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Low Enthalpy Geothermal Energy Utilization for Greenhouse Heating in the Aegean Region of Turkey

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ABSTRACT

Plant freezing and plant growth inhibition are among the major problems in greenhouse cultivation in the Aegean region of Turkey, especially in regions far from the seaside.

An overview of geothermal resources in the Aegean region has been made. Geothermal resources suitable for greenhouse heating are emphasized. A system of heating by geothermal source of a greenhouse used for flower growing is analyzed during a period of three months during which heating was necessary. Water inlet temperature as well as air temperature and humidity inside the greenhouse and also ambient air temperature are analyzed. Economical benefits for such systems are also emphasized.

1. INTRODUCTION

In the Aegean region of Turkey there are many areas where low enthalpy geothermal sources could be found easily and exploited at a very reasonable cost. This region exhibits a mild Mediterranean climate with soft verdant springs, hot summers, sunny autumns and relatively warm winters marked by occasional showers and snow in parts away from the sea shore. This area is very favorable for greenhouse agriculture due to frequent sunny days even in winter period. The average of sunshine duration for the Aegean region is 2726 hours per year as may be seen from Table 1.

However, in winter periods, especially for the regions distant from the sea side, greenhouse heating is necessary at night, sometimes even at day times when it is cold and cloudy. The average, as well as the lowest and the highest monthly temperatures are given in Table 2. for the city of Aydin where the greenhouse investigated in this paper is situated; relative humidity and precipitation values are also given in Table 3. It may be noticed that during 5 months: November, December, January, February, March; the temperature may be under freezing temperature of water, so that a greenhouse heating system is necessary. Due to the taxation policy of the state, the oil prices in Turkey are the highest in Europe, so if the greenhouse is heated for long periods with oil the agricultural products so obtained would not be at a competitive price. Geothermal energy could be a very economical energy, meeting greenhouse heating requirements throughout the year, and leaving only a few very cold days for oil or similar conventional energy sources to provide the necessary back-up. In Table 4, the costs for heating 1000 Kcal. are given for different fuel types, it may be noticed that geothermal heating which is 0.580 – 1.160 cents for 1000 Kcal is the most economical

Table 1. Solar energy potential for Aegean regions of Turkey and its major city, Izmir.

Region		Aegean	Izmir
Radiation Energy	Average (kWh/m^2y)	1407	1230
	Maximum (kWh/m^2y)	2028	1965
	Minimum (kWh/m^2y)	492	456
Sunshine duration period	Average (h/y)	2726	2770
	Maximum (h/month)	371	387
	Minimum (h/month)	96	109

Table 2. Monthly temperatures for the city of Aydın – Turkey.

Months	**Average temperature (ºC)**	**Highest temperature (ºC)**	**Lowest temperature (ºC)**
January	8	23.2	-11
February	9.3	25.2	-5.4
March	11.5	31.0	-5
April	15.7	33.8	0
May	20.7	40.2	4.6
June	25.4	42.1	8.4
July	28.1	44.6	13.4
August	27.2	43.0	11.8
September	23.3	40.2	7.6
October	18.1	38.0	1.6
November	13.4	30.5	-4.7
December	9.5	25.9	-5.3
Annual	**17.5**	**44.6**	**-11**

Source: General Directorate of Meteorology of Turkey.

Table 3. Meteorological data for the city of Aydın – Turkey.

Months	Relative humidity (%)	Daily maximum precipitation (mm)	Average precipitation (mm)
January	75	67	121
February	71	90.5	95.5
March	68	68.2	71.1
April	64	48.2	45.5
May	59	51.3	33.5
June	51	46	14
July	48	33.2	3.5
August	51	24.4	2.2
September	56	60.1	14.4
October	64	60.6	47.5
November	72	57.3	74.4
December	76	80.2	135.1
Annual	**63**	**90.5**	**657.9**

Source: General Directorate of Meteorology of Turkey.

Table 4. The cost of some energy types used in heating in 2002 in Turkey

Fuel	Cost (cents/1,000 Kcal)
Natural gas	2.567
Fuel-oil	4.606
Diesel fuel	8.702
Electricity	10.559
Imported coal	2.813
LPG 12 kg	8.097
Geothermal	0.580–1.160

heating (Acar, 2003), the nearest being natural gas which is more than twice as expensive and moreover natural gas is usually not available in rural areas of Turkey, as it requires an expensive piping system.

Geothermal energy has proved to be very beneficial for agriculture and other related activities, so that the Aegean Regions is by far the most important part of Turkey for greenhouses heated by geothermal sources which constitutes about 80% of the county by area, see Table 5.

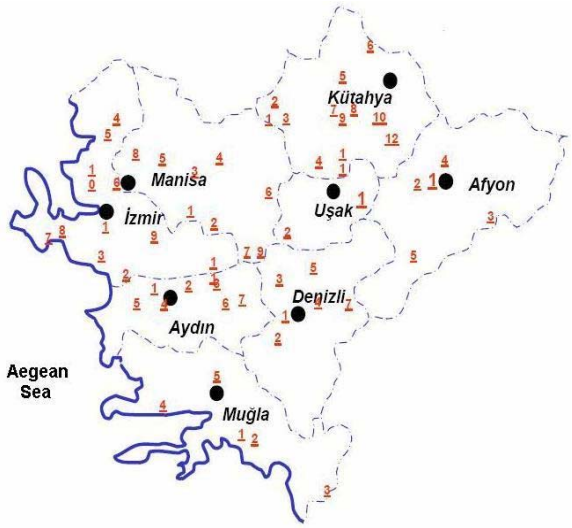
Table 5. Greenhouses in the Aegean Region heated by Geothermal Energy.

Location	Temperature (˚C)	Area (ha)
Afyon-Ömer- Gecek	50-105	0.55
Aydın-Germencik	-	0.05
Aydın- Gümüşköy	41	1.365
Denizli-Gölemezli	65	0.1
Denizli-Kızıldere	85-200	1.395
Denizli-Tekkehamam	85-116	0.8
İzmir-Balçova	100-140	10
İzmir-Bergama	60	0.2
İzmir-Dikili	55-100	12
İzmir-Seferihisar	153	0.6
Kütahya-Gediz	77-98	0.8
Kütahya-Simav	162	12
Manisa-Urganlı	70	0.9
Total-Aegean Region	-	40.76

2. GEOTHERMAL POTENTIAL OF THE AEGEAN REGION OF TURKEY

Turkey is located on the Mediterranean sector of Alpine-Himalayan Tectonic Belt, this constitutes the main reason for having a high geothermal potential. In the Aegean Region of Turkey, Geothermal fields are caused from the Graben systems of Western Anatolia. Figure 1 shows the geothermal fields in the Aegean Region of Turkey, Mertoglu at al ((2003). Turkey is one of the world's top countries using direct geothermal energy (Fridleifsson, 2001). The main uses of geothermal energy in Turkey are: space heating and domestic hot water supply, greenhouse heating, balneology, CO_2 and dry-ice production process, heat pumps and electricity generation. With the existing geothermal wells and springs, the proven geothermal capacity calculated by MTA is 2600 MWt (exhaust temperature as assumed to be 40 °C), whereas the geothermal potential is estimated as 31,500 MWt, Batik et al. (2000).

Geothermal sources may be classified into three categories: a) low temperature, low enthalpy (less than 90°C), b) moderate temperatures (90 °C -150 °C), c) high temperatures (greater than 150 °C). Turkey is the 7th richest country in the world in geothermal potential. Upon the 170 geothermal fields discovered by MTA (General Directorate of Mineral Research and Exploration), 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications such as district heating, greenhouse heating, industrial heating. From Table 6 , it may be seen that 62% of the geothermal wells in Western Turkey, which includes Eagean and Marmara regions, have temperatures below 90°C, Batik et al. (2000).



AFYON	2. Seferhisar-Doğanbey	12. Hamamköy
1. Ömer-Gecek	3. Doğanbey Burnu	**MANİSA**
2. Arapderesi	4. Dikili-Kaynarca	1. Kurşunlu
3. Heybeli	5. Bergama-Dibek-	2. Urganlı
4. Gazlıgöl	6. Bademli	3. Sart
5. Hüdai (Sandıklı)	7. Çeşme	4. Saraycık
AYDIN	8. Şifne	5. Menteşe
1. Germencik-Ömerbeyli	9. Nebiler	6. Şehitler (Emir-Kula)
2. Çamköy-Alangüllü	10.Aliağa	7. Horzum Sazdere
3. Salavatlı	11. Bayındır-Dereköy	8. Eskihisar
4. Şehir içi-İmamköy	**KÜTAHYA**	9. Alaşehir-K.dere
5. Gümüşköy	1. Eynal	**MUĞLA**
6. Davutlar	2. Naşa	1.Delibey
DENİZLİ	3. Çiftgöl	2.Sultaniye
1. Kızıldere	4. Abide- Gediz	3.Fethiye-Gebeler
2.Tekkehamamı	5. Yoncalı	4.Rızaçavuş
3. Gölemezli	6. Kızılsın (Ilıcaköy)	5.Selgirme
4. Karahayıt	7. Emet	**UŞAK**
5. Kamara-Yenice	8. Yeniceköy	1. Banaz
6. Pamukkale	9.Dereli-Günlüce	2. Eşme-Örencik
İZMİR	10. Sarmık	
1. Balçova	11. Muratdağı	

Figure 1: Geothermal Sources in the Aegean Region of Turkey.

Greenhouses are among the most interesting and widespread applications of low temperature geothermal energy as a heat source. In Turkey, the first greenhouse heating system by geothermal energy was founded in Denizli-Kizildere geothermal field in 1985 and had an area of 0.45 ha and has grown to 1.395 ha up to date. In recent years, greenhouse heating by geothermal energy is gaining more and more importance in Turkey, over 50 hectares of greenhouse area heated by geothermal energy, exist presently in Turkey, see figure 2 .

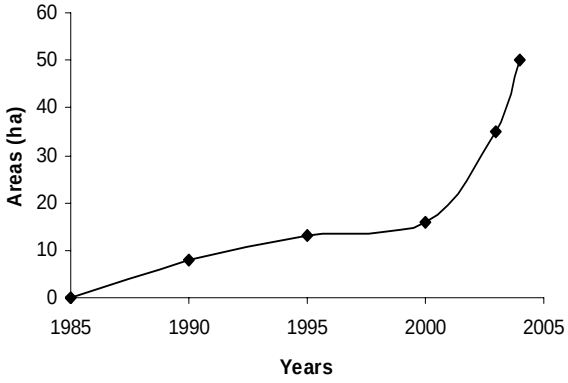


Figure 2. Development of greenhouse areas heated by geothermal energy in Turkey in years.

Table 6. Geothermal well temperatures and their percentages in Western Turkey.

Percentage (%)	Temperature(°C)
1	240-250
2	230-240
2	220-230
5	200-210
11	190-200
5	170-180
2	130-140
7	110-120
3	100-110
21	90-100
5	80-90
8	70-80
7	60-70
9	50-60
7	40-50
5	30-40

3. GREENHOUSE DESCRIPTION AND HEATING SYSTEM BY GEOTHERMAL SOURCE

For the greenhouse under investigation in this study, the geothermal source is situated in Germencik - Aydin in the village of Gumuskoy. The geothermal reservoir is a low enthalpy system with a temperature of 41 °C with a well depth of 60 meters. Chemical analysis of the geothermal fluid has shown a high concentration in metals: Ca (66 mg/l), Mg (58 mg/l), Na (1001 mg/l), K (109 mg/l). The concentrations of Cl (1115 mg/l), HCO_3 (2355 mg/l) and SiO_2 (131 mg/l) were also relatively large, which could lead to corrosion and scaling problems in pipes of the greenhouse heating system. In order to prevent this problem polyethylene piping is used for the heating system. The well is only 60 meters away from the greenhouse ant the flow rate is 50 lt/h.

The basic greenhouse unit, 60 m in length, 6 m in width and 1.8 m in height which makes the total area of the greenhouse 7560 m^2. The overall greenhouse layout is shown in Fig. 3 and the photograph of the interior of one of the greenhouses is shown in Fig. 4. The greenhouse consists of a metal frame, cover material, irrigation and a heating system. The metal frame is used to support the cover material, which provides thermal insulation and also enhances solar radiation, for this greenhouse transparent HDPE cover material is used due to its durability and low cost. The soil is not used for plant growing, instead, perlite in pots feeded with city water mixed up automatically by the necessary ingredients for plant growing, is used as a medium for plant growing. Only one type of flower, gerbera, is grown in the greenhouses. In the ideal conditions, this plant needs a minimum temperature of 14°C and a maximum temperature of 25°C, a relative humidity of 50% and intensity of light 15 000 -20 000 lux. Flower growing continues the whole year. There is a need for heating during 5 months: November, December, January, February, March especially during the night time. In October and April occasional heating needs may arise for exceptionally cold days and nights. The selection of the heating system depends on many parameters, such as the temperature of the geothermal fluid, its composition, the heating requirements of the greenhouse and the cost of installation and the operation cost. A very simple direct heating system is used which consists of bringing the geothermal water having a temperature of 41 °C with PVC pipes of 90 mm in diameter to the greenhouses and circulating this water in the greenhouse with flexible, carbon black filled 63 mm diameter polyethylene pipes lied on the ground between the flower pots, The geothermal water is then discharged. The corrosion problem is prevented because polymer based piping, fittings are used everywhere.

The greenhouse heating system has proven itself to be efficient even during the coldest days in winter. It may be seen from Fig.5 that for the 16th of January during which the minimum temperature (-3°C) of the year 2003 was attained; the temperature inside the greenhouse remained between 15°C and 20°C, whereas the temperature of the soil remained practically constant at about 17- 18°C during 24 hours of the day.

Figure 6 shows the daily average temperatures outside and inside of the greenhouse as well as the soil temperatures taken at intervals of 5 days during 1st of October 2002 and 19th of January 2003. It may be seen from this figure that the air and the soil temperatures inside the greenhouse fluctuate between 16°C and 23°C which is adequate for flower growing.

Figure 7 shows the daily average relative humidity outside and inside of the greenhouse and also the daily average natural solar lighting in Lux., taken at intervals of 5 days during 1st of October 2002 and 19th of January 2003. It may be seen from this figure that the relative humidity inside of the greenhouse is between 75% and 85% which is good for flower growing.

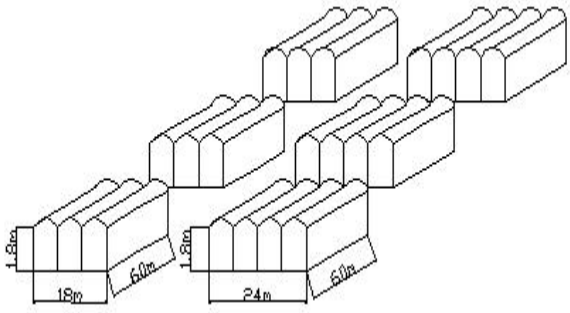


Figure 3: The Overall Greenhouse Layout.

Figure 4: Photograph of the Interior of one of the Greenhouses.

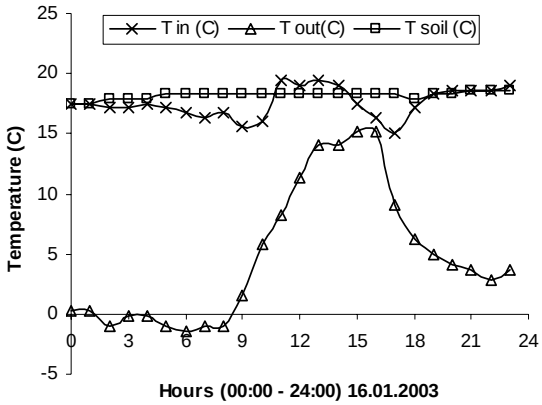


Figure 5: Temperatures Inside and Outside of the Greenhouse as well as Inside Soil Temperatures during 16th of January.

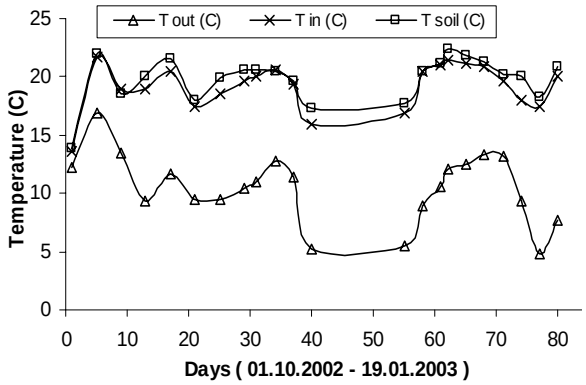


Figure 6: Daily Average Temperatures Outside, Inside of the Greenhouse and the Soil Temperatures during 1st Oct.2002 and 19th Jan. 2003.

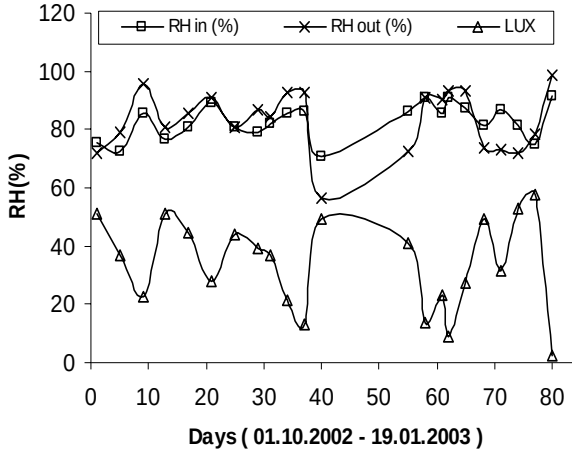


Figure 7: Daily Average Relative Humidity Outside and Inside of the greenhouse and the Daily Average Natural Solar Lighting in Lux during the period, 1st Oct. 2002 and 19th Jan. 2003.

4. CONCLUSIONS

Greenhouse heating is one of the most common uses of geothermal resources especially low temperature, low enthalpy resources which are inadequate for electricity production and city heating. The use of geothermal energy in greenhouses enables the agriculture of vegetables, fruits and flowers during the whole year. As the out of season prices are rather high for vegetables, even in domestic markets, this kind of agriculture ensures the farmer with good revenue. One of the major disadvantages of geothermally heated greenhouses is the high-investment cost for the geothermal well, pipelines, regulation systems and using this investment for only part of the year. But if the geothermal source is very near the greenhouse as it was for the example given in this paper, then the use of geothermal energy for heating the greenhouses is an economical solution. Furthermore, the example of the greenhouse given in this work has a rather cheap direct heating system which could be used for geothermal sources under 75°C. Taking into account Turkey's geothermal energy potential, it may be concluded that the use of geothermal energy in heating greenhouses is very low, and that this area will be the most rapidly growing use of geothermal energy in Turkey in years to come.

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REFERENCES

Acar H.I: A Review of Geothermal Energy in Turkey, E*ergy Sources*, **25**, (2003), 1083-1088.

Balik H., Koçak A., Akkus I. : Geothermal Energy Utilisation Development in Turkey – Present Geothermal Situation and Projections - , *Proceedings World Geothermal Congress 2000*, Kyushu – Tohoku, Japan (2000), 85-91.

Fridleifsson I., : Geothermal Direct Use Around the World, *GRC Bulletin*, **27**, (2001), 235-239.

Mertoglu O., Bakir N., Kaya T. : Geothermal Applications in Turkey, *Geothermics*, **32**, (2003), 419-428.