Proceedings European Geothermal Congress 2007
Unterhaching, Germany, 30 May-1 June 2007

Update and Characteristics of Low-Enthalpy Geothermal Applications in Greece

N. Andritsos[1], P. Dalabakis[2], G. Karydakis[3], N. Kolios[4] and M. Fytikas[5]

[1]Dept. Mechanical & Industrial Eng., University of Thessaly, Pedion Areos, 383 34, Volos, Greece

E-mail address: nandrits@mie.uth.gr

[2] Land Reclamation Institute, NAGREF, 574 00 Sindos, Thessaloniki, Greece

E-mail address: dalabakis.lri@nagref.gr

[3]Institute of Geology and Mineral Exploration, Geothermal Energy Section, Mesogeion 70, 11527 Athens, Greece

[4]Institute of Geology and Mineral Exploration, Branch of Central Macedonia, Frangon 1, 54626, Thessaloniki, Greece

E-mail address: kolios@thes.igme.gr

[5]Department of Geology, AUTh, GR 54006, Thessaloniki, Greece

E-mail address: fytikas@geo.auth.gr

Keywords: country overview, potential, direct uses, prospects, geothermal heat pumps

ABSTRACT

The aim of the presentation is to give a brief overview of the direct geothermal uses in Greece and to discuss their characteristics. Greece holds a prominent place in Europe regarding the existence of promising geothermal resources (both high and low-enthalpy), which can be economically exploited. Currently, no geothermal electricity is produced in Greece. The installed capacity of direct uses in the beginning of 2007 is estimated at about 88 MWt, exhibiting an increase of about 18% compared to the figures reported at the World Geothermal Congress 2005. Still, balneology and open-door or closed-door pool bathing exhibits the largest share, following by greenhouse and soil heating. Earth-coupled and groundwater (or seawater) heat pumps have shown a significant increase during the past 2-3 years, due to increasing oil prices and easing of the permit requirements for drilling vertical wells.

1. INTRODUCTION

Greece, like many other Mediterranean countries (e.g. Italy and Turkey) is rich in geothermal energy. This is because the greatest part of the country is located in an area geodynamically very active, as a result of the movement of the African plate towards the Eurasian plate.

Geothermal energy, in the form of thermal waters for bathing and medicinal purposes, has been known in the area from prehistoric times. However, the systematic exploration of the geothermal potential of Greece, started only in the early 1970s, by the Institute of Mineral and Geological Exploration (IGME). These exploration efforts were mainly focused on areas related to the south Aegean volcanic arc (Milos, Nissyros, Methana, Soussaki etc.) and on Lesvos Island (see the geothermal map of Greece in Figure 1). The evaluation of the geothermal resources was continued in the 80's and 90's covering the greatest part of Greece. Around 1980 the first use of thermal waters (apart for balneology) was materialized for greenhouse heating. In the late seventies, the Public Power Corporation (PPC) expressed an interest in the generation of electric power from the high-enthalpy geothermal field of Milos Island. After extensive and successful exploration efforts, a double-flash 2-MWe power plant was installed in 1985 in Milos and operated intermittently till 1989, when it was shut down because of some technical problems (which, however, could be coped successfully) and environmental protests by the island's inhabitants (due to H_2S emissions to the atmosphere). Since then no attempt has been taken for the exploitation of the large high-enthalpy potential in several islands in the Aegean volcanic arc. In the past few years the Public Power Corporation (PPC) has started exploratory work to find geothermal waters of suitable temperature and quantity for the installation of a binary ORC unit in Lesvos Island. In fact, the National Authority for Energy has given recently a positive recommendation to PPC for an 8-MWe binary plant in the island.

The use of geothermal waters for greenhouse heating started in Greece in the early 1980s. The next decade soil heating for off-season asparagus production was practiced in Thrace. Although, during the past ten years these two main uses seem to be in a standstill, several new and sometimes novel applications appeared (e.g. tomato drying, spirulina cultivation).

The present paper deals with the reviewing of the direct geothermal applications in Greece, focusing on the developments accomplished during the past 2-3 years and the specific characteristics of the various direct uses.

2. ENERGY CONSUMPTION AND THE ROLE OF RENEWABLES

The primary energy supply in Greece was estimated at 33 ktoe in 2004 according to European Commission (2007). About 30% of the energy supply is produced domestically. The energy balance in Greece relies heavily on two fossil fuels: (a) Lignite dominates domestic production, with an 84% share, and it is used primarily for electricity generation (representing 60% of total generation), mainly in Western Macedonia. (b) Imported oil is the most important fuel source, accounting for approximately 60% of total energy consumption. In addition, imported oil is the fuel that is used for power generation in the islands. Natural gas has been introduced ten years ago, and its consumption has been steadily increasing, reaching a 6.5% share in 2005 of the total energy consumption (BP Statistical Report, 2006). Although the energy consumption per capita is 2800 ktoe/cap, as compared to the EU-27 average of 3689 ktoe/cap, the generation of electricity mainly from lignite results in high CO_2 intensity values (3.1 tn of CO_2/toe as compared to 2.2 tn of CO_2/toe for EU-27).

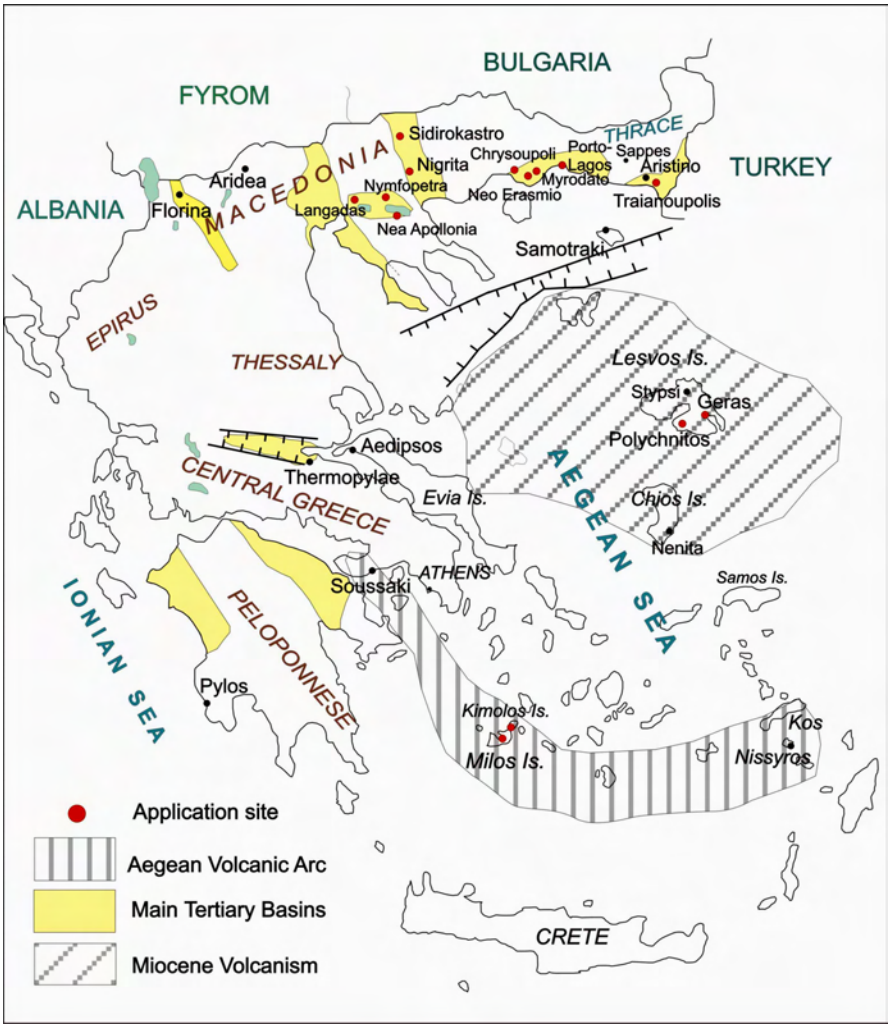

Figure 1: Geothermal map of Greece indicating the sites of direct uses (the balneology sites are not included).

Renewable sources, the supply of which has shown a small increase in recent years, account for only 5.1% of total primary energy supply, not far away from the EU-27 average of 6%. Table 1 presents the renewable energy balance in 2004. Since then, the installed wind capacity has been roughly doubled, while the capacity of the other renewable sources remains rather constant. In 2006, Greece was the 11th largest country in terms of installed wind capacity in the EU-27. Geothermal energy accounts for only a 0.8% share in the total renewable energy production.

Table 1: Contributions of various energy sources in the total renewable energy production in Greece in 2004 (Ministry of Development, 2007)

Energy Source	Energy production (ktoe)	% share
Biomass	954	61.0
Solar	100	6.4
Geothermal	13	0.8
Wind	96	6.1
Hydropower	401	25.6
Total	1564	100.0

Greece aims at increasing the share of electricity produced from renewables from 9.6% in 2004 to 20.1% by 2010 in the context of the EU Renewables Directive 2001/77/EC. Geothermal energy can contribute undoubtedly to this target. According to the 3rd National Report Regarding Penetration Level of Renewable Energy Sources in the Year 2010, issued by the Ministry of Development, the installed capacity of geothermal electric plants will range between 5 and 8 MWe by 2010. This capacity refers only to binary units and no thought has been expressed for flash-type units after the failure of Milos project.

Renewable energies, including geothermal energy, are promoted for electricity generation by preferential feed-in tariffs introduced by Law 2244/94 and consolidated in 2006 by Law 3468 (Official Gazette A' 129/27.06.2006), which were enacted primarily for the liberalization of the electricity market. According to the latter law, the average feed-in tariff for geothermal electricity is €83/MWh in the interconnected system and €84.6/MWh on the non-interconnected islands. Additionally, for the production of electricity using geothermal energy (or other RES) a relevant authorization is required, to be granted by the Minister of Development following an opinion from RAE (Regulatory Administration of Energy). Exemption from this obligation is granted for small geothermal plants, with an installed capacity less than 0.5 MWe and the use of generated electricity by the owner.

3. GEOTHERMAL POTENTIAL

As it was stated in the Introduction, Greece has a large geothermal potential. The proven potential of the well-explored high-enthalpy fields of Milos and Nissyros Islands for power generation purposes amounts to more than 250 MWe. Prospective areas with medium-temperature fluids up to 120ºC, suitable for electricity generation with binary cycle plants, have been identified in the islands of Lesvos, Chios and Samothraki and in the geothermal fields of Aristino (Alexandroupoli) and Akropotamos (Kavala). In these areas, water temperatures in the range of 90-100ºC have been measured in wells drilled at depths less than 1000 m. In the Eratino area a water temperature of 125ºC was measured at 1350-m depth.

Discussion on the numerous low-enthalpy geothermal resources (with fluid temperature less than 100ºC) can be found in Fytikas et al, 2000 and 2005. The thermal potential of low-enthalpy geothermal resources in the whole country exceeds 1000 MWe. In the past 2-3 years IGME continued to carry out exploratory work on existing and hopeful geothermal areas. Two more wells were completed in Akropotamos, Kavala, which yield more than 40 kg/s at temperatures 83ºC and 91ºC. The thermal potential of this field exceeds 30 MWt. Other areas investigated recently in Central Macedonia include Aridea (water temperature 42ºC, probable thermal potential 2 MWt), Nea Apollonia-Lake Volvi (45ºC, 3 MWt) and Alexandria (38ºC, 2 MWt).

4. GEOTHERMAL APPLICATIONS IN GREECE

Direct heat applications in operation during the winter 2006-2007 are summarized in Table 1. The installed capacity of direct uses in the beginning of 2007 reached 88 MWt, exhibiting a 18% increase compared with the capacity reported for the end of 2004 (Fytikas et al, 2005). The greatest part of this increase is attributed to the rapid expansion of geothermal heat pump installations. All other applications do not show any clear increase in the installed capacity in the past few years. A small increase is shown in soil heating. In addition, some geothermal greenhouses and the desalination plant built in Kimolos Island are out of operation for reasons not related to the geothermal technologies. The novel desalination plant in Kimolos does not produce valuable fresh water for the inhabitants of the island because it has not been connected with a pipeline with the main water tank of the island. Furthermore, despite the significant share of balneology and open-door or closed-door pool bathing to the total capacity, this sector (with some exceptions) does not show any sign of expansion or use of the hot waters heating the structures. Finally, the completion of a 2-MW project for the heating and cooling of several public buildings in the town of Langadas, Thessaloniki, with geothermal heat pumps by utilising shallow wells with water temperature in the range 20-40ºC was suspended due to administrative problems.

4.1 Greenhouse and Soil Heating

The first geothermal greenhouses were constructed in the early 1980s in Nea Apollonia and Langadas (Perfecture of Thessaloniki), Nigrita (Serres), N. Kessani (Xanthi) and Polichnitos (Lesvos island). Currently, the covered area of geothermal greenhouses in the whole country is 18.2 ha.

Since about 1995 there is not any real increase in the covered area of geothermal greenhouses. Some new greenhouses were constructed, but greenhouses totalling about 6.5 ha have been out of operation for reasons not directly related to the geothermal energy. Table 3 presents information on currently active and inactive greenhouses by geothermal field.

Table 2: Summary of the installed capacity of direct uses and of annual energy use in 2007.

Use	Installed Capacity (MWt)	Annual Energy Use (10^{12} J)
Space heating	1.4	16
Greenhouse & soil heating	26.5	248
Agricultural drying	0.8	4
Aquaculture*	9.3	76
Bathing and swimming	36	182
Geothermal heat pumps	14	80
Total	**88**	**606**

* Fish Farming & Spirulina Cultivation

Table 3: Greenhouse heating applications in Greece by geothermal field (2006-2007).

Locality	Covered area (ha)	Maximum Utilization			Energy Utilization (TJ/yr)
		Flow Rate (kg/s)	Inlet Temp. (°C)	Capacity (MWt)	
Nigrita, Serres					
In operation	3.50	47.0	37-51	3.25	34.0
Inactive	4.80	39.0	45-58	2.75	
Sidirokastro, Serres					
In operation	2.70	50.1	37-63	3.20	36.9
Inactive	0.40	10.1	45	0.60	
Langadas, Thessaloniki					
In operation	2.20	14.4	35-37	0.82	8.6
Inactive	0.42	6.0	36	0.55	
Nea Apollonia, Thesssaloniki					
In operation	5.50	83.0	32-46	5.51	64.6
Eleochoria, Chalkidiki					
Inactive	0.20	5.6	30	0.23	
Neo Erasmio, Xanthi					
In operation	0.30	4.0	60	0.42	5.1
Nea Kessani, Xanthi					
Inactive	0.60	25.0	72	2.30	
Islands (Lesvos and Milos)					
In operation	3.95	31.0	46-85	5.10	45.7
Total					
In operation	18.2	230.0	32-85	18.30	195
Inactive	6.40	85	30-72	6.40	

Almost a decade ago, the use of geothermal water for soil heating was developed in Neo Erasmio, Xanthi, for off-season asparagus production. Soil heating usually starts in mid January and off-season asparaguses are produced between February and April, with higher prices that in-season produced asparaguses. This attempt was the first geothermal application world-wide in non-covered intensive cultivations. The soil heating is accomplished by the direct flow of the geothermal water through corrugated poly-propylene (PP) pipes with an outside diameter of 28 mm, laid underground. Soil heating can raise the soil temperature by 4-10ºC, depending upon the ambient conditions (temperature, moisture, winds, precipitation), the water flow rate and temperature, the presence of the foil coverage etc.

The total cultivated area with soil heating in the beginning of 2007 was 20 ha. A 3.5 ha field in Nigrita stopped operating in 2003. In the meantime, the Nymfopetra unit was expanded by 2.0 ha, currently totalling 7 ha. A new 2.0-ha soil-heating unit was installed in Myrodato, Xanthi, in 2005. Originally, it was designed for off-season production of watermelons, but the next year the cultivation was turned to asparagus. Finally, a novel and promising effort has been carrying out during the past year in Chrysoupoli, Kavala, with the soil heating of an area of 1.0 ha for off-season asparagus production with an open (ground water) geothermal heat pump system. This installation will expand by 1 ha next year.

4.2 Space Heating

There is no any new development in this sector. The use of geothermal energy for space heating is practiced only in a spa complex (space area 2000 m^2) in Traianoupoli, Thrace, in a hotel in Milos, in several individual houses in Macedonia and Thrace and in a high-school building in Thrace. As it has been discussed in Fytikas et al. (2005) the heating of a few houses in Milos Island is accomplished by a kind of "downhole heat exchangers". Similar systems have been also tested in Soussaki and Polichnitos, Lesvos Island. The installed capacity of the space heating units in the country is estimated as 1.4 MWt.

4.3 Dehydration of Agricultural Products

A tomato dehydration unit has been operating since 2001 in N. Erasmio, 25 km south of Xanthi, and produces "sun-dried" tomatoes (Andritsos et al, 2003). The unit uses low-cost geothermal water to heat atmospheric air to 55-56°C through finned-tube air heater coils. During the first six years of operation more than 37 tn of high quality dried tomatoes have been produced. The unit has been modified two years ago to double the drying capacity and a new expansion is planned for the next year. The unit can be easily modified to dehydrate many other vegetable products (e.g. peppers, onions, mushrooms and asparagus) or fruits. In fact, more than one ton of peppers, figs and apricots have been dried so far. With this application, geothermal energy undergoes one of the most appropriate and efficient tools for high quality and energy saving drying process.

4.4 Aquaculture

Anti-frost protection/heating of aquaculture ponds in Porto Lagos and Neo Erasmio (both in Perfecture of Xanthi) is practiced since 1998. It concerns mainly the heating of wintering ponds (earth channels) with giltheads, a very delicate fish which is very sensible to the abrupt drop of temperature in winter time. In Porto Lagos, the water comes from two production wells near the farming ponds. The protection of a 0.48 ha wintering pond against freezing requires a flow rate of up to 40 m^3/h of geothermal fluids with a mean temperature of about 34ºC. The water in the pond (about 20,000 m^3) is constantly replaced, receiving water either from the sea or from the neighbouring shallow Lagos Lagoon. The injection of warmer fluids into the pond not only protected the fish stock from bad weather, but also increased fish production (Gelegenis et al, 2006).

In the N. Erasmio installation, the water, at a flow rate of 60 m^3/h and temperature of 60ºC, is transported from a distance of 4.5 km through insulated plastic pipes (HDPE). Due to the high water temperature, geothermal water is initially mixed with seawater. The final mixture is injected into the ponds with a mean temperature of 30°C.

The installed thermal capacity of both installations exceeds 8 MWt. The use of geothermal energy in these fish farms proved indispensable during the heavy frosts in the 2001-2002 and 2002-2003 winter periods and averted severe damage of the fish stock that has occurred in other farms of the region. It is estimated that both investments were repaid during the first three years of operation.

The second use of geothermal waters in aquaculture in Greece refers to the cultivation of the green-blue algae spirulina in Nigrita, Serres. This application was started in the late 1990s. The cultivation of spirulina requires significant quantities of CO_2, most of which come from the dissolved CO_2 in the geothermal waters. The local geothermal waters contain about 4 kg of pure CO_2 per cubic meter of water produced. The local geothermal water cannot be used directly in the cultivation ponds, something that would be desirable, since it contains about 0.50 ppm As. The geothermal water, with a temperature of 51°C and a flow rate of 0.5 kg/s, is first directed to a separator and then flows through a specially-designed heat exchanger, that allows easy inspection and cleaning in case that calcium carbonate scales are formed. The heating of the cultivation water with geothermal energy and the use of geothermal CO_2 use increase significantly micro-algal production (by optimizing photosynthesis) and reduce its cost.

Spirulina is cultivated between April and November in 8 ponds made of concrete, each occupying an area of 225 m^2 and holding about 40 m^3 of water (see Figure 2). Smaller ponds are used for the initial stages of the algal production. All the cultivation ponds are situated in a greenhouse, covered with plastic foil (Fournadzhieva et al, 2002)

The production of dry spirulina in 2006 amounted to 1500 kg (in the form of capsules or powder), while the plans for 2007 are 3000 kg, due to expansion of the cultivation tanks and the extension of cultivating period. The drying of the wet product is accomplished inside the greenhouse by laying the product on plastic tables..



Figure 2: Picture of geothermally heated ponds for spirulina cultivation in Nigrita, Serres.

4.5. Bathing, Spas

More than 750 thermal springs have been recorded in Greece. Some of them flow continuously for more than many centuries (e.g. the thermal springs at Thermopylae are flowing at a rate of 30 kg/s for at least 2500 years), while other ceased flowing in recent times due to the drilling of wells in the same area.

Currently, there are 56 thermal spas and bathing centres operating in Greece, mostly operated during the traditional balneological period (June-October). It is interesting, though, that more and more spas remain open all year around. Only recently there has been an interest for systematic work to assess the thermal use in the spas and

bathing centres in Greece and to record the problems related to the geothermal waters (scaling, corrosion). The total water flowrate from the Greek spas exceeds 1000 kg/s, while the water temperatures range between 18 and 90ºC. A conservative estimate (assuming that the temperature of water leaving the bathing facilities is 30ºC) of the total thermal capacity of the Greek spa resorts is 36 MWt, with a mean load factor of 0.16. These figures include the cases of open-door and closed-door pools heated by geothermal waters.

4.6. Characteristics and problems of direct uses

The following information is based on an extensive survey of geothermal applications and site visiting during the winter 1998-1999 (Andritsos et al, 1999). The balneology and bathing applications are not included in this survey. This information was updated in the late 2004 and recently, either by visiting the sites or by personal communication.

The depth of the geothermal wells used currently in direct applications in the country ranges from 10 m (actually simple wells in the island of Milos) to 450 m, for the heating of aquaculture ponds in Porto Lagos. The average depth of the 30 geothermal productive wells is 140 m.

In Greece the main function of the geothermal direct-use well pumps is to carry the water to the surface and from there either to circulate it directly to the geothermal installation (e.g. soil heating) or to direct it to pass through a heat exchanger. At the moment, no pump functions to maintain the water under pressure so that to alleviate the problems of $CaCO_3$ scaling and corrosion. The selection of the type of the pump is in general dictated by the water level (or whether artesian flow conditions exist), the flow and pressure requirements of the system, the water temperature, the availability of spare parts and maintenance personnel and, above all, the cost. Power consumption costs are not usually taken into consideration. Three types of pumps are in use: lineshaft turbine pumps, submergible pumps and centrifugal pumps in connection with artesian wells. The latter are either placed directly on the head of the well or next to a holding tank, where the water is directed from the artesian well. The share of each type in pumping the 342 kg/s of geothermal water used in the direct-use applications in Greece is presented in Figure 3.

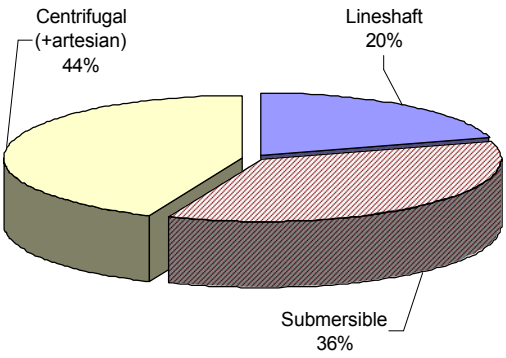

Figure 3: Share of the various types of pumps used in direct applications (total pumping flow rate 342 kg/s).

Most of the geothermal installations are rather close (20-200 m) to the geothermal well or to the holding tank. However, two transmission pipelines exceed 1 km. The longest, 4.5 km, is the buried insulated transmission line that carries the water to the aquaculture ponds in Neo Erasmio, Xanthi. The other long pipeline (non-insulated), in the island of Lesvos, carries the water at a distance of 2.5 km to a geothermal greenhouse. The total length of direct-use geothermal pipelines is 13 km.

PVC is by far the most widely used material for the transmission pipelines, having a share of 93% with respect to the pipe length. The use of PVC is widespread not only due to its availability and low cost, but because the majority of waters used have a temperature less than 50ºC, as it will be discussed below. The rest materials include PE (2%), PP (1%) and carbon steel or iron (3%).

The vast majority of short transmission pipelines are not insulated. Despite of the above, about half (48%) of the total pipeline length is insulated due to the 4.5-km long insulated pipeline in Neo Erasmio. It is also noted, that the trend in recent years is to use insulated pipes.

Figure 4 provides a breakdown of the quantities of waters used in the direct applications with respect to their temperature and their electrical conductivity. The majority (>63%) of the geothermal waters have a temperature less than 50ºC despite the existence of geothermal waters at much higher temperature. Regarding the water quality, more than 70% of the water quantities currently in utilisation in direct uses have an electrical conductivity less than 2000 μS/cm.

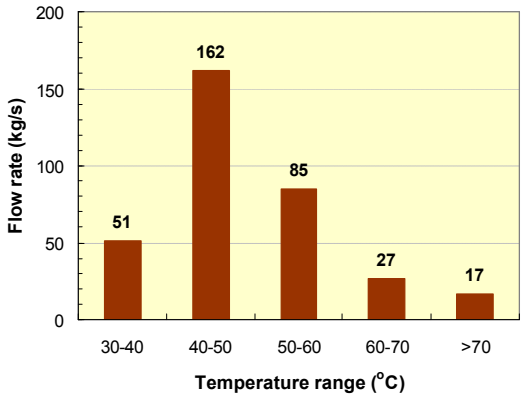

Figure 4: Distribution of water flow rates by temperature range (total flow rate 342 kg/s).

As it has been reported earlier, the total area of geothermal at the beginning of 2007 is 18.2 ha. Glasshouses with steel or aluminium frames represents about 67% of the total covered area, while 30% of the greenhouse are covered with plastic film on metallic or wooden frame. One installation is covered by rigid plastic (polycarbonate).

Currently, greenhouse heating is accomplished by the direct use of geothermal water using a variety of heating methods. Heat exchangers were utilized in four installations, now inactive (2 in Nigrita, one in N. Kessani and one in Milos). The following heating methods (or some combination of these) are used in the geothermal greenhouses:

a) Corrugated polypropylene (PP) pipes of o.d. 28 mm. These pipes are placed on the ground (next to the plant row), under or on the benches or they are suspended at a certain height. The number of pipes depends on the heating requirements and the water temperature. The PP pipes usually last between 3 and 7 cultivating periods.

b) Plastic polyethylene tubes having a diameter of about 0.2 m. These tubes are laid on the ground next to the plant rows. The upper part of the tube heats the air and the lower

warms the soil. They are used only for one cultivating period, while they are prone to rupturing. Fortunately, they usually carry low-temperature and low-conductivity waters and the consequences of any leakage are not catastrophic.

c) Finned metallic tubes. At the moment this method is applied in only one floriculture installation in Nigrita.

d) Fan-coil heaters. They are usually used when the water temperature exceeds 60ºC; in all cases this heating method is combined with direct heating with PP pipes, in a cascading use.

A breakdown of the heating methods is illustrated in Figure 5. Clearly, the use PP pipes is the choice for more than 50% of the greenhouse area.

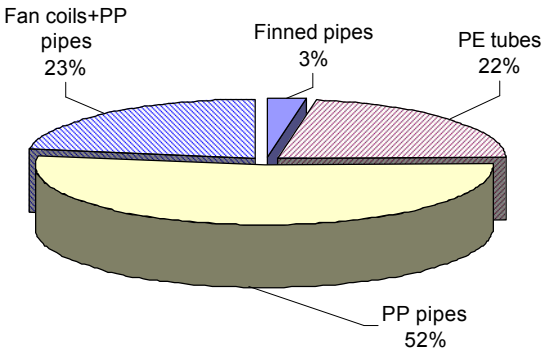

Figure 5: Distribution of the heating systems in geothermal greenhouses (total covered area 18.2 ha).

Finally, the share of geothermal water that is reinjected after the use accounts for about 33%, a clear improvement over the last few years.

The main problems encountered in the existing systems are well leakage of hot water from ill-constructed wells (e.g. in Nigrita and N. Apollonia), reduction of water production from wells (e.g. Porto-Lagos), heat losses during transmission, scaling and corrosion in wells, heat exchangers (in two currently inactive greenhouse installations) and in the fluid transmission pipe system and failure of the pumping units. In addition, in three geothermal fields (N. Apollonia, Langadas and Sidirokastro) the produced water quantities are not adequate to the local demand (due to also to low water temperatures), and a systematic exploration is needed to expand the capacity of the existing wells. Drilling costs for new wells are high and cannot be afforded by the local producers.

Scaling and corrosion problems have been encountered in certain areas (Nigrita, N. Kessani, Polichnitos). The corrosion problems can be mitigated by the use of plastic pipes, the proper selection of metallic pipes (e.g. to avoid the contact of metallic materials different in the galvanic series) and the use of heat exchangers to isolate the corrosive geothermal water. Scaling can be mitigated by keeping the water under pressure or by using threshold inhibitors. Strangely enough, the latter method has not been allowed by the regional authorities of Central Macedonia.

4.7 Geothermal Heat Pumps (GHP)

The use of geothermal heat pumps in Greece is not as widespread as in some other countries, especially in Central and Northern Europe. Depending upon land limitations, favourable geothermal conditions, local climatic conditions and the size of the installation, these units consist of earth-coupled heat pumps (horizontal heat collectors, vertical heat exchangers), or low-temperature geothermal or ground water heat pumps. In recent years there is also an increased interest in sea-water space cooling, especially for seaside hotels, operating only during the summer.

The authors have been recorded more than 160 applications of GHP units in Greece with a total installed capacity of 7 MW. The exact number of such units presently installed in the country is not known, but the above figure can be at least doubled. More the 14 installations have a capacity higher than 100 kW. Horizontal ground-source heat collectors are installed only for houses and are laid in a depth in the range of 1.5-3 m. The depth of the boreholes in the vertical GHP systems ranges from 60 m to 100 m. The open-loop systems use groundwater (which is always reinjected), brackish water and sea water (e.g. in Hydra island). With a mean estimated COP of 3.5 and for a heating equivalent load of 2000 hr/year, the thermal energy used for the 7-MW installed capacity is estimated at about 40 TJ/year.

In favour of the recent penetration of GHP systems is that in the last decade, the electricity cost decreased in real terms by as much as 25%. On the other hand, currently there is no subsidy for such systems for households (the same is true also for other renewable technologies), but a small tax deduction of the order of 200 Euros. Additionally, the VAT for GHPs (or other renewable) equipment is set to 9%, whereas the VAT for natural gas systems is 19%. Despite of the absence of any state support, the interest and the number of installations has been surged during the past year. More than 20 companies related to the design, sale or installation of GHP systems have participated in two recent Energy Expositions (March 2007) held in Athens and in Thessaloniki.

5. ON-GOING GEOTHERMAL PROJECTS

Several geothermal projects are in the stage of implementation or in the design stage. Some of these projects are:

- Aristino, Evros: a 0.4 ha greenhouse using geothermal water with a temperature of 62ºC has been completed, but it was not put in production yet.

- Porto-Lagos, Xanthi: expansion of the heated aquaculture lagoons from 0.5 ha to 1.0 ha.

- Neo Erasmio, Xanthi: expansion of soil heating area by about 3 ha. In the same field, the doubling of the drying tomato capacity is expected to be completed by 2008.

- Pylos, Messinia: a 3-MWt GHP project is under implementation for the heating and cooling of a large hotel and a number of tourist houses. Both open (groundwater and seawater) and closed horizontal systems will be implemented.

6. CONCLUSIONS

The current level of utilization of geothermal energy in Greece represents only a very small fraction of the identified geothermal resources. The potential for power generation is particularly high, exceeding 250 MWe, but this potential is located in the non-interconnected islands of the Aegean volcanic. Furthermore, the ill-dated 2-MWe power plant in Milos Island is still in the memories of the inhabitants of the island.

The installed thermal capacity of the direct uses in Greece increased from 75 MWt at the end of 2004 to 88 MWt today. Most of that increase is due to the rapid expansion of geothermal heat pump installations. Balneology accounts approximately to 40% of this capacity. This sector did not show any development during the past 10 years, apart from the building of several open-door and closed-door pools. The geothermal water is used only in one spa for space heating and domestic hot water, although there are more than 50 spas in operation (some of them all the year around). Greenhouse and soil heating have the second largest share in the installed capacity. However, the total covered area of geothermal greenhouses has remained stagnant since 1995, while the soil heating has been expanded somehow. Uses introduced during the past 10 years include fish farming, spirulina cultivation, and vegetable and fruit dehydration. Geothermal energy offers the possibility (both technically and economically) for the further development of certain added-value agricultural products (e.g. asparagus, microalga).

The significant increase of the GHP systems is due to several factors: the change of the attitude of the people to the "new" technology, the increased interest of the air-conditioning sector, the promotion campaign from the members of the Association of Greek Geothermists (AGG), the easing of the permits for the drilling of a "closed" well and, certainly, the soaring oil prices in connection to the stable prices of electricity. No state support exists at the present for the domestic installations, despite the pertinent attempts by GUG.

REFERENCES

Andritsos, N., Dalabakis, P., and Kolios, N.: Use of Geothermal Energy for Tomato Drying, *GeoHeat Center Quarterly Bul.*, 24(1), (March 2003), 9-13.

Andritsos, N., Karabelas, A.J., and Fytikas, M. Utilization of geothermal energy in Greece: current status, technical problems and prospects (in Greek), Proceedings, 6th National Conference on Renewable Energy Sources, Vol. A, pp. 461-470, Volos, Nov. 3-5, 1999.

European Commission, Energy, Energy for a Changing World, Fact sheets by country 2007, [ec.europa.eu/energy/energy_policy/facts_en.htm], accessed 2007, March 28.

Fournadzhieva, S., Pilarsky, P., Arvanitis, A., Fytikas, M., and Koultsiakis, E. Use of geothermal Fluids for cultivation of microalaga Spirulina in Nigrita-Serres, Proceedings, 7th National Conferences on Renewable Energy Sources, Vol. B, pp 97-104, Patras, Nov. 6-8, 2002.

Fytikas, M., ?ndritsos, N., Karydakis, G., Kolios, N., Mendrinos, D., Papachristou, M. Geothermal exploration and development activities in Greece during 1995-1999. *Proceedings World Geothermal Congress 2000*, (ed. S. Rybach et al.), Kyushu-Tohoku, Japan, May 28 - June 10, 2000.

Fytikas, ?., ?ndritsos, ?., Dalabakis, P., and Kolios, N.: Greek Geothermal Update 2000-2004. *Proceedings* World Geothermal Congres-2005, Imternational Geothermal Association, Antalya, Turkey (2006).

Gelegenis, J., Dalabakis, P., Ilias, A.; Heating of wintering ponds by means of low enthalphy geothermal energy. The case of Porto Lagos, Geothermics, 35, (2006), 87-103.

Karagiorgas, M., Mendrinos, D., and Karytsas, C. Solar and geothermal heating and cooling of the European Centre for Public Law building in Greece, *Renewable Energy*, 29, (2004), 461-470

Ministry of Development, National Information System on Energy, [www.ypan.gr/fysikoi_poroi/cms_index.htm], accessed 2007, March 28.