INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy

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Division of Earth Sciences

EXAMPLES OF LOW ENTHALPY GEOTHERMAL ENERGY APPLICATIONS IN AGRICULTURE AND GAINGO EXPERIENCE

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1. Introduction

The Agricultural University of Athens started activities on geothermal energy applications in agriculture, at Lesvos Island in the year 1983.

The Agricultural University of Athens in cooperation with the Institute of Geological and Mineral Research (IGME) and the Industrial Development Bank (ETVA), developed several demonstration activities in Nea Kessani (Xanthi), in Lesvos island, in Milos island and in Nissyros island. The main purpose of these activities were the development of technology for the use of geothermic fluids and the demonstration of the operation in such systems, to the local authorities and private farmers, in order to promote the use of geothermy as a tool for local socioeconomic development.

Some examples of these activities and the experience gained are given below:

With low enthalpy we consider geothermal fluids with temperatures lower than 100^0 C.

The normal uses of the geothermal energy in low Enthalpy are related with heating purposes as they are:

- Space heating and domestic hot water.
- Agricultural applications of heat
- Aquaculture. Rise of temperature of water used in fish farming.
- Industrial applications of heat, like hot water, drying etc.
- Desalination of sea or brackish water.

From all these possible applications of geothermal energy the common agricultural uses of low enthalpy geothermal energy are:

- Greenhouses heating for out of season production of vegetables, flowers and other crops.
- Soil heating in open air plantations to force earlier production or for frost protection of plants.
- Soil disinfection or sterilization.
- Fish farming.
- Drying of agricultural products.

2. The economic conditions of the use of geothermal energy in agricultural applications.

In the majority of the cases, the use of geothermal energy is not a so low cost energy application, as the non-initiated people believe. The cost of an application is related both, with amortisation of the investment and the operational cost.

A. <u>The investment cost</u> has to do with

1. <u>Geothermal research cost.</u> A complete geothermal research is a must before proceeding further on to other investments. The geothermal research will evaluate the extend and the type of the local geothermal field, the depth limits of the geothermal fluids, their temperature and chemical analysis, the prediction about the future exploitation and the rate of it, the expected environmental problems and their solution and other parameters.

2. <u>Infrastructure cost</u> for the optimum exploitation of the geothermal field as they are: The exploitation boreholes, the installation of the network for the fluids pumping, transportation and up to their final disposal, by re-injection or other solutions. The heat exchanger and the heat application to the final use. The magnitude of the investment cost depends on the geological conditions of the geothermal field (depth, dry rock or fluids, chemical composition of fluids, etc.) It depends also on the technology used for the heat exchanger and distribution network to the user (high cost heat exchanger and distribution network or the use of simple plastic tubes on the soil surface, etc.)

B. The operational cost is composed mostly by the:

1. Electricity consumption, for fluid pumping and water circulation and for the re-injection.
2. Chemical treatment of the geothermal fluids.
3. Maintenance of the equipment and the network.
4. Geothermal follow up of the field.

As it is obvious, the cost of the amortisation of the investment is related directly to the amount of geothermal energy finally used per year. In other words, it depends on the temperature and the flow of the fluids used and the time of the use of the pumped power during the year.

So, the lower the temperature and the flow of fluids, the higher will be the cost. But the main cost problem of the use of geothermal energy in agriculture is the limited time in a year of the need for heating. Especially under the Mediterranean climatic conditions, where some extreme winter conditions have a short duration. So, there is a need for a relatively high investment to face some limited in time extreme conditions. We say that the degree hours in agriculture are limited in the islands and south Greece conditions (see table 1).

Table 1. Installed power to cover a certain Δt and corresponding energy consumption in a greenhouse in Athens where is needed a Δt_{max}=15 °C (1)

Installed power to cover t, P=f(k, t)		Energy consumption, E=f[k, (DH)]	
_t	% of max.		% of max.
15	100.00	11543	100.00
12	80.00	11471	99.40
10	66.60	11281	97.70
8	53.30	10706	92.70
6	40.00	9407	81.50

Where: DH=Degree hours needed to keep the greenhouse temperature above the minimum during a year

Δt= Difference of temperature between the desired minimum internal temperature and the outside temperature

3. Agricultural products drying

The main problem to the geothermal energy for drying under the Greek climatic conditions is the very limited time in a year when each product needs to be drying. So a multi purpose and low cost geothermal installation is needed. Otherwise the competition is in favor of solar energy low cost technologies (see table 2).

Table 2. Heat energy needed for drying some Agricultural products under the Greek conditions

Drying activity	Energy in TOE	Duration of the activity /year	Season
Corn	0,008 TOE/t	20 days	October
Grapes (sultans or Corinthians)	0.029 TOE/t	15 days	September-October
Tobacco	0.0350 TOE/t	20 days	September-October
Figs	0.074 TOE/t	20 days	September
Vegetables	1.160 TOE/t	6 months	Spring to Autumn
Wood	0.0056		All year round

4. Desalination

The desalination of brackish or sea water with low enthalpy geothermal fluids could be justified as an agricultural activity in the case where fresh water is very expensive and the fresh water will be used for specific purposes (drinking water for animals and farmer family, greenhouses etc.)

Table 3: Heat for desalination of sea or brackish water

Desalination system	Energy needed in TOE/m^3
Multi Stage Flash Evaporation	0.005-1.010
Multi Effect Distillation	0.0026-1.010

Note: For low enthalpy fluids is needed also electrical energy for vacuum conditions. The lower is the temperature of fluids the more expensive is the desalination operation

5. Greenhouse Heating

From all the thermal applications of the low enthalpy geothermal energy, the more attractive appears to be the greenhouse heating, even for south Greek conditions. The parameters to be considered in a study for greenhouse heating is from one part the different amount of power needed to assure a certain Δt to the plantation and from the other part the time during the year when these temperatures Δt are needed. These parameters are what we call the Degree hours/year.

One simple formula to evaluate approximately the energy requirements in a greenhouse, to keep a desired internal temperature t_i, is the following:

$$q_H = \frac{A_s}{A_f} U\,(t_i - t_e) - q_{gi} n P_r$$

where:

- q_H: Energy needed in W/m^2 for each hour of applying _t=t_i-t_e
- U: Total coefficient of thermal losses of the greenhouse in W/m^2 ^oC
- t_i: The desired temperature of the air inside the greenhouse
- t_e: The temperature of the air outside the greenhouse
- A_s: The surface of the covering material in m^2
- A_f: The surface of the covered area in m^2
- q_{gi}: Intensity of the total solar radiation in W/m^2
- P_r: Permeability of the greenhouse to the radiation (0.55-0.70) simple cover, 0.5-0.6 double cover
- n: Coefficient of transform of the radiation to heat inside the greenhouse (0.5-0.6)

Table 4: Average amount of the total coefficient U according the covering material of the greenhouse (2).

Type of coverage	Average U 9W/m^2 ^oC
Glass	
-new construction	6.3
-old construction	6.8
-double glass	4.2
Polyethylene	
-good construction	6.8
-common construction	7.8
-double polyethylene	4.2
Fiber glass and good construction	6.0
Acrylic double force 15 mm and good construction	
Polycarbonate	4.0
Curtins inside the greenhouse	4.5
-simple curtins	“U” reduction by 25%
-special curtins	“U” reduction by 50%

§A very simplified formula to calculate approximately the total energy requirements of a greenhouse all year round is the following:

E= U Δ(DH) in GWh

The DH and the maximum power needed in the Aegean islands and South Greece, except the mountainous area, are as follows:

a. Aegean islands in average

a_1: DH
84 DH/day during the 3 winter months/ year plus 40 DH/day during 2 more months/year

a_2: Maximum power, N=U_t for Δt_{max}= 10-C

b. South Greece except mountainous area

b_1: DH
140 DH/day for the 3 months of the winter/year, plus 50 DH/day for 3 more months/year

b_2: Maximum power, N=UΔt for Δt_{max}=17 °C

6. Low tunnel plastic coverage heating

A part of the normal greenhouses in use are the plastic covered low tunnels, with the purpose to protect vegetables against frost or for a relatively earlier production or for both.

In these tunnels the heating energy keeps the inside air temperature, during the night, in a minimum of t_i=2 °C and the soil temperature >10 °C. Geothermal energy is mostly given by plastic tubes placed on the soil surface or in a depth around 15 cm into the soil. The needed heat into the tubes is less than 30 °C and the temperature application, sometimes, exceeds the 3 months /year.

7. Some applications of geothermal energy for greenhouse heating in Greece and experience gained (5)

The described applications have been done with the contribution of the Agriculural University of Athens

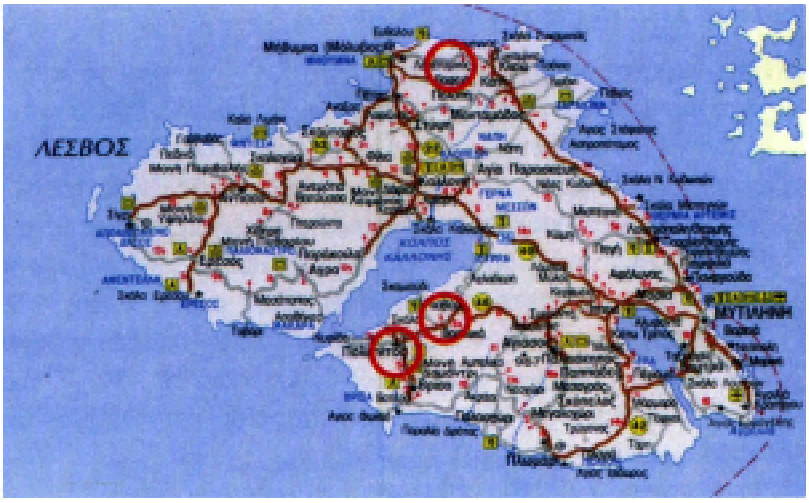

Photo 1: Under the circle, the geothermal fields in Lesvos where the greenhouses activities took place

1. Greenhouse heating in Lesvos island

1.1 Polichnitos

In the region, and close to the ancient thermal baths of Polichnitos there are 5 thermal sources with a total flow of 100 m^3/h and temperatures between 70°-90° C.

The geothermal research in the area by IGME certified a geothermal field of 10 km^2 and in depth between 50 to 150 m. The geothermal fluids analysis gave NaCl, Lithium, CO_2, N_2, O_2 traces of Nitrates and Strondium, Fe and H_2S. The total (TDS) salinity is 10 g/l.

The certified potential of the field is 300 m^3/h with possibility to go up to 1000 m^3/h. So the, thermal power is 1,65 TOE/h and the possible one 5,5 TOE/h (rejected t=25 ^oC). The first greenhouse trials based on the geothermal sources dated before 1983, with the installation of an experimental greenhouse of 600 m^2. The research, conducted by the Local Agricutural Research Station and the Agricultural University of Athens, with the objective the low cost heat exchangers (D.I.Y). Under this target and with the given geothermal flow, the plastic tubes or the plastic double sheets with the geothermal fluids circulated between the two layers, appear as an efficient, economical and practical solution.

The second effort has been done by ETVA in cooperation with IGME, Agricultural University of Athens and the Local Municipality, where a greenhouse unit of 10000 m^2 was installed. The installation was provided by an advanced and resistant to geothermal fluids heat exchanger. The exploitation of the unit was given to the local municipality.

The technological aspects of the installlation were very satisfying, but the bad management during the operation of the unit had as a result the abandonment of the exploitation. The good news from the technical demonstration is the attraction of 5 farmers in the same region to apply the geothermal energy of the field in their own greenhouse units, in a total surface of 20500 m^2.

1.2 Lisvori

In the region of Lisvori there is a thermal source with a flow of 20 m^3/h and temperature 69 ^oC. The chemical analysis of the geothermal fluids gave a composition similar to that of Polychnitos.

The geothermal field is extended to 2,5 km^2 and between 50 to 150 m in depth.

The certified potential is 100 m^3/h or power 0.55 TOE/h, that most probably can reach the 1,3 TOE/h. The first greenhouse exploitation dated from 1989 with a demostration unit of 3000 m^2. The unit belongs to the local municipality and was under the scientific supervision of the Agricultural University of Athens and CRES.

The exploitation of the unit with flowers was a successful story this time and that because of the vision and the care of the major of Lisvori.

1.3 Arginos

In the region of Arginos the geothermal research certified an interesting geothermal field in a surface of 5 km^2, and depths between 40-150 m. The temperature of the fluids is high 80-90 ^oC and the chemical analysis gave a TDS of 12 g/l with an H_2S content of 500-1000 ppm.

Probably the potential can reach the 1500 m^3/h that means a probable power of 8 TOE/h (with fluids exploitation down to 25 ^oC)

Very promising estimations made by experts , double the probable potential and rose the temperatures after deeper boreholes.

The installation and operation of a greenhouse in the region, belonging to local authorities, showed that the operation of a community greenhouse rent by a private farmer can give better results than the exploitation by the community itself with employees.

2. Greenhouse heating in Milos island

The geothermal field in Milos island is extended in th major part of the island, 30 km^2 and depths from 10 to 100 m (in some places the rise of temperature starts from the surface). The temperature of these low enthalpy geothermal fluids in Milos are between 30 to 75 ^oC.

According to the experts, a very interesting extension of the geothermal field should be expected in depths more than 100 m, with very interesting range of temperatures.

The certified minimum low enthalpy potential is 200 m^3/h, but very promising estimations give a potential 5 times more.

If we consider the hot dry rock the possibilities of the potential are much more interesting.

The chemical analysis of the fluids gave a TDS between 5-30 g/l with H_2S content.

The initial trials for the exploitation of the low enthalpy were undertaken by some farmers with small greenhouse units. But the most systematic operations are a private greenhouse unit of 5500 m^2 and one unit of 7000 m^2, belonging to the local municipality and installed with the financial support of ETVA and the scientific cooperation of the Agricultural University of Athens. Both units are based on geothermal fluids with a temperature of 30^0 C, pumped from a depth of 10 cm. The heat is given to the greenhouses by the low cost plastic tubes. In the unit of municipality, it was tasted also an other prototype of low cost heat exchanger, able to heat and to desalinate the geothermal water (3). The experience gained from these two units situated nearby under the same conditions, is that the construction cost of the private unit is lower than the other belonging to the municipality and the management of the operation of the private unit is a very successful story, in comparison to the other unit and that because of the managerial capability and the interest of the private farmer.

From the technology point of view, it has been proven that, low cost heat exchangers, under the specific conditions can give very interesting results in economy, energy efficiency and low maintenance. From the other part the low cost and do it yourself desalination unit can cover the major part of water requirements of the greenhouse.

Concerning Milo's conditions and possibilities for greenhouse enterprises, one can say that they are very promising, but under a good private management able to face, not only the operational problems of the production, but the most crucial of the marketing of the products, because the local market is already saturated.

Photo 2: Milos' geothermal greenhouse erection

3. Nea Kassani in Xanthi region

In the Nea Kessani region greenhouse activities were initiated after a productive geothermal research by IGME and the installation of a productive borehole.

A greenhouse unit of 6000 m^2 had been installed by ETVA and under the scientific and technical care of the Agricultural University of Athens.

In the initial study was the provision to heat the greenhouse unit and to use the same heat exchanger and the same borehole for a corn dryer unit. It was provided also that, the final effluents after the heating of the greenhouse to be used for an aquaculture unit. So, finally the total time of using the geothermal installation and the heat exchanger was prolonged, covering a total period of 7 months/year for the greenhouse and the corn drying and all year round for the aquaculture. The total power covered by the installed heat exchanger dt=13 ^oC it was the 60% of the total (dt max = 22^0 C), covered by a stand by classical unit with oil, but the corresponding energy saving it was more than 93% of the total per year. The heat exchanger, able to serve both units (space heating and corn drying) was studied by the Agricultural University of Athens and constructed by a small company in Athens. The demonstration phase of the greenhouse heating was very successful and after that the whole unit, with the plantation, inside was given to the local municipality and the local farmers union for exploitation.

Photo 3: Nea Kessani' s greenhouse

Unfortunately, once again in Kessani, it was proved that a technically perfect unit, without the appropriate management and private interest, most probably, will be conducted to the failure and that is what happened in N. Kessani. After the successful technical results and with the hope that the geothermal low will change in favor of the private enterprises, the bank of ETVA proceeded further on to the exploitation of the geothermal field in the region investing in geothermal research, boreholes and piping network, without any use of that in investment so far. The geothermal field in the region is extended to 15 km^2 and the depth of the deposit is 150 m to 1000 m. The average temperature is of 75^0 C. The certified potential is 350 m^3/h (power 1,75 TOE/h), with possibility to be 3 times more important. The chemical analysis gave a TDS of 5 g/l, CO_2 , N_2, CH_4 (0.04 %) and H_2S (3-8 ppm).

Conclusions

Agricultural applications of geothermal energy of low enthalpy are very attractive, if the targeted agricultural activity happened to be inside the geothermal field. The disadvantage of the agricultural applications lies with limited time in a year of energy requirements, especially in mild Mediterranean conditions, as they are the Aegean islands. To face this disadvantage the cost of investment should be limited. It has been proved that they are low cost installations with very interesting results in practice. The crucial problem with the agricultural applications in Greece is that their management and the corresponding economic interest should be given to private farmers or enterprises. So, there is an urgent need for the state to change the today law for the geothermal exploitation, that practically prohibits private investments from the exploitation of the geothermal fields.

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