CARBON DIOXIDE TARGETS OF GREEK ELECTRICITY SECTOR FOR 2020: EVALUATION AND PROSPECTS

KALDELLIS J.K., KONDILI E.*, LIAROS ST. and SCHORETSANITIS K.

Soft Energy Applications and Environmental Protection Laboratory, *Optimisation of Production Systems Laboratory, Piraeus University of Applied Science, Greece, P.O. Box 41046, Athens 12201, Greece
E-mail: ekondili@teipir.gr

ABSTRACT

Climate change mitigation refers to actions being taken for the reduction or prevention of greenhouse gases (GHG) emissions and by such limiting the magnitude or rate of long term climate change caused by anthropogenic activities. Electricity generation sector is by far the major contributor of carbon dioxide emissions due to the extensive use of fossil fuels.

European Union and Greece have undertaken serious and practical efforts in order to limit the GHG emissions since 2005. Recently EU has committed to restrict its GHG emissions by the year 2020 to the levels of (-20%) in comparison with 1990. In this context, Greece has prepared an ambitious plan in order to contribute in the entire EU effort during the period 2012-2020. However, the recent economic crisis and the instability in the electricity generation market pose serious questions about the implementation degree of this national effort.

The present work investigates the applicability of the proposed schedule for the electricity generation sector, taking into consideration several implementation scenarios. Actually, one pessimistic, one optimistic and the business as usual (BAU) scenarios are extensively analyzed concerning both the expected electrical energy demand and the participation of the renewable energy resources in the corresponding fuel mix.

Finally, using realistic values from the GHG trading (long-term averages) one may estimate the potential cost from the overrun of the national emissions or the potential income from the gas emissions surplus sales to other parties.

According to the results obtained and despite the long-term economic recession our country is marginally near the EU target concerning the GHG emissions, thus systematic effort is required in both the energy saving and the renewable energy sources' application sectors.

Keywords: greenhouse gases (GHG), fossil fuels, RES, EU target, climate change, GHG trading

1. Introduction

During the last 30 years climate change has been widely related with the increase of greenhouse gases (GHG) participation in the atmosphere of our planet. More precisely, the vast majority of the scientific community is almost persuaded that the long-term climate change encountered is caused by anthropogenic activities. On top of this, the energy supply security is a global ongoing issue that seriously concerns modern societies, governments, policies and forms geopolitical alliances and conflicts. In this context, the wide utilization of carbon containing fossil fuels (coal, oil, natural gases) in the electricity generation sector has been found responsible for more than 50% of the annual carbon dioxide emissions of our planet. In order to tackle the forthcoming climate change, the EU is working hard to cut its greenhouse gas emissions under the Kyoto protocol to 20% below 1990 levels. The two major initiatives to reduce GHG emissions are the EU Emissions Trading System and Effort Sharing Decision for the period 2013-2020. These policies will help EU to reduce the industrial and airlines GHG emissions cost-effectively and move Europe towards a low-carbon economy with increased energy security. In parallel, EU introduced the Directive 2009/28/EC according to which all members of the Union have to achieve some mandatory national targets as far as the renewable energy sources (RES) are concerned until the end of 2020.

More specifically, for Greece it is set that the contribution of the energy produced by RES to the gross final energy consumption should be 20%. Furthermore, the contribution of the electrical energy produced by RES to the gross electrical energy consumption should be at least 40%. Apart from the above, the contribution of the energy produced by RES to the final energy consumption for heating and cooling should be also at least 20%, whereas the contribution of RES to the gross energy consumption of the transportation sector should approach 10% at minimum. More precisely, Greece, as a member of the EU, has committed to implement the above goals by the end of 2020. As a matter of fact, the expected large scale penetration of RES calls for a well-organized plan on behalf of the Greek State to find and proceed with the most suitable energy mix required.

2.1. Current status

In the frame of European policy on Energy and the Environment the Greek Ministry of Environment, Energy and Climate Change, according to ministerial decision 19598/01.10.2010, defines the desired ratio of installed capacity of various renewable energy technologies to reach the objective targets in 2020 according to Table 1. In this table one may also find the deviation from 2014 and 2020 targets. This paper investigates the carbon dioxide time evolution up to 2020 on the basis of implementing the scheduled participation of RES in the energy mix of Greece. According to the available data in 2014 the real installed wind power is less than 50% of the expected one, while on the other hand the target for photovoltaics has already been reached. However with the recent introduction of net-metering the participation of PV technologies in the electrical generation mix of the country is expected to increase further.

Table 1: 2020 target of RES expected power (MW) and the current situation (LAGIE S.A., 2015)

	January 2015	Target 2014	Target 2020
Hydro electric	**3.238**	**3.700**	**4.650**
Small (0-15MW)	220	300	350
Large (>15MW)	3.018	3.400	4.300
Photovoltaics	**2.223**	**1.500**	**2.200**
Solar thermal	-	120	250
Wind (On shore and Off shore parks)	1.978	4.000	7.500
Biomass-Biogas	47	200	350

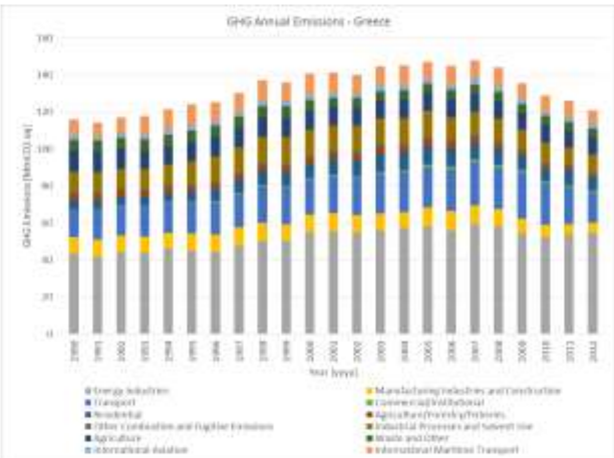

Figure 1: Annual GHG emissions per activity sector for Greece (Data: EC, 2014)

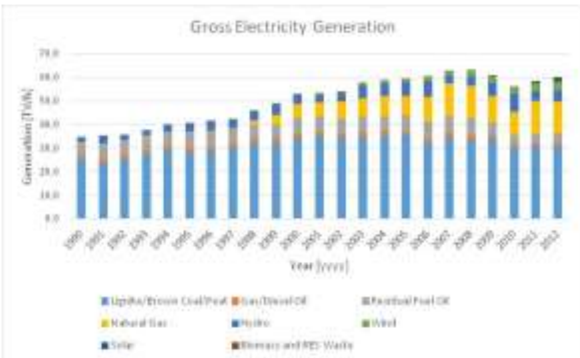

Figure 2: Time Evolution of Greece Annual Gross Electricity Generation (Data: Eurostat, 2014)

In order to obtain realistic results the current analysis has adopted several scenarios concerning the time evolution of the national electricity consumption in Greece up to 2020. Keep in mind that as already mentioned, the power sector is responsible for a significant share of GHG emissions (figure 1). Furthermore one may also estimate any potential revenues/cost resulting from the sale of surplus greenhouse gas emission allowances or due to non-compliance with the targets set respectively.

2.2. Scenario development

The present study has examined a large number of realistic electricity demand scenarios for Greece up to 2020. However, three representative scenarios concerning the future trends of the national electricity demand have been analyzed here. Actually, the first one is the business as usual (BAU) scenario based on the assumption that the electricity demand growth rate will remain at levels equal to the mean value of the last 20 years, figure 2. Accordingly, the optimistic and pessimistic ones have been developed by increasing or decreasing by 1% the mean annual (growth rate) value of BAU scenario respectively.

Accordingly, for each one of the energy demand cases (strongly dependent on the economic prospects of the country) three sub scenarios have been introduced considering the implementation degree of the RES-based projects already possessing a permanent connection offer to the local electrical network by the Greek Independent Power Transmission Operator – IPTO S.A. (IPTO, 2015b). More specifically, the high RES penetration sub-scenario considers that 100% of the licensed projects (end of 2013) will be implemented by 2020. Accordingly, the Mid RES and Low RES penetration scenarios assume that 75% and 50% of the licensed projects are going to be implemented respectively by the end of 2020. For each of the aforementioned cases the annual electricity generation mix from 2012 to 2020 has been estimated on the basis of the mean capacity factor of each technology, including the electricity branch self-consumption and taking also into account the Transmission and Distribution (T&D) losses (EC, 2014a, 2014b, 2014c; Eurostat, 2014; HEDNO, 2015; IPTO, 2015a, 2015b; LAGIE, 2015).

Subsequently, the emission factors for each of the technologies participating in the national electricity mix have been considered in order to calculate the annual carbon dioxide emissions produced by the local electricity sector (WEC, 2004; K. Kavouridis *et al*., 2007; Kaldellis *et al*., 2011). Finally, the calculated carbon dioxide quantities have been directly compared with the corresponding allocated amount for Greece according to Commission's Decision 2013/162/EU (EC, 2013) for the 3rd phase (2013 – 2020) of EU's Emission Trading System (EU ETS) as modified by 2013/634/EU (EC, 2013b).

On top of these, the resulting quantities of carbon dioxide emissions, for each case examined, have been translated into an equivalent annual Revenue/Cost for the local economy by utilizing the appropriate carbon dioxide spot market price (SENDECO2, 2015). In this context, recent historical data have been taken into consideration in order to predict the corresponding future carbon dioxide value (SENDECO2, 2015) in 2015 € values. All scenarios developed take also into account the net imported electrical energy contribution in the local electricity balance using average annual values of the last 10 years.

3. Results and discussion

Applying the developed methodology one may calculate the expected "E_j" annual energy yield of each technology "j" using the following relation (1):

$$E_j = 8760 \cdot CF_j \cdot P_j \tag{1}$$

where "P_j" is the installed (in operation) power (e.g. Table 1) of technology "j" and "CF_j" is the corresponding capacity factor, valid for every technology adopted in Greece. For example in 2012 the in operation lignite plants total installed power was approximately $4600MW_e$ and the corresponding CF was almost 60%. On the other hand, during the same year the installed wind power was a little higher than $1750MW_e$ and the corresponding CF value was taken equal to 25%. Accordingly, the total annual carbon dioxide emissions are calculated using the energy yield of each technology "j" and the corresponding emission factor "ε_j" derived by the available data for Greece and Europe (Kaldellis J.K., Kondili E.M. and Paliatsos A.G., 2008; Kaldellis, Mantelis and Zafirakis, 2011). Thus one may write:

$$C_{tot} = \sum_j E_j \cdot \varepsilon_j \qquad (2)$$

Finally, one may estimate the gain or loss of the national electrical system due to the low or high carbon dioxide emissions "C_{tot}" in comparison with the value allocated in the Greek electricity generation sector "C_{max}", taking also into consideration the appropriate carbon dioxide spot market price. For example during 2014 the annual mean value was approximately 7€/tn of CO_2.

Table 2: Development of the Scenarios

BAU Scenario, 2.8% Annual Growth, Demand@2020 = 66TWh				
	Generation [TWh]	RES Penetration [%]	Emissions [MtnCO2]	Revenue/Cost [2015 M€]
High RES	61.6	35	48.4	39.1
Mid RES	61.4	30	52.9	22.4
Low RES	61.5	25	57.9	3.6
PES Scenario, 1.8% Annual Growth, Demand@2020 = 57TWh				
High RES	56.7	38	41.2	65.9
Mid RES	56.7	32	45.5	49.7
Low RES	56.4	27	49.8	33.8
OPT Scenario, 3.8% Annual Growth, Demand@2020 = 71TWh				
High RES	66.6	32	56.2	9.9
Mid RES	66.5	28	60.4	-5.8
Low RES	66.3	23	65.4	-24.4

Using the above analysis one may find in Table 2 the expected total annual electricity generation in comparison with the energy demand for the three main electricity time evolution scenarios adopted. More specifically, for the BAU scenario the expected annual energy demand is 66TWhe, while the corresponding national electricity generation is approximately 61.5TWhe, calculated on the basis of equation (1). In this case the net electricity imports from the neighbor countries is 4.5TWhe, representing approximately 7% of the total electricity demand. Analogous values are given for the pessimistic and the optimistic scenarios. In order to obtain a clear cut picture of this information in figure 3a and 3b one may find the time evolution of the annual electricity generation mix for two of the scenarios examined and for the high RES penetration sub-case. Furthermore, in the same Table 2 one may see also the RES contribution in the national electricity demand in 2020 and compare the results provided with the target of 40% set by the local authorities. As we can see in no case this target will be accomplished, while in some cases the RES participation is even less than 25%.

Figure 3a: BAU electricity demand scenario

Figure 3b: PES electricity demand scenario

Subsequently one can estimate (using equation (2)) the total annual carbon dioxide emissions for all 3x3 case studies analyzed. According to the results provided the annual carbon dioxide production of the national electricity generation sector varies significantly between 41 and 65 Mtn/year, for the pessimistic economic-high RES penetration and for the optimistic economic-low RES penetration scenarios respectively.

Finally, one may easily compute the total gains (or loss) due to the deficit or surplus of the sector carbon dioxide emissions in comparison with the limit allocated by EU and Greek State. For this purpose in figure 4a, 4b and 4c one may demonstrate the annual gains/loss of the electricity generation sector resulting from the carbon dioxide production for the three economic scenarios investigated here. Note that in each figure one may find different values for the High, Mid and Low RES participation cases studied.

The scenarios presented concern the total electricity demand for the interconnected and non-connected (autonomous islands) network for the period 2014-2020, using as a reference year the year 2012. The results are comparable with those presented by Greek IPTO in the power efficiency study for the period 2013-2020, according to which the forecast for 2020 are: low demand (59600 GWh), reference (62040 GWh), high demand (63800 GWh). The projections of the IPTO, apart from the Hellenic Mainland Transmission System's (HTS) demand, also include the demand for the Cyclades and Crete assuming that by 2019 the interconnection of these islands will be achieved.

The composition of the proposed energy mix comprises power stations with fossils fuels like lignite, natural gas, oil and CHP. Correspondingly the mix of renewable energy technologies include wind, photovoltaic, solar thermal, large hydro, small hydro and biomass.

During the calculations of the scenarios presented one has taken into consideration the network losses and the energy imports from neighbor countries. Depending on the degree of penetration of RES per scenario, the energy produced by the power plants using lignite varies in order to cover the demand. This variable lignite-based power plants exploitation dictates the corresponding gains and losses as regards the import cost of natural gas and GHG emissions (Kaldellis and Kapsali, 2014).

On the basis of the results obtained one may see that for the BAU scenario (figure 4a) the carbon dioxide balance is marginally positive, especially for 2019, and for the low RES penetration sub-case. During 2020 the situation is slightly ameliorated, since according to the national plan of PPC (IPTO, 2013) almost 600MW of lignite will be retired, replaced by approximately 370MW of natural gas and 125MW of large hydro.

Accordingly no carbon dioxide emissions problem has been encountered (figure 4b) for the pessimistic evolution of the local economy case, since the total electricity demand is modest and even in 2020 is less than the corresponding value of 2010. However, this low carbon dioxide situation is unfortunately neither the result of energy saving and rational energy use nor of energy efficiency improvement.

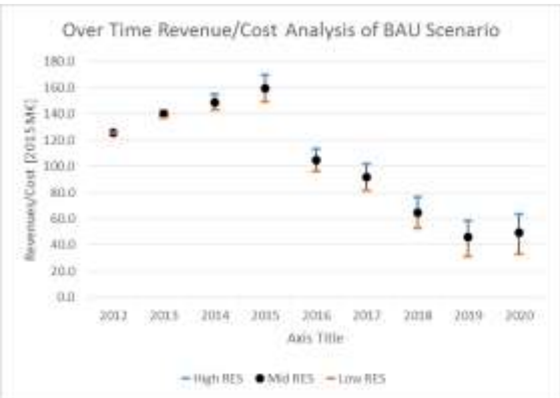

Figure 4a: BAU scenario.

Figure 4b: PES scenario.

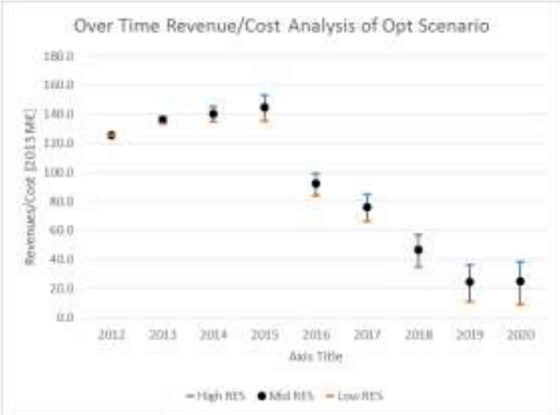

Figure 4c: OPT scenario. Time evolution of the gain-loss balance related with the electricity generation sector carbon dioxide production

Finally, for the optimistic scenario of the local economy time evolution the electricity sector violates the corresponding carbon dioxide quota (figure 4c), excluding the high RES penetration sub-case, which however may be not so realistic due to the increased investment capital requested (9-12 billion euro). The result of the increased carbon dioxide emissions is an additional annual penalty of almost 100 million euro that may even double in case that the carbon dioxide spot market price approaches 15€/tn of CO_2.

4. Conclusions

According to the results of the proposed analysis, for Greece it is almost impossible to achieve the target of 40% RES participation in the electricity generation mix in 2020. Unfortunately, there is already a significant delay in the implementation of RES-based investments hence even the 2014 targets are not implemented. On top of the economic crisis, there are several other serious reasons that discourage the implementation of already decided investments (resulting in a lower penetration of RES) like the difficulties arising during the licensing process, unforeseen difficulties during the construction stage, siting and network problems. Recently, the arbitrary planning of huge RES-based investments all over the country provokes the reaction of the local communities which may even block the realization of several analogous investments.

This relatively low penetration of RES in the national electrical system, partially explained by their impact on the reliability of the network due to their stochastic nature, along with the slow application of energy saving measures do not at all contribute on limiting the carbon dioxide emissions of the country.

In this context, as far as GHG emissions are concerned the developed model forecasts that Greece will marginally achieve the EU proposed target in most of the scenarios examined excluding the optimistic one, where the carbon dioxide emissions exceed the corresponding upper values. In any case, only by significant RES penetration in the electricity generation mix, our country will not violate the quota set.

Recapitulating, it is almost clear that the goal of 40% RES participation in the electricity generation mix of our country cannot be easily implemented up to 2020. Additionally, Greece will marginally achieve the GHG emission targets for 2020 due to the expected fair economic development. However, in case that systematic effort is put in the fields of energy saving and RES exploitation not only the carbon dioxide emissions will be quite lower than the EU target but all these energy sector activities will support and motivate the local economy in order to overcome the economic recession of the last years.

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