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ENERGY RESOURCES OF GREECE: FACTS AND MYTHS

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Abstract

Energy is essential for human life and civilization being extremely crucial for the continuation of human development. The main concern worldwide is to meet rising demand for energy in a sustainable way and at reasonable cost. Greece has significant lignite and some uranium reserves and remarkable potentials in renewable sources. However, the primary energy mix used in the country today is based on lignite and imported oil and gas, the latter increasing country's dependency on foreign suppliers, while renewable sources play a minor role. The public opinion is misinformed and sometimes confused in respect of some aspects concerning energy issues. This strongly influences important decisions on energy projects and in overall, the energy policy of the country.

Key words: *energy sources, greenhouse gas emissions, Greece, primary energy.*

1. Introduction

Energy is essential for human society and civilization; it is one of the fundamental prerequisites to achieve economic growth, social and cultural development, which by turn are improving our standard of living.

Before the industrial revolution, the energy demands were modest. Man relied on the sun and the biomass for heat, on animal muscles and the wind power for transportation, on own and animal muscles as well as on wind and water power for labour tasks. Over time the energy demands of the mankind were continuously rising. It is estimated that *homo hunter* needed 20 MJ per day, *homo agricola* 40 MJ and *homo industrialis* 175 MJ (Bell, 1995). In 1800 by a global population of around 1 billion, the annual energy use per capita did not exceed some 20 GJ on average. Some 200 years later, the global population has risen by a factor higher than 6, while the per capita annual energy consumption is estimated to have risen by a factor of 20 (Grübler, 2004).

The increase of the world population, the technological and industrial development and the life modernization resulted in the rapid increase of energy demand globally. Among the mineral resources exploited annually worldwide, fossil fuels posses the first places in terms of quantity and economic significance (Fig. 1). Energy became obviously the backbone of every national economy and today the security of energy supply is among the first priorities for all the national governments. The access to reliable energy sources at reasonable cost and the environment-friendly energy generation are essential for future economic growth and the prosperity of the society. The global energy needs are covered to more than 80% by fossil fuels, namely oil, gas and coal, whereas nuclear power and renewable sources contribute to only 6.5% and 13.5%, respectively (Fig. 2a).

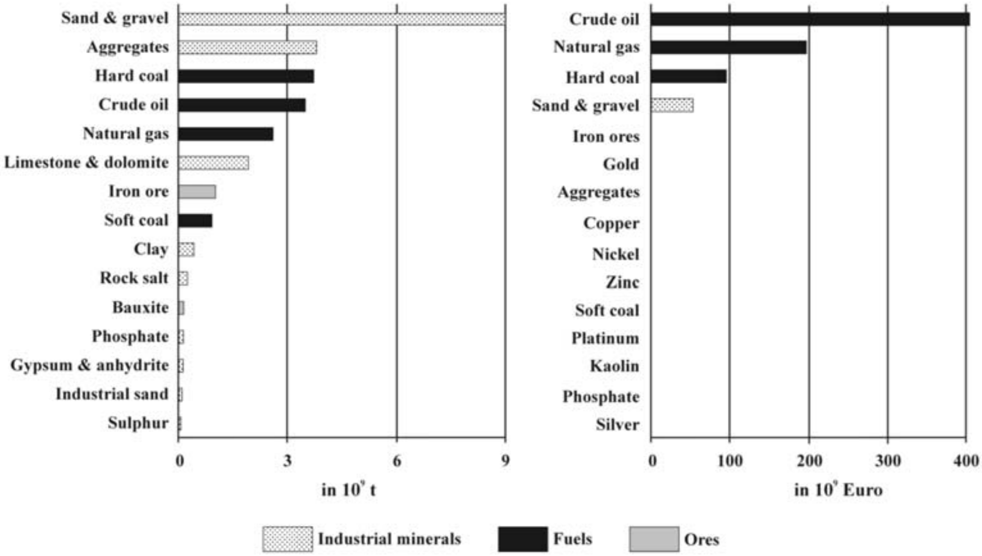

Fig. 1: The top-15 mineral resources globally produced in 2002 ranked by quantity (left) and value (right) (after Lüttig, 2007).

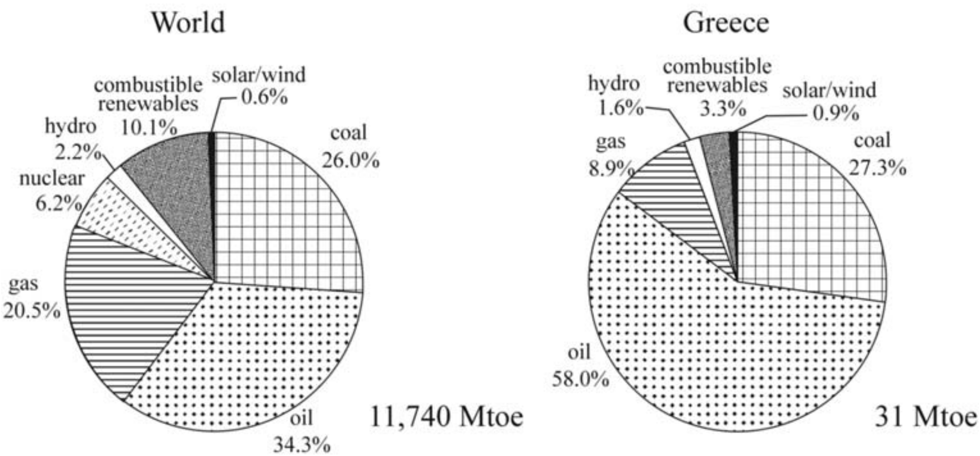

Fig. 2: Share of primary energy production in 2006 in the world (left) and in Greece (right) (IEA, 2008).

2. The primary energy status of Greece

In 2006 Greece relied on energy imports by 72%, being well above the EU average of 54% (EUROSTAT, 2009). The primary energy mix of the country is based to $^2/_3$ on hydrocarbons (IEA, 2008). Coal is a domestic fuel used mainly for electric power generation, while the renewable energy sources cover <6% of the demand (Fig. 2b). Greece does not own nuclear power plants.

2.1 Oil

The crude oil reserves of Greece are estimated to amount some 10 Mbbl (EIA, 2009). Promising oilbearing areas might exist. Crude oil resources in Western Greece and the North-Aegean Sea are speculated but further exploration is necessary. The domestic production from Prinos, Northern Greece, amounts c. 1,000 bbl/d, which cover only c. 0.2% of the daily consumption (432,000 bbl). Thus, Greece strongly depends on oil imports, mainly from Iran, Saudi Arabia, Russia, Libya, Egypt and Kazakhstan, with Russia and the Black Sea countries becoming more important after finishing the construction of the Burgas-Alexandroupolis pipeline. Although the demand for oil has increased in the last years, its percentage contribution to total primary energy production is gradually decreasing due to the rising introduction of natural gas (IEA, 2008).

2.2 Natural Gas

With reserves of only 70 Gcf (EIA, 2009), Greece does not produce natural gas. Consumption, however, has increased significantly and this trend is expected to continue and possibly tripling over the next ten years. Despite the recent strong demand growth, the share of natural gas in total energy consumption is still small, reaching 8.9% in 2006 (Fig. 2b). Greece imports c. $^2/_3$ of its natural gas demands from Russia and the remaining $^1/_3$ from Algeria as LNG.

2.3 Coal

Greece relies heavily on domestic lignite reserves amounting 4.3 Gt. Around 63.6% of the exploitable reserves are hosted in the tectonic trench of Western Macedonia (Florina, Amyntaeo, Ptolemais, Kozani), 28.8% in Eastern Macedonia (Drama), Northern Greece, and 7.6% in Megalopolis Basin, on Peloponnese (Kavouridis, 2008). Several lignite deposits are distributed over the country but there are no plans for exploitation. The main production areas are these of Western Macedonia and Megalopolis. With an annual lignite production exceeding 70 Mt in 2006, Greece is the second largest European lignite exploiter after Germany.

The country does not own hard coal reserves; small amounts, c. 0.5 Mt of bituminous coal, are yearly imported from South Africa, Russia, Venezuela, and Colombia (EIA, 2009).

2.4 Nuclear energy

Uranium reserves are known in the areas of Drama and Xanthi, at the North-East part of the country. The reserves could support a nuclear power plant but after a political decision in early 1980's, nuclear energy is not a priority.

2.5 Renewable sources

Due to the geographic position and the geomorphologic conditions, Greece has high solar and wind potentials. Annual solar radiation ranges between 120 kWh/m^2 in the northern part to 150 kWh/m^2 in the southern part (Tsilingiridis and Martinopoulos, 2010) and the average wind energy flux is in excess of 600 W/m^2 per year at 10 m height (Lalas et al., 1983). Both parameters are sufficient to supply large-scale power generation units, which can substitute to a high extent fossil fuel power plants being responsible for 50% CO_2, 80% SO_2 and 33% NO_x of the domestic release (Kaldellis et al., 2008). This could be very well applicable in the case of small-scale industries, as well as in isolated areas like the islands. Wind farms are already installed on the Greek islands of Crete, Evia, Andros, and Samos, whereas Naxos possesses also a high wind potential for large scale-electricity generation (Fyrippis et al., 2010).

Another renewable resource of Greece is geothermal energy. Due to recent volcanism, geothermal fields are located throughout the country; Santorini, Milos and Nissyros Islands are the most promising high-enthalpy fields for electricity generation. Unfortunately, trials to install a 2-MW geothermal power plant on Milos Island failed in late 1980's (Delliou, 1990), and hence geothermal energy did not recover since, mainly due to social and political reasons.

Hydropower is responsible in a positive way to whatever progress Greece had achieved after World War II. The construction of large dams coupled with hydro-power plants during the 1950's and the 1960's provided electricity to major industries at that time like the aluminium industry and revived the countryside population, especially in the indigent Western Greece. Most of the dams are built along major rivers, especially in Western Greece, where the annual rainfall and water reserves are relatively abundant.

The biomass potential is also significant due to the high agricultural production, which yields high amounts of wastes; recent studies show that the climate is suitable for the cultivation of several plants suitable for bio-fuel production (Tuck et al., 2006).

3. Facts and Myths

After the first oil crisis in 1973, the public awareness on the limitation and the depletion of the fossil-fuel reserves begun to increase steadily. Simultaneously, the environmental aspects of all human activities, particularly the energy generation, attracted increasingly attention. The interrelationship among energy supply and security, economic prosperity and environmental impacts became a favourable topic of the daily discussions in the developed countries. Scientists from irrelevant disciplines, ecologists considering selective data sets only, politicians following advisors with minor knowledge, speculating media, companies with variable interests, lay persons, all following sometimes paths beyond any logic, did and do judgements and statements on related topics resulting in the disinformation of the public opinion and confusing the people. This results in the lack of social concurrence, which is a prerequisite for the implementation of certain energy projects.

The present paper aims to clarify some aspects of the Greek energy sector that are presented to the publicity in a subjective way causing misinterpretations.

3.1 Oil

Although oil combustion is a significant CO_2 emitter, a surprising low publicity is given to this. In fact, oil is emitting only around 20% less CO_2 than coal for the same power generated. In the transport section, however, oil and its derivatives are exclusively used contributing significantly to the greenhouse gas (GHG) emissions. Oil is the main fuel consumed in Greece (58%; see Fig. 2b). According to EUROSTAT (2007) the GHG emissions from transportation sector in Greece reached c. 18% of the total GHG emissions being second after the power generation sector (45%). Additionally, the increased rate of GHG emissions from transport is higher than the respective from power generation during the last decade indicating the increasing environmental impact from oil combustion and vehicle emissions. All these, along with some other activities, requiring oil combustion like building heating systems and private, small-scale power generators particularly used in the agricultural and stock-farming sector, prove that although oil is environmentally friendlier than coal, in terms of absolute values it is also a major greenhouse gas source.

Apart from environmental issues oil is not a domestic energy source meaning that its use requires import from and hence, dependency on other countries. This, in turn, has a direct impact on both the economy and the policy of Greece.

3.2 Natural Gas

The introduction of natural gas into the Greek energy market was advertised in the 1990's as a clean and environmental friendly source. Over the last decade the natural gas contribution to Greece's gross energy generation has increased by an amazing 7,500% (!).

Natural gas consists of methane, which by burning is oxidised to CO_2. Of course, the amount of CO_2 emitted by gas combustion is c. 50% lower than this emitted by oil combustion for the same energy output (IEA, 2009a). In this sense, the truth is that natural gas is, indeed, cleaner and friendlier than oil and coal but not at all 'clean and environmental friendly'. Indisputably natural gas is the least emitting fossil fuel; however, the extraordinary increase in its use over the last years yields considerable amounts of CO_2 released in the atmosphere.

On the other hand, the reliability of the natural gas supply was hardly tested at the time of the conflicts between Russia and Ukraine, particularly in January 2009. The dependence on Russia but also on the countries the pipeline is coming through is a fact. Thus, a major part of Greece's energy sources relies not only upon typical trade rules like price bargain but also on geopolitical scenarios and foreign affairs.

3.3 Coal

Coal is considered the 'dirtiest' fuel contributing significantly to the greenhouse effect, thus being blamed for climatic change.

The fact is that coal combustion really emits huge amounts of CO_2, more than every other fossil fuel used for power generation. CO_2 emitted from hard coal and lignite combustion is c. 1.3 and 1.45 times, respectively, the amount released by oil combustion for the same energy output (IEA, 2009a). Over the last decades it has been told that the human CO_2 footprint, mainly due to coal combustion, causes global warming, which results in melting of polar caps, threatens life on our planet and implies huge social, political and economic impacts. The fact is that fossil-fuel based power generation contributes significantly to the increase of the CO_2 concentration in the atmosphere with coal combustion being the 'champion' followed by oil and gas. Climate change, a more careful expression of global warming transferred to the Greek media as 'over warming', is based on speculative projections.

Additional coal combustion by-products are also SO_2, NO_x, fly ash and volatile trace elements (some of them being hazardous pollutants), which however, do not attract significant attention and remain out of publicity. There are only two thermal power plants (TPPs), these of Meliti and Megalopolis B, which are equipped with desulphurisation plants for SO_2 removal, whereas measures to reduce NO_x, like the installation of fluidised-bed combustion units, have not been adopted in Greece.

Clean Coal Technologies (CCTs) such as Carbon Capture and Storage (CCS), coal gasification and coal liquefaction, provide workable solutions to these problems. However, the electricity cost will be rise as the existing coal-fired power plants cannot easily adapt to the CCTs. On the other hand, investing in the optimization of a domestic power supply will prove for the benefit of the medium and long-term efficiency of both our economy and environment.

In the last years there are suggestions to import hard coal for feeding new coal-fired TPPs. The supply and economic dependence on imports from other countries and the small improvement in the CO_2 emissions do not offer a rigid solution to the energy supply of the country.

3.4 Nuclear power

There are several pro and contra arguments concerning the installation of nuclear fission power plants in Greece.

Nuclear power generation can perhaps be regarded as clean since it has zero emissions. This is true under conditions of safe operation, and without considering the radioactive wastes. However, the accidents at Three Mile Island and Chernobyl, as well as dozens of others with smaller impacts, showed that every human construction, even the safest one, as a nuclear fission power plant, has weak points and a finite duration of life. Therefore, even if there is a very small risk of an accident in a nuclear power plant, in case it happens the damage will be enormous on both population and environment and it will also have long term effects on living organisms.

Greece is characterised by intense seismic activity, which might damage a nuclear power plant with enormous environmental impacts. Nevertheless, seismicity cannot be regarded as a severe threat since countries with essentially higher seismicity, e.g. Japan, successfully apply nuclear power generation already since several decades.

Greece owns domestic uranium reserves capable to support the operation of a 1000-MW nuclear power plant. This is partly true. It is economically not feasible though to operate plants for preparing the fuel rods as well as for re-processing the used fuel rods. This means that the uranium from the Greek deposits should be locally processed to produce the yellow cake, which should be transported abroad, and later the fuel rods should return back to Greece. After the fission in the reactor the used fuel rods have to be sent abroad to a re-treatment plant in order to remove useful elements such as U and Pu, and to isolate the high radioactive substances. All these will increase Greece's dependence on several foreign countries.

Finally, the problems of the final deposition of the radioactive wastes and of the decommissioning and final deposition of the reactor by the end of its life cycle still remain unsolved.

3.5 Renewable sources

Wind and solar potential could substitute a large part of the fossil fuels resulting in a reduction of GHG emissions and a decrease of oil and natural gas dependencies with positive effects on both environment and economy. However, in several cases the geomorphologic conditions of the country impose technical complications in terms of bringing wind and solar power to the grid, as the optimal locations for power generation are in remote areas away from the grid (EUROSTAT, 2009). Of course, the operation of solar and wind units are emission-free with negligible environmental impacts since they do not involve fuel combustion. Despite all these, however, one should see beyond this deceivable inference. Modern technology for the conversion of wind and solar energy to electricity requires the use of special composite compounds, which in turn require the use of expensive raw materials. Although the cost of photovoltaics has fallen during the last decades, it still is 4-6 times higher than the cost of power generation from fossil fuels (Şen, 2004). It is estimated that the photovoltaic modules in a solar power plant account for 50% of the total cost, whereas their efficiency reaches only 10% and the manufacturing of the cells requires primary energy (Afgan and Carvalho, 2002). Moreover, the efficiency of wind and solar systems is relatively low demanding the occupation of vast areas in order to cover the energy needs of a large number of consumers. Thus, the installation of large-scale facilities might be not feasible causing a severe alteration on the landscape, being a weak point, which won broad publicity and caused protests against such installations in several cases. The availability of these systems is also restricted depending strongly on the meteorological conditions; in days of inability to generate power, the demand has to be covered by other primary energy sources. Overall the major disadvantage that renders wind and solar energy inappropriate for massive application is the inability of storage. Electricity must be consumed whenever it is available or – in other words – demand determines the power generation. Thus, despite the fact that solar and wind energy utilization neither produces GHG nor volatile and toxic compounds, they are not absolutely innocent from environmental point of view as they have been advertised and are also still expensive energy sources compared to the conventional fuels.

Geothermal energy is included in the renewable energy sources, although each geothermal reservoir hosts finite heat reserves. It could significantly contribute to the energy budget of the country. Most of the geothermal fields are of low enthalpy (e.g. Northern Greece) not proper for electricity generation; however, they could very well be exploited for heating purposes contributing to the reduction of oil use and thus, having benefits for both national economy and environment. However, due to inappropriate management of the high-enthalpy geothermal field on Milos Island in the 1980's (Delliou, 1990) this energy source is heavily defamed and the public opinion is negative towards the exploitation of geothermal energy for power generation. Apart from small- or pilot-scale private initiatives the large geothermal potential remains unexploited.

The hydroelectric power plants are always a reliable solution, particularly during periods of high energy demand as in the summer. The water reservoirs of the dams in Greece are also used for irrigation of the adjacent cultivated fields. As the demand for irrigation during summer is also high, both uses for irrigation and power generation are sometimes in conflict. As agriculture has a social advantage, hydropower is far from optimal exploitation. Moreover, the construction of large-size dams bind huge water reserves lowering the water table in the downwards areas and at ecologically sensitive places such as the river deltas. The retention of sedimentary load by the dam seriously affects river mouths or estuaries and the concomitant shoreline (erosion). The construction of new small-scale dams or the modification of the already existing ones could be a feasible solution of all these problems. Although, it has to be kept in mind that hydroelectric energy relies strongly to the climatic conditions, meaning that prolonged dry seasons would minimize any usage of this source.

Although biomass is one of the first energy sources used by humankind, nowadays it is considered not obsolete but promising and environmental friendly. This is due to the fact that it is regarded cleaner and cheaper than fossil fuels. This statement however, is not accurate enough as biomass is a very broad term including various and heterogeneous materials mostly derived from living plants and animals. Having this in mind one cannot argue for or against it as a unique group and compare it to the well-defined and tight group of fossil fuels. Simple burning of biomass for power generation is inefficient, as heat losses are high resulting to the combustion of large amounts in order to obtain the requested energy. Biomass could be economically feasible only in terms of secondary production, i.e. the production of liquid and gas fuels through pyrolysis or of ethanol-based fuels (bio-fuels) through fermentation. The worldwide leading country in this direction is Brazil, which has substituted oil and its derivatives with bio-diesel to a high extent. However, the massive biomass production requires the binding of extended areas (energy farms) either cultivated for crops or forested. This results in either the rise of the crop prices or the diminishing of forestland, respectively. Thus, steps towards biomass production in energy farms require long-term careful planning to reduce the above mentioned impacts.

3.6 Other energy-related aspects

Some further general aspects related to energy and the confused public opinion, are to mention here:

(a) Hydrogen technology: Fuel cell technology offers an alternative to substitute conventional engines, as they convert the energy derived from an oxidized fuel to electricity and water. Several types of fuels are used or tested but the most common is hydrogen with oxygen playing the role of the oxidant. The major disadvantage is still the very high cost of fuel cells, which is unmatchable by the conventional fuels despite the significant decrease being achieved during the last decade (Boudghene-Stambouli and Traversa, 2002). Should their cost become competitive to other energy sources, they could constitute a powerful solution to the GHG emissions, although the disposal of the used cells made from precious but toxic metals (platinum, palladium) would also be an issue of environmental concern. Of course, hydrogen is beyond the frame of the present paper dealing with primary energy sources only. Furthermore, the hydrogen production has to be also considered in the calculation of the efficiency and the emissions of the entire system.

(b) Economic measures to reduce emissions: Carbon tax, a 'green' tax on carbon dioxide emissions, and emission trading, an administrative tool applied since 2005 within EU, are measures aiming to reduce emissions of CO_2 mainly from power generation and other energy-intensive industries like the production cement, iron and steel, glass, ceramics, and the manufacture of vehicles (EU-ETS, 2009). Both measures aim also to increase the competitiveness of the renewable energy sources. They result in an increase of the energy cost, and beyond any positive or negative criticism on the administrative application of these measures, studies reveal that poor consumers spend a greater proportion of their income on energy-intensive goods and fuel, i.e. higher energy cost tends to affect more the poor than the rich people (Neuhoff, 2008).

(c) Carbon dioxide vs climate change: The perspective of Earth's climate change due to fossil fuel combustion accounting for c. 80% of the global GHG emissions (Omer, 2008), dominates in the public opinion today. Every environmentalist and every sensitive citizen on this planet is aware of this as it is stated in the daily discussions, the media, and the policies over and over again. However, Earth's climate was changing significantly and sometimes rapidly in the past before man begun combusting fossil fuels. Earth's climate system is complex and the scientific knowledge about all climatic functions is still poor; thus, science is not at a level to give definite and precise answers for the causes of global warming (Florides and Christodoulides, 2009). Human-induced global warming is an unproven hypothesis derived from speculative projections inside computer programs (Plimer, 2009).

4. Conclusion

The greatest challenge of our society today regarding the energy sector is how to meet rising demand for energy in a sustainable way and at reasonable cost. Greece is facing, of course, the same challenge; the country has significant lignite and some uranium reserves and remarkable wind, solar, hydropower and geothermal potentials. However, the primary energy mix used in the country is based on lignite and imported oil and gas. Renewable energy sources play currently a minor role (<6%). The latter resources are capable to increase their contribution, if the cost of energy generation will become more competitive in comparison to this from fossil fuels; and in fact due to environmental taxation the fossil fuel prices are in an increasing mode.

In many energy aspects policy plays a dominant role. Politicians, environmentalists, journalists, sometimes also scientific groups representing different positions, create confusion in the public opinion. Over-sensationalism leads sometimes to fear without any reason. On the other hand, science offers solutions if facts and figures are examined carefully on a pure scientific basis.

Energy independency should be a key factor for the decisions of the Greek State in order to consolidate a viable economy along with sustainability. We haven't yet exploited the potentialities of the domestic resources, even in a moderate satisfactory level. Coal reserves are utilized without the mobilization of all the elements that could add value to optimize the benefits, both economic and environmental. Clean coal technologies along with more efficient mining and processing techniques could improve the exploitation of our domestic resources. Geothermal fields are not even part of the discussion, whereas other countries without any high-enthalpy fields are investing significant amounts in hot-rock systems. Oil and coal exploration in Greece are highly 'flammable" topics.

There is a need for a wider cooperation between government, local communities, NGO, academic and research bodies and industries under Research and Technology Initiatives, which will enable us to develop a sustainable energy strategy for short, medium and long-term planning. The challenge for the modern Geoscientists lies exactly there; to provide viable and sustainable solutions to the "Energy Issue".

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