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Environmental impacts of the Greek electricity generation sector

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ABSTRACT

Anthropogenic activities, such as the use of fossil energy sources for electricity generation, are the main contributors to the pollution of the environment. The main energy source used in the Greek electricity generation sector is lignite as there are large reserves in the country. Petroleum is also used at a great extent mainly in the islands in the autonomous power generation systems, while the use of natural gas is also increasing. Although lignite is a "cheap" energy source, the environmental impacts associated with its use are high, something that applies also for petroleum and in a lower extent with natural gas. The total net production of electricity from thermal power plants in Greece accounts for almost 90% of the total electricity production, while only 10% derives from hydroelectric energy and other renewable energy sources (RES). A typical example of the significance of the environmental impacts associated with the electricity generation sector is the fact that almost 74% of the total CO_2 emissions in the country derive from this sector. The work presented in this paper is focused in investigating the environmental impacts associated with the atmospheric emissions and other wastes that are produced during the life cycle of the energy sources (fossil and RES) used for electricity generation in Greece. The environmental evaluation of the different energy sources is performed through the life cycle analysis methodology and the Eco-indicator 99 method and the results are used for comparison purposes.

Introduction

Energy has significant effects in the evolution of economy and technology. Electricity was the major actor during the transition from the industrial to the technological revolution, almost all the financial and economic activities depend directly on it and any development coincides with an increasing demand of electric energy. Electricity, a conversion product of other energy forms, highlights the importance of primary energy. An "energy system" can be defined as the connection, a physical way, of the facilities of energy generation/conversion, to a certain form (e.g. electricity, heat), the storage facilities, the transmission facilities and the distribution facilities, that operate as a complete system. The need for electricity is met worldwide mainly from the exploitation of fossil/conventional energy sources, i.e. coal/lignite, natural gas and petroleum in a percentage of about 80% [1]. During the last years, the use of renewable energy sources (RES), cleaner fuels and more effective technologies (e.g. cogeneration) for electricity generation is increasing, mainly due the depletion of fossil fuels reserves, geopolitical reasons and the environmental pollution [2]. It seems that the increasing demand for electric energy is connected with previously mentioned determining factors of the future of fossil fuels. Thus, the necessity for changes in energy policy and planning and in the design of power generation systems is highlighted.

Despite the obvious benefits, the irrational exploitation and use of energy sources brings to surface many problems. The environmental pollution caused by anthropogenic activities has caused many serious environmental problems, such as the global climate change, ozone layer depletion and acidification. A typical example of the environmental impacts caused is the increase of the global mean temperature by 0,6 °C since the end of the 19th century, while there are explicit evidences of an apparent climate change in the current century (the estimated increase of the global mean temperature will be in the range of 1,4 and 5,8 °C). According to the Intergovernmental Panel on Climate Change (IPPC) this change derives from the concentration increase of the greenhouse gases in the higher atmosphere layers [3]. Greenhouse gases emissions, as well as other pollutants, have mainly anthropogenic origin. Especially, emission of CO_2 derives at its greatest extent from the exploitation, production and use of fossil fuels, e.g. for electricity generation and in the transports sector. At the same time deforestation in a global level results in the decrease of CO_2 fixation capability through the photosynthesis process and therefore in the increase of CO_2 concentration in the atmosphere [3].

In this work, the environmental pollution that derives from the use/exploitation of different energy sources, either fossil/conventional (e.g. lignite, petroleum and natural gas) or renewable (e.g. wind, hydro, etc.) in the Greek electricity generation sector, is

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examined. Words, such as "use/exploitation" do not refer only to the "combustion" of fossil energy sources or the "exploitation" of RES. Analysis of the energy sources is not restricted only in the operation stage of the electricity generation facilities (using fossil energy sources or RES), but a life cycle or "cradle-to-grave" approach is implemented. Therefore, the different life cycle stages of the energy sources used in electricity generation are examined. Fig. 1 presents a general diagram of the life cycle stages.

The life cycle approach for the environmental assessment of the energy sources used in electricity generation is implemented through the life cycle analysis (LCA) methodology. LCA has been used in the past mainly in studies of environmental assessment of products for the improvement of their design. It has started progressively to find application in the field of electricity generation, and it is suitable to be used for the environmental assessment of the life cycle of different energy sources and technologies used for electricity generation as well as for the environmental assessment of energy systems in general [4–13]. Most of research efforts related to the environmental assessment in the field of electricity generation are restricted in the operation stage of the power plants and in the creation of an inventory of inputs and outputs (mass, energy and emissions) [14,15]. In other words, in many cases these inputs and outputs are not associated with the environmental impacts of the final product in order to create a total environmental performance score or index. However, association of inputs and outputs of the inventory phase of the total life cycle with the environmental impacts can be done through suitable factors like the ones proposed in Eco-indicator 99 method [16–18]. This method is a reliable and practical tool in identifying the areas where the most improvements need to be made [19]. Using the life cycle approach, i.e. examining the complete life cycle of an energy source/energy system, ensures that all inputs and outputs of all the stages of a system are examined and included in the analysis. Moreover, the results are more realistic and comprehensive and it is easier to identify which stages of the life cycle contribute more to the total environmental performance and to the individual impacts and damage categories. A complete description of the LCA methodology can be found in SETAC's and ISO's guidelines [20,21] and for the Eco-indicator 99 method in PRe's manual [16–18].

Greek electricity generation sector overview

The significant contribution of the Greek electricity generation sector in the problem of the environmental pollution is shown characteristically in Fig. 2, where the total evolution of the greenhouse gases is presented for different Greek energy sectors. In order to enhance understanding of the burdens that are being placed on the environment from the use of fossil fuels for power production, many studies and efforts are based on environmental evaluation tools, such as LCA [20,21]. In the context of these tools, many useful conclusions can be made concerning the use of alternative fuels or RES, in order to minimize the environmental impacts imposed by the high use of fossil energy sources.

In more detail, electricity generation, distribution and sale, has been mainly appointed to Public Power Corporation of Greece (PPC), a government owned enterprise. Only insignificant amounts of electricity are produced by others or are imported (2%, used mainly by industries that produce it and sell the excess amount to PPC). Following the energy crisis of the '70s, and after the establishment of new policies, an effort was made towards the decrease of energy dependence from oil, so efforts were made towards other energy sources exploitation. Therefore, the fossil fuel that is used mainly for power production in Greece is lignite, accounting for

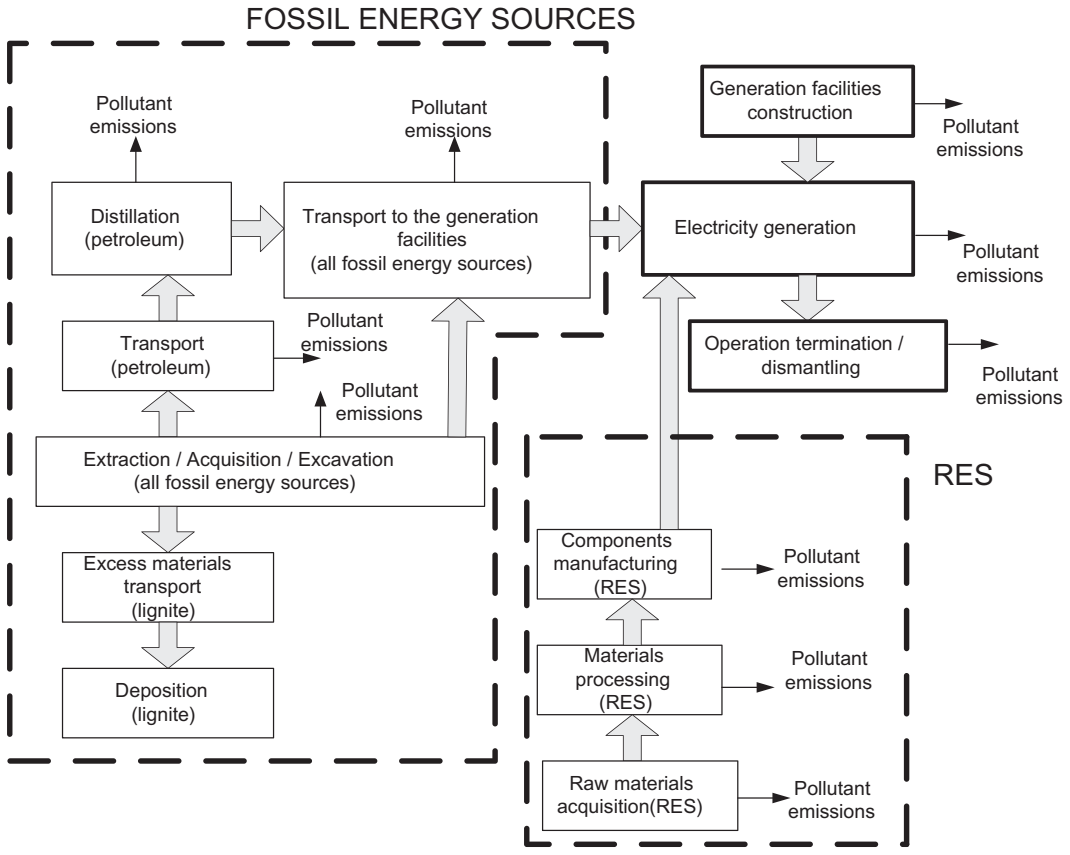

Fig. 1. General diagram of the life cycles stages of the energy sources (fossil/conventional and RES) used in the Greek electricity generation sector.