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Geothermal Developments in Greece – Country update 2010-2014

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ABSTRACT

The paper gives a brief summary of the direct geothermal uses in Greece. Greece is rich in geothermal resources and has a long history of bathing for therapeutic purposes. Currently, no geothermal electricity is produced in Greece, despite the fact that a pilot 2 MWe power plant was built and operated for about two years in the 1980s on Milos Island. The installed capacity of direct uses at the end of 2013 is estimated at about 220 MWt, showing a significant increase compared with the figures presented in WGC2010. However, this increase is almost exclusively attributed to the growth of the geothermal heat pump sector, whereas the other uses are rather static.

1. INTRODUCTION

Greece can be considered rich in geothermal resources, since the greatest part of the country lies in a region with active tectonics. The high enthalpy geothermal resources appear to be confined in the active South Aegean volcanic arc, with a proven potential exceeding 250 MWe on the islands of Milos and Nisyros. However, no geothermal power is produced in the country and it can be attributed partially to the negative sentiment of the people of these islands towards geothermal development after the shut-down in 1989 of the ill-fated 2 MWe power plant in Milos Island.

During the past two years, the Greek Ministry of Environment, Energy and Climate Change announced the leasing of four promising geothermal fields to a joint venture of two companies and called for tenders for the leasing of the right to explore the geothermal potential in several other areas.

Low enthalpy geothermal fields (with water temperature less than 100 ºC) are numerous in Greece, most of which are located in basin in Northern Greece, as well as in many Aegean islands. Present data indicates that the proven low enthalpy potential in the country exceeds 1,000 MWt. A small share of this potential is currently exploited mainly for greenhouse heating and for balneological uses.

By the end of 2013, the total installed capacity of direct uses in Greece is estimated to exceed 220 MWt, exhibiting a modest increase of 65% compared with data presented at the WGC2010 (Andritsos et al., 2010 and 2011). Geothermal heat pumps exhibit the largest share (more than 65% of the installed capacity), followed by bathing and swimming (including pool heating) and greenhouse heating. Direct applications (without GSHPs) remained rather static over the past few years with small changes; there were some new facilities, while others were closed, mostly for reasons unrelated to geothermal energy. On the other hand, ground-source heat pumps were being installed at a 25% average annual growth rate over the past five years, although a decline has been recorded in the past few years. The broader use of GSHPs in the country started in the middle of the past decade, it peaked about 3 years ago and it is now affected by the economic recession. However, some large GSHP installations are in the planning stage. An interesting application of geothermal heat pumps has been carried out in the past years in several places in northern Greece. Open-loop geothermal heat pump systems are used for soil heating for off-season asparagus cultivation, now exceeding 20 ha.

The present paper reviews the direct geothermal applications in Greece, focusing on the developments made since WGC2010, and comments activities related to the preparation for 2020.

2. ENERGY CONSUMPTION AND THE DIRECTIVE 28/2009

The annual primary energy supply in Greece, which has a population of 10.82 million (2011 census), has peaked in 2006 and 2007 at 34.9 Mtoe and in 2012 was decreased to 28.75 Mtoe (BP Statistical Review, 2013). Figure 1 shows the annual energy supply in the period 1963-2012, classified by energy sources. Despite the significant decline in the primary oil consumption due to the continued severe recession since 2008, with further decline expected for 2013 and 2014, imported oil still dominates the energy balance in Greece, accounting for approximately 53% of the total energy consumption. Lignite dominates domestic energy production, with a 78% share, and it is used primarily for electricity generation. As of early 2014, the share of lignite in the total electricity consumption is 46% of the total generation.

Renewable energy sources (RES) accounted for 13.8% of the final energy consumption in 2012 (the EU-28 average was 14.1%). The corresponding figure for the electricity generated from RES was 13% at the end of 2011, 16.8% in 2012 and 26% in early 2014. Traditional hydropower used to have the biggest share in the renewable electricity production, although after 2011 the combined production of PV and wind energy exceeded that of hydropower. The supply of RES varies somehow on a year basis mainly due to weather conditions that affect the performance of large hydroelectric plants. It is noted that the PV installed capacity in 2014 reached an installed capacity of 2,523 MWe, surpassing the target for 2020 which was set to 2,200 MWe. The installed wind energy capacity at the end of 2013 was 1,809 MWe. The present and the planned for 2020 production of electricity is given in Table 2. Table 2 presents the RES energy production in the country in 2012. Geothermal energy holds a very small share, contributing an estimated 1.1 percent of the total RES production, although according to our estimates the share is 1.3%.

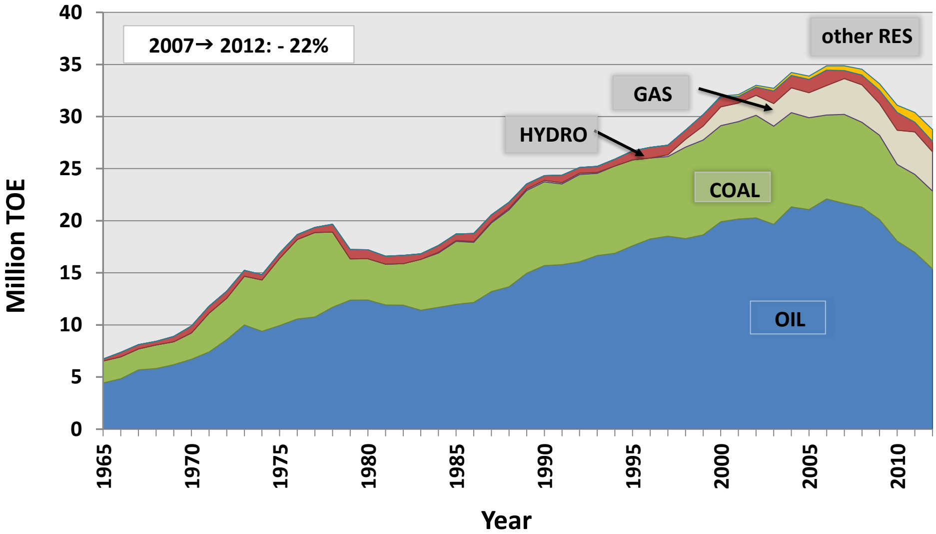

Figure 1: Primary energy consumption (in Mtoe) by energy source for the period 1965-2012 (Source: BP Statistical Review, 2013).

Table 2: Contribution of various energy sources in the total renewable energy production in Greece in 2012 (Eurostat, 2014).

Energy Source	Energy production (ktoe)	% share
Biomass and renewable wastes	1,212	53.3
Solar	330	14.5
Geothermal	25	1.1
Wind	330	14.5
Hydropower	378	16.6
Total	2,275	100.0

A breakdown of the final energy consumption in Greece by sector for 2012 is presented in Figure 2. Transport is the most energy-consuming sector, with a 43% share, while households and services exhibit a total share of 34% in final energy consumption, mainly for space-heating and hot water.

With regards to Directive 28/2009, Greece has pledged to raise the share of renewable energy in gross total final consumption to 20% by 2020, which is 2% higher than the 18% which was assigned to Greece in the Directive. The country has also set a specific target for RES to provide 40% of electricity generation by the same year, and to provide 20% of primary energy for heating and cooling in 2020. A noteworthy contribution to the accomplishment of the latter target could be the more intense utilization of the numerous low-enthalpy geothermal fields (in areas with geothermal resources) and the expansion of geothermal heat pumps, especially in the northern and mountainous regions of the country, with higher heating needs. The Green national renewable energy policy is regulated by the law L.3851/1010 and is described in the National Renewable Energy Action Plan (NREAP, 2012).

3. GEOTHERMAL EXPLORATION AND POTENTIAL

Geothermal exploration efforts started in Greece in the early 1970s and were focused on the high-enthalpy fields on Milos Island and Nisyros Island. Later in the same decade, several low-enthalpy fields in northern Greece and on some Aegean Islands were studied. Discussion on the numerous low-enthalpy geothermal resources (with fluid temperature less than 100 ºC) can be found in Fytikas (1988), Fytikas et al. (2000) and (2005) and in Mendrinos et al. (2010).

The proven potential of the well-explored high-enthalpy fields of Milos and Nisyros Islands for power generation purposes is estimated to exceed 250 MWe. Prospective areas with medium-temperature fluids up to 120ºC, suitable for electricity generation with binary cycle plants, have been identified on the islands of Lesvos, Chios and Samothrace and in the geothermal fields of Aristino (Alexandroupoli) and Akropotamos (Kavala).

Limited geothermal exploration has been carried out since 2008. However, geothermal exploration has been planned for 2014 by the Institute of Geology and Mineral Exploration (IGME) in the following areas: northern part of the known Sidirokastro field (Macedonia, Northern Greece), Eastern Thessaly (Central Greece), eastern part of Lesvos Island (Aegean Sea) and Limnos island (Aegean Sea). These exploration works will be funded by the National Strategic Reference Framework (NSRF).

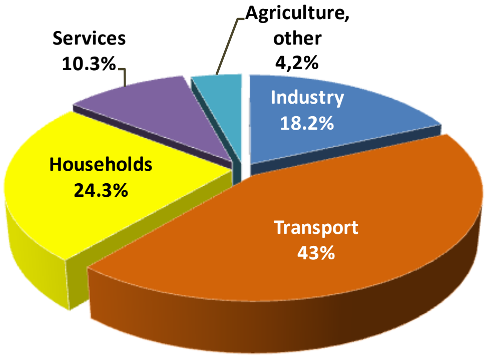

Figure 2: Distribution of the final energy consumption by sector in Greece in 2012. (Source: Eurostat, 2014.)

In 2013, three new large diameter geothermal wells were drilled in the Neo Erasmio geothermal field (Thrace). Two of them having a total depth of 550 m are used for the production of geothermal water of 60°C to heat a new geothermal greenhouse complex. Another 230 m deep well was drilled for the reinjection of the geothermal waters. Finally, during 2008-2014, some exploration work, including geophysical studies on Milos and Kimolos Islands, evaluation of previous geothermal data, additional geophysical measurements on Nisyros Island and feasibility and environmental studies, was funded by Public Power Corporation Renewables (PPCR) S.A.

In early 2011, international open tenders were announced for the leasing of the right to explore the geothermal potential of four promising areas: Central/Southern Chios, Nestos River Delta, Evros River Delta and Samothrace Island (depicted in the map of Figure 3). The interest has been focused on probable medium enthalpy geothermal resources for binary cycle power generation. A consortium of two Greek private companies was awarded all the tenders, although no exploration work has been carried out so far. In addition, PPC Renewables S.A. was awarded recently the right for exploration in four other promising areas, namely Spercheios basin, Akropotamos (Kavala area), Soussaki and Ikaria Island.

Figure 3: Location of the leasing areas.

4. DIRECT USES

4.1 Background

The direct utilization of geothermal energy includes the heating of greenhouses and aquaculture facilities, soil heating, space heating, agricultural drying, and ground-source heat pumps. Direct heat applications in operation at the end 2013 are summarized in Table 5 with regards to installed capacity and the annual energy use. It should be noted that values for the capacity of bathing facilities and geothermal heat pumps are only approximate (and probably conservative), since it is rather impossible to determine the exact figures. The installed capacity is 220 MWt and the annual energy use is estimated at 1,326 TJ. Since 2009, the largest application is geothermal heat pumps (with almost 50% of the energy use), and the next largest direct-use is balneology and pool heating. Direct utilization (excluding geothermal heat pumps) remained rather static over the past 10 years with gains balancing losses, as clearly illustrated in Figure 4.

4.2 Greenhouse and Soil Heating

The agricultural applications of geothermal fluids consist of greenhouse heating and soil heating. Heating greenhouses using geothermal energy began in Greece in late 1970s. The majority of Greece's greenhouses are located in the north of the country and about 70% of them are glass covered. Currently, there are 26 greenhouses in operation in northern Greece and on the islands of Lesvos and Milos using geothermal energy. These cover an area of 25.6 ha, whereas the installed capacity is estimated to be 31.8 MWt and an annual energy use of 246 TJ/yr. Table 4 lists the greenhouse heating units and the estimated installed capacity and the annual thermal utilization. The operation of some older greenhouses without a legal license has been recently suspended.

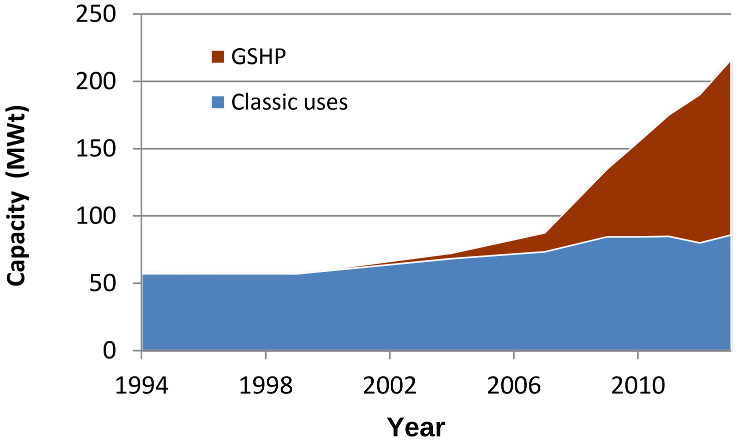

Figure 4: The installed capacity of "classic" direct uses and of recorded GSHP applications since 1994.

The latest addition to the greenhouse units is the hydroponics greenhouse, constructed within the geothermal field of Neo Erasmio, just east of Nestos River. It is actually covering 4.2 ha. The installation consists of four separated planting units of 1 ha each. Two of them produce tomatoes and the other two cucumbers. An additional greenhouse space of 0.2 ha houses the sorting and packaging process line, the cold storage rooms and the administration and management offices. The latter (0.1 ha) are underfloor heated with the outcoming geothermal waters with temperature as low as 40°C before reinjection process. The cultivation process of tomatoes and cucumbers is based on an eleven month growing period per year. The investment cost approached US$ 7,000,000 and more than 60 persons work since the beginning of 2014. An expansion of 4.0 ha is under consideration and it is believed that it will be in operation by the end of 2016. It is by far the biggest geothermal production investment ever made in Greece. A picture of the new greenhouse complex is shown in Figure 5.

Figure 5: Outside view of the Neo Erasmio 4.2 ha greenhouses.

The main vegetables grown in geothermal greenhouses are tomatoes, sweet peppers and cucumbers. Other agricultural products grown occasionally in these greenhouses include lettuce, green beans, strawberries and certain herbs. The glass-covered greenhouses are equally used for vegetables and for cut flowers (roses, lilies, chrysanthemums), potted plants and in a lesser degree for nursery stock. All the greenhouse units but two cover almost entirely their heating needs with geothermal energy.

Greenhouse heating is accomplished mainly by circulating hot water in pipes located on the floor or at a certain height. Other methods include forced circulation of warm air, finned metal units and combination of the above methods. Geothermal greenhouses in Greece utilize waters with temperature as low as 35ºC. The vast majority of the geothermal waters used in greenhouse heating and soil warming have a temperature less than 60ºC. More details on the greenhouse heating characteristics can be found in Andritsos et al. (2011).

The use of soil warming appears quite attractive for several reasons: it can extend the growing season, provide frost protection and increase the total yield. Soil warming is currently used in Greece only for earliness and out-of-season asparagus production. Lettuce has also been cultivated using soil heating in covered beds for several years. Asparagus is considered a vegetable with a high added value when produced out-of-season. The soil heating is accomplished by the direct flow of geothermal water through corrugated polypropylene (PP) pipes with an inside diameter of 28 mm, placed underground at least 20 cm deeper that the plants. Heat may be applied from early February and harvesting starts early March and ends in mid-April.

The total cultivated area for asparagus production using low-temperature geothermal waters exhibited a significant decrease, from about 20 ha in 2007, to about 7 ha currently, although 20 ha make use of open system geothermal heat pumps for soil heating as will be discussed later. The main reason for this decline is that most plants exceeded the productive period which is about 10-12 years, combined with the economic recession of the country, the lack of a strong domestic consumption base and the limited exports.

4.3 Space Heating

At present only two spa facilities (in Traianoupolis, Thrace, and in Nea Appolonia, close to Thessaloniki) are heated with low-enthalpy geothermal waters. Space heating is also provided to a hotel in Milos (which, however, is closed in winter), in a three-room school building and in some individual houses in Macedonia and Thrace. The installed capacity of the space heating units in the country is estimated at 1.4 MWt. The spa complex in Nea Apollonia, with a space area of more than 4,000 m^2, is heated directly using a good quality geothermal water of 57ºC. The spa building in Traianoupolis is heated indirectly by geothermal water with temperature of 52ºC.

It has to be noted that the first pilot district heating scheme in Greece (“Thermopolis” project) has been completed in Polichnitos, Lesvos Island, but it is out of operation due to the failure of the submersible pump. This system will provide heating to five public and municipal buildings. The water temperature is 88ºC and a titanium heat exchanger is employed to isolate the recirculation water due to the high salinity of the water. There is great hope that it will start operating during the next heating period.

4.4 Dehydration of Agricultural Products

A novel tomato dehydration plant started operations in 2001 in Neo Erasmio, 25 km south of Xanthi. Since then more than 140 tn of “sun-dried” tomatoes have been produced. The unit uses geothermal water of 60°C to heat atmospheric air to 55-58°C through finned-tube air heater coils. A description of the initial layout of the unit can be found in Andritsos et al. (2003), while a theoretical modeling of the process can be found in Kostoglou et al. (2013). The unit is capable of drying many other agricultural products, such as peppers, onions, mushrooms, olives, asparagus, figs, apples and cherries.

4.5 Aquaculture Pond and Raceway Heating

Geothermal aquaculture projects have been in place in Greece since the late 1990s and include the heating of fish wintering ponds and the cultivation of spirulina in raceways.

Anti-frost protection/heating of aquaculture ponds in Porto Lagos and Neo Erasmio (both in Thrace) is practiced since 1998. In Porto Lagos the warm water comes from three production wells near the farming ponds, although currently only one of these operates properly. In Neo Erasmio, the 60°C water comes from a production well at a distance of 4.5 km and it is transported through insulated plastic pipes. The geothermal water is initially mixed with seawater before entering the ponds with a mean temperature of 30°C. The installed thermal capacity of both installations is about 8 MWt, although the energy use is relatively small. The injection of warm water into the pond not only protects the fish stock from bad weather, especially during winter time, but it has been shown that it also increases fish production (Gelegenis et al, 2006). The major species raised in the ponds are the Mediterranean seabass (*Dicentrarchus labrax*) and the gilt-head sea bream (*Sparus aurata*).

Cultivation of the green-blue algae spirulina is practiced in two plants in the Nigrita field (each having a covered area of 0.4 ha), and one in the Sidirokastro field. The annual production of dry spirulina amounts to more than 7000 kg in the form of capsules or powder and the installed capacity of the three units reaches 0.9 MWt.

Finally, a new pilot project of ornamental fish breeding has been launched in Neo Erasmio, Xanthi, at the beginning of 2014. The project is based on the availability of good quality geothermal waters (with conductivity 1040 μS/cm) with a temperature close to 50°C. The scope of the project is to investigate the growing and heating prerequisites and conditions of fish breeding. After five months of breeding process, the ornamental fishes show a very good adaptability to the geothermal water as a growing medium. The ornamental fishes grow in plastic tanks filled with geothermal water cooled down at temperatures between 25-30°C.

4.6 Spas and Swimming Pools

There are more than 750 thermal springs in Greece and, currently, there are more than 60 spas and bathing centres in the country using thermal waters both for therapeutic purposes and/or for recreation. The major balneological sites are in Loutraki (Corinth), Methana, Kaiafa and Killini in Peloponnese, Aedipsos, Kamena Vourla, Ypati, and Smokovo in Central Greece, Langadas, Nigrita, Sidirokastro, Angistro, Loutraki (Pella) and Nea Apollonia in Macedonia, Icaria Island, Samothrace Island, Thermi and Polichnitos in Lesvos Island. There are also more than 25 outdoor swimming pools using geothermal water with a combined surface area of about 7,000 m^2.

Although, more and more spas remain open all year around, most units operate during the traditional balneological period in Greece (June-October). There is no known systematic study of the energy use in the balneological centers in Greece. A conservative estimate (assuming that the temperature of water leaving the bathing facilities is 30ºC) of the total thermal capacity of Greek spa resorts is 43 MWt, with a mean load factor of 0.19. These figures include several outdoor and indoor pools heated by geothermal waters.

4.7 Geothermal Heat Pumps

Despite the significant increase of the GSHP systems in Greece; their use is still not as widespread as in some other countries, especially in Central and Northern Europe. The broader use of GHPs in the country started in the middle of the past decade, it peaked about 3 years ago and it is affected now by the economic recession, although not as high as other sectors. It is also noted that there is a strong competition from natural gas and air-water air-condition units.

The authors have recorded more than 850 applications of GSHP systems in Greece with a total installed capacity of 85 MWt. The exact number of such units presently installed in the country is not known, since many companies involved in the sector did not answer to our questionnaire. The total number of GSHP installations is estimated to exceed 1,000 with an installed capacity of more than 130 MWt, since the response rate to our questionnaire was only 60%. More than 100 installations have a capacity higher than 100 kWt. Horizontal ground-source heat collectors are installed only for houses and are laid in a depth ranging from 1.5 to 4 m. The depth of the boreholes in the vertical closed-loop systems ranges from 60 m to 110 m. The open-loop systems use groundwater (which is always reinjected), brackish water and sea water.

About 61% of the recorded installed capacity refers to open-loop systems as shown in Figure 6. It is noted that the out of more than 800 GSHP applications, only a handful of them are related to agriculture and food processing, excluding those for out-of-season asparagus production. One application refers to the heating of a poultry farm, while five greenhouses with a total area of 1.4 ha use geothermal heat pumps for heating. There is a clear trend with increasing interest in GSHPs (Figure 4), but it seems that the financial and economic crisis of the past five years and the stagnation of the construction sector have slowed down a greater penetration of the GSHPs. For 2013, fewer than 100 new installations were reported with an installed capacity of about 15 MWt.

An interesting and promising application of geothermal heat pumps has started seven years ago in the region of Chrysoupolis, Macedonia. Open-loop geothermal heat pump systems are used for soil heating for earliness and off-season asparagus production. The region of Chrysoupolis is well known for the extended asparagus fields covering almost 1,000 ha. More than 95% of the annual yield is exported to European countries and the out-of-season production of this vegetable in low tunnels is of great economic importance for many Greek farmers. In these GSHP applications, with a total capacity of 2,100 kWt, water temperature varies between 16ºC and 20ºC, and COP values as high as 6 have been recorded. The water is pumped from rather shallow wells (30 to 100 m) and it is rejected with a temperature drop of 5 to 10°C. The temperature drop range can be regulated following the initial inlet temperature of the water of the well. Taking into consideration the reduced cost of electricity for farmers, open-loop heat pumps offer a low-cost method for soil warming of the covered asparagus fields. The total cultivated area is 20 ha.

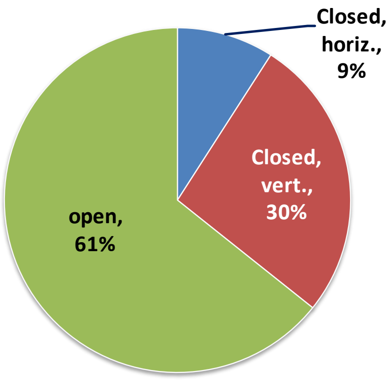

Figure 6: Share of the various GSHP configurations. Total recorded installed thermal capacity 85 MWt.

5. ONGOING GEOTHERMAL ACTIVITIES

As mentioned earlier an international open tender was announced in 2011 for the leasing of the exploration right for four areas, shown in the map of Figure 3: (i) Evros River Delta in Thrace (approximately 1,307 km^2); (ii) Nestos River Delta in Macedonia (803 km^2); (iii) Samothrace Island (181 km^2); (iv) Central and Southern Chios Island (476 km^2). The exploration right for all the areas was awarded to a consortium of Terna Energy S.A and ITA Group S.A. The exploration activities will focus in finding medium-enthalpy geothermal resources, suitable for binary cycle power generation. Unfortunately, the lease contracts for the exploration rights have not been signed till now and it is possible that the consortium will withdraw from the exploration projects.

A similar situation exists for the second international open tender announced in September - November 2011, concerning the exploration in four promising areas, i.e. Spercheios basin (Central Greece), Akropotamos (Kavala area), Soussaki (Central Greece and Ikaria Island. The exploration right was awarded to PPC Renewables S.A., but again no contract has been signed so far.

Regarding low-enthalpy fields, in 2012 there was a call for binding investment proposals for leasing the management and exploitation rights in ten geothermal fields in Greece. For the following fields leasing contracts have been signed with a total estimated budget of 70 million € for the period 2013-2020.

(1) Geothermal Field of Aristino-Alexandroupolis (Thrace). This is a relatively large, about 20 km^2, proven geothermal field with fluid temperatures in the range of 52-90°C. The Municipal Authority of Alexandroupolis won the tender and plans are under way for the heating of municipal buildings and a complex of 5 ha of greenhouses.

(2) Geothermal Field of Neo Erasmio (Thrace). This is one of the most explored geothermal fields in northern Greece (covering an area of 16-24 km^2), where novel applications, such as soil heating of out-of-season asparagus cultivation, vegetable drying and antifreeze protection of aquacultures are in operation. The exploitation and development rights have been awarded to the industrial company Thrace Plastics Co S.A., which has constructed a 4.2 ha vegetable greenhouse, as mentioned in subsection 4.2.

(3) Geothermal Field of Eratino-Chrysoupolis (Eastern Macedonia). The field has been awarded to the Municipal Authority of Nestos. Large quantities of water with temperature up to 65°C will be extracted and used for the heating of more than 70 ha of asparagus plantations or other protected cultivations. The infrastructure (heat exchange station, wells and piping) for this 8 MWt is almost completed.

(4) Geothermal Field of Nigrita (Macedonia). Until recently this field was by far the most exploited low-enthalpy field in Greece with two spirulina cultivation protected units and several greenhouses. Some of these greenhouses have been abandoned for various reasons not related with problems from the geothermal energy use.

Finally, the Decentralized Administration Authorities of Macedonia-Thrace and Epirus-Western Macedonia have announced recently a call for the expression of interest in investment proposals, development and management of some proven low temperature geothermal fields.

6. PROFESSIONAL GEOTHERMAL PERSONNEL

The number of professional personnel in the geothermal sector increased during the past four-five years due to the involvement of more than 30 companies and consulting firms in the area of GSHP systems. However, the personnel working in the classical geothermal sector declined, mainly due to a significant personnel reduction at the Institute of Geology and Mineral Exploration (IGME). The professional personnel related to geothermal activities (shown in Table7) is estimated as follows: about 30 in state agencies and organizations (10 at the Centre of Renewable Energy Sources - CRES, 7 at IGME, 7 at Public Power Corporation Renewables S.A., 2 at the Ministry of Environment, Energy and Climate Change and 4 at the various Decentralized Administration Authorities), 4 in Universities and Research Institutes and more than 25 in the private sector and consulting companies. Finally, it should be added that in the past decade about 10 Ph.D. thesis have been completed in Greek Universities dealing mainly with aspects of GSHPs.

7. LEGISLATIVE ISSUES AND PREPARATION FOR 2020

Greece, as all the EU countries, has agreed to raise the share of RES in the final energy consumption to 20% by 2020 (Directive 2009/28/EC). This value (20%) for Greece is 2% above the mandatory level of 18% set by Directive. To reach this (rather ambitious) target, substantial new investments in the sector are obviously required and new financial incentives have to be put in place.

The 20% target will be achieved through the combination of measures for energy efficiency as well as for the enhanced penetration of RES technologies in electricity production, heat supply and transport. According to the National Renewable Energy Action Plan for Greece (NREAP, 2010), specific targets for each of the main RES technologies have been chosen. It is implicitly stated that geothermal energy can play a rather small but significant role in fulfilling this target, in both the electricity and the heating and cooling sector.

As stated in the NREAP, the annual energy use of geothermal energy in 2020 (excluding geothermal heat pump applications) is set at 51 ktoe, which is about three times the energy use in 2013. The authors believe that this target can be easily fulfilled, provided that there will be a "liberalization" of the Law that regulates the use of geothermal energy and the establishment of certain incentives. Regarding geothermal heat pump systems, the target was close at 50 ktoe. Similarly, this target can be easily satisfied, provided that a yearly increase rate of 20% is maintained through the period 2014-2020.

The existing building regulation (Energy Performance of Buildings Regulation) is considered as the main legislative tool for the promotion of RES systems (and particularly of GSHP systems) for heating and cooling at the tertiary and residential sector, but also in industry and the agricultural sector. Currently, incentives for GSHP systems are regulated through the national program "Energy Saving at Home", which aims mainly at reducing the energy needs of buildings. The incentives include (i) interest rate subsidy (up to 100%), (ii) Subsidy on the final eligible budget, and (iii) minimum cost coverage for energy inspectors. However, the implementation of GSHP heating and cooling in existing buildings is rather complicated and only a handful of applications have been implemented so far.

For RES in the electricity sector, the installation of 120 MW of geothermal energy power plants is foreseen for 2020 (see Table 1), together with 13,150 MW of wind energy, photovoltaic, CSP, biomass and hydro plants resulting in a 40% RES share in electricity production. The projected geothermal installed capacity for 2015 is 20 MW, something impossible to be implemented with the current situation as described previously. In the financial support system for electricity generation from geothermal energy, there is a special category for a feed-in tariff (FIT) scheme for electricity produced from low temperature fluids (<90°C) set by Law 3851/2010, which is 150 €/MWh. For power generation from medium and high enthalpy fluids the feed-in tariff was set at 99.45 €/MWh for both the mainland and the non-interconnected islands. The FIT is guaranteed for 20 years and it can be increased by 20% in case the project is not funded by national or European projects. The tariffs will increase by 50% of the consumer price index of the previous year.

8. CONCLUSIONS

Geothermal energy is used in Greece only for direct utilization. No geothermal electric power is generated in the country, despite the large high-enthalpy geothermal potential. However, by 2020 there will be hopefully some electrical production. The current level of utilization of geothermal energy in Greece represents only a very small fraction of the identified geothermal resources. The installed thermal capacity of direct uses in Greece increased substantially since 2010, reaching 220 MWt. However, this increase is almost exclusively attributed to the boost of GSHP market.

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STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014	0		10600		3393		0	0	4332*		18325	61000
Under construction in December 2014	0		1100		0		0		300		1400	
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	120	736	12000		4530	6576	0		10510**	21514	27160	

* PV: 2523 MWe, Wind: 1809 MWe

** PV: 2200 MWe, Wind: 7500 MWe, Other: 810 MWe

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

[1] I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain. fruit. vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less.
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Nigrita 2	G (flowers)	15	42	27			0.94	5.40	10.68	0.36
Nigrita 2b	G (veg.)	9	37	25			0.45	3.00	4.75	0.33
Nigrita 3	G (veg.)	10	51	30			0.88	3.20	8.86	0.32
Nigrita 3c	G (veg.)	10	51	28			0.96	2.60	7.89	0.26
Nigrita 4	G (veg.)	10	37	21			0.67	2.80	5.91	0.28
Sidirokastro 1a	G (flowers)	10	48	34			0.59	3.50	6.46	0.35
Sidirokastro 1b	G (flowers)	7.8	63	35			0.91	2.80	10.34	0.36
Sidirokastro 1c	G (flowers)	8.3	43	33			0.35	3.00	3.96	0.36
Sidirokastro 2a	G (flowers)	14	37	25			0.70	5.80	9.18	0.41
Sidirokastro 2b	G (flowers)	5	36	25			0.23	2.00	2.90	0.40
Sidirokastro 3	G (veg.)	10	45	30			0.63	3.50	6.92	0.35
Langadas 2	G (flowers)	14	36	22			0.82	4.60	8.49	0.33
Langadas 2b		5	36	22			0.29	1.60	2.95	0.32
Langadas 3	G (veg.)	6	35	22			0.33	2.00	3.43	0.33
N. Apollonia	G (veg.)	7	51	32			0.56	2.20	5.51	0.31
N. Apollonia 2	G (flowers)	10	41	27			0.59	3.00	5.54	0.30
N. Apollonia 3	G (flowers)	12	45	30			0.75	4.50	8.90	0.37
N. Apollonia 4a	G (veg.)	10	47	28			0.79	3.70	9.27	0.37
N. Apollonia 4b	G (veg.)	7	32	22			0.29	2.30	3.03	0.33
N. Apollonia 5	G (veg.)	13	45	30			0.82	4.00	7.91	0.31
N. Apollonia 6	G (flowers)	4	36	22			0.23	2.00	3.69	0.50
Polychnitos (4 units)	G (veg.)	50	83	35			10.04	16.00	101.30	0.32
Polychnitos 2	G (veg.)	9	67	35			1.20	2.90	12.24	0.32
Geras. Lesbos	G (veg.)	5.8	40	35			0.12	1.90	1.25	0.33
Milos	G (veg.)	4.2	46	24			0.39	0.90	2.61	0.21
N. Erasmio	G (veg.)	70	60	35			7.32	24.50	80.79	0.35
N. Erasmio	G (s.h)	7	60	25			1.03	2.20	10.16	0.31
Myrodato	G (s.h)	10	50	25			1.05	2.70	8.90	0.27
									0.00	
Trainoupoli	H	16.7	52	38			0.98	5.90	10.89	0.35
N. Apollonia	H	10	57	45			0.50	3.30	5.22	0.33
N. Erasmio	H	4	42	32			0.17	1.30	1.71	0.32
N. Erasmio	A	9.7	59	52			0.28	1.94	1.79	0.20
N. Erasmio	F	38	38	8			4.77	9.40	37.20	0.25
Porto Lagos	F	40	25	8			2.85	10.10	22.65	0.25
Nigrita*	O	4.8	50	30			0.40	1.54	4.06	0.32
TOTAL		476.3					43.88	152.08	437.39	0.33

* Cultivation of spirulina

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	1.65	17.8	0.33
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating	33.9	335	0.34
Fish Farming	7.61	59.8	0.25
Animal Farming			
Agricultural Drying[5]	0.28	1.79	0.2
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	43	260	0.19
Other Uses (specify)	0.4	4.06	0.32
Subtotal	85.8	678	0.25
Geothermal Heat Pumps	135	648	
TOTAL	220.5	1326	

4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	0	0	0	0	0
Production	>150° C	0	0	0	0	0
	150-100° C	0	0	0	0	0
	<100° C	0	2	0	0	0.55
Injection	(all)	0	1	0	0	0.23
Total		0	3	0	0	0.78

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Progr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	6	25	na	na	na	na
2011	6	27	na	na	na	na
2012	6	26	na	na	na	na
2013	6	24	4	0	0	25
2014	6	24	4	0	0	25
Total						

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	na	na	na	0	na	na
2000-2004	na	na	na	0	na	na
2005-2009	na	na	na	0	na	na
2010-2014	1.068	0.041	7.49	0	87.1	12.9

na = not available

2010-2014
5.5 million € = 7.49 million USD *(Neo Erasmio, Thrace Plastics Co SA, production/utilization)*
0.095 million € = 0.127 million USD *(geoth. exploration projects funded by National Strategic Reference Framework - NSRF)*
0.030 million € = 0.041 million USD *(geoth.l exploration and development funded by Municipality of Iraklia)*
0.150 million € = 0.204 million USD *(hydrogeological study funded by Municipality of Kos*
0.042 million € = 0.057 million USD *(hydrogeological studies funded by Public Properties Co. S.A. curative thermal springs)*
0.500 million € = 0.68 million USD *(geothermal exploration projects funded by Public Power Corporation Renewables S.A.)*