

Energy Mineral Resources of Greece

Ananias Tsirambides and Anestis Filippidis

Department of Mineralogy-Petrology-Economic Geology, School of Geology, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece

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Abstract: Greece, in relation to many other countries of similar size, is very advantageous for the mineral wealth it possesses. Great variety, mostly industrial and metallic minerals, and energy mineral raw materials such as lignite, are in its subsoil. The probable and proven reserves of most of the mineral resources of Greece are unknown, as detailed investigations (e.g., drillings, measurements, analyses, etc.) are lacking. In our assessment the total value of the reserves is about €1.5 trillion and is four times its total debt (€360 billion). The total value of the indicated reserves of the Industrial Minerals & Rocks is €60 billion. The total value of the indicated reserves of the Metallic Minerals is €72 billion. The total value of the indicated reserves of the Energy Mineral Raw Materials is €1,362 billion, of which €268 billion belong to the lignites which are exploited for decades to produce only electricity. The indicated oil reserves are 10 billion barrels with current value of €85 billion and the corresponding of natural gas 3.5 trillion m³ with current value of €109 billion.

Key words: Energy mineral resources, indicated reserves, Greek crisis.

1. Introduction

The recent sharp economic crisis in Greece is expected to touch the mining industry. The last three years, Greece is absent from the list of the international firm Behre & Dolbear [1] specializing in investments in the mining sector due to the negative investment climate. Necessary conditions for the immediate change of this negative climate is the creation of a stable tax system, with emphasis on the reduction of tax rates, elimination of bureaucracy, modernization of legislation, limitation of the conditions and the significant reduction of the licensing time and the substantial improvements in telecommunications, energy and transports. We must soon incorporate in our law the new European policy Verheugen for the raw materials, reduce the projects and activities which require environmental permits, reduce the licensing time in the EU average (currently it is up to 5 times) and remove the premeditation of

environmental impacts.

Greece has avoided bankruptcy with the agreements of the leaders of the Eurozone on July and October of 2011 and on February of 2012 for aid packages exceeding €200 billion. Europe decided to help Greece, under the suffocating pressures of the markets and fears that the debt crisis may spread in the core of the Eurozone. This package will give the country the breaths needed to restore growth and competitiveness.

Privatizations, imposition of new taxes and spending cuts in the period 2011-2015 to hold the deficit to 7.5% of GNP (gross national product), are foreseen. In particular, the following reforms are foreseen: Streamlining wage costs, operating costs reductions, closures/mergers of bodies, decreases of subsidies, reorganization of PEE (public enterprises and entities), reduction of defense spending, streamlining of healthcare costs, reduction of costs and improvement of profits of the 32 SSO (Social Security Organizations) and combating of evasion, enhancing tax compliance with new tax measures, tax cuts reduction and increase of the revenues of LAO

Corresponding author: Ananias Tsirambides, professor emeritus, main research fields: industrial minerals & rocks, environmental impacts. E-mail: ananias@geo.auth.gr.

(Local Authority Organizations).

OECD (Organization for Economic Cooperation and Development) provides that in order to return the public debt of Greece to sustainable levels it will have to go “over a generation” Under conservative assumptions regarding growth and interest rates, and if fiscal and structural reforms are fully implemented, the debt/GDP ratio could peak in 2013 and fall below 60% of GDP in the next two decades. The package contains measures to enhance investments and growth, and will give Greece the time needed to implement reforms, which will improve competitiveness and export performances. Despite the short-term costs, the reforms that have been implemented or planned will benefit Greece for many years to come, as they will raise growth, living standards and equity.

IFI (International Financial Institute), which reflects the positions of more than 400 banks, expects that the debt of Greece will be reduced to 120% of GDP by the end of 2020, taking into account the impact from the involvement of banks in the country support plan.

The advantages of Greece are its geostrategic position, which allows access to markets of 170 million consumers in the Balkans, the diptych sun-sea which encourages investments in tourism, where there is still much room for growth, and in RES (renewable energy sources) and the exploitation of mineral raw materials which hitherto stay unexploited (e.g., oil, gas, gold, copper, etc.). The negatives of the country include: bureaucratic obstacles to establishing and operating of new businesses, opacity, high taxation and constant changes in the institutional framework. The changes in these areas are urgent.

2. The PERC Code

Results of a survey of a mineral resource or mineral reserve include data and information produced by research projects and can be made available to potential investors. The mineral resource is a concentration or occurrence of material with financial interest in or on the earth's crust in such form, quality

and quantity that there are reasonable expectations for final extraction. Increasing the geological certainty the mineral resources can be classified as hypothetical or indicated or measured, while the mineral reserves as probable or proven [2].

According to the PERC Code (Pan-European Reserves and Resources Reporting Committee) from 2008 specific and strict requirements apply for moving from one category of deposits to another. Moreover, the credibility and the equipment of body performing the research and the sustainability study of the probable investment are taking into account. Therefore, to be characterized probable or proven the reserves of a mineral resource there must be not only measured quantitative and qualitative data, but studies of exploitability and sustainability of these reserves at this time that would take into account all the variable parameters such as extracting and processing costs, international markets, legal, environmental, social and governmental factors, etc..

According to this code, the indicated reserves of the mineral resources of Greece currently exploited, and those resources presenting good prospects for exploitation, with their value are shown in Table 1. Fig. 1 shows the areas of the most important mineral resources of Greece. The exploitable reserves of the mineral resources of Greece are unknown. Drillings, measurements, analyses and other scientific works have not been performed for most of them. However we present adequate references plus the recent reports of the enterprises concerning these resources. According to our assessment the total value of these reserves is about €1.5 trillion and is four times Greece's total debt (€360 billion). Therefore, in a horizon of just 20 years the revenues of the country only from the rational exploitation of these resources can recoup it fully. Our conclusion is reinforced by the fact that the value of a processed mineral resource in many cases exceeds 20 times that of the raw. Thus, vertically integrated mining and processing plants, which have the ability to produce finished products

Table 1 Indicated reserves and value of mineral resources of Greece.

Mineral resource	Indicated reserves (thousand tons)	^a Price (€/t)	Value (m. €)
Industrial minerals & rocks [3]			
Total			60,100
Attapulgitite	13,000	20	260
Bauxite	250,000	20	5,000
Bentonite	100,000	35	3,500
Feldspars	80,000	15	1,200
Gypsum/anhydrite	350,000	6	2,100
Huntite	4,000	40	160
Kaolin/clay	50,000	15	750
Magnesite	280,000	35	9,800
Olivine/dunite	50,000	10	500
Perlite	1,200,000	10	12,000
Pumice/pozzolan	400,000	10	4,000
Quartz	5,000	20	100
^b Diatomite	100,000	25	2,500
^b Garnet	1,500	30	45
^b Graphite	500	30	15
^b Halite	20,000	4	80
^b Micas	800	25	20
^b Phosphorites	500	20	10
^b Talc	1,000	20	20
^b Vermiculite	500	40	20
^b Wollastonite	500	40	20
^b Zeolites	600,000	30	18,000
Energy mineral raw materials [4-6]			
Total			1,361,850
Coals (Lignite + Peat)	6,700,000	40	268,000
Natural gas	3.5 trillion m ³	3.3/28.26 m ³	408,700
Oil	10 billion barrels	68.5	685,000
Uranium (U ₃ O ₈)	1.80	83,500	150
Metallic minerals [7]			
Total			72,030
Mixed sulphides (Lead Pb + Zinc Zn)	3,100	1,500	4,650
Nickel (Ni)	1,500	15,030	22,540
^b Chromium (Cr)	1,200	1,960	2,350
^b Copper (Cu)	2,600	6,020	15,650
^b Gold (Au)	0.5	1055/ounce	18,610
^b Manganese (Mn)	2,400	2,400	5,760
^b Silver (Ag)	2.8	25/ounce	2,470
Grand total			1,494,000

^aas excavated; ^b good prospect of exploitation;

€1 = \$1.45 (Sept. 2011), 1 oil barrel (159 liters) = \$100 = €68.5, 1 MMBtu = 28.26 m³ = \$4.83 = €3.3, 1 ounce = 28.349 g.

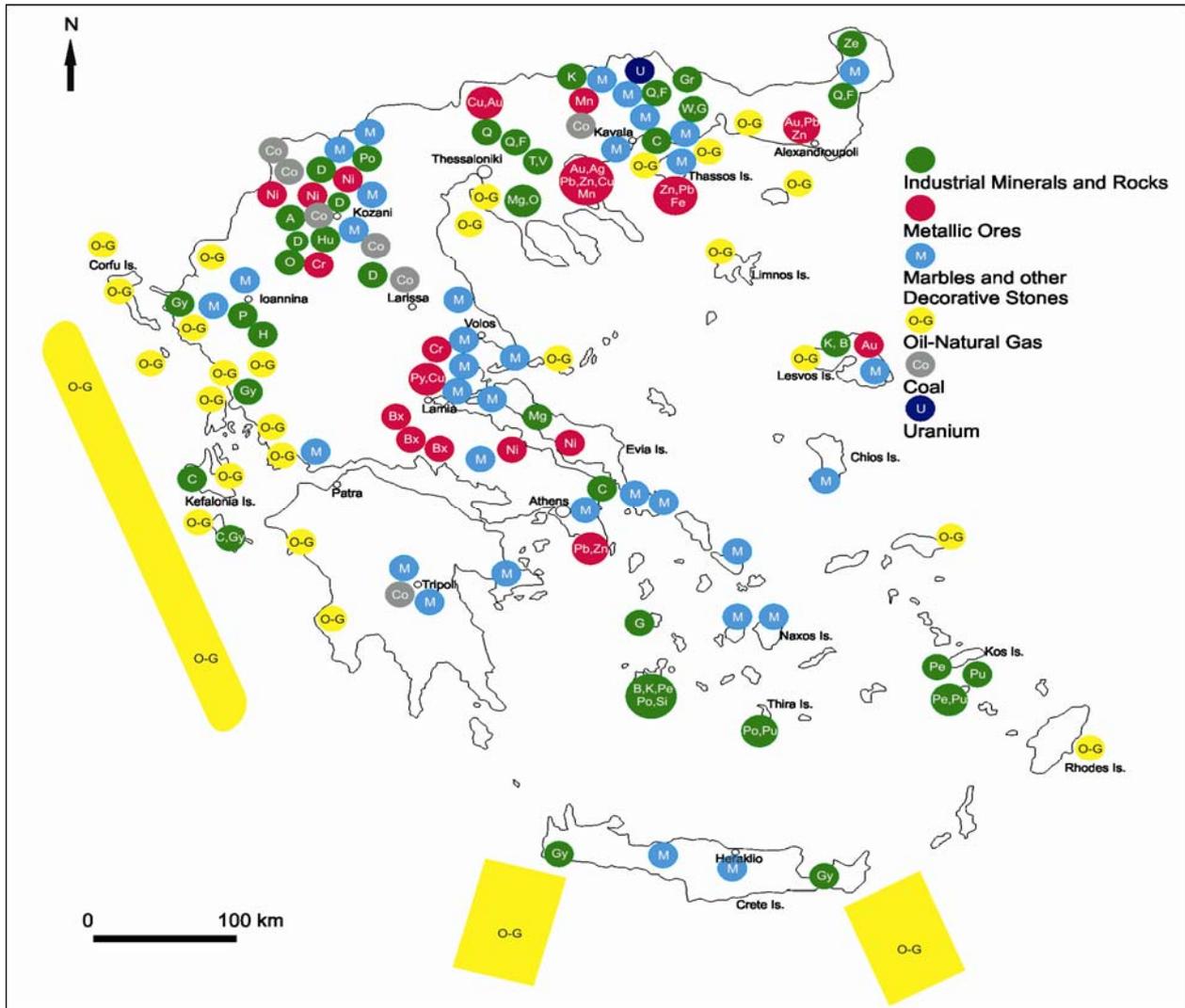


Fig. 1 Mineral resources of Greece.

Industrial minerals & rocks:

A = Attapulgite, B = Bentonite, C = White carbonates, D = Diatomite, F = Feldspars, G = Garnet, Gr = Graphite, Gy = Gypsum, H = Halite, Hu = Huntite, K = Kaolin, Mg = Magnesite, Ol = Olivine, P = Phosphorites, Pe = Perlite, Po = Pozzolan, Pu = Pumice, Q = Quartz, Si = Amorphous silica, T = Talc, V = Vermiculite, W = Wollastonite, Ze = Zeolite.

Marbles-Decorative stones:

Mr = White to colored marbles, dolomites, travertines, onyxes, alabaster, sandstones, schists, volcanic rocks, zeolite-bearing tuffs.

Metallic ores:

Ag = Silver, Au = Gold, Bx = Bauxite, Cu = Copper, Cr = Chromium, Fe = Iron oxides, Mn = Manganese, Ni = Nickel, Pb = Lead, Py = Pyrite, Zn = Zinc.

Energy mineral resources:

Co = Coal, O-G = Oil-Natural gas, U = uranium ore.

with high added value, will contribute much more quickly to the elimination of this debt and therefore to the rapid development of the National Economy.

A brief description of the energy mineral resources of Greece and the enterprises which exploit or process

them are followed.

3. Energy Mineral Raw Materials

3.1 Coals

Greece holds the second position in the EU and

11th worldwide in the production of lignite. The most important lignite ores formed in intercontinental basins as the Ptolemaida-Florina, Drama and Megalopolis, while small marsh-deltaic lignite ores formed in Orestiada, Alexandroupoli, Serres, Pangeo, Ioannina, Preveza, Ellassona, Aliveri, Oropos, Megara, Egio, Pyrgos, Olympia, Pellana Laconia, Plakia Rethymno and Chania [8-26]. Among the approximately 43 coalfields of Greece 16% are of the Quaternary, 75% of the Neogene, and 9% of the Paleocene. Within each basin the number and thickness of the coal layers vary considerably. In the basins of the Eocene lignite layers are few and thin. In contrast, the younger basins host lignite layers with substantial thickness. For example, in Ptolemaida thickness reaches 60 m, in Proastio and Ellassona 45 m, while in the basin of Anargyri Amynteo and in Megalopoli 30 m.

In Greece are mostly peat, lignites and small occurrences of bituminous coals. Generally the quality of Greek lignites is low. The calorific value of these is 975-1,380 kcal/kg in the regions of Megalopoli, Amynteo and Drama, 1,260-1,620 kcal/kg in Ptolemaida and 1,920-2,260 kcal/kg in the regions of Florina and Ellassona. An important advantage of the Greek lignites is their low content in sulphur.

Extensive ores of peat exist in the dried lake Xyniada Fthiotida and in the dried marshes of Philippi. Most interesting is the second with reserves of 4

billion m³. The lignite ores are over 200, but only a few are in operation. Most are located in the basins of Ptolemaida-Florina, Megalopoli and Drama. The largest reserves are of Miocene-Pliocene age and belong to soft lignites. Bituminous coals appear on the island of Chios, central Evia and Monemvasia in the form of lenses with thickness 0.3-1.2 m and a length of few tens of meters.

Almost all the Greek lignite is consumed domestically by the PPC SA (Public Power Corporation SA), to produce electricity. The total installed capacity of electricity in 2009 amounted to 12,800 MW. The period December 2010-November 2011 the needs of Greece's electricity were covered by 46% lignite, 25% natural gas, 8% oil, 8% RES, 8% hydro and 5% interconnections (Fig. 2). The lignite production in 2010 was 54 mt, well below the 65 mt in 2006. With the schedule of the medium-term financial framework for exit of Greece from the crisis, in 2013 the Greek State, from the entire 51% of PPC shares it holds, will provide for sale the 17%.

The indicated reserves of coals amount to 6.7 bt and their value to €268 billion. Of these reserves, with the current technical and economical conditions of extraction, the 4.5 bt are considered immediate exploitable. With an annual production of 50 mt and an annual increase in electricity demand by 3%, these reserves are sufficient until about 2080.

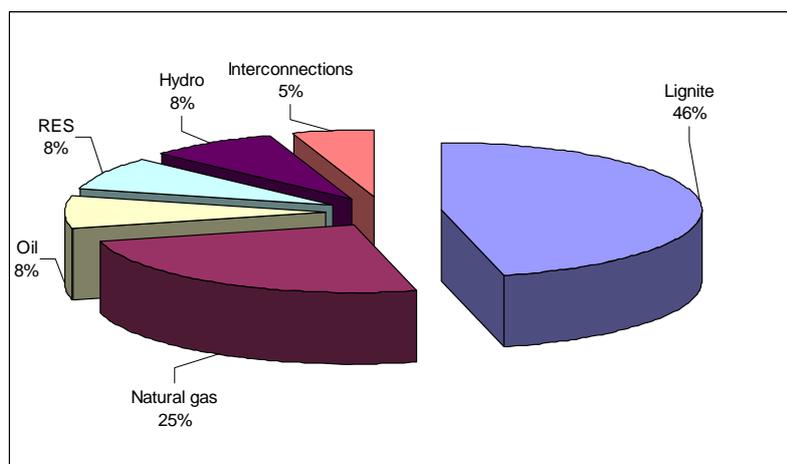


Fig. 2 Percentage contribution of raw materials in the production of electricity in Greece (Period December 2010-November 2011).

3.2 Natural Gas

Precursor of the natural gas in Greece was the illuminating gas. It was placed on the market for first time in 1857 by the French Gas Company, which in 1939 was ceded to the Municipality of Athens, so the Municipal Gas Company was created (DEFA). In 1988 the Public Gas Corporation SA (DEPA SA) was founded which in 1997 incorporated in its potential and the network of DEFA. In 2005, the subsidiary of DEPA SA, Manager of National Natural Gas System SA (DESFA SA) was created, which took full control in the management, exploitation and development of natural gas.

Today, the ownership structure of DEPA SA is: 65% Greek State and 35% EL.PE. SA. With the schedule of the medium-term financial framework for exit of Greece from the crisis, in 2012 the Greek State, will allocate for sale the 55% from the 65% of the shares of DEPA, and the 31% from the 65% of the shares of DESFA it holds, respectively. Furthermore, in 2013 the Greek State will allocate for sale the entire shares (100%) it holds of the submarine natural gas ore "South Kavala".

The existing natural gas transportation network in Greece consists of the following main sections:

- Main pipeline of transportation of high-pressure gas (70 bar), from the Greek-Bulgarian border to Attica, of total length of 512 km;
- Branches of transportation of high-pressure gas to the East Macedonia and Thrace, Thessaloniki, Volos and Attica, of total length of 440 km;
- Metering and regulating stations for measuring the gas flow and pressure regulation (Border Station of Promachonas);
- Remote control system, operational control and telecommunications;
- Operation and maintenance centers in Attica, Thessaly, Thessaloniki and Xanthi.

The plant of LNG (liquefied natural gas) on the island Revithoussa (Gulf of Megara Attica), is

intended to cover peak demand for natural gas and increase the system's reliability. It includes two LNG tanks, of total capacity of 130 billion m³, tanker mooring facilities, cryogenic systems and gasifiers for regasification of liquefied gas. For the supplying of the continental distribution network a twin pipeline has been built linking Revithoussa with the coast of Agia Triada, where also a terminal station has been built [25].

The use of natural gas has very positive effects on energy balance of Greece, because it contributes significantly to reducing use of imported oil, but the domestic lignite. In the period December 2010-November 2011 gas was involved approximately by 25% in the electricity production of the country.

For the future needs of Greece the following projects are in progress:

- Pipeline Turkey-Greece-Italy (ITGI): So far the interconnection of the gas network between Greece and Turkey has been realized (2006) and projects of the corresponding interconnection with Italy through a submarine pipeline are progressing;
- Bulgaria-Greece pipeline (IGB): It is planned to open in 2014;
- TAP (trans Adriatic pipeline): It will connect Greece with Italy via Albania and the Adriatic Sea. It is anticipated to operate in 2017;
- Pipeline South Stream: It is co-funded by the Russian Gazprom and Italian ENI, will pass from the Black Sea and through Bulgaria will be branched into two, one branch in a northwestern direction to Austria and Central Europe and one in Greece and Italy. The start of construction work is planned for 2016.

An IGTS (Independent Gas Transmission System) of the Gastrade Co (Copelouzos Group) will be constructed over the next 48 months, investing €97 million. It concerns an offshore dock of temporary storage and regasification of Liquefied Natural Gas, 22 km southwest of the port of Alexandroupoli (NE Greece) and just 10 km from the coast, and the pipe

connecting it to the national gas system.

An interdisciplinary study of the Institute of Energy for South East Europe (I.E.S.E.E.) states that more than €240 billion will be invested by 2020 in the energy sector in SE Europe countries. The largest percentage will be applied to investments in the RES (renewable energy sources), a sector in which Greece has particular advantages. Today, energy from RES is only 8%.

Today, it exploits only the gas of Thassos which is almost depleted. However large reserves have been found in the Ionian Sea and in the two basins SW (Syrti Basin) and SE (Herodotus Basin) of Crete. Other smaller deposits have been located in Babouras Thassos and Epanomi Thessaloniki [27]. The Energy Director of the Cyprus Republic, S. Kasinis, estimates that 70% of the world gas reserves exist in the huge basin of the Mediterranean Sea and the surrounding countries (pers. comm.). At least 5% of it belongs to Greece.

In 2010 the American company Noble Energy discovered in the EEZ (exclusive economic zone) of Israel (basins Leviathan, Tamar and Dalit) huge gas reserves (about 0.8 trillion m³ in total). On December 2011 the same company discovered in the EEZ of Cyprus another large gas reserve of about 0.2 trillion m³.

According to published reports-studies of the USGS (US Geological Survey), the IODP (Integrated Ocean Drilling Project), the Geophysical Institute of France (FIGR) and the Norwegian seismic survey company TGS-Nor, which have made the last 40 years numerous explorations and sufficient drillings in the international waters of the Eastern Mediterranean (and hence within the Greek EEZ), natural gas reserves may be in the order of tens of trillion m³. This version is acceptable by a large number of other special Greek scientists (A. Foscolos, I. Konofagos, C. Nikolaou, V. Papageorgiou, A. Zelilidis, pers. comm.).

Methane hydrates have been detected in the Eastern Mediterranean, in the submarine Anaximander

Mountains east of Rhodes. The region has about 250 million m³ hydrates containing 96.5% methane and 3% ethane [28-30]. Exploiting the hydrates with the current technology is economically disadvantageous.

The indicated reserves of natural gas in Greece are 3.5 trillion m³ and their value reaches €409 billion.

3.3 Oil

To date, no sufficient data to substantiate the presence of proven oil reserves in Greece exist, except that of Thassos. Hypothetically, however, we can accept the presence of oil (and natural gas), since all the neighboring countries of Greece in the Eastern Mediterranean exploit such resources for decades. Last confirmation of this hypothesis is the agreement in 2010 on the delimitation of the EEZ between Israel and Cyprus.

Today, it exploits only the oil of Thassos. The daily output of oil reached 26,000 barrels in 1987, but lately it has been limited to 3,000 barrels. The Kavala Oil Co. SA, a subsidiary of Aegean Energy SA, is a continuation of the North Aegean Petroleum Company, which began the exploration of oil in the Gulf of Kavala in the late 1960s and its production in the beginning of early 1980s [25].

Encouraging evidence for the existence of oil are in Katakolo Iliia, in the huge basin of the Ionian Sea and in the two basins SW (Syrti Basin) and SE (Herodotus Basin) of Crete. Also, in all the Ionian islands (Zakynthos, Kefalonia, Lefkada, Paxi, Corfu, Diapontian Islands), in Delvinaki Ioannina, Filiates Thesprotia, Arta, Preveza, Astakos, Etoliko, Filiatra Messinia, basin of Grevena, Gulf of Thermaikos, Chalkidiki, Babouras Thassos, in Stavros and Maronia Rhodope, Tavri Evros, in islet Zourafa east of Samothrace, in Limnos, Lesvos, Ikaria, Skopelos, SE Cyclades and in the basin of Rhodes [27, 31].

Prompted by the discovery of oil and gas ores in 1973-1974 in the sea area of Thassos (Prinos position), the PPC SA (Public Petroleum Company SA) was founded in 1975 for the exploration and extraction of

oil in Greece. In 1998 the PPC SA renamed to Hellenic Petroleum SA (EL.PE. SA), merging the PPC, ELDA and EKO (refineries/chemicals). This company during the period 1997-2002 participated in joint ventures with the companies Triton Hellas and Enterprise Oil for the exploration and exploitation of hydrocarbons in four regions of Western Greece (Ioannina, Etoloakarnania, NW Peloponnesus, and Patra Gulf). Geological and geophysical studies were prepared and five drillings were made at depths of 1,500 m to 4,000 m. This was followed by geochemical and petrographic analyses of cores from drillings and final reports were prepared that have not yet been published.

In 2003, the company Petrola Hellas SA merged in EL.PE. SA and acquired the refinery of Elefsina. Today, EL.PE SA operates four refineries in Aspropyrgos, Elefsina, Thessaloniki and Skopje, and is the largest in Greece. Its share in the Greek market is 76%, while operates and 1,175 service stations. The company participates with a 35% of stocks in DEPA SA. In 2009, EL.PE. SA acquired the business activities of BP in Greece that included the 1,200 service stations and storage facilities.

Today, the ownership structure of EL.PE. SA is: 35.5% Greek State, 41.2% Pan European Oil & Industrial Holdings SA (S. Latsis) and 23.3% retail investors. With the schedule of the medium-term financial framework for exit of Greece from the crisis, in 2012 the Greek State will allocate for sale all the shares (35.5%) it holds.

The Greek Hydrocarbon Management Company SA (G.H.M.C. SA) established in 2011 by the Ministry of Environment and Climatic Change (YPEKA), in which today the EL.PE. SA belongs, will manage the exclusive rights of the public on the prospecting, exploration and exploitation of oil and gas and will prepare and carry out the procedures for the concerned oil companies. Thus, from 2012 down it is anticipated to commence the international tenders for the concession areas initially in the Ionian Sea and south

of Crete. Of course, should precede agreements with neighboring countries for the delimitation of the EEZ (exclusive economic zones). Such an agreement has been signed with Italy in 1977.

The agreement between Russia, Bulgaria and Greece on the construction of the Burgas-Alexandroupoli oil-pipe, signed in 2005, has not materialized so far. Since 2008 the American company Hamilton Oil realizes marine explorations in the EEZ of Albania, north of Corfu.

Today, the annual oil consumption in Greece is 120 million barrels. Moderate projections of special scientists speak of the existence of reserves of 1.2 billion barrels of oil, likely to cover 30% of the energy needs of Greece for the next 30 years. Also, the National Energy Strategy Council (NESC), which is a statutory advisor of the state for energy issues, states that there are indications of oil in the Greek underground, enough to cover 50% of demand in Greece, with a daily production of 200,000 barrels. But according to published reports-studies of the USGS) (US Geological Survey, the IODP (Integrated Ocean Drilling Project), the FIGR (Geophysical Institute of France) and the Norwegian seismic survey company TGS-Nor, which have made the last 40 years numerous explorations and sufficient drillings in the international waters of the Eastern Mediterranean (and therefore within the Greek EEZ), oil reserves may be in the order of tens of billion barrels. This version is acceptable by a large number of other special Greek scientists (A. Foscolos, I. Konofagos, C. Nikolaou, V. Papageorgiou, A. Zelilidis, pers. comm.).

The indicated reserves of oil in Greece are 10 billion barrels and their value is €85 billion.

3.4 Uranium

In Greece the right of exploration and exploitation of uranium deposits belongs to the State, the interest of which is now located in Vathi Kilkis, Vrontou Serres, Loutra Eleftheron Kavala, Paranesti Drama, Kotyli Xanthi and Kirki Evros. Occurrences of

radioactive minerals are in the beds of tributaries of Kroussovitis (near Sidirokastro) and in granite of Fanos Kilkis [32]. Concentrations of uranium have been found both in the Tertiary carbonate formations of the Rhodope cover and in the phosphorus horizons of the Lower Jurassic of the Ionian Zone [33, 34]. Also in the coastal area of New Peramos-Loutra Eleftheron Kavala have been recorded very high surface concentrations of uranium at an average rate of 22 ppm and a maximum of 92 ppm, within the alanite, which is enriched in UO_2 and rare earths [35].

The uranium mineralization in Paranesti is located in the heart of the Rhodope crystalline Massif [36, 37]. So far 22 positions of uranium ore have been identified in the granites of Skaloti and Paranesti [38]. In the Spilia Paranesti the richest ore (1.5% of uranium metal) is found. The uranium minerals identified are: pitchblende, renardite, autunite, meta-autunite (hexavalent uranium phosphates) and coffinite (silicate of tetravalent uranium). Also 7 out of 14 rare earths and yttrium have been located.

The indicated reserves of uranium (U_3O_8) are 1,800 t [39] and their value €150 million.

4. International Calls for Exploration of Hydrocarbons in Greece

(a) To participate in acquisition of seismic survey data of non-exclusive use within the marine areas of Ionian Sea and south of Crete. Eight companies have submitted bids, evaluation of which will be completed until September 2012.

(b) To grant concessions through the “open door” process to explore and exploit hydrocarbons in the marine areas “Patrikos Gulf (west)” and “Katakolo” and in the land area “Ioannina”. The three areas include estimated reserves of around 250 million barrels. Until now nine oil companies have submitted tenders the evaluation of which will be done in August 2012. Next year the set-up of the first drilling platform is expected.

(c) In 2013, another 10 land plots (e.g.,

Alexandroupoli, Kavala, Serres, Thessaloniki, Grevena, etc.) will be given to explore hydrocarbons.

5. Conclusions

The geostrategic position of Greece and the diptych sun-sea encourage investments in tourism, where there is still much room for growth, in RES (renewable energy sources) and in the exploitation of mineral raw materials which are unexploited (e.g., oil, gas, gold, copper, etc.).

The total value of the mineral wealth of Greece is about €1.5 trillion and is four times its total debt (€360 billion). In our assessment, in a horizon of a generation the revenues of the country only from the rational exploitation of these resources can recoup it fully.

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