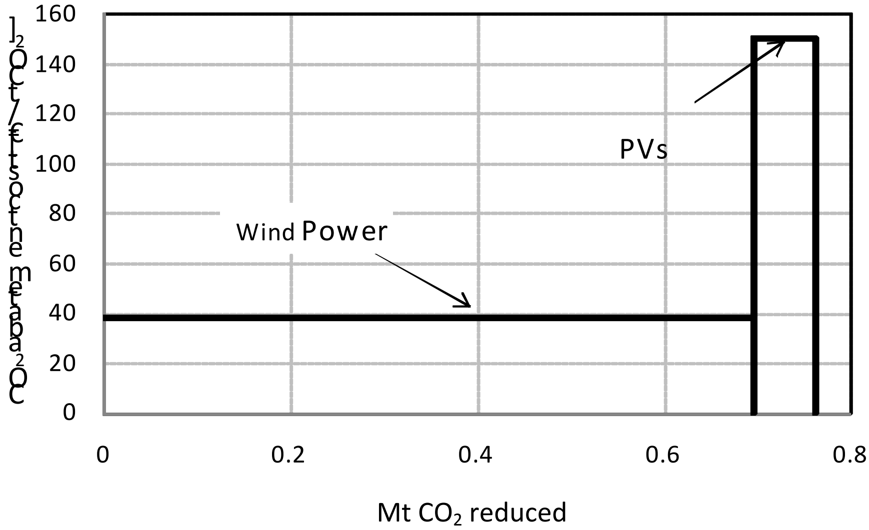

Fig. 3: Marginal cost mitigation curve for the considered RES technologies

It should be noted that the analyses in the EnergyPLAN model are conducted for the closed energy system, which means that the total demand for electricity and heat is covered by own production. Furthermore, it is assumed that at least 30 % of the power at any hour must come from power units capable of supplying ancillary (central power plant, CHP and hydro power plant). Under these assumptions, critical electricity excess production/export (CEEP) is observed (Fig. 4), meaning that the technical regulation strategy used for the balancing between CHP and wind production is not sufficient.

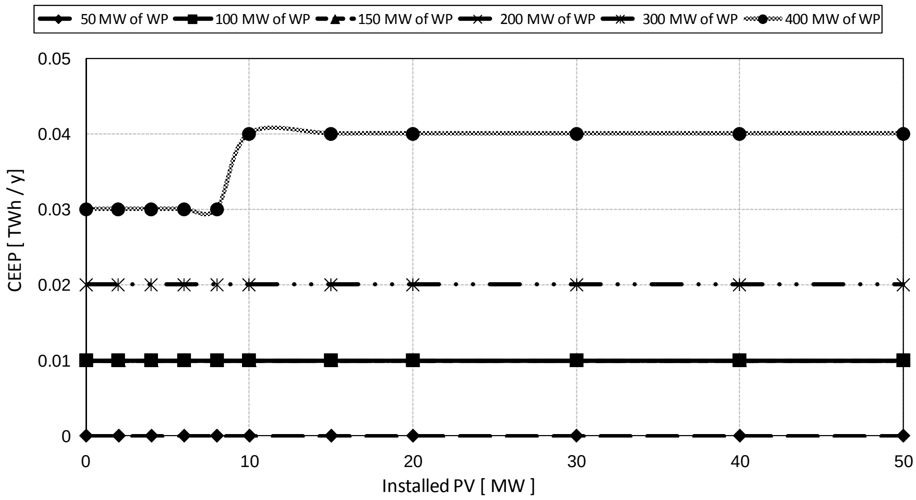

Fig. 4: Critical excess of electricity production in a closed energy system analysis of the reference energy system with gas CHP plant and with different installed wind and PV capacity

4. Conclusion

Analysis conducted for different installed capacity by taking in the account the wind and solar potential specified in the Macedonian RES strategy, shows that the emissions of the CO_2 from the energy sector can be reduced between 0.87 % and 8.26 % depending on the level of penetration of wind and PV. Furthermore, it is shown that wind power has significant reduction potential with relatively low marginal cost compared to PV. Analysis shows that electricity excess production occurs and the needs for electricity cannot be covered by own production. Some of the possible solutions to decrease CEEP and increase the RES share are pumped hydro storage, electric vehicles and heat pumps. The introduction of these technologies in the energy system should be further analyzed. Also, the increased penetration of RES would require investment in the regulation system of the existing lignite fired power plants.

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