Sustainable energy production and consumption in Greece: A review

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Abstract: Electricity is considered to be one of the most important and vital goods. Each country should be energy independent and efficient in order to cope with its citizens needs and abstain political, economical and social after effects. Greek electrification initiated and evolved in a much slower pace than the rest of Europe. The foundation of the Public Power Cooperation S.A. (PPC) in 1950 was one of the most significant steps for essential, more organized and further growth of electrification. In this paper a thorough analysis of the Greek electrical energy sources, such as lignite, oil, natural gas, hydroelectric power and renewable energy sources is made and their percentage participation in electrical energy production is examined. After obtaining a broad picture of the current electrical energy production state in Greece, it is concluded that there is the need for the development of environmental friendly unexploited energy forms. Several measures towards that direction combined with Greek policy and objectives are demonstrated.

Key-Words: Production; Renewable Energy Sources (RES); Public Power Corporation S.A. (PPC); Policy.

1. Introduction

The advantages of electric energy against other forms of energy are: a) the instantly transformation into other energy forms, b) the easily transportation with small cost to large distances and c) the distribution in small as well as in big quantities.
In Greece, the electric energy is produced mainly from thermal and hydraulic energy. However, the constant ground fuel reserves reduction - mainly liquids - forces the electrical production to focus on the hydraulic energy, as well as on other energy forms, solar and wind energy, that are renewed and are permanently not exhausted.

The increased cost of energy production, the high and continuously rising price of fuels, especially oil, the European pressure for bigger release of Greek energy market and the threat upon Greek industries after 2013, when the new European Commission regulation for energy inefficient industries is placed in force - fine for each gram of dioxide of coal released in atmosphere, contrary to relatively small taxes that are in effect today - will lead to significant alterations considering the electrical energy production in Greece.

2. Historical energy retrospection of Greece

2.1 Period before the foundation of the Public Power Cooperation S.A. (PPC)

The first electric current production unit was manufactured in Athens, Greece in 1889. The same period in Thessalonica, which was then under Turkish control, a Belgian Company undertook the construction of an electric energy production factory for the purpose of city lighting. Ten years later, the American company Thomson–Houston, with the attendance of National Bank, founded the Greek Electric Company. In 1873 began the exploitation of Greek lignite layers in Aliberi, Evia. In 1922 the annual lignite production reached 23,000 tons and was maintained up to that level until 1927. Up to 1929, electric power was supplied to 250 cities with population over 5,000. Private individuals or Community undertook electrification for distant regions. In 1950, roughly, 400 electric energy production companies existed in Greece [1, 2]. The raw materials used for electric power production were oil and coal, both imported. Segmentation of electrical production in combination with imported fuels, pushed the price of electric current to heights. Electricity was considered as a luxury commodity and in most

cases, was provided by schedule and with unexpected breaks.

2.2 Foundation and operation of the Public Power Cooperation S.A. (PPC)

The Public Power Cooperation S.A. was founded in 1950. In 1951, the annual lignite production reached 750,000 tones and electric power, produced by its combustion, reached 230 MW. In 1955 LIPTOL Company was founded, with the purpose of Greek lignite's exploitation and utilization. In 1956 began the PPC's effort to repurchase all private and municipal electric energy production enterprises in order to create a united institution of power management. In 1959, 90 % of LIPTOL action was devolved to the Public Power Cooperation S.A. In 1975, LIPTOL and the PPC were incorporated. In 1959 the lignite production was 1,300,000 tons, in 1975 was 11,700,000 tons, in 1985 was 27,300,000 tons and in 2004 was 53,700,000 tons.

Today, PPC possesses, roughly, 89 % of installed electric power in Greece (12,695 MW) produced from lignite, hydroelectric, petrol units, units of natural gas as well as from wind and solar parks. Electric energy production from lignite reaches 50 %-58 % of total electric energy production in Greece (2nd bigger producer of electric energy from lignite in the European Union). The length of the national system of electric energy transportation is 11,650 km and the total length of the distribution network is 210,200 km [2].

3. Energy sources of Greece

Greece uses five important primary energy sources for electric energy production, which are lignite, natural gas, oil, hydroelectric, solar and wind renewable energy sources (RES). There are also potential sources (geothermal energy, biomass). The percentage with which each energy source contributes to final electricity consumption is shown in Fig. 1 [3].

4. Lignite

The electrification of Greece was based on lignite. Lignite is found in loads in the Greek subsoil. Greece possesses the second place of lignite production within the European Union and the sixth place worldwide. It is calculated that the existing quantities of lignite suffice for the next 45 years. Up to today, 1,300,000,000 tons of lignite have been extracted in total while the exploitable reserves are estimated to be 3,100,000,000 tons,

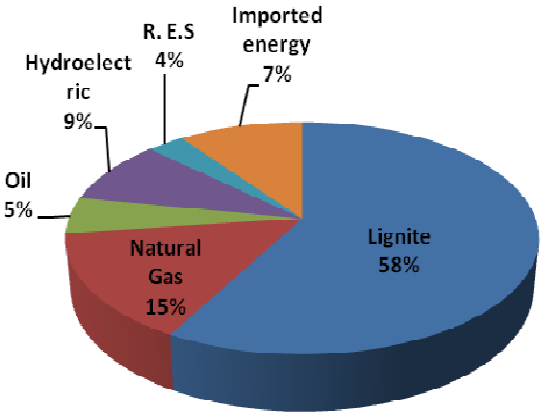

Fig.1 2008 electric energy production in Greece

equal to 450,000,000 tons of oil. Today there are 6 lignite electricity production units property of the Public Power Cooperation S.A. (PPC):
1. Ptolemaida unit, with 620 MW total installed power, 2. Megalopolis unit, with 850 MW total installed power, 3. Aminteo unit, with 600 MW total installed power, 4. Ag. Dimitrios unit in Kozani, with 1595 MW total installed power, 5. Kardia unit in Kozani with 1250 MW total installed power and 6. Florina unit, with 330 MW total installed power. The lignite units are accountable for the 3 5% of national CO_2 emissions in total.

The lignite is a fuel of strategic importance, due to its low excavation cost and stable price. The main exploitable layers of lignite exist in the regions of Ptolemaida, Aminteo and Florina with calculated reserves of 1,800,000 tons, in the region of Drama with reserves of 900,000,000 tons, in the region of Elassona with 170,000,000 tons, and in the region of Megalopolis with 240,000,000 tons. In the region Ptolemaida-Aminteo one of the biggest Lignite Centres in the world is created. In that region operate four lignite mines.

In general, the Greek lignite is of low quality. The Greek lignite's calorific value fluctuates between 900 and 1100 kcal/kg in the regions of Megalopolis, Aminteo and Drama, between 1250 and 1350 kcal/kg in the Ptolemaida region and between 1800 and 2300 kcal/kg in the Florina and Elassona regions. Important advantage of Greek lignite is its low content in sulphur [4].

5. Oil

The total quantity of oil used for electricity production in Greece is imported. Two types of oil

are mainly used for the production, the diesel and the crude oil. .After 1973 due to the "oil crisis" and the high price of oil, the contribution of oil in the annual electrical energy production started to decline. Though, in cases where the use of lignite is impossible or disadvantageous, the oil is still used as fuel. Such examples are the islands that are not connected to the PPC's distribution system. In such cases a fuel with high calorific value and easy transportation is required. Moreover, oil is used in thermal power plants that are located near Athens for the reason that the emissions of pollutants are less than those of the lignite. The oil used in Greece for electrical production is of two types: the crude oil 3500 REDW and Diesel.

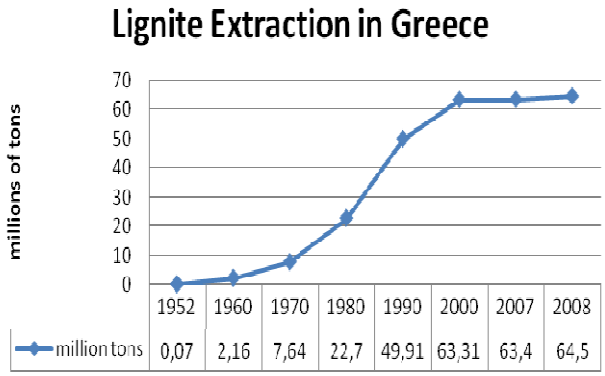

Fig.2 Modification of Greek lignite extraction.

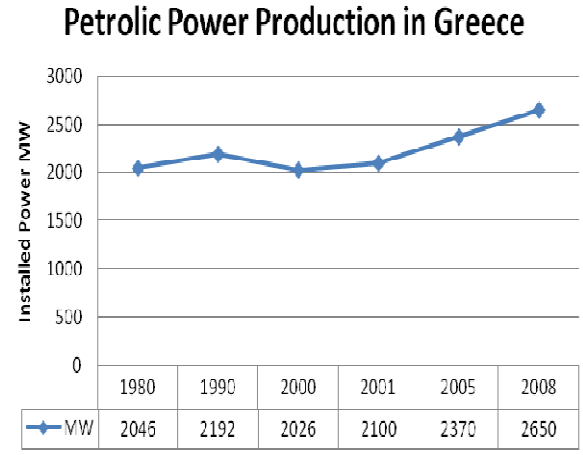

Fig.3 Annual modification of installed oil power production in Greece.

6. Natural Gas

Natural gas participates in Greek electricity production with a percentage of 15 %. The total quantity of natural gas used for electricity production in Greece is imported by three suppliers. Main supplier is Russia, which delivers to the Greek-Bulgarian borders 2,240,000,000 m^3 (with the possibility of expansion up to 2,800,000,000 m^3) of gas annually, covering 80 % of country's total requirements. Second supplier is Algeria, from which 500,000,000-700,000,000 m^3 of liquefied natural gas are transported to Rebithousa. Since 2007, Turkey is the third supplier, transporting annually, via the Greek-Turkish borders, 750,000,000 m^3 of natural gas. Since 2006, natural gas units of installed electrical power of 1980 MW, have been manufactured by the PPC.

7. Hydroelectric Plants

Greece is a mountainous country (over 80 %), with most of its mountains assembling in the north-western part, that is suitable for hydroelectric growth. Hydroelectric are called the plants that exploit the kinetic and dynamic energy of water. The Greek annual theoretical hydrodynamic energy is 80 TWh. The economically exploitable hydrodynamic energy reaches the level of 12 TWh of which, up to today, only the 40 % has been developed. The total installed power of hydroelectric plants is 3,060 MW and the average annual electrical energy production is roughly 5000 GWh. In Greece, the hydroelectric plants are property of the PPC, and are classified into four large scale units, two independent hydroelectric plants and to other small scale plants, which are the following: 1. Acheloos Unit: Kremasta, Kastraki, Stratos I and II, Gkiona and Glaykos with 925.6 MW total installed power, 2. Aliakmonas Unit: Polyfyto, Sfikia, Asomata, Makrochori, Agras, Edessaios, Vermio with 879.3 MW total installed power, 3. Arachthos Unit: Aoos Sources, Pournari I, Pournari II, Louros with 553.9 MW total installed power, 4 Nestos Unit: Thesaurous, Platanovris with 500 MW total installed power, 5. N. Plastiras Plant with 129.9 MW total installed power, 6. Ladonas Plant with 70 MW total installed power and 7. Remaining small scale hydroelectric plants: St. Ioannis in Serres, Agia, Almiros, with 1.3 MW total installed power.

The average annual hydroelectric power production, depending on the year's hydraulicity, covers 9 %-10 % of electricity production. Fig. 4 represents the Greek mainland electrical energy production and distribution system [5].

8. Renewable Energy Sources (RES)

In 2008, the percentage of electricity production from renewable sources was 4 % of the total Greek annual production. In September 2008, the sum of

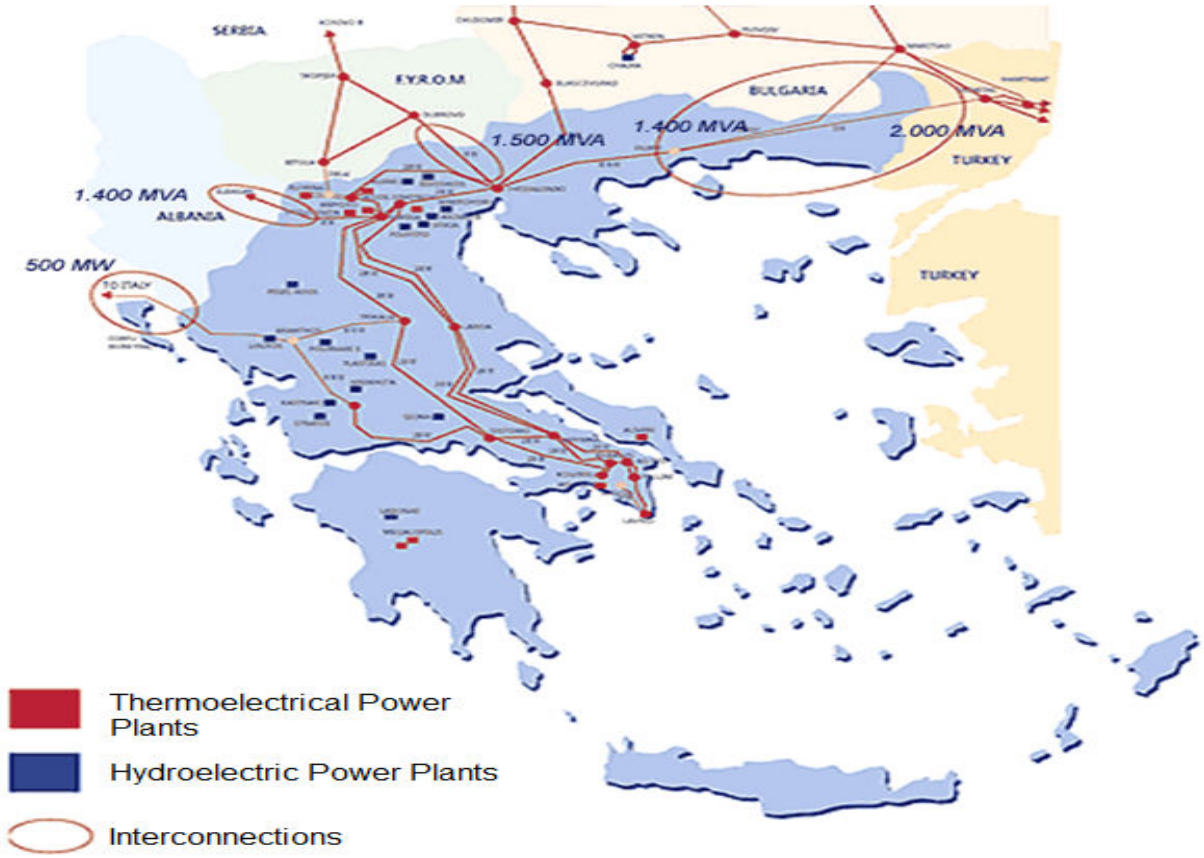

Fig. 4 Greek map representation of electric energy production and production units' interconnection.

installed electrical power coming from renewable sources was 1166 MW, of which 800 MW were interconnected with the national distribution system. The 83 % of power is produced from wind parks, 12.8 % from small hydroelectric stations and the rest 4 % from solar energy and biomass. **In** Greece, the production of electrical energy with RES is prohibited to exceed the amount of 30 % for remote areas, not connected with the national distribution system.

8.1 Aeolian- Wind energy

The level of Aeolian potential in Greece is the second highest in Europe, after Scotland. It is estimated that the exploitable Aeolian potential comes up to 6.46 TWh per year. In 2008, the installed power of Greek solar parks was up to 980 MW [6].

Regions with average annual wind speed more than 6 m/s are selected for wind parks installation [7]. The above limits are indicative and are altered due to the technology evolution and the market conditions. In Greece there are some big scale wind parks such as: the 30 MW wind park located in Cephalonia and belongs to Edf company and the wind park located in Panahaiko mountain with nominal electrical power generation to 35MW.

PPC plays a significant role in wind electrical energy production. Fig. 5 demonstrates the wind parks owned by PPC and their characteristics.

LOCATION	INSTALLED POWER [MW]
Kythnos	0.7
Limnos	1.1
Lesvos	1.8
Samos	2.9
Ikaria	0.4
Chios	3.5
Psara	2.0
Karpathos	0.3
Crete	19.8
Leros	8.4
Andros	1.8
Samothrace	0.2
Marmari	5.1
Lavrion	0.5
Skyros	0.1

Fig.5 PPC's wind parks and their characteristics.

Fig. 6 demonstrates the modification of total installed wind power in Greece over the last years.

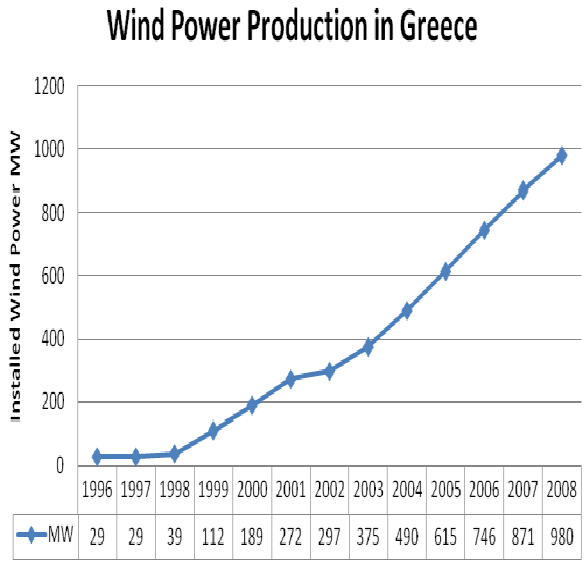

Fig.6 Annual modification of installed wind power production in Greece.

8.2 Photovoltaic - solar energy

Essential requirements for solar energy exploitation are increased sunlight duration and average annual solar energy more than 1.5 kW/m^2. Despite the fact that the Greek climate facilitates solar electrical energy production, due to the high percentage of sunlight all around the year, the installed power of solar electric units until 2008 is only 20 MW in total.

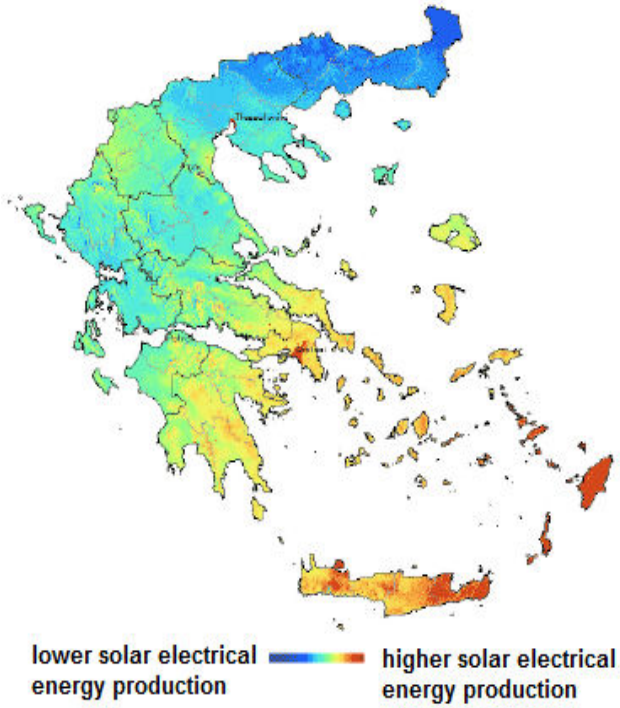

Fig.7 Sunlight intensity and duration distribution.

Fig. 7 demonstrates the ability of a photovoltaic system installed in Greece to produce electrical energy. Photovoltaic power units, owned by PPC are located mainly on islands and are the following: 1. Kithnos photovoltaic unit with 380 KW total installed power, 2. Arkii photovoltaic unit with 250 KW total installed power, 3. Antikithira photovoltaic unit with 30 KW total installed power, 4. Sifnos photovoltaic unit with 60 KW total installed power, 5. Gavdos photovoltaic unit with 10 KW total installed power [2].

Nowdays, the cost for a photovoltaic system is roughly around 5,500-6,000 Euros per KW.

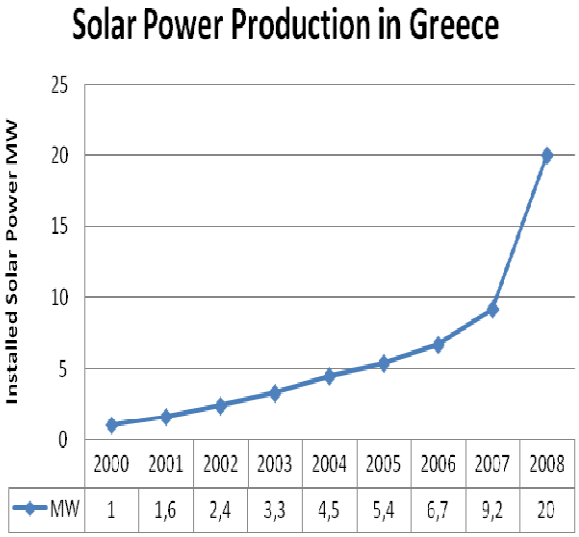

Fig. 8 Annual modification of installed photovoltaic-solar power production in Greece.

9. Environmental friendly energy sources in Greece with utilization prospective.

Beside the use of RES that are environmental friendly, there are several energy sources that their use is less cost effective and less pollutant than the classic ones. Their exploitation is either in an initial stage so that they do not contribute considerably in the electrical energy production or there are just exploitation schemes**.**

The Geothermal energy is a practically inexhaustible source, it is a clean form of energy, friendly to the environment, while it does not cause emissions of greenhouse gases, is available 365 days per year and its efficiency is more than 90 %. Depending on the temperature level, geothermal energy can have various uses. For the production of electrical energy, two categories of geothermal energy are utilizable, the category of High Enthalpy (> 150 °C) and the one of Medium Enthalpy (80 until 150 °C). Because of suitable

geological conditions, Greece allocates significant geothermal sources of all categories (high, medium and low enthalpy) in depths between 100-1500 m. In certain, cases the depths of geothermal tanks are so small, that makes geothermal exploitation particularly appealing in economical terms.

The research for geothermal energy began substantially in 1971 by the Institute of Geological and mineral research and up to 1979 involved only the regions of high enthalpy. The PPC's main interest was placed on the electricity generation and undertook the productive drillings for high enthalpy, financing the researches in potential such fluid geothermal regions. Since 1971 the following regions were inspected: Milos, Nisyros, Lesvos, Methana, Sousaki Korinthia, Kammena Vourla, Thermopyles, Aidipsos, Kimolos, Santorini, Kos, Southern Thessaly, Strimonas region, Xanthi region, Samothrace and other. The most significant ones are the following: 1. Mylos island, where measured temperatures rise up to 325 °C in depth of 1000 m. This drillings could support units of electricity generation of 20 MWe, while the potential power production is estimated at 200 MWe, 2. Nisyros island, where measured temperatures rise up to 325 °C in depth of 1500 m. This drillings could support units of electricity generation of 5 MWe, while the potential power production is estimated at 50 MWe. This means that the exploitation of Nisyros' geothermal field will create the center for "green" energy production in Dodekanese, since the produced electric energy is sustainable for the electrification of 7 non interconnected islands: Leros, Kalymnos, Kos, Pserimos, Gialos and Tilos.

The PPC received from the Ministry of Development in 2003, the authorization for electrical power of 8 MW production in Lesvos' geothermal field. The aim is to cover the island's basic load. In December 2007, a Memorandum of Collaboration between the PPC and "S&B Industrial Mining" was signed aiming to the joint research, management and exploitation of the geothermal field of Milos–Kimolos islander cluster.

10. Measures for environmental protection during Electrical Energy Production.

There are several measures that should be implemented in order to improve the environmental as well as the residential quality at the facilities close to electrical plants and mines. These are: a) the filters at the electrical plants should be replaced with contemporary ones, in order to reduce the pollutants emission, b) the mines and plants environmental space should be restored, c) implementation of biological cleaning, d) utilization of the ash, which is product of lignite exploitation. There is the possibility to transform ash into cement and inactive materials for road construction, d) exploitation of geothermal energy and e) minimization of building's thermal losses through specifically studied insulation methods.

11. Greek energy policies and objectives.

One of the most important stated political views is the exclusion of nuclear energy at least up to 2020. Since 1994, a change in the legislative frame and improvement of motivation for energy production from RES takes place. Due to the subsidy at 30-40 % in the stage of manufacture, the absorption of produced electric energy as a matter of priority from the Hellenic Transmission System Operator S.A. (HTSO), combined with the lucrative sale prices, the RES market began to present high economic efficiency- more than 15 % including taxes [8]. All the above made RES investments very attractive and more private electroproductive companies started to take their place in market. Though there are still several problems as the decision of the Ministry of Environment Planning and Public Works in May 2009 of excluding the use of RES in areas of sheer residence and at the traditional settlements and moreover, in suspension remains the program of photovoltaic roof installation [9].

Under the recent European Committee direction 2009/28, Greek market has undertaken the binding objectives of 20 % of RES infiltration, 20 % of energy saving and 20 % of emitted pollutants restriction by the year 2020. The interpretation is that the objective for the RES electric energy production should reach roughly the amount of 33 %. According to Council of National Energy Strategy estimations, in 2020 the production of electric energy sources should contribute to the interconnected system the amount of electrical power of 21,500 MW on account to 12,000 MW that is today and should provide annually the amount of energy of 81,000 GWhe opposite to 56,000 GWhe [10].

12. Conclusions

Greece's electrification initiated later and with a slower rate of growth in comparison to the rest of the European countries. The main Electricity production is based upon lignite, a fuel that is

extracted from the Greek subsoil. Today, the lignite electrical energy production reaches 53 %. Greece is still energy dependent from other countries, either in the form of energy sources importation such as oil and natural gas or in the form of imported electrical energy. This dependency reaches roughly 27 % of the annual electrical energy production leading to economic as well as political after-effects. Greece could be energy independent, as there is an excess of renewable energy sources (solar, wind, hydrodynamic, etc.) Hardly 10 % of the consumed electric energy emanates from renewable energy sources (RES), due to deficient exploitation. The estimates of the Council of National Energy Strategy is that up to 2020, the electrical power production in Greece will change dramatically due to several reasons as the release of Greek energy market and Greece's objectives placed by the EU which are the infiltration of RES in energy production up to 20 %, energy saving up to 20 % and restriction of emitted pollutants up to 20 %.

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