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Greenhouse Gases Emissions and the Energy System of Greece

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Abstract — There has been a consensus developed among climate scientists that the world is warming alarmingly and that human activity is playing the major role. Most of the global warming gases originate at the electricity production systems and the fuels used for transportation. Humanity requires an energy system that can provide a high standard of living for all without further damage to the earth. The survival of humanity may depend on how soon and how boldly we act. The energy system of Greece for providing electricity is mainly used on carbon fuels. In the last few years there have been efforts to introduce renewable energy systems for the reduction of GHG emissions so as to be within the limits set by the European Union. In this work the environmental impact of the current energy system of Greece is examined and models preding the emissions in the next twenty years are examined. It has been found that the based on the climate conditions of Greece it is possible to reduce the GHG emissions by the tear 2020 by great amounts overpassing the limits set by the European Union

Keywords — energy system; Greece; GHG; renewable energy systems

1 INTRODUCTION

Energy constitutes an essential ingredient for social development and economic growth. The uses of energy are well-known, as it provides basic needs and services (heating, cooling, lighting, cooking, and transportation) and is a critical production factor in virtually all sectors of industry. Nevertheless, the production and consumption of energy places a wide range of pressures on the environment and on public health, some of which have been decreasing. The emission of greenhouse gases (GHGs) and their implications to climate change have sparked global interest in understanding a country's energy system. According to the Intergovernmental Panel on Climate Change [1], the world emits approximately 27 Gt of CO_2 from multiple sources, with electrical production emitting 10 Gt, or approximately 37% of global emissions.

Energy-related greenhouse gases emissions (GHG) in Europe remain dominant, accounting for 80 % of the total emissions, with the largest emitting sector being electricity and heat production, followed by transport. Between 1990 and 2005, energy-related GHG emissions in the EU-27 fell by 4.4 %. The intensity of CO_2 emissions from public conventional thermal power plants in the EU-27 decreased by 27 % due to efficiency improvements and the replacement of coal with gas in the power sector. In adittion, during the period of 1990 and 2005, energy-related emissions of acidifying substances, tropospheric ozone precursors and particles in the in the EU-27 decreased by 59 %, 45 % and 53 %, respectively, mainly due to the introduction of abatement technologies in EU-27 power plants and the use of catalytic converters in road transport [2].

In this study Greece's energy system as well as the emitted GHG are investigated. Based on data from the 5th Greece's National Report as well as from Greece's National Statistical Service and Eurostat the total GHG emissions (CO_2, CH_4, N_2O, HFC, PFC and SF_6) for the period of 1990 - 2008 the trends as well as future projections regarding the potential penetration of renewable energy systems in the Greek energy system and the forecasted reduction of greenhouse gases are investigated. It is noticed, that the majority of GHG emissions (55.5%) in 2008 derived from energy industries, while the contribution of transport, manufacturing industries and construction and other sectors is estimated at 21.8%, 9.0% and 12.2% respectively. The rest 1.5% of total GHG emissions from energy derived from fugitive emissions from fuels. The substantial increase of GHG emissions from road transport is attributed to the increase of vehicles and the increase of transportation activity.

2 GREECE'S ENERGY PROFILE

Greece has a total area of 13,195,740 ha and is located at the southern part of Balkan region. The total population of the country is approximately 10.35 million inhabitants, presenting an increase of 6.5 % during the last decades [3]. Greece's energy sector relies on fossil fuel combustion. The gross

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inland consumption in 2008 amounted to approximately 1282 PJ [4].

The consumption of solid fuels and oil products accounts for 83% of total consumption, while the contribution of biomass and of the rest RES (mostly hydropower, solar and wind energy) is 2% and 2.4% respectively. Finally, the share of natural gas in gross inland consumption is more than 11% while the rest 1.6% of gross inland consumption is covered by electricity (net imports – exports). In 2008, gross inland consumption increased by approximately 44% compared to 1990, presenting a 2.1% average annual rate of increase. It should be mentioned that up to 1996 supply of natural gas was exclusively minor quantities from domestic primary production. In essence, the introduction of natural gas in the Greek energy system started in 1997 and since then its consumption has been continuously increasing.

Fig. 1 presents the increase of Greece's total energy consumption. Additionally, Greek oil consumption has increased during the past decade (Fig. 2). Greece has oil reserves of just 7 million barrels. The domestic production in 2004 reached 6,411 barrels per day (bbl/d). Greece relies heavily on imports to meet its 429,000 bbd/d oil consumption. Oil is Greece's most important fuel source, accounting for approximately 63% of total energy consumption in 2003. Greece has natural gas oil reserves of only 35 billion cubic feet and produces negligible amounts. Greece currently consumes 2, 8 billion cubic meters of gas per year of which 2, 2 bcm come from Russia via pipeline and the rest from Algeria in liquefied form. Consumption, however, has increased significantly from 15 thousand of toe in 1990 to 461 thousand toe in 2004, and is expected to continue to increase-possibly tripling over the next ten years (Fig.3).

Lignite is Greece's only significant fossil fuel resource, with reserves reaching 4.3 billion short tons. In 1998 lignite stood up to almost 80% of inlands electricity production whereas 18% was from renewable with hydroelectric and 2 % from crude oil. In 2004 lignite production reached 8,547 thousand toe. Greece has no hard coal reserves; for this reason hard coal is imported from South Africa, Russia, Venezuela and Colombia. As far as the electricity generation is concerned, in 2004 Greece generated 55.5 billion kWh of electricity, of which approximately 76% was from steam turbines, 20% was hydroelectric and 4% was other renewables. The majority of the steam based electricity is of lignite-base while new plants will be gas-fired. Over the past decade electricity demand has grown nearly 50%. In addition, Law 2773/99 as revised with Law 3175/03 , established the liberalization of the electricity market in Greece in agreement with the provisions of the Directive 96/92/EC ; concerning "common rules for the internal market in electricity".

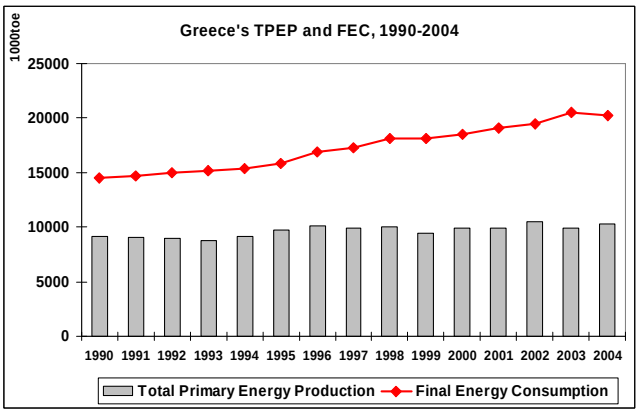

Fig. 1. Greece's Total Primary Energy Production (TPEP) and Final Energy Consumption (FEC) for the period 1990-2004 [5].

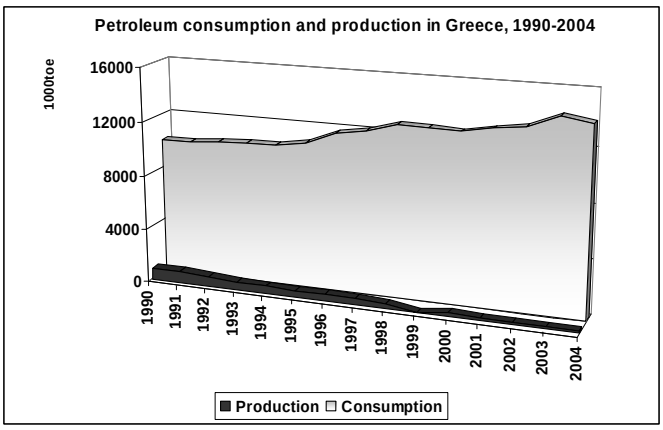

Fig. 2. Greece's primary production and final energy consumption of crude oil and petroleum products for the period 1990-2004 [5].

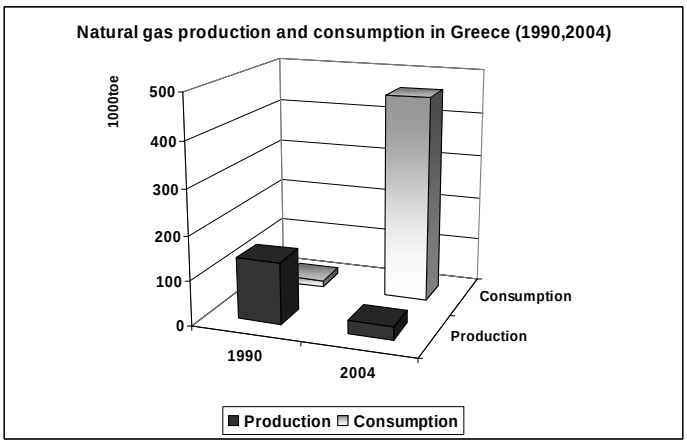

Fig. 3. Greece's primary production and final energy consumption of natural gas in 1990 and in 2004 [5].

The contribution of RES to the national energy balance in 2008 was approximately 7.8% of gross final energy consumption and around 16.3%, of primary energy production. Primary energy produced from RES in 2008 was 1.64 Mtoe. Out of these, biomass use in households accounts for 600ktoe, and the use of biomass in industry for 265

ktoe. Moreover, 285 ktoe are produced by hydroelectric plants, 193 ktoe from wind power plants, 174 ktoe from solar thermal systems, 63 ktoe from biofuels, 35 ktoe from biogas, mainly for electricity generation and 17 ktoe from geothermal energy. Greece has considerable wind and solar energy potential, which has already attracted investment interest, as well as a promising biomass and geothermal potential, which, however, still remain untapped. It is noted that the wind parks in 2005 had a total installed capacity of 573 MW. The use of solar energy is of a capacity equal to 1.4 billions kWh each year.

3 GREENHOUSE GASES EMISSIONS TRENDS IN GREECE

The trend of GHG from 1990 to 2008 by source category is presented in Fig.4. The source categories include: energy, industrial processes, solvents, agriculture and waste. The energy category takes into account emissions resulting from the stationary combustion (solid fuels, liquid fuels, and gaseous fuels) of energy industries as well as manufacturing and construction industries, the transport sector (road transport, navigation, aviation) and the coal mining and handling. The industrial processes category takes into account emissions resulting from the production of: cement, lime, nitric acid, glass, ammonia, aluminium, iron and steel as well as from ozone depleting substances substitutes. The agricultural category takes into account emissions stemming from the enteric fermentation and agricultural soils (direct and indirect emissions and animal production). Finally the waste category includes emissions coming from the solid waste disposal on land and wastewater handling. The Land Use, Land Use Change and Forestry sector is not taken into account.

In 2008, greenhouse gases emissions came up to 126.89 Mt CO2 eq showing an increase of 22.85% compared to 1990 levels. Greenhouse gases stemming from the energy sector, in 2008, accounted for 82% of total greenhouse emissions and increased by approximately 34.13% compared to 1990 levels. Emissions from industrial processes in 2008 represent a percentage of approximately 8.40% of the total emissions and increased by approximately 10.69% compared to 1990 levels. The fluctuation observed is attributed to the cease of HCFC-22 production. The contribution of the solvents and other products use sector to total emissions is minor (0.25% of the total emissions) and has slightly increased compared to 1990 level of emissions. The agriculture sector accounted for 7 % of total emissions, in 2008, decreased by approximately 21.42% compared to 1990 levels. Emissions reduction is mainly due to the reduction of N_2 O emissions from agricultural soils, because of the reduction in the use of synthetic nitrogen fertilizers. The contribution of the waste sector to total emissions came up to 2%. The abovementioned data are presented in Fig.5.

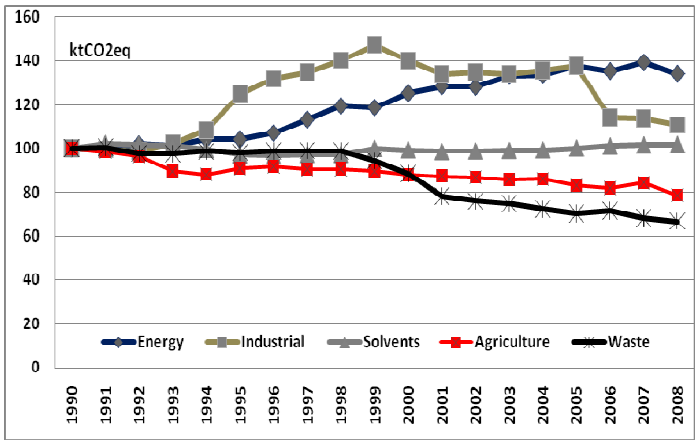

Fig. 4. Greenhouse gases emissions trends for the period of 1990- 2008 [index (base year =100] [4]

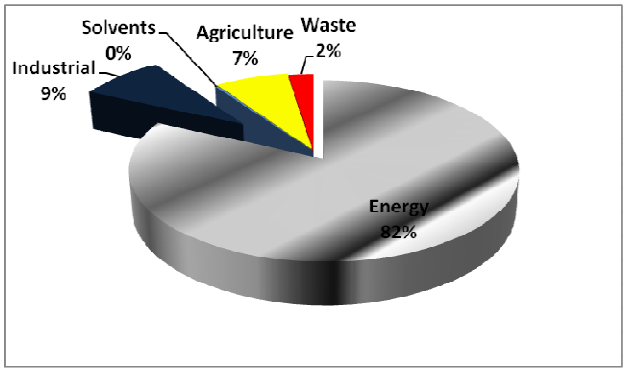

Fig. 5. Greece's GHG emissions per sector in 2008 [4]

From previous studies [6] it has been pointed out that during the past decade the Gross Domestic Product (GDP) has significantly grown in Greece. This growth was strongly related to an increase in the energy consumption, which in turn was related to an increase in the volume of emissions of greenhouse gases. Furthermore, in the same study it was shown that the generation of municipal waste was a positive function of aggregate income levels and economic prosperity, as the higher the gross income of Greece in the past decade was, the higher its waste generation. It is pointed out that during the period of 1990 – 1995 the GHG increased with an average annual rate of 0.85% while GDP increased with an annual rate of 1.7%. During the period of 1996- 2000, GHG increased with an annual rate of 3.8% which is higher than the rate of increase of GDP for the same period (3.4%). Finally, the average annual rate of emissions decreased during the period of 2000 – 2008 at 0.9% while GDP increased with a rate of approximately 4% [3].

The substantial increase of GHG emissions from road transport is directly linked to the increase of vehicles fleet and to the increase of transportation activity. Mobility during the period of 1990-2008 was of clear economic importance in Greek society, allowing factors of production (people and goods) to move around to where they could be profitably employed. Nevertheless mobility is associated with transport per passenger, which is strongly related to energy consumption and GHG [7]. A number of elements influencing the increased demand for private transportation during the period of 1990-2008 are: (**a**) the increasing GDP, and therefore the increased income of households allowing householders to travel in more "luxury", benefiting from faster and more accessible private transportation as well as being a symbol of wealth; (**b**) distances travelled to work, shopping and leisure activities increased ensuring that total distance travelled by private cars, measured in 1000 mio pkm, continued to increase; (**c**) the modal split of transport use by households is dominated by the car.

As far as the energy efficiency of buildings is concerned, it is noted that over 74% of the existing Greek housing stock has inadequate insulation [8-9] resulting in total yearly energy loss of 83.5 million GJ. The energy loss through walls accounts for 79 MJ/m^2 per year whereas energy loss through roofs comes up to 53 MJ/m ^{2} per year. Wall insulation and weather proofing of openings can reduce the CO2 emissions by at least 4 Mtonne CO_2 eq [8]. Larger energy savings can achieved when building new houses with the use of environmental friendly technologies such as solar cooling, geothermal cooling [10].

4 PENETRATION OF RENEWABLE ENERGY SOURCES IN GREECE

In order to meet the targets set within the Directive 2009/28/EC regarding the promotion of the use of energy from RES (RES) requires the elaboration of policies and measures targeting at the fulfillment of the "20-20-20" obligations and the acceleration of the Greek economy through "green" development and enhanced competitiveness of the private sector.

In this context law L3851/2010 (OG A/85/4th June 2010) on "*Accelerating the development of RES to deal with climate change and other regulations in topics under the authority of the Ministry of Environment, Energy and Climate Change*" aims at [11]: (**a**) simplifying the licensing procedure; (**b**) rationalizing the feed-in-tariff scheme; (**c**) tackling existing barriers at local level; (**d**) establishing specific regulations for the use of RES in buildings in accordance with the recently approved "Energy Performance of Buildings Regulation" - KENAK (OG 407/B/2010). According to law L3851/2010, the protection of the climate, through the promotion of electrical energy production from RES, constitutes an environmental and energy priority of the highest significance for Greece and sets specific targets for RES electricity share (40%), RES heating and cooling share (20%), RES transport share (10%), so as to achieve the national target of contribution of the energy produced from R.E.S. to the gross final energy consumption by a share of 20%. The target regarding the share of RES in final energy consumption in 2020, will be achieved through the combination of a mix of measures related to the implementation of policies in the field of energy efficiency and the large penetration of RES technologies both in electricity production, heat supply and transport sector.

The forecasted RES utilization during the period of 2010 -2020 in Greece, broken down by sector along with the projected surplus, in the gross national final energy consumption are shown in Fig.6. The projected contribution of different technologies and fuels, during the period of 2010-2020, in electricity production is presented in Fig.7; whereas Fig.8 illustrates the estimated installed RES capacity for the electricity production. It is obvious (Fig.7) that during the period of 2010-2020 significant changes in the Greek energy system are going to be made: (**a**) significant increase of RES (**b**) increase of natural gas utilization between 2010 and 2015 (**c**) decrease of fuel oil use and lignite use.

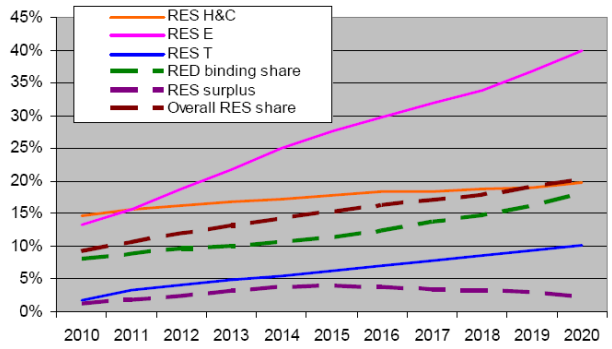

Fig. 6. Projections of RES share in the final consumption of electricity, heat & cooling and transport sectors; overall RES share; expected surplus in gross final energy consumption until 2020 [12]

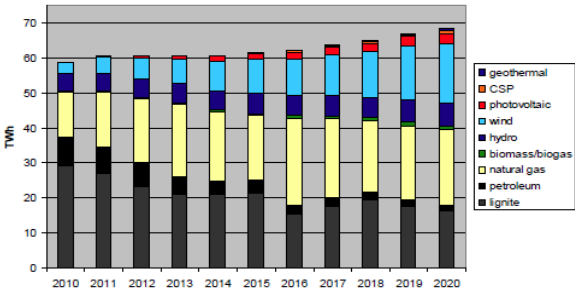

Fig. 7. Projected electricity generation from different technologies and fuels until 2020 [12]

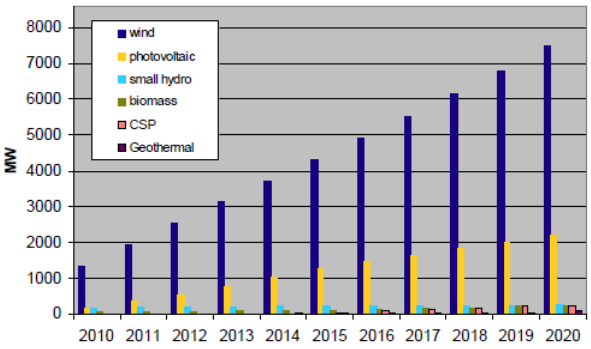

Fig. 8. Estimated installed RES technologies and fuels capacity until 2020 [12]

For the purpose of this study three RES penetration scenarios – in accordance with Greece's National Renewable Energy Policy- are investigated. The scenarios are based on economic forecasts – in accordance to the Greek recovery plan (Stability, Development and Reconstruction Program). These scenarios are characterized as Reference Scenario, Compliance Scenario and Accelerated Economic Recovery Scenario. The scenarios, refer to key variables able to address policies, economy energy, society and mobility, as well as industrial and technological issues.

The reference scenario is based on the assumptions that after an initial stabilization period, the economy is expected to grow with moderate rates peaking at about 2.7% in 2015 and remaining at that level with a slight increase to 2.9 by 2020 and a slight decrease later on towards 2030. It is also assumed that oil prices will increase coming up to 100$/bb in 2020. The reference scenario takes into consideration the implemented policies and measures for reducing GHG emissions and assumes that no additional emission reduction actions are adopted. The RES share, under the reference scenario, in gross final energy consumption is estimated at 14,17%. In this context, Greece fails to meet its targets regarding its 20-20-20 obligations.

The compliance scenario is based on the same economic and social parameters as these of the reference scenario. Under the compliance scenario the lignite power plants, are using "CCS ready" technology and are adapting new technologies for biomass residues exploitation, through cofiring and CO_2 emissions reduction, in conjunction with the gradual decommissioning of the less efficient and more pollutant ones. Large scale RES plants, mainly wind farms and large hydro plants are constructed. Moreover, new financial incentives for the support of the heat production from biomass and geothermal energy are given. Emphasis is given to the penetration of biofuels as well as energy efficient vehicles in the Greek vehicle market. In general, all the specific targets regarding the energy sectors of heating and cooling, electricity and transport are implemented. The RES share in gross final energy consumption under the compliance scenario comes up to 20,4% (40% electricity, 20% heating and cooling and 10% transport). In this context, Greece complies with Directive 28/2009/EU and meets its targets regarding its 20-20-20 obligations.

The accelerated economic recovery scenario supports the same environmental measures as the compliance scenario. Under the accelerated economic recovery scenario the growth rates after 2015 are projected to increase at a rate of 4%, in order to make up for the demand reduction of 2010-2015, and are projected to remain at that level throughout the rest of the period. The increased growth is going to affect the final energy consumption, even though energy efficiency is expected to increase thus further decoupling economic growth from energy use. The additional growth of energy use is projected to require even larger amounts of RES utilization to meet the target of 20% as the absolute amount of RES contribution will increase proportionally to the final use. Based on the aforementioned data, the RES share in gross final energy consumption comes up to 21%. Table 1, summarizes the scenarios under study and Fig.9 illustrates the gross final energy consumption for each scenario.

Table 1. Share of RES in Gross final energy consumption for all scenarios under study

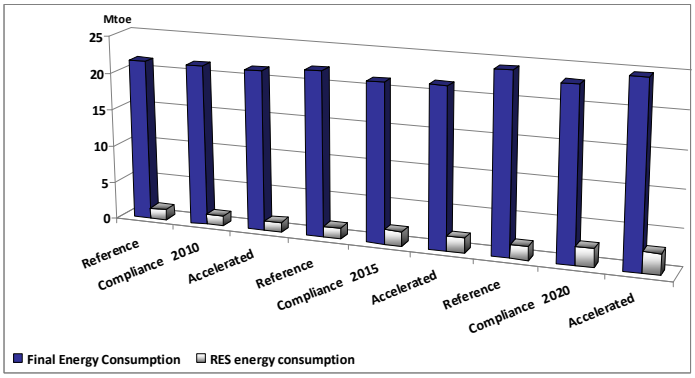

Fig. 9. Gross final energy consumption analysis for the three scenarios, Reference, Compliance and Accelerated Economic Growth until 2020.

The expected gross final energy consumption of Greece's energy system in heating and cooling, electricity and transport until the year of 2020, taking into account the effects of energy efficiency and energy saving measures is presented in Fig.10. Based on a combination of measures for energy efficiency and penetration of RES technologies in electricity production, heat supply and transport sector the estimated share of RES until 2020, in these sectors- in accordance with the national target are presented in Fig.11.

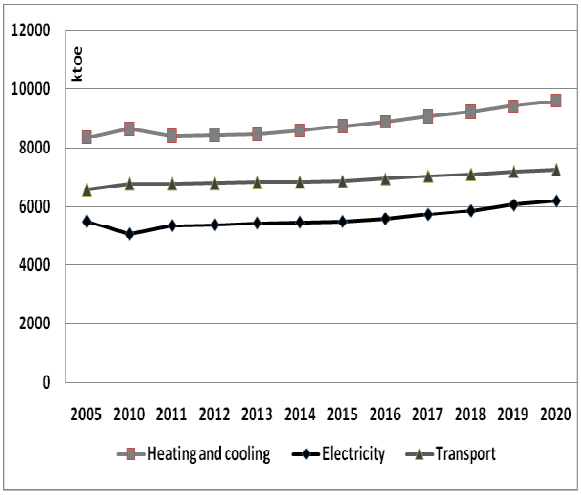

Fig. 10. Greece's expected gross final energy consumption in heating and cooling, electricity and transport sector until 2020 [12]

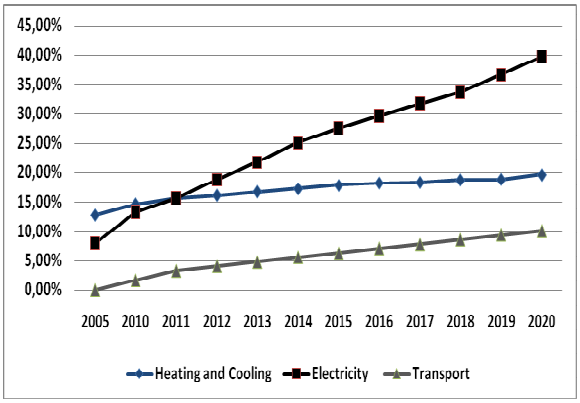

Fig. 11. Greece's estimated energy trajectory from renewable sources in heating and cooling, electricity and transport sector until 2020 [12]

5 CONCLUSIONS

Climate Change is already perceptible in Greece. There are clear indications of warming in the country from the early 1990s [13], which is gradually strengthened and record-breaking hot summers days are an increasingly regular occurrence. Furthermore, in total the trend of precipitation in Greece is negative both on annual as well as on seasonal basis [14].

In this study Greece's energy profile as well as the GHG trends for the period of 1990- 2008 were examined. It is obvious that the environmental impacts of basic sectorial trends (electricity, heating and cooling, transport) as well as human activities directly affect the environment. It was shown that in 2008, greenhouse gases emissions came up to 126.89 Mt CO2 eq showing an increase of 22.85% compared to 1990 levels. Furthermore, the penetration of RES in the Greek energy system was investigated. Three penetration scenarios based on economic forecasts and on specific targets and policy measures presented in the National Renewable Energy Action Plan and in accordance to Stability, Development and Reconstruction Program present the way towards the fulfillment of Greece's obligations to Directive 2009/28/EC. The mitigation of climate change and the reduction of GHG emissions, through the promotion of electrical energy production from RES as well as the implementation of energy efficiency policy measures, constitute an environmental and energy priority for Greece. Specific targets are set for RES electricity share (40%), RES heating and cooling share (20%), and RES transport share (10%) in order to achieve the national target of 20% contribution of the energy produced from RES to the gross final energy consumption.

The implementation of Greece's obligations will be achieved through a combination of measures for energy efficiency and RES utilization and adaptation from all stakeholders. It is pointed out that all the targets regarding greenhouse gas mitigation need to be fully implemented.

REFERENCES

[1] IPCC, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (1996 IPCC Guidelines), IPCC, Bracknell, 2007

[2] EEA (European Environment Agency), "Energy and environment report 2008", No 6/2008, 2008

[3] General Secretariat of National Statistical Service of Greece: **www.statistics.gr**

[4] Ministry of Environment Energy and Climate Change, " Annual Inventory Submission under the Convention and the Kyoto Protocol for greenhouse and other gases for the years 1990-2008", 2009

[5] European Commission –Eurostat Europa database **http:// europa.eu.int**

[6] Koroneos, C. and Nanaki, E., "Measuring Greece's progress towards energy sustainability", Int. Journal of Global Energy Issues, Vol. 27, issue 1, pp.77-101, 2007[a]

[7] Koroneos, C. and Nanaki, E., "Environmental assessment of the Greek transport sector", Energy Policy 35:5422-5432, 2007b

[8] Balaras C., Gaglia A. et al, *European residential buildings and empirical assessment of the Hellenic building stock, energy consumption, emissions and potential energy savings.* Journal Building and Environment vol.42,no3,pp.1298-1314, 2007

[9] Healy, J.D., "Housing conditions, energy efficiency, affordability and satisfaction with housing: a pan-European analysis". *Housing Studies* **18**, no. 3, pp. 409-424, 2003

[10] Koroneos C., Nanaki E. and Xydis G., "Solar Air Conditioning systems and their applicability- An exergy approach", Journal of Resources, Conservation and Recycling, Vol. 55, Issue 1, pp. 74-82

[11] L3851/2010 (OG A/85/4th June 2010) on "Accelerating the development of RES to deal with climate change and other regulations in topics under the authority of the Ministry of Environment, Energy and Climate Change", Ministry of Environment, Energy and Climate Change, 2010.

[12] Ministry of Environment Energy and Climate Change, MINENV, Submission of information under the Directive 2009/28/EC "National Renewable Energy Action Plan in the scope of Directive 2009/28/EC", 2010.

[13] NOA (National Observatory of Athens on CC impacts in Greece), Climatic changes in Mediterranean, 2001

[14] NOA (National Observatory of Athens Database accessed on February 2011): **http://www.meteo.noa.gr/ENG/iersd_climat-hydro.htm**