Proceedings World Geothermal Congress 2005
Antalya, Turkey, 24-29 April 2005

Geothermal Applications in Turkey

Orhan Mertoglu

ORME JEOTERMAL Inc. Hosdere cad. No:190/7-8-12, 06550 Cankaya - Ankara-TURKEY

orme-f@tr.net

Keywords: Turkey, geothermal, direct use, electricity, development

ABSTRACT

Most of the development in Turkey is achieved in geothermal direct-use applications with 65,000 residences equivalence using geothermal heating (750 MWt) including district heating, thermal facilities and 635,000 m^2 geothermal greenhouse heating. Geothermal water is used in nearly 200 spas for balneological purposes (327 MWt). Engineering design of over 300,000 residences equivalence of geothermal district heating has been completed. By summing up all these geothermal utilizations, the geothermal direct use installed capacity is 1077 MWt in Turkey in October 2004.

The electricity generation has been increased from 90 GWh to 108 GWh in Kizildere geothermal power plant which is the single existing geothermal power plant of Turkey. Besides electricity generation at Kizildere, the CO_2 set free in the condenser is partly supplied to a liquefied CO_2 and dry ice factory installed next to the plant and about 120,000 t/year dry ice and liquefied CO_2 is produced for Turkey's beverage industry.

Only 3.5 % of Turkey's geothermal potential is utilized so far.

1. INTRODUCTION

The estimated geothermal heating potential of Turkey is 31500 MWt (5 million residences equivalence geothermal heating). According to today's technical and economical conditions, the total geothermal heating potential is 1 million residences equivalency.

One of the main developments achieved in geothermal district heating was Salihli 20,000/24,000 residences equivalence geothermal district heating system (GDHS) which started up in January 2002. Moreover 2000 residences equivalence capacity geothermal air-conditioning system is planned to be operational in the coming years.

The contribution of the existing geothermal energy applications to the Turkish National Economy by electricity production, geothermal district heating, CO_2 production, thermal tourism and other utilizations is about US$ 1,400,000. The total employment is 40,000 people in geothermal sector. Fuel-oil equivalency of the existing geothermal utilization is 500 Million US $ per year by August 2004.

2. GEOTHERMAL PRODUCTION

54 geothermal production wells have been drilled by MTA, since 2000. This makes the total geothermal production well number 382. With the wells drilled by the private sector the total number of geothermal production wells has been estimated as about 500. With the existing geothermal wells and springs the proven geothermal capacity is 3293 MWt by June 2003 (exhaust temperature is assumed to be 40°C) [1].

3. GEOTHERMAL DISTRICT HEATING SYSTEMS

Today 13 cities are heated partially with geothermal in Turkey. These geothermal district heating systems have been constructed since 1987 and many developments have been achieved in technical and economical aspects. The rapid development of geothermal district heating systems in Turkey is mostly depending on [2];

- construction of suitable geothermal district heating systems according to Turkey's conditions,
- participation of the consumers to the GDHS investments by about 50-60% without any direct financing refund, called "Turkish Financing System"
- geothermal heating is about 50-70 % cheaper than natural gas heating.

The existing geothermal district heating systems including Dokuz Eylul University Campus heating are given in Table 1.

Table 1: The existing geothermal district heating systems including Dokuz Eylul University Campus heating

Name	Residences	Start-up date	Geoth. Water T. (°C)	Investor
Dokuz Eylul Uni.Camp.	1500	1983	115-60	Rectorship of Univ.
Gonen	3400	1987	80	*
Simav	3200	1991	137	Municipality
Kirsehir	1800	1994	57	**.
Kizilcahamam	2500	1995	80	*.
Balçova	12500	1996	137	******
Afyon	4500	1996	95	**
Kozakli	1000	1996	90	**
Narlidere	1500	1998	125	***
Sandikli	3200/5000	1998	70	*
Diyadin	400	1999	70	****
Salihli	3000/24000	2002	94	Municipality
Saraykoy	1500/5000	2002	140	*
Edremit	500/7500	2003	60	*****

(*= Joint Stock Company shares are belonged heavily to Municipality, **= Joint Stock Company shares are belonged heavily to Governorship (also shares of Municipality exist), ***= Limited Company shares are belonged heavily to Governorship, ****= Joint Stock Company shares are belonged heavily to Governorship, *****= Limited Company shares are belonged heavily to Municipality, ******= Limited Company shares are belonging heavily to Governorship)

In Kirsehir City, 1800 residences are heated with 57 °C geothermal water. Some other low temperature geothermal thermal facilities heating are as follows:

- Afyon-Orucoglu Thermal Facilities, 48 °C
- Bolu-Karacasu Thermal Facilities, 44 °C
- Rize-Ayder Curing Center, 55 °C
- Hatay-Kumlu Thermal Facilities, floor heating with 37 °C
- Samsun-Havza Thermal Facilities, 54 °C

Also, a mosque in Haymana City is heated geothermally by floor heating with 45 °C temperature water.

4. THERMAL FACILITIES HEATING AND BALNEOLOGICAL APPLICATIONS IN TURKEY

Turkey is one of the rare countries, where combining sea/sun/cultural tourism with thermal tourism and balneological applications is possible. The main advantage of this combination is the increase of the variety and number of the tourists and the extension of the high tourism season to the whole year, instead of limiting it to 4-5 months which is mostly the case by the sea/sun/cultural tourism. This will bring an important economical development to these regions. Some of the regions that are suitable for sea and thermal tourism combination are; Bodrum, Kusadasi, Datca and Edremit cities which are located at the Aegean and Mediterranean Seas. In Cesme (district of Izmir City), thermal water is transported to the hotels for balneological utilization and this combination is applied there with a great success.

A possible producable potential amount of geothermal flowrate (~40°C) that has been estimated for the balneological use in Turkey, is 50,000 l/sec. This equals to the benefit of 8 million people/day from thermal waters in spas in Turkey [3].

The number annually expected local thermal curists is around 7 million and the number of the foreign thermal curists is around 10,000 in Turkey [3].

Bolu-Karacasu (44 °C) and Cankiri-Cavundur (56 °C) thermal facilities heating have been started up in 2001 with a total capacity of nearly 100 residences equivalence. Construction of Balpas thermal facilities (main building and geothermal water transportation pipeline) in Balikesir Pamukcu have been completed. Two geothermal production wells with 67 °C temperature and 40 l/sec flowrate will feed the geothermal heating and balneological utilization system of the thermal facilitiy.

The foreign curist target number is 1 million and the local curist target number is 30 million for the year 2020 [3].

5.GREENHOUSE HEATING

The geothermal greenhouse heating capacity has been increased to 145 MWt, especially due to additional construction of total 190,000 m^2 greenhouses in Dikili (District of Izmir) and other places. The existing geothermal greenhouses in Turkey are as shown in Table 2).

A 100 m^2 geothermal heat pump assisted greenhouse project in Erzurum City is approved by UNDP Energy for Sustainable Development Thematic Trust Funds Standing Committee in June 2002.

Table 2: The existing geothermal greenhouses in Turkey (*Load factor is 0,6)

LOCATION	AREA (m^2)	CAPACITY (MWt*)	LOCATION	AREA (m^2)	CAPA-CITY (MWt*)
Sanliurfa	106.000	24,5	Dikili	190.000	38
Simav	120.000	33	Gölemezli	1000	0,2
Sindirgi	2000	0,4	Seferihisar	6000	1,06
Afyon	5500	1,5	Bergama	2000	0,4
Kizildere	10750	2,4	Germencik	500	0,1
Balcova	100.000	17,6	Edremit	49.620	8,7
Kestanbol	2000	0,4	Ezine	1500	0,3
Saraykent	2000	0,6	Niksar	500	0,14
Tekkehamam	8000	1,8	Kizilcahamam	5000	1,45
Yalova	600	0,12	Gediz	8500	2,1
Kozakli	4000	1,2	Canakkale-Tuzla	50.000	9

6. GEOTHERMAL ELECTRICITY PRODUCTION

Geothermal electricity production is advantageous because of the relatively low installation and operational cost as well as being more environmentally benign, in comparison to the conventional thermic and hydraulic power plants. At present, ten of the geothermal fields of Turkey are of high enthalpy and are appropriate for the geothermal electric energy generation by binary cycle or by flashing cycle. These fields are [4]:

1. Denizli-Kızıldere Field (242 °C)
2. Aydın - Germencik -Omerbeyli Field (232 ° C)
3. Manisa –Salihli-Göbekli Field (182 ° C)
4. Çanakkale- Tuzla Field (174 ° C)
5. Aydın-Salavatlı Field (171 °C)
6. Kütahya-Simav Field (162 °C)
7. Manisa- Salihli-Caferbey Field (150 °C)
8. Izmir- Seferihisar Field (153 °C)
9. Izmir-Balçova Field (142°C)
10. Aydın-Yılmazköy Field (142 °C)

It has been estimated that the Aydin-Germencik geothermal field would have 100 MWe power production capacity.

At present there is one operating geothermal power plant in Kizildere (Figure 1). A geothermal power plant in Germencik (on the Aydin-Germencik geothermal field) is expected to be constructed in the very near future.

6.1 Kizildere geothermal power plant

The plant operates on single flash with condensing cycle. Geothermal steam and brine mixture of about 12 % quality with 150°C well head temperature and 15 bar pressure is separated to dry steam and brine at 147 °C and 3.5 bar. The dry steam is supplied to a turbine which drives an electric generator and a compressor.

In 2002 electricity generation has been increased from 90 GWh to 108 GWh in Kizildere geothermal power plant, due to the drilling of a new well with 242 °C downhole temperature and connecting it to the system. 25 % of the produced geothermal brine is reinjected back to the reservoir.

Figure 1: Kizildere geothermal power plant

6.2 Germencik geothermal power plant

At Germencik 25 MWe B.O.T. project; according to the programme, the utilized field consists of 5 production wells and 3 reinjection wells. Total flow rate of geothermal fluid is 1434 t/h, at 210 °C with well head pressure of 15-18 bar. The foundation has not been realized yet.

7. MINERAL RECOVERY

The yearly production of 120,000 tons of liquid CO_2 and dry ice production is continuing from the factory connected to the Kizildere power plant.

8. OTHER PROJECTS

Feasibility reports have been prepared for Salihli (district of Manisa City), Aliaga (district of Izmir City), Edremit (district of Balikesir City) and Sivas City Geothermal Utilization Systems. Also prefeasibility reports for Denizli-Saraykoy and Bursa geothermal utilization systems have been prepared.

Some examples of the main geothermal district heating projects and applications are described in the following paragraphs.

8.1 Salihli Geothermal District Heating Project

Thoughts about utilizing the geothermal resources in Salihli area began in 1992 with the drilling of 3 geothermal production wells by MTA General Directorate in Kursunlu geothermal field.

Salihli Geothermal Integrated System includes geothermal district heating, geothermal air-conditioning, balneological utilization, greenhouse heating and raisin production. Now geothermal district heating and balneological utilization is operational in Salihli City.

The geothermal field is at 3-4 km distance from the city with a higher altitude of 100 m. Geothermal fluid is carried to the heating center located very near to the city center and transported again to the geothermal field for reinjection.

28 MWt capacity heat exchanger and pump group has been installed in the heating center of the system which is suitable for modular extension. Each module (unit) has a power of 14 MWt (Figure 2).

During the 2003-2004 winter season, 3000 residences equivalence geothermal district heating was operational. According to the further plans, the installation and connection of residences is continuing for the extension of the system.

The total investment in the Salihli Integrated Geothermal System is 35 Million US$. Pay-back period of this investment is 7.4 years.

Figure 2: Salihli Geothermal Heating Center

8.2 Edremit Geothermal District Heating Project

Edremit geothermal project includes 7500 residences equivalence geothermal district heating system. The fuel-oil equivalence of the used geothermal energy in the system is 17,318 tons/year. By avoiding burning of this amount of fuel-oil, CO_2 emission of 53,586 tons/year will not be discharged to the atmosphere. It has been advised in the feasibility report also to integrate the greenhouses which will be newly installed to the geothermal district heating system, which will make the good economic conditions even better.

The total investment in Edremit geothermal project is 8.5 million US$ and the pay-back period is 8 years.

The foundation ceremony took place on 19 May 2003 and the installation of the pipeline and production system has begun. Now 1500 residences equivalence is going to be heated geothermally in the 2004-2005 winter season. Two production wells (60-62 °C, total 110 l/sec. production with downhole pump) and one reinjection well exist in the Derman geothermal field that feeds the system (Table 3).

Table 3: The existing situation of Edremit Geothermal Wells.

Well Number	Depth (m)	Flowrate (l/sec.)	Temperature (°C)
ED1	190	80	60
ED2	496,5	1,5-3	55
ED3	495	24	60-61

The distance between the geothermal field and city center is 3.5 km. The temperature loss is 0.5 °C for the 3.5 km

transportation pipeline at the existing flowrate. After the increment of the flowrate this temperature loss will be decreased in this pipeline.

Beside these two production wells, one new deep well (500 ± 100) is under drilling now.

8.3 Aliaga Geothermal District Heating Project

Aliaga geothermal project includes 7500 residences equivalence district heating and domestic hot water supply, 30,000 m^2 greenhouse heating and thermal water supply to the thermal facilities. The foundation has not taken place yet.

Total installed capacity of 7500 residences equivalence geothermal district heating and 30,000 m^2 greenhouse heating system is 56,650 kW, whereas 45,900 kW is met by geothermal and 10,750 kW is met from the peaking system by means of conventional fuels. The existing situation of the Aliaga geothermal wells is shown in Table 4.

The fuel-oil equivalence of the geothermal energy used in the system is 11,215 tons/year. By avoiding burning of this amount of fuel-oil, CO_2 emission of 36,132 tons/year will not be discharged to the atmosphere.

The geothermal field is about 4 km distance from the city. It has been planned that the heat load demand will be met by changing the circulation flowrates of produced geothermal water and clean hot water.

Table 4: The existing situation of Aliaga Geothermal Wells.

Well Number	Depth (m)	Flowrate (l/sec.)	Temperature (°C)
SM-1	625	60	96,6
SM-2	1136	30	89,2
SM-3	1146	30	89,3

The total investment amount of Aliaga geothermal project is 11 Million US$ and the pay-back period is 7 years.

8.4 Sivas-Sicakcermik Geothermal District Heating Project

Sivas-Sicakcermik geothermal project includes 7300 residences geothermal district heating, thermal water supply to the thermal facilities, treatment of geothermal water to drinking water, production of irrigation and water for fire department from Yildiz River, collection and treatment of thermal discharge water.

The total installed capacity is 97,700 kW, where 71,000 kW is met by geothermal fluid and 26,700 kW is met from the peaking system by means of conventional fuels. The fuel-oil equivalence of the used geothermal energy in the system is 30,261 tons/year. By avoiding burning of this amount of fuel-oil, CO_2 emission of 73,569 tons/year will not be discharged to the atmosphere.

The total investment in Sivas-Sicakçermik geothermal project is 13 Million US$ and the pay-back period is 7 years.

For further development of new geothermal projects “Geothermal Utilization Development Reports” have been prepared by Turkish Geothermal Association for different geothermal fields in Turkey. Geothermal fields of Aydin, Nevsehir, Yozgat, Usak, Eskisehir, Mugla and Afyon cities are constituting the content of these reports. The existing situation of the Sivas geothermal wells is shown in Table 5.

Table 5: The existing situation of Sivas Geothermal Wells.

Well Number	Drilling Date	Depth (m)	Reservoir (m)	Production Flowrate lt/sec	Well Head Temp. (°C)
MTA 1	1976	241	155	35	46,5
DSİ 1	1986	172	157	85	49,0
DSİ 2	1987	184	145	100	49,0
MTA 2	1996	225	150	70	46,0
MTA 3	1997	245	176	98	48,5
MTA 4	1997	610	172	81	49,0

9.CONCLUSION

The development achieved in geothermal direct use over the last 4 years in Turkey is 31 % in direct use, 20 % in electricity generation (Table 6).

By utilizing the estimated total geothermal heat potential (31500 MWt) in residences heating, air-conditioning, greenhouse and thermal facilities heating, balneology, mineral recovery, industrial utilization, 20 Billion US$/year net domestic value could be targeted.

With Turkey's total geothermal potential, it is possible to meet 5 % of the electricity needs and 30 % of the heat energy demand of Turkey. By taking the weighted mean of these values, 14 % of Turkey’s energy demand for electricity and heating could be met by geothermal energy.

For the further development and extension of the geothermal applications in Turkey, 15-20 % financial support of the Turkish Government would be appropriate.

31,500 MWt total geothermal heat potential by the year 2010 is estimated in Turkey, of which 500 MWe is power production and 3500 MWt is space heating.

With the huge thermal tourism capacity potential of Turkey, the target is to increase the number of local curists (tourists in thermalism) to 30 million people by the year 2020. In this case, additional domestic economic activity of 15 billion US$ will be created. The foreign thermal curist number is targeted as 1 million by the year 2020, where 2 billion US$ economic activity will be created. In this case a total of 17 billion US$ economic activity could be created.

The portion of the consumers' financial contribution (non return as grant) in each geothermal district heating investment is 50-60% in the final situation in Turkey. This financial model is called the “Turkish Finance Model”. The meaning of this model is; 1250-1850 US$/100$m^2$ residence contribution and connection fee (non return as grant) is paid by the consumers (customers) to;

a) Directly to the Municipalities,

b) The company formed by local government and municipalities,

in order to get connected to the geothermal district heating network.

Table 6: Comparison of the geothermal applications for the years 2000 and 2004

Applications (Install capacities)		**2000**	**2004**	**Change in %**
Space Heating (Residences + Thermal facilities)		392 MWt	605 MWt	54 ↑*
Greenhouse Heating		101 MWt	145 MWt	44 ↑
Bathing and Swimming		327 MWt	327 MWt	-
Total Direct Use		**820 MWt**	**1077 MWt**	**31** ↑
Mineral recovery		120.000 t/year	120.000 t/year	-
Electricity Production	**Installed capacity**	20,4 MWe	20,4 MWe	-
	Generation	90 GWh	108 GWh	20 ↑
Existing proven capacity of Wells and Natural springs		2600 MWt	3293 MWt	27 ↑

* ↑ = change in form of increase

REFERENCES

[1] Oral Conversation with Dr. Ibrahim Akkus, MTA General Directorate, June 2003.

[2] Mertoglu, O., N. Bakir, T. Kaya, 2003."Geothermal Application Experiences in Turkey" .European Geothermal Conference, Szeged, Hungary.

[3] The Importance of Geothermal Energy for Turkey and New Strategies for the Year 2003, Preliminary Issue of Turkish Geothermal Association, 2003.

[4] Simsek, S., Mertoglu, O., Kocak, A., Bakir, N., Akkus, I., Durak, S., Dilemre, A., Sahin, H., Akilli, H., Suludere, Y., Karakaya, C., Tan, E., State Planning Organisation, 8th 5 Year Development Plan, Geothermal Energy Report, 2001.

[5] Web page of Turkish Electricity Establishment www.teias.gov.tr, 2003.