# Geothermal Energy Use, Country Update for Greece

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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-$MW_e$ operated for about two years in the 1980s in Milos Island. The installed capacity of direct uses at the end of 2012 is estimated at about 180 MWt, showing a significant increase compared with the figures presented in EGC 2007. 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

Geothermal energy exploitation in Greece is limited only to direct uses. No geothermal power is produced in the country, despite the significant high-enthalpy potential, especially in the South Aegean active Volcanic Arc. Direct applications include the heating of greenhouses, pools and spas, and aquaculture facilities, soil warming, vegetable drying, and ground-source heat pumps (GSHP).

By the end of 2012, the total installed capacity of direct uses in Greece is estimated to exceed 180 MWt, exhibiting a modest increase of 40% compared with data presented at the WGC2010 and an increase of more that 100% with regards to data presented at the EGC 2007 (Andritsos et al., 2007). The largest application is geothermal heat pumps (more than 60% 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 reason 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 2012.

The present paper reviews the direct geothermal applications in Greece, focusing on the developments made since EGC 2007, 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 10,790 million, has peaked in 2006 and 2007 at 34.9 Mtoe and in 2011 was 30.5 Mtoe (BP Statistical Review, 2012). Figure 1 shows the annual energy supply in the period 1963-2011, classified by energy sources. Despite the significant decline in the primary oil consumption due to the continued economic recession since 2008, with further decline expected for 2012 and 2013, imported oil still dominates the energy balance in Greece, accounting for approximately 56% of the total energy consumption. Lignite dominates domestic energy production, with an 80% share, and it is used primarily for electricity generation (representing about 50% of total generation in 2012).

Renewable energy sources (RES) accounted for only 9.2% of the final energy consumption in 2011 (the EU-27 average was 12.5%). The corresponding figure for the electricity generated from RES was 13% in 2011 and 16.8% in 2012. Traditional hydropower still contributes the largest amount to the above figures. 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 PV installed capacity almost doubled during 2012 reaching 1520 MWe. The installed wind energy capacity at the end of 2012 was 1752 MWe. Table 1 presents the RES balance in 2011. Geothermal energy holds a very small share, contributing an estimated 1.3 percent of the total RES production.

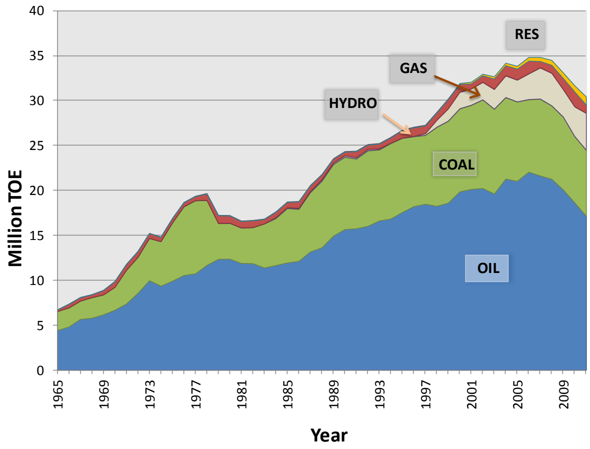


**Figure 1: Primary energy consumption (in Mtoe) by energy source for the period 1965-2011 (Source: BP Statistical Review, 2012).**

**Table 1: Contribution of various energy sources in the total renewable energy production in Greece in 2011 (Eurostat, 2012).**

| Energy Source | Energy production (ktoe) | % share |
|---|---|---|
| Biomass and renewable wastes | 1085 | 54.9 |
| Solar | 235 | 11.9 |
| Geothermal | 26 | 1.3 |
| Wind | 285 | 14.4 |
| Hydropower | 345 | 17.5 |
| Total | 1976 | 100.0 |

A breakdown of the final energy consumption in Greece by sector for 2010 is presented in Figure 2 (EU Energy in Figures, 2012). 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.

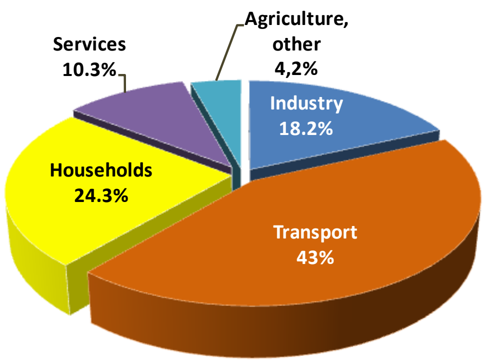


**Figure 2: Distribution of the final energy consumption by sector in Greece in 2010. (Source: EU Energy in Figures, 2012)**

With regards to Directive 28/2009, Greece ha 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 in 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 $MW_e$. Prospective areas with medium-temperature fluids up to 120 ºC, suitable for electricity generation with binary cycle plants, have been identified in the islands of Lesvos, Chios and Samothrace and in the geothermal fields of Aristino (Alexandroupoli) and Akropotamos (Kavala).

No further geothermal exploration has been carried out since 2008. However, in early 2011, international open tenders were announced (the first of this kind in Greece) 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. Another international open tender announced in September - November 2011, regarding the exploration in four more areas: Spercheios basin, Akropotamos (Kavala area), Soussaki and Ikaria Island.

## 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 2012 are summarized in Table 2 with regards to installed capacity. 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 180 MWt and the annual energy use is estimated as 1000 TJ. Since 2009, the largest application is geothermal heat pumps (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 3.

**Table 2: Summary of the installed capacity and of annual energy use of direct applications as in March 2013.**

| Use | Installed Capacity (MWt) | Annual Energy Use ($10^{12}$ J) |
|---|---|---|
| Space heating | 1.4 | 16 |
| Greenhouse & soil heating | 27 | 271 |
| Agricultural drying | 0.3 | 3 |
| Aquaculture* | 9.3 | 80 |
| Bathing and swimming | 42 | 230 |
| Geothermal heat pumps | 100 | 480 |
| **Total** | **180** | **1080** |

* Fish Farming & Spirulina Cultivation

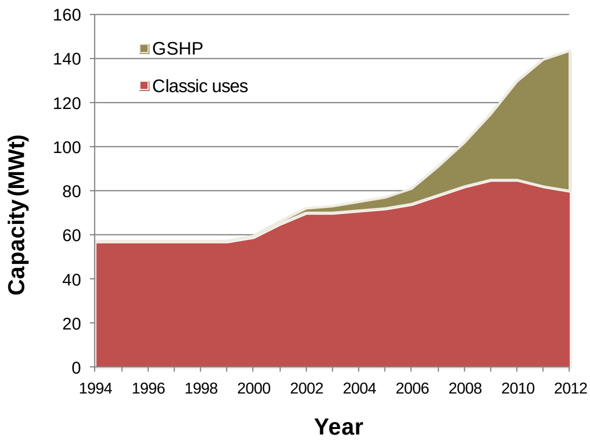


**Figure 3: The installed capacity of "classic" direct uses and of recorded GSHP applications since 1994.**

### 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 25 greenhouses in operation in Northern Greece and in the islands of Lesvos and Milos using geothermal energy. These cover an area of 21 ha, whereas the installed capacity is estimated to be 24 MWt and an annual energy use of 246 TJ/yr. Table 3 lists the major greenhouse heating sites and the estimated installed capacity and the annual thermal utilization. The operation of some older greenhouses without a legal licence has been recently suspended.

**Table 3: Greenhouse heating applications in Greece by geothermal field (2012-2013).**

| Locality | Covered area (ha) | Maximum Utilization | | | Energy Utiliz. (TJ/yr) |
|---|---|---|---|---|---|
| | | Flow Rate (kg/s) | Inlet Temp. (°C) | Capacity (MWt) | |
| *Macedonia* | | | | | |
| Nigrita | 2.8 | 35 | 42-51 | 2.78 | 27.4 |
| Sidirokastro | 2.7 | 55 | 37-63 | 3.40 | 39.7 |
| Langadas | 3.5 | 19 | 36 | 1.10 | 11.2 |
| Nea Apollonia | 5.7 | 63 | 32-46 | 4.03 | 43.4 |
| *Thrace* | | | | | |
| Neo Erasmio | 0.3 | 5 | 60 | 0.52 | 5.3 |
| *Islands* | | | | | |
| Lesvos | 5.5 | 65 | 40-85 | 11.6 | 116 |
| Milos | 0.5 | 4.2 | 46 | 0.40 | 2.6 |
| TOTAL | 21 | 242 | 32-85 | 23.8 | 246 |

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 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 been also 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 8.5 ha currently. 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. More information of the soil heating applications is presented in Table 4.

**Table 4: Soil heating applications for off-season asparagus production by geothermal field (2012-2013).**

| Locality | Cultiv. area (ha) | Maximum Utilization | | | Energy Utilization (TJ/yr) |
|---|---|---|---|---|---|
| | | Flow Rate (kg/s) | Inlet Temp. (°C) | Capacity (MWt) | |
| Neo Erasmio, Thrace | 3.5 | 12 | 60 | 1.76 | 13.9 |
| Myrodato, Thrace | 5.0 | 14 | 50 | 1.46 | 10.9 |
| **Total (direct)** | **8.5** | **77.0** | **50-60** | **3.22** | **24.8** |
| Chrysoupoli, Macedonia (GSHP) | 20.0 | 72.0 | ~17 | 2.10 | 22.0 |
| **Total** | **28.5** | **149** | | **5.42** | **46.8** |

### 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 4000 m$^2$, is heated directly using a good quality geothermal water of 57 ºC. The spa building in Traianoupolis is heated indirectly by geothermal water with temperature of 52 ºC.

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 submergible pump. This system will provide heating to five public and municipal buildings. The water temperature is 88 ºC and a titanium heat exchanger is employed to isolate the recirculation water due to the high salinity of the water.

### 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 120 tn of "sun-dried" tomatoes have been produced. The yearly production of dried tomatoes is presented in Figure 4. 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). The unit is capable of drying many other agricultural products, such as peppers, onions, mushrooms, olives, asparagus, figs, apples and cherries.

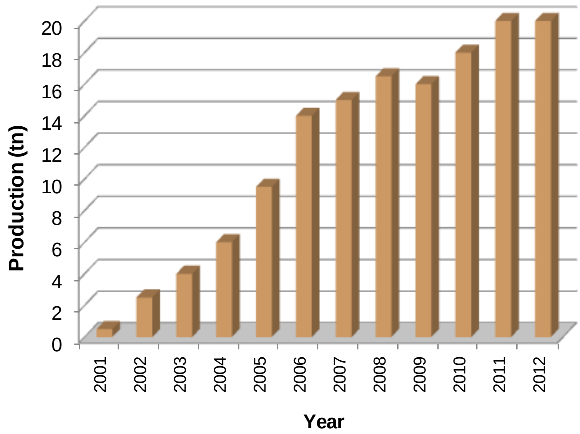


**Figure 4: Yearly production of "sun-dried" tomatoes since 2001.**

### 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).

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.

### 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 any known systematic study of the energy use in the balneological centres in Greece. A conservative estimate (assuming that the temperature of water leaving the bathing facilities is 30 ºC) of the total thermal capacity of Greek spa resorts is 42 MWt, with a mean load factor of 0.17. 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 mid of the past decade, it peaked about 3 years ago and it is affected now by the economic recession as well as by strong competition from natural gas and air-water air-condition units. However, the turnover of the Greek economy expected to take place during 2014, should result in GSHP market recovery to before crisis levels.

The authors have been recorded more than 800 applications of GSHP systems in Greece with a total installed capacity of 64 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 1000 with an installed capacity of more than 90 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 5. 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.

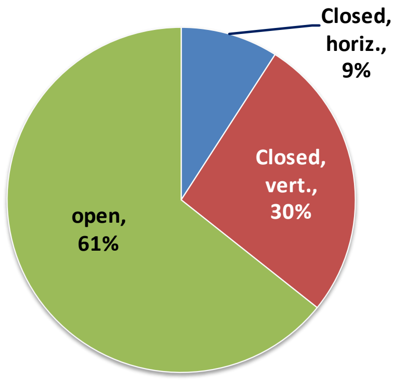


**Figure 5: Share of the various GSHP configurations. Total recorded installed thermal capacity 64 MWt.**

There is a clear trend with increasing interest in GSHPs (Figure 3), 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 2012, fewer than 100 new installations were reported with an installed capacity of about 7 MWt. During the past few years GSHP systems also face the competition from air-to-water heat pumps, which are more economically attractive.

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 1000 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 2100 kWt, water temperature varies between 16 ºC 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. A picture of such cultivation is shown in Figure 6.

## 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 7: (i)

Evros River Delta in Thrace (approximately 1307 km$^2$); (ii) Nestos River Delta in Macedonia (803 km$^2$); (iii) Samothraki Island (181 km$^2$); (iv) Central and Southern Chios Island (476 km$^2$). The exploration right for all the areas was awarded to the consortium of Terna Energy S.A and ITA Group S.A. The concession regards a five-year period. Under the terms of their agreement with the Ministry of Energy, they must invest 95 million € in geothermal exploration within the first two years. 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 signed till now (March 2013).

**Figure 6: Picture of asparagus beds heated using open-loop geothermal heat pumps in Chrysoupolis, Macedonia.**


**Figure 7: Location of the leasing areas.**

As mentioned earlier a second international open tender was 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. The same company has called an open invitation of an expression of interest for the selection of a long-term strategic partner for the development of five geothermal power plants in four geothermal fields. .

Regarding low-enthalpy fields, last year (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 SA. As a first step, its subsidiary, Greenhouse Thrace SA, will build a 5-ha geothermal greenhouse for tomato production. The investment is expected to be implemented later in 2013 with an initial outlay estimated 1.7 million €.

(3) Geothermal Field of Eratino-Chrysoupolis (Macedonia). The field has been awarded to the Municipal Authority of Nestos. Large quantities of water with temperature up to 65 °C can be extracted and used for the heating of more than 70 ha of asparagus plantations or other protected cultivations.

(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 called 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 is estimated as follows: about 20 in state agencies and organisations (10 at the Centre of Renewable Energy Sources, CRES, 6 at IGME 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. theses have been completed in Greek Universities dealing mainly with aspects of GSHPs.

## 7. LEGISLATIVE ISSUES AND PREPARATION FOR 2020

In pursuit of accomplishing the National Renewable Energy Action Plan and the "20-20-20" target, amongst else, initiatives for the support of the heat production from the shallow geothermal energy should be considered in the near future. In addition, energy saving policies must be developed, fostering new supporting (financial) instruments for the buildings energy saving including GSHPs as the spearhead along with the implementation of all the technical measures that are described in the "Energy Performance of Buildings Regulation" (KENAK), aiming to achieve the country's targets. The new building regulation which is expected to act as the main market penetration tool for RES and energy savings in heating and cooling systems at the tertiary and residential sector and at the agricultural and industry as well, should be supported by promotion actions in order to encourage the end-users and SMEs to invest in GSHPs reliable technology. Furthermore, successful implementation of energy saving measures in end-use along with development of new market mechanisms (i.e. ESCOs) for both public and private sector are to be proved essential to achieve the projected RES share in heating and cooling (Ministry of Environment, Energy & Climate Change, 2010).

Present incentives for GSHPs are limited to direct grants up to 10 500 € and zero or subsidised interest loans up to 4 500 € for residential and commercial buildings (programme "Energy Savings at Home"), direct grants for up to 40% of the investment for hotels (programme "Green tourism"), as well as price reductions offered by installers (programme "Building the Future").

The country aims at meeting the EU heating and cooling RES targets with the inclusion of 50 ktoe from GSHP systems in 2020. This corresponds in an installed GSHP capacity of 265 $MW_{th}$ with a technology mix share of 45% closed, 40% open and 15% horizontal systems. In order to achieve this objective the GSHP market should increase from present levels to 40 $MW_{th}$ of new installations annually by 2017. The corresponding investments to achieve this objective are estimated at around 320 million euro of GSHP installations (CRES, 2012).

According to the National Renewable Energy Action Plan for Greece (Ministry of Environment, Energy & Climate Change, 2010) the installed capacity for geothermal power should be 120 MWe in 2020. This implies installation of the first plants of 10-20 MWe at the geothermal concessions allocated to PPC-Renewables S.A. (PPCR) on Milos Isl., Kimolos Isl., Lesvos Isl., Nisyros Isl. and Methana peninsula, as well as at the geothermal concessions of Chios Isl, Samothrace Isl, Alexandroupolis basin and Nestos river delta basin described earlier. The remaining geothermal concessions of Soussaki, Spercheios graben, Akropotamos and Ikaria Isl. allocated to PPCR will be exploited at a later stage. Generation of geothermal electricity is supported by a feed-in-tariff guaranteed for 20 years of 99.45 €/MWh for resources above 90°C. This FIT rate increases by 20% in case that the project is not funded by national or European grants and it is adjusted by 80% of the change in the Greek consumer price index.

## 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 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 more than doubled, compared with figures reported in EGC 2007, reaching 180 MWt. However, this increase is almost exclusively attributed to the boost of GSHP market.

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**Tables A-G**

**Table A: Present and planned geothermal power plants, total numbers**

| | Geothermal Power Plants | | Total Electric Power in the country | | Share of geothermal in total | |
|---|---|---|---|---|---|---|
| | Capacity ($MW_e$) | Production ($GWh_e/yr$) | Capacity ($MW_e$) | Production ($GWh_e/yr$) | Capacity (%) | Production (%) |
| In operation end of 2012 | - | - | 13816 | 51 907(1) | - | - |
| Under construction end of 2012 | - | - | 1200(2) | - | - | - |
| Total projected by 2015 | 20(3) | 123(3) | 20500(3) | 62 000(3) | - | - |

(1) IEA, Monthly electricity statistics, Dec. 2012; (2) Estimate, Thermal 700 MWe, PV 500 MWe; (3) NREAP, 2012.

**Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers**

| | Geothermal DH Plants | | Geothermal heat in agriculture and industry | | Geothermal heat in balneology and other | |
|---|---|---|---|---|---|---|
| | Capacity ($MW_{th}$) | Production ($GWh_{th}/yr$) | Capacity ($MW_{th}$) | Production ($GWh_{th}/yr$) | Capacity ($MW_{th}$) | Production ($GWh_{th}/yr$) |
| In operation end of 2012 | - | - | 27.3 | 274 | 42 | 230 |
| Under construction end of 2012 | 0.55(1) | - | - | - | - | - |
| Total projected by 2015 | 2 | - | 40 | - | 50 | - |

(1) Completed, but not in operation

**Table D: Existing geothermal district heating (DH) plants, individual sites**

| Locality | Plant Name | Year commiss. | Is the heat from geo-thermal CHP? | Is cooling provided from geo-thermal? | Installed geotherm. capacity ($MW_{th}$) | Total installed capacity ($MW_{th}$) | 2012 geo-thermal heat prod. ($GWh_{th}/y$) | Geother. share in total prod. (%) |
|---|---|---|---|---|---|---|---|---|
| Traianoupolis | Spa | 2000 | No | No | 0.25 | - | 0.88 | 100 |
| N. Apollonia | Spa | 2008 | No | No | 0.65 | - | 2.20 | 100 |
| Milos | Hotel | 2005 | No | No | 0.25 | - | 0.55 | 100 |
| Various | houses | - | No | No | 0.25 | - | 0.80 | 100 |
| | | | | | | | | |
| **total** | | | | | **1.40** | | **4.43** | |

**Table E: Shallow geothermal energy, ground source heat pumps (GSHP)**

| | Geothermal Heat Pumps (GSHP), total | | | New GSHP in 2012 | | |
|---|---|---|---|---|---|---|
| | Number | Capacity ($MW_{th}$) | Production ($GWh_{th}/yr$) | Number | Capacity ($MW_{th}$) | Share in new constr. (%) |
| In operation end of 2012 | 1200(1) | 100(2) | 135 | 140 | 10 | n.a. |
| Projected by 2015 | 2400 | 200 | 270 | | | |

(1) estimate, reported 800; (2) estimate, reported 64 MWt

**Table F: Investment and Employment in geothermal energy**

| | in 2012 | | Expected in 2015 | |
|---|---|---|---|---|
| | Investment (million €) | Personnel (number) | Investment (million €) | Personnel (number) |
| Geothermal electric power | 1 | 8 | 30 | 40 |
| Geothermal direct uses | 0.5 | 10 | 7 | 20 |
| Shallow geothermal | 14 | 150 | 33 | 300 |
| **total** | **15.5** | **168** | **70** | **360** |

**Table G: Incentives, Information, Education**

| | Geothermal el. power | Geothermal direct uses | Shallow geothermal |
|---|---|---|---|
| Financial Incentives – R&D | none | none | none |
| Financial Incentives – Investment | none | none | DIS, LIL |
| Financial Incentives – Operation/Production | FIT | none | none |
| Information activities – promotion for the public | no | no | no |
| Information activities – geological information | yes | yes | yes |
| Education/Training – Academic | yes | yes | yes |
| Education/Training – Vocational | no | no | no |

Key for financial incentives:

| | | | | | |
|---|---|---|---|---|---|
| DIS | Direct investment support | RC | Risc coverage | FIP | Feed-in premium |
| LIL | Low-interest loans | FIT | Feed-in tariff | REQ | Renewable Energy Quota |