INTERNATIONAL SUMMER SCHOOL
on Direct Application of Geothermal Energy

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EXAMPLES FROM TURKEY

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ABSTRACT

Turkey is located on the Mediterranean Sector of Alpine-Himalayan Tectonic Belt, which constitutes an important geothermal potential.

Relation between human being and geothermal started through bathing. From ancient times to now, geothermal water is used for bathing and thermal curing purposes. With the development of technology, utilization is increased and geothermal fluids have been started to be used in space and greenhouse heating, electricity production, hot tap water production and dry ice production in Turkey.

History of geothermal district heating systems in Turkey goes as far as to the year 1987, where the first geothermal district heating system of Turkey in Gonen City, with 1400 residence equivalence had started. This system was followed by Simav, Kirsehir, Kizilcahamam, Balcova, Afyon, Kozakli, Sandikli, Diyadin, Narlidere and Salihli geothermal district heating systems.

Most of the development is achieved in geothermal direct-use applications in Turkey with 57.000 residences equivalence geothermal heating (540 MWt) including district heating, thermal facilities and nearly 500,000 m^2 geothermal greenhouse heating. 195 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of nearly 300,000 residences equivalence geothermal district heating has been completed. Total direct use installed capacity is 867 MWt (Table 1).

1. INTRODUCTION

The district heating system applications have been started with large scale geothermal district heating systems (GDHS) in Turkey, whereas, the geothermal district heating distribution networks have been designed according to the geothermal district heating system parameters. This constitutes an important advantage of GDHS investments in Turkey in terms of technical and economical aspects.

Table1: Capacities in Geothermal Utilization in Turkey (June 2002)

Geothermal Utilization	Capacity
District Heating	540 MWt
Balneological Utilization	327 MWt
Total Direct Use	867 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

Turkey's geothermal resources are mostly water dominated. For this reason, they are generally used for space heating. The temperature of geothermal fluid used in space heating is as low as 43°C without heat pump utilization.

Besides of the geothermal direct use applications in Turkey, also geothermal power production (Kizildere, 20 MWe installed capacity) and integrated liquid

carbondioxide and dry ice production (120.000 tons/year) exist.

2. GEOTHERMAL DIRECT USE APPLICATIONS IN TURKEY

The operational capacities of the existing city based geothermal district heating systems (GDHS) in Turkey are as the following (Table 2):

Table 2: Operational capacities of the existing city based geothermal district heating systems (GDHS) in Turkey

City Name	Capacity (Residences)	Year of Comm.	Geoth. Water Temp. (°C)	Geoth. Heating Fee paid by the Residences ($) (2001/2002 winter season)**
GONEN	3400	1987	~ 80	25,73
SIMAV	3200	1991	~ 120	21,69
KIRSEHIR	1800	1994	~ 57	13,60
KIZILCAHAMAM	2500	1995	~ 80	18,38
IZMIR-BALCOVA	11.500	1996	~ 137	16,17
AFYON*	4000	1996	~ 95	18,67
KOZAKLI*	1000	1996	~ 90	21,69
IZMIR-NARLIDERE	1500	1998	~ 98	16,17
DIYADIN*	400	1999	~ 70	n.d.***
SANDIKLI	2000	2000	~ 70	13.01
SALIHLI	1500	2002	~ 94	n.d.***

*Construction is not realized by ORME
** 1 $ = 1.360.000 TL, January 2002
*** not defined yet.

To give detailed information about some of the geothermal district heating systems in Turkey, one high temperature (Izmir) and one low temperature (Kirsehir) application has been selected. Also, the mostly recent started geothermal district heating/cooling system in Salihli City with the target capacity of 24.000 residences heating and 2000 residences cooling will be included in this paper.

2.1. Izmir Geothermal District Heating System

Balcova geothermal field is located 10 km to Izmir city center at the historical Agamemnon spa area. In this site, the first geothermal well of Turkey has been drilled in 1963.

In Izmir geothermal district heating system, the newest technologies are used and the operational costs are very low. This system is operational successfully since 1996 and has reached 11500 residences equivalence heating in Balcova district. Moreover, 1500 residences are heated in Narlidere district since 1998.

Until 1981 the geothermal fluid has been used only for bathing purposes in Balcova, where after this year the downhole heat exchanger was used for the first time in Turkey. Without using chemical inhibitor and without discharging the geothermal fluid to the environment, the downhole heat exchanger system has been used for 10 years. But, due to the disadvantage of partial heat extraction, the system has been revised to the production with pumps. With the usage of the production pumps, reinjection application has started also.

In Izmir GDHS variable speed drivers are used in every downhole and supply pump. This leads to a very low electricity cost of heating, 1 Million kcal requires 26 kWh electricity that costs only 2,5 USD. The used downhole pumps are working at 140 °C. By a 125 °C artesian geothermal water + vapour + gas production, separator is used to separate the gas, and by the aid of additional condensation settings nearly all the vapour is getting condensed which steam exhaust is prevented.

Two types of LSP (USA origin Lineshaft Pumps) deep well pumps are used. For the shallow wells, the local

manufactured pumps are installed (Installation depths are about 70 – 80 m). For the deep wells, Icelandic design deep well pumps are needed (Installation depths are about 150 – 200 m, capacity as 40-45 kg/sec, and operating temperature is 150 °C).

By utilising deep well pumps in Balcova, a large-scale GDHS is realised. Before the application of deep well pump, downhole heat exchangers were used in this geothermal field and totally 6 MWt was produced from 9 shallow wells. But now, 11500 residences equivalency, Dokuz Eylül University Medical Faculty and Campus, 100.000 m^2 greenhouses and Thermal Facilities are heated from Balcova geothermal field (total 131 MWt, Figure 1)

In order to prevent calcite scaling, scale inhibitor according to European Specification ISO 9002, has been injected into the well below the pump by using special chemical injection line.

Figure 1: Drilling of BD-3 well in Balcova Geothermal Field in the city

Balcova Geothermal District Heating System has been developed stage by stage.

1st Stage: With the beginning of the 1st Stage 2500 residences geothermal heating fed by one production well (BD-2, depth: 622 m) and reinjection was done to one well (BD-3, depth: 750 m). As the artesian flowrate was enough for this first stage no pump was used. The distance between these two wells are 330 m. During the heating season 134.784 tons of geothermal water with 50 °C temperature has been reinjected into the BD-3 well. During this reinjection period, wellhead pressure and the production temperature has been followed and no negative effect has been observed.

2nd Stage: With the beginning of the 2nd Stage, the BD-3 well was used as production well. At the beginning this well had 55 °C production temperature. But, this temperature has been increased to 120 °C after the 3rd day of production. The highest production temperature observed in this well is 136 °C.

3rd Stage: With the end of the 2nd stage, the geothermal production amount has reached to 60 kg/sec. 15 kg/sec of this amount was used for balneological/bathing purposes, the rest could be reinjected to the shallow reinjection wells. At the end of this stage 217.000 tons of geothermal

water was reinjected to the reservoir.

At the end of the 3rd stage the geo-thermal production has reached 88 kg/sec. flowrate.

4th Stage: The cooling effect of reinjection made by B-9 well had been observed by the shallow wells, but the tracer test has not confirmed it. At the beginning of the tracer tests it was thought that the chemicals would be encountered earlier than the cooling effect, but the contrary happened and the cooling effect had been observed earlier than the chemicals effect.

2.2. Kirsehir Geothermal District Heating System

In addition to the spa heating facilities with low temperature geothermal fluid, there exist also a low temperature geothermal district heating system in Turkey, which is Kirsehir GDHS.

System is operational since 1994 and uses 54-57°C geothermal water produced from artesian wells within Kirsehir City. Since the wells are very close to the heat plant, transportation line cost was kept in minimum.

City distribution network is made by pre-insulated fiberglass pipes. In the return line non-insulated pipes were used to obtain investment economy. Due to the characteristics of fiberglass pipe, no heat expansion joints were used. Pipes are kept between two fixed concrete blocks and expansion is prevented. Therefore, strain is applied to pipes as stress. Branching is done using steel muff.

Temperature loss in these pipes are minimum. In bigger dimensions, DN 300 and above, it is about 0.1 °C/km. In small dimension pipes, it is about 0.5 °C/km.

System discharge temperature is 40°C. In the building station only self operated temperature and flow control valves, circulating pump, pressure and temperature gauges are used as equipments. These are used to decrease investment costs and make the investment economically and technically feasible.

Heat plant heating circulation pumps are divided into three stages to keep electricity costs as minimum. These are low, medium and high flowrate pumps. According to the average outside temperature, pumps are operated. Supply and return temperatures are always kept the same. This is the basic rule of all our geothermal district heating systems.

The geothermal water has corrosive and scaling characteristics. To minimize scaling problems, $CaCO_3$ scale inhibitor is injected to the wells. This enables operator to clean heat exchanger once in a year. Due to the chemical properties of the geothermal water fibreglass pipes and titanium plate heat exchangers are used in this system.

Today 1800 residences equivalence is heated geothermaly with 18 MWt capacity (Figure 2).

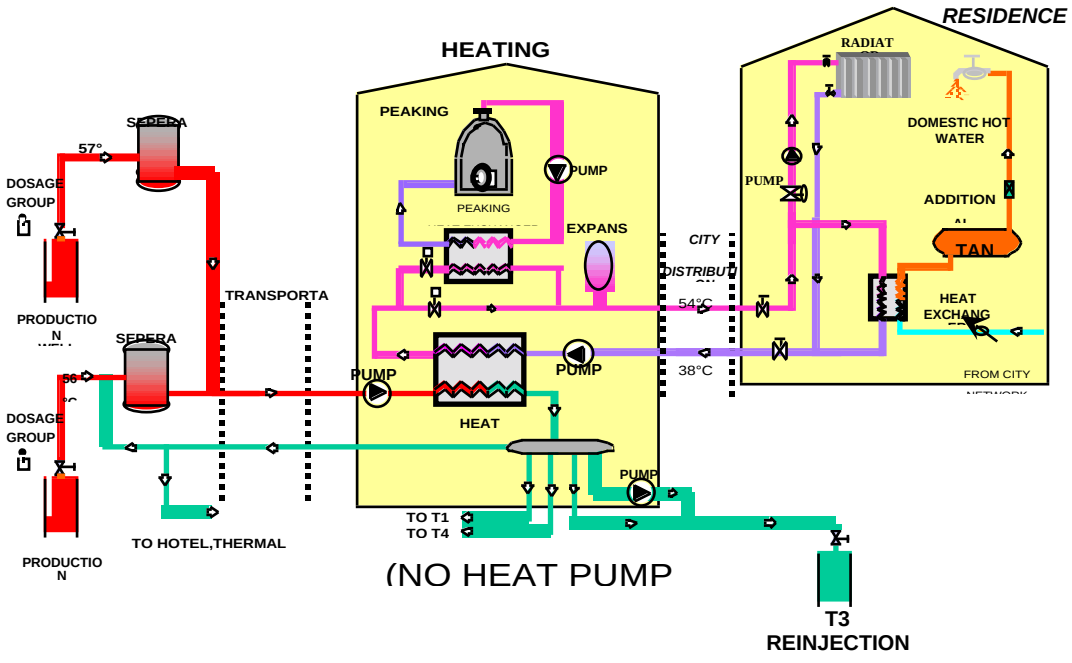

Figure 2: Flowchart of Kirsehir Geothermal District Heating System

2.3. Salihli Geothermal District Heating System

Salihli GDHS is fed from Salihli geothermal field which is 4-5 km away to the city center.

Beside of the 24.000 residences heating target capacity, also 2000 residences cooling is included to the project.

Now, 1500 residences are connected to the system and until July 2008 the whole capacity should be reached. Totally 18 new wells will be drilled (13 production + 5 reinjection) in addition to the existing 2 production wells (total 100 kg/sec) and 1 reinjection well.

The system supplies heating in winter, hot tap water during the whole year and cooling during summer. The geothermaly heated clean water is transported via preinsulated pipes until their residences.

The returning water is planned to be used for vegetables and fruit drying during summer and for greenhouse heating in winter season.

Figure 3: Salihli K-5 Geothermal Production Well, 110 °C, 45 kg/sec

The cooling part of the project will start according to the public demand.

CONCLUSION

- Geothermal Direct use capacity has reached 57.000 residences equivalency district heating (540 MWt, incl. Residences, Thermal facilities and Greenhouse heating) in Turkey. 195 spas exist for balneological purposes (327 MWt). Total direct use capacity is 867 MWt according June 2002.
- Utilization of low temperature springs started via spa and curing purposes. Technological developments encouraged them to be used in heating systems. Innovations in pipes, chemical industry and heat exchanger technology enable us to use these waters in space heating and hot tap water preparation and greenhouse heating.
- The geothermal hot springs as low as 43°C could be used efficiently in district heating, spa&hotel heating without using any auxiliary equipment like heat pumps. The systems are supported with the peaking systems. Therefore, both investment and operating economy are obtained.
- The beginning of large scale district heating systems with geothermal in Turkey has brought numerous technical and economical advantages.
- 11 city based geothermal district heating systems exist in Turkey with total capacity of 34.300 residences equivalency (Thermal Facilities and Greenhouse heating excluded).
- By utilising deep well pumps in Balcova, a large scale GDHS could be realised.
- Kirsehir GDHS is the single GDHS running with as low as 57ϒC geothermal water without heat pump utilization.
- Salihli GDHS is the biggest one in Turkey with 20.000/24.000 residences heating and 2000 residences cooling capacity.

GÖNEN Geothermal District Heating System;

This system has been operational for 10 years. The total installed capacity is 37 MWt, where 3000 residences, a 600 bed capacity hotel is heated geothermally. The number of heated residences will be expanded to 4000 residences. Moreover, the heat and process hot water demand of

tanneries have been supplied from Gönen geothermal district heating system. The flowrate of the geothermal fluid for heating in GÖNEN is 120 kg/sec. and its temperature is 70/80 °C. Geothermal used water is pumped at one bar pressure into the reinjection well (110 m deep). According to the made observations on the wells, dynamic water level has increased for 15 meters and no temperature decline has been recognised.

S MAV Geothermal District Heating System;

Construction of the Simav Geothermal District Heating System began in March 1991, and started operation in December 1992 with a 3500/6500 (33 MWt/ 66 MWt) dwellings heating capacity which is running for more than 3 years. The geothermal fluid is transported to a 4 km distance with a temperature loss of only 1 °C, and as heat is supplied for district heating. The used geothermal fluid is transported back again 4 km and 80 % of the water is reinjected at a 0,2 bar pressure to the reservoir and the rest is used for balneological purposes. In the heating system of residences clean water circulates in closed cycle at a temperature of 60 °C/40 °C.

KIR_EH_R Geothermal District Heating System;

This system has a 1800 dwelling capacity, and 240 kg/sec. average flowrate is required. In this system, 97 % of the energy is supplied by geothermal energy and 3 % by means of fuel-oil. The existing peaking system has a capacity of 6 MWt. 5-8 % of the geothermal fluid is used in thermal facilities and the rest is reinjected to the reservoir.

The temperature loss in the city centre distribution network is only 0.4 °C/km. The heating systems of the dwellings are working with 52-60/40 °C cycling temperature. The heat capacity for 1800 dwellings equivalency is 18,25 MWt at -5 °C outside design temperature. Some other systems like geothermal heating of pedestrials during winter, supply of process heat for industrial utilisation, fishfarming, indoor and outdoor swimmingpool complexes for balneological purposes could be integrated to the geothermal district heating system.

KIZILCAHAMAM Geothermal District Heating Sysytem;

Has been on operation for more than 1 year with 700 residences equivalency. The total installed capacity is 16,5 MWt. The capacity of heated residences will be expanded to 2250 residences. The flowrate of the geothermal fluid for heating in KIZILCAHAMAM is 80 kg/sec. and its temperature is 80 °C. Heating circulation temperature is 70/40 °C. The geothermal water whose energy is withdrawn will be given at about 45 °C to thermal facilities at a flow rate of 20 kg/sec. Heat loss gradient is a minor value as 0,5 °C/km in city distribution network. An energy peaking system is going to be installed to the system with 4,7 MWt capacity.

ZM_R-BALÇOVA geothermal district heating air-conditioning system;

This system has a capacity of 7500/5000 (Total 25.000 residences capacity heating and 5000 residences air-conditionin capacity) residences heating (62 MWt). The first stage of the system as 5000 residences capacity will be fed by 80 kg/sec. and 125 °C geothermal fluid from BALÇOVA Geothermal Field. During winter the clean hot water will be circulated at 90/40 °C. In Summer this clean water temperature will be circulated at 90/70 °C and will serve for air-conditioning for 1500 residences (first stage) by means of absorbtion units. Pumping of geothermal water and control of the city circulation pumps are made by frequency converters in accordance with outside temperature.

Beside of these geothermal district heating systems in Turkey there are many other examples such; Dokuz Eylül University, Campus of Medical Faculty and Hospital Building (approximately 30000 m^2) has been heated geothermally since 1983 fed by the Balçova geothermal field. The pay-back time for the investment was 6 months based on fuel oil burning. BALÇOVA (_ZM_R) Thermal Facilities (435 bed capacity) are operational since 1985 with 7 MWt capacity. Moreover the BALÇOVA THERMAL PRINCESS Hotel (624 bed capacity) is operational since December 1994 The total capacity of the systems fed from Balçova geothermal field is 23 MWt. Moreover, geothermal heating of Sivas sicak Çermik Thermal Facilities

(2100 m^2, 46 °C), Afyon-Oruço_lu Thermal Resort Facilities by means of a slab heating system (2.350.000 kcal/h, 48 °C), Afyon-Ömer Thermal Units, spas and 5000 m^2 greenhouses (2.200.000 kcal/h), Afyon-Gazl_göl Thermal Facilities (550.000 kcal/h, 68 °C), Afyon-Bolvadin (900.000 kcal/h), Simav-Eynal (1.900.000 kcal/h) Thermal Facilities and hotels, Rize-Ayder curing centre, thermal water system and the district heating system (55 ^{o}C, 210.000 kcal/h), Gediz Spas and hotels (78 ^{o}C, 525000 kcal/h), and Salihli Thermal Facilities (220.000 kcal/h). In Rize-Ayder curing centre heating and Haymana mosque heating, the applications of geothermal water without using heat exchangers and pumps, due to the suitable chemical composition of water (44-55 °C) was possible.

SANDIKLI (AFYON) is another big geothermal district heating system under construction with 4000/7000 residences capacity. The most important property of this geothermal district heating system is that it has the longest geothermal water transportation pipe-line of 8600 m, whereas 60 % of this pipeline installation has been completed. The heating capacity of 4000 residences is 37 MWt by outdoor design temperature of - 12 °C. The system will be fed by present 2 geothermal wells (70 °C, total 97 kg/sec.) and natural geothermal discharges (45 - 70 °C, 90 kg/sec.). Heating media of the system will be cyclic as 60/38 °C.

HATAY-REYHANLI-KUMLU geothermal water transportation pipeline of 5000 m length has been completed at the end of 1996.

Moreover SALIHLI 7000 residences geothermal heating and 1000 residences geothermal air-conditioning capacity system, ÇESME (Izmir) 1. stage 1800 residences (total 9000 residences) geothermal district heating system are under construction.

RESULTS

Geothermal district heating systems (GDHS) are the major geothermal utilization applications in Turkey, which provide to the people a clean environment and comfort in their residences in more economic conditions.

Some of spa & thermal curing centre application and low temperature applications are as follows :

- Gediz spa & motel facilities are heated by 78°C. geothermal brine since November1987. Capacity is 200.000 kcal/h.

- Floor heating system was applied in Havza spa. Heated area is 1000 m2 and geothermal water is 54°C. Total capacity is 600.000 kcal/h or 0.7 MWt.

* Rize Ayder thermal curing center is heated with a geothermal water of 54°C. And altitude of this space is 1700 m above sea level.

* Two mosques in Haymana are heated by 43°C geothermal water. In this system operation cost is zero. This seems to be unbelievable but it is true. Since geothermal is producing in artesian mode, electricity cost does not exist. Due to the characteristics of geothermal fluid, scale inhibitor is not used. Floor heating system is fed by geothermal water directly and plastic pipes were used. If all these benefits are added up, with a small investment cost fully free of charge heating system has been obtained.

* Sivas Sicak Çermik Spa is heated by 46°C geothermal water. Area of heated space is 2100 m2. In addition, geothermal water is in sanitary hot tap water production and in greenhouses.

* Afyon Gazligöl Spa facilities uses 68°C geothermal water for heating and curing purposes. System capacity is 550.000 kcal/h.

* Another thermal curing center using low temperature geothermal water is Oruçoglu Thermal Resort. Geothermal water temperature is 48°C.