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Energy potential of geothermal energy in Greece

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ABSTRACT

The use of the geothermal heat in Greece could be used to satisfy a big part of the existing and the future energy demand. The available potential is an extremely important factor in determining the extent to which geothermal energy could play a major role in the future development of Greece and especially the economic and social development of the country. The existing geothermal potential is very high due to the geological favorable conditions.

High enthalpy geothermal steam has been located in the islands of Nisyros and Milos. Middle level enthalpy geothermal steam resources have been pinpointed in the Northern Greece and in the islands Lesvos, Chios and Santorini. Low enthalpy resources are all over Greece. Geothermal fluids with temperature values up to 95^{0}C have been located in economically exploitable depths. The chemical characteristics are from good to very good.

There exist many geothermal wells that could be potentially used for the production of electricity and low enthalpy heat. The potential of geothermal energy in Greece could increase dramatically if an effort is done to start using systematically some of the already known resources.

KEYWORDS

Geothermal energy, resources, applications, environment, Greece

1. Potential of geothermal resources

Geothermal research that started in Greece in the seventies has revealed high geothermal potential, both of high and low enthalpy, in several areas of the country. Lately, geothermal related exploration activities have been focused on the low enthalpy fields of Thrace and Macedonia and of Sousaki in central Greece [1]. Table 1 presents the geothermal potential of Greek regions. From this table it can be observed that there are some very high quality geothermal resources the temperatures of which are above 90 °C. Of major interest are the cases of Mylos and Nysiros where observations have showed that geothermal fluid temperatures exceed 300 °C and therefore can be used for electricity production.

Table 1. Potential and characteristics of the geothermalfields in Greece [2],[3]

Geothermal Areas	Flow rate (m^3/h)	Temperature (°C)	TDS (gr/lt)	Dissolved Substances	Thermal Power (T.E.P/h)
Alexandroupolis					
Aristino	100	90-92	15	Na-Cl	0.65
Tyhero	150	35-40	0.5		0.22
Komotini-Xanthi					
N. Kessani	350	40-82	5	Na-Cl, CO_2, N_2	1.75
Mitriko lake					
Sappes		35-50			
Nestos					
N. Erasmio	400	40-65	1-12	Na-Cl. Na-HCO_3	1.1
Erateino	500-600	40-70			1,65
Strymonas					
Sidirokastro	200	40-67	1.5	HCO_3-Na	0.5
Lithotopos	200	33-62	1.2	HCO_3	0.5
Nigrita	400	40-60	0.8-3.7	Ca-HCO_3-Na-CO_2	1
Mygdonia					
Nymfopetra	200	37-44	<1	SO_4Na-HCO_3	0.3
Lagadas	300	35-40	0.7	SO_4Na-HCO_3	0.37
N. Apolonia	200	45-50	0.7-1	SO_4Na-HCO_3	0.45
Korinthos Sousaki					
Upper Collector	400	50-77	43	CO_2, H_2S	1.5
Lower Collector	200	60-80	49	CO_2, H_2S	1
South Aegean Sea					
Mylos	200	325	5-30	H_2S	
Nysiros	100	350	10-30	H_2S	
Lesvos Island					
Polihnitos	300	70-90	1.65		1.65
Lisvori	100	70-90	0.55		0.55
Aargenos	600	80-90	3.6		3.6
Kaloni		23-61	2		2

:.P: Tons of Equivalent Petrol

1.1 Geothermal potential of Alexandroupolis

In the year 1994 was discovered in the western part of the sink of Evros a geothermal field of 3 km^2 area. Two productive drills of 150-200 in depth were executed in the area of ***Aristino*** with total flow rate 100 m^3/h. The pilot drills indicated that the rejection temperature of the fluids will be 25 "C. It is estimated that the geothermal field has a thermal performance capacity of 7.5 MWt or 0.65 tons of equivalent petrol per hour. In the same area (*Tihero*) have been discovered meteoric origin geothermal sources of limited area. Results from a two hundred-meter depth drill showed a flow rate of 40 "C fluid greater than 150 m^3/h. The thermal performance capacity for a rejection temperature of 25 "C was calculated around 2.5 MWt or 0.22 tons of equivalent petrol per hour.

1.2 Geothermal potential of Komotini and Xanthi

Extensive drilling investigation up to 500-meter depth in the area of Kessani revealed a thermal flaw of 15 km^2 area. The certified flow rate of the field comes up to 350 m^3/h and potential one to 1000 m^3/h. The thermal performance capacity based on the certified flow rate was calculated 20.3 MWt which corresponds to 1.75 tons of equivalent petrol per hour. In the area of Kessani there are operating geothermal greenhouses of *6* km^2 total area. Geothermal fluid of 72 "C temperature is used in a fluid/air heat exchanger and **an** overground pipe system. The total installed power is estimated to 1.1 MWt (120 T.E.P/year). In the region of Sappes in the southeast borders of the same area, in geological ground similar to the one of Kessani, have been conducted geothermal drills in 350-500 meters depth and have been ascertained fluid temperatures of 35-50 "C. The range of interest has a total area of over 30 km^2.

1.3 Geothermal potential of Nestos

Eastward of river Nestos has been located the geothermal field of ***New Erasmio*** with total area 15 km^2. In the territory have been conducted concertedly 20 investigative and 3 productive drills from which has been spotted geothermal fluids of temperatures 40-65 "C in depths up to 200 to 400 m. Reserves are certified to the flow rate level of 400 m^3/h and the thermal performance capacity is estimated to 12.7 MWt, namely 1.1 tons of equivalent petrol per hour. In the region west of Hrysoupolis, around ***Eratino*** village, has been detected thermal irregularity of total area 40 km^2. In 550-650 meter depth, dominate water-permeable rocks where temperatures have been recorded between 40 and 70 "C. Most conservative estimations calculate the flow rate of the filed up to 500-600 m^3/hr with potential for power production up to 19 MWt or 1.65 tons of equivalent tons of petrol per hour (assumed rejection temperature: 25 "C).

1.4 Geothermal potential of Strymonas

In the region of *Sidirokastro* has been detected an important geothermal field where have been conducted 19 investigative and 3 productive drills. Results revealed geothermal sources in depth 25-50 m. Exploitable reserves are estimated up to 200 m^3/h flow rate with average temperature 50 "C. The thermal power of the field, for rejection temperature 25 °C, is calculated to 5.8 MWt or 0.5 tons of equivalent petrol per hour. Existing geothermal applications in Sidirokastro today totally consume 145 m^3/hr. Consequently, there are fundamentals for the development of new geothermal applications (eel breeding etc).

In the region of of Lithotopos there is an area of 25 km^2 where 10 investigative drills have exposed fluids of 33-62 °C temperature with an average flow rate of 200 m^3/hr. The thermal performance capacity of the field is estimated to 5.8 MWt, that represents 0.5 tons of equivalent petrol per hour. Despite the low concentration of dissolved solids (1.2 gr/lt) there have been no productive drills for the exploitation of the geothermal power of the area. Thermal irregularities are also contacted in the region of *Nigrita* covering a total area of 16 km^2. The maximum flow rate is calculated to 400 m^3/hr of fluids with low T.D.S. that cause sludge phenomena. The estimated potential performance of the field is 11.6 MWt (1 T.E.P/h).

1.5 Geothermal potential of Mygdonia

In the territory of ***Nymfopetra***, west of Volvi lake, have been detected a geothermal field of 2 km^2 total area. Temperatures of the extracted fluids vary between 37 and 44 "C. Based on the results of preliminary pumping the potential flow rate of the geothermal field is calculated to 200 m^3/hr and the thermal power to 3.5 MWt (0.3 T.E.P/h). The geothermal field of the territory of *Lagadas* is spread between the city of Lagadas and the Lake of Agios Vasileios (6 km^2 area). Results from seven investigative drills in maximum depth 330 m, showed that the fluid, of extremely low T.D.S., temperature may rise up to 40 "C. The thermal performance capacity was calculated around 4.35 MWt or 0.37 tons of equivalent petrol per hour. The geothermal territory of ***New Apolonia***, known for its medical hot baths (51 "C), is situated south of lake Volvi. The low concentration in dissolved solids permits the direct use in greenhouse cultivation installations. The estimated potential flow rate rises up to 200 m^3/hr of fluid that has the capability of power performance 5.22 MWt (0.45 T.E.P .).

1.6 Geothermal potential of Korinthos Sousaki

From investigations that concluded in 1993 trough a 10 km^2 area were detected two geothermal sources in depths 120-200m (fluid temperature 50-77°C) and 600-900m (fluid temperature 60-80°C) respectively. The certified potential of the upper source rises up to 400 m^3/hr with potential of thermal power performance 17.8 MWt, namely 1.5 tons of equivalent petrol per hour. Correspondingly, the deeper source is characterized by a certified flow rate of 200 m^3/h that can yield 10.4 MWt of power or 0.9 tons of equivalent petrol per hour.

1.7 Geothermal potential of Mylos Island

All the geothermal wells of Mylos island are located at see level and the water produced is wann with low salt concentration. The areas where these wells are located are the following:

- Alykes, with temperature 58 °C,
- the area of Mavra Gremna,
- the areas of Kastanas and Boudia, with temperature 75 °C,
- Paleochory, temperature 65 °C,
- the area of Schinioty, with temperature 52°C,
- Komia-Tria Pegadia, with temperature 56 "C.

There are also many other common wells for producing drinking water with temperatures above 40 °C. The total area of the geothermal field is estimated at about 30 km^2. The temperature of the water, found near the surface at depths 10-100m, is between 30 and 75 "C. The certified flow rate is 200 m^3/h with potential for increase up to 1000 m^3/h. The main disadvantages of the geothermal water in Mylos island are its high concentration of the dissolved solids and H_2S. Several installations have been utilized in the past for electricity production as well as for greenhouse heating. The Nevertheless, the forenamed applications do not exhaust the potential of geothermal resources and therefore there are perspectives for their further development. During the recent years, development of high enthalpy geothermal resources in Greece has been suspended, while exploration of low and medium temperature fields and planning for their direct use development has been stressed.

1.8 Geothermal potential of Nisyros Island

The explorative drills at large depths, made by DEI during the years 1982-83, show the existence of geothermal fluids with temperatures varying between 350-400 "C but with unfavorable conditions for exploitation. The total high enthalpy geothermal potential of the island is estimated at 40 MW. The low enthalpy geothermal fluids emanate from reservoirs at depth 30-120 m with temperatures 25-95 "C. Because of the limited number of explorative drills the exact determination of the geothermal field is not possible. The verifiedflow rate is estimated at 100 m^3/h. The total dissolved solids are up to 10 to 30 gr/lt and the conciseness of hydrogen sulfide (HS) is at high level. At Nisyros exist geothermal greenhouse with total area of 1500 m^3

2. Geothermal energy applications

Apart from their therapeutic properties geothermal fluids may also be used for energy purposes. Geothermal energy is a mildly, renewable fonn of energy which can be used to supply an important percentage of the energy need in Greece. The most common use is for the heating of greenhouses while geothermal energy can find applications in tele heating, pisciculture, demineralization of water as well as for industrial uses such as drying of agricultural products.

2.1 Greenhouse heating

Preservation of certain climate conditions inside a greenhouse allows the cultivation of several off-season vegetable species and furthermore accelerates the rate of development. The heating needs of a green house depend mostly on its space and volume, the cover material, the desired interior temperature, the environment temperature and the frequency of air changes in it. In order to maintain the desired temperature inside a greenhouse, energy must be offered to compensate for the heat loss to the environment. The main causes of energy loss are focused in:

- loss from the radiation of the ground and of the plants,
- loss during the transfer between the greenhouse walls,
- loss due to the circulation of air in the interior of the greenhouse,
- loss of heat to the ground.

Country wide geothermal development has resulted in approximately 160 acres of geothermal heated greenhouses in operation, fifty percent of which were commissioned in the past 7 years. From the data presented 242 kg/s of fluid are used solely in heating greenhouses, giving a total estimated installed capacity of 23 MWt with total energy utilization of 133 TJ/year. Geothermal greenhouses in Greece cover today the surface of approximately 34 hectares and are placed mainly in Northern Greece, Lesvos and Milos, while some (~ 4 ha) of them are un-functional [1]. Of the latter ones, the majority is classic greenhouses, while some have undersurface heating for cultivation – ripping of asparagus's. Availability of geothermal gases of average temperature 45-60 °C makes a potential investment on geothermal energy installation very attractive[2]. Considering a mean value of energy consumption 150.000 Kcal/h/km^2, the conserving of energy may reach up to 2.5 tons of equivalent oil/km^2 or nearly 2.500.000 drx/km^2.

2.2 Tele heating

Space heating and tele heating by means of geothermal energy has met great development in countries such as Iceland, France and Hungary. To the contrary, this form of energy transfer has not found many applications in Greece since it is demands a very high investment cost. The density of the heat-demand as well as the climatologic conditions are critical factors for the assessment of the investment. When the exploitation of geothermal gases reaches a certain degree in combination with the use of conventional fuel for the coverage of peak loading, geothermal energy tele heating systems present some very strong advantages[4]:

- Energy saving from the substitution of conventional fuels that are already used in organized settlements.

- Environmental protection with substantial decrease or complete nullification of emissions.
- Reduction of the energy cost that derives from the advantage of geothermal energy in comparison with conventional fuels as well as from the potential for financial aid of the project.

2.3 Demineralization of water with low enthalpy geothermal energy

Demineralization of seawater is a sector where geothermal energy may be applied with success in order to solve the major problem of water famine of several Greek islands and coastwise areas. Geothermal demineralization has the greatest coefficient of application in comparison with solar and 'aeolian' demineralization. Demineralization is a high energy demanding process that supersedes at a degree of 50% the cost of clean water production; thus the reservation of cheap geothermal energy is an aspect of major importance. The fermentation may be integrated without particular technical difficulties with the use of hot water 60-100 °C. **A** demineralization project that is in progress in the island of Kimolos, will produce clean water at an amount of 200 m^3/day using as an energy source geothermal water of temperature 58-60°C. It is estimated.that the cost of demineralized water (up to 5ppm) will be 350 drx/m^3. The same process with oil or electricity as energy means would raise the cost to 800-1000 drx/m^3.

2.4 Dehydration and drying of agricultural products

Dehydration and drying of agricultural products is a process that demands certain amounts of energy in a time that there is no energy request for greenhouse heating. The technique of drying is applied broadly, targeting to a point in which humidity level reaches such amounts so that the preservation of products may be achieved without problems. With the use of geothermal energy it is possible to accomplish high level performance by substituting the conventional heater with an air-water heat exchanger ensuring:

- Conservation of several tones of conventional fuels that are demanded in large dehydrating units for every drying period.
- High quality of the final products, suitable for social consuming.

Statistical data indicate that a neoteric drying unit of capacity 30 ton/hr consumes 390 lt. of oil to cover its thermal energy needs. This amount of fuel for a drying period **of** 50 days represents nearly 468.000 lt. of petrol with an annual cost of 60.000.000 dr. Utilization of geothermal gases with only a slight modification of the present drying units could reduce the cost of operation by a substantial percentage.

2.5 Industrial uses

Geothermal energy could be exploited in industrial processes to cover a part of the total power requirement [5]. In dependency with their temperature, geothermal gases may be used in case such as warm up of canning food, bottling and vegetable bleaching. If the temperature of the geothermal fluids is too low, there is the capability to use fluids in preheating proceses or to raise that temperature by means of a heat pump.

3. Geothermal energy and environment

High enthalpy geothermal fluids are produced under high pressure through deep drills and consist of natural steam (which contains practically only H_2O in vapour condition) and gases. Drill water contains usually a large amount of dissolved solids (sometimes useful), twice as much as the amount of sea water. Geothermal water sometimes contains harmfull elements such as B, As, Hg and Pd in nilpotent amounts. Gases consist mainly of non-toxic CO_2 and in lower percentages of H_2S, NH_3, H_2, Ar and Ne. Geothermal fluids do not derive from combustion and for that matter do not contain suspended particles, ash and smoke. Pollution problems from geothermal gases are created exclusively from H_2S that is toxic in concentrations above 100 ppm and has an unpleasant scent. However in geothermal drills of high enthalpy H_2S never reaches that limit while geothermal drills of low enthalpy are completely H2S free. For the safety of the personnel working in a geothermal installation should be utilized a 30 m chimney that would attenuate the H_2S in the atmospheric air until admissible limits. Usually though are adopted two even better more efficient and economic techniques: restraint of H_2S with the Stretford method and OIEI recanalization of the geothermal fluids (steam, air and water) in another deep drill, in a closed circuit.

Table 2. Typical daily atmospheric burden from various types of energy (tons/installed MWe) [4]

Type of energy	CO_2	SO,	NO,	Suspended particles	NH_3	Metal traces	Sold waste
Coal	22	0.56	0.08	0.7	0	$40*10^{-5}$	0.8-2
Oil	18	0.28	0.08	0.02	0	$7*10^{-5}$	0.8-4
Natural gas	12	$4*10^{-5}$	*0.07*	0	0	0	0
Nuclear power	0	0	0	0	0	0	$4\text{-}33*10^{-4}$
Hydroelectric power	0	0	0	0	0	0	
High enthalpy geothermal power	3.36	0	0	0.11	0.02	0	0.19

The production of H_2S and the lack of equipment for its removal have created a problem in a few geothermal fields of Greece. Both geothermal exploitation power plants operated in Greece in Cyclades (Mylos) and in Dodecanese (Nysiros) have been shut down due to residents complain on environmental grounds. Greek geothermists have expressed disappointment in the stagnation of the geothermal power projects. Expectations are that in the near future the resident's objection can be overcomed and progress on other high enthalpy projects will be resumed since geothennal energy is one of the cleanest forms of energy together with wind and hydroelectric power. The superiority of environmental geothermal energy production is shown on table 2 as compared to other forms of energy production.

References

1. Fytikas et al. 1995. Geothermal Exploration and Development Activities in Greece during 1990-1994.
2. Koroneos C. J., Andritsos N. & Fytikas M. 1999. The State of Geothermal Energy in Greece Recent Developments.
3. Informative Guide for the Potential Exploitation of Geothermal Energy in Greece, March 1996.
4. Fytikas M., Kolios N. & Dalabakis P. 1996. Geothermal Energy: The Thermal Energy of the Earth, Energy.
5. B.R.G.M. 1998. Technical and Economical Feasibility of Low Enthalpy Geothermal Projects in the E.E.C, Luxembourg.