GEOTHERMAL APPLICATION EXPERIENCES IN TURKEY

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Abstract

Utilization area of geothermal energy is mostly focussed on direct use applications in Turkey. Today 61.000 residences equivalence is being heated geothermally (665 MWt, including residences, thermal facilities, 565.000 m^2 greenhouse heating). Moreover, with the balneological utilisation of geothermal fluids in 195 spa's (327 MWt), the geothermal direct use capacity is 992 MWt. ORME Geothermal Inc has completed the engineering designs of nearly 300.000 residences equivalence geothermal district heating system.

170 geothermal fields (Figure 1) have been explored in Turkey. There is a single flash power plant with 20,4 MW_e installed capacity. A liquid CO_2 and dry ice production factory is integrated to this power plant. A binary cycle geothermal power plant with an installation capacity of 25 MW_e is going to be constructed at Aydin/Germencik.

The proven geothermal heat capacity according to the existing geothermal wells and natural discharges is 3132 MWt [1].

1. INTRODUCTION

There are 11 city based geothermal district heating systems in Turkey. These geothermal district heating systems have been constructed since 1987 and many development has been achieved in technical and economical aspects. The rapid development of geothermal district heating systems in Turkey is mostly depending on;

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

Beside of geothermal heating of the residences, 26 thermal facilities are geothermally heated in Turkey.

With the total geothermal heat potential of 31500 MWt and 2000 MWe geothermal electricity production potential, 5 % of the electricity demand and 30 % of the heat energy demand of Turkey can be met. This equals to 14% (average weighted mean) of the total energy demand of Turkey [2].

The total geothermal heat potential of 31500 MWt equals to the heating of 200 Million m^2 greenhouses heating or is equal to 5 Million residences heating in Turkey.

There is a high thermal tourism potential in Turkey. Moreover combining thermal tourism with the sea/sun/cultural tourism brings important economical development to the region and country.

The portion of geothermal in Turkey's total electricty production in 2002 is 0,05 % [3].

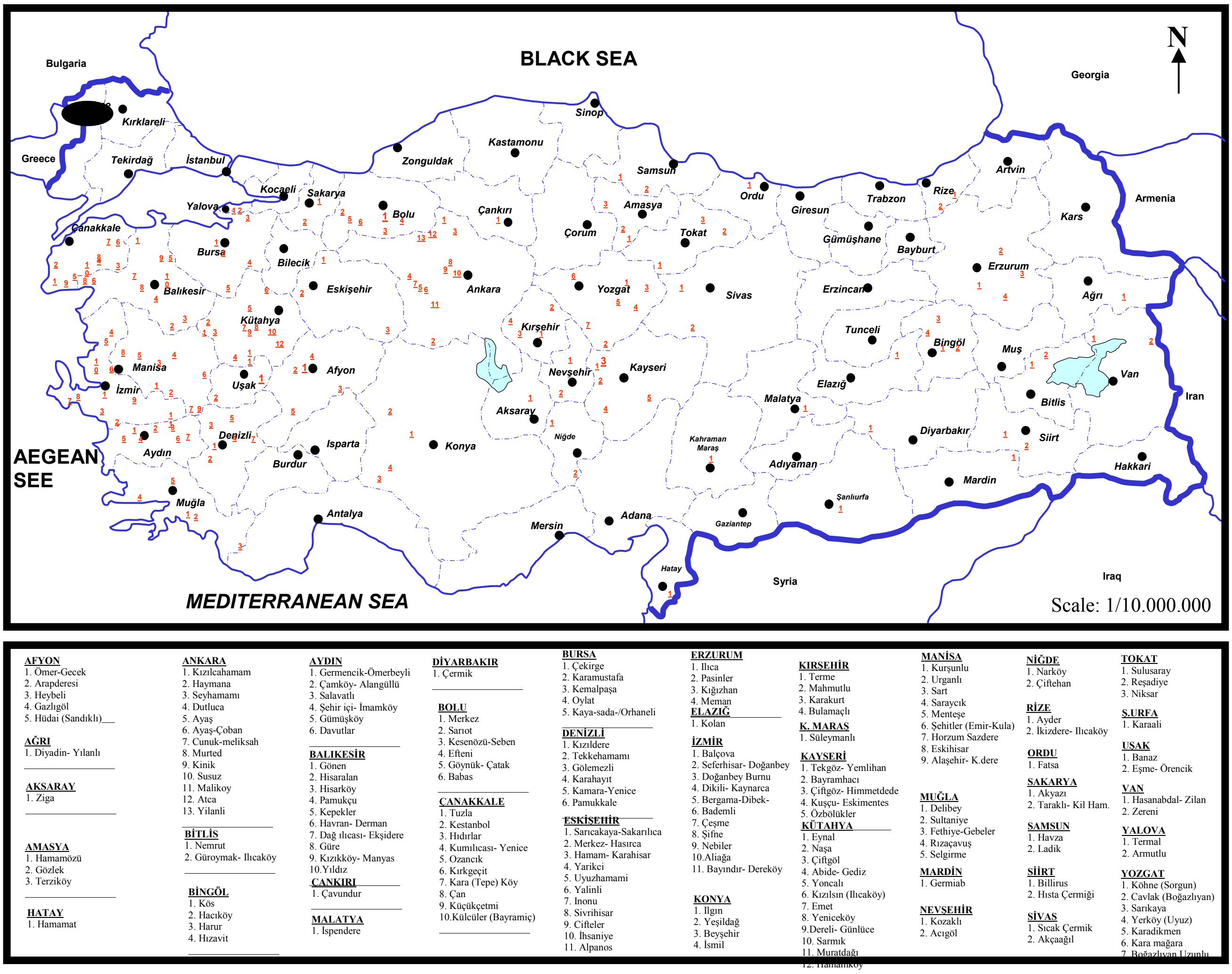

Figure 1: Geothermal fields of Turkey

2. GEOTHERMAL DISTRICT HEATING APPLICATIONS

District heating systems have been started with the installment of geothermal district heating systems in Turkey. Below are the important points, which makes geothermal more adventagous compared to other energy sources:

1- As the geothermal heat selling price is held constant for the whole year, the geothermal heating projects are supported by the consumers. Geothermal heating fee including hot sanitary water varies from 14 – 28 $/month for 100 m^2 residence for the existing geothermal district heating systems in Turkey. As this fee remains the same for the whole year in Turkish Lira basis and is not reflected from the rate of exchange, this brings an important economical advantage to the consumers if compared with fossil fuel types.

2- The existing heating systems are connected to geothermal district heating systems directly.

3- The radiator area previously designed according to 90/70 °C temperature interval for conventional heating systems, has not caused any problem at temperature intervals like in 80/40 °C, 80/45 °C and 70/50 °C by geothermal as could be seen in some examples. This shows that the radiator heating surface in original had been set larger than necessary before.

4- The investment amount per residence of the GDHS varied between 1,250 – 1800 USD in Turkey (radiator installation in the residence excluded). The geothermal district heating investments are paying themselves back commercially in 5-8 years in the investment conditions of Turkey. Moreover, they have a relatively low initial and operational costs and low selling price of heat in comparison to conventional fuels (coal, fuel-oil etc.).

5- About 40-50% of the investment has been paid by the consumers as a connection subscription fee like cash in capital. As a result of this, the economy of GDHS investments is getting to a better position.

To utilize the geothermal fluid in maximum, the leaving temperature of the fluid is kept as minimum as possible. To achieve this goal, it is needed to control the radiator return water temperature of the buildings. The control of the radiator return water temperature is done with self operating, flow, temperature and pressure difference control valves. Logicaly, the less the return water temperature entering the heat exchanger in the Heat Center, the more heat is extracted from geothermal fluid, and the more the geothermal fluid is utilized. The circulation pump is controlled by means of a PC network that leads pumping of adequate amount of water to the city.

Heat consumption in GDHS are variable according to the outdoor temperature. Thus, the energy amount supplied to the consumers is also variable. This variability could be obtained by holding the water temperature to and from the consumers constant and leading variable flowrate use instead of variable temperature. So, to hold the temperature constant prevents the damage at the pipes forming due to the temperature difference, replies immediately and 100% to the different heat demands of the consumers and its operational cost is much lower. To save electricity (because, electricity cost is 9 cent/kWh), geothermal water and chemical substances, the related pumps are running in accordance with the variable speed drivers. Due to good operation plan and full automatic control of variable speed driver pumping system, the electricity consumption rate decreases 63% annually. In order to prevent corrosion and scaling in the well, geothermal water transportation line and close circulation networks, corrosion and scale inhibitors are used with water treatment plant and pH control system.

Figure 2: Kirsehir geothermal district heating center

Heating has been done mostly by coal and other fossil fuels, which is also now mostly the case in Turkey. This results in serious air-pollution in big cities. Kirsehir City was the third mostly air polluted city of Turkey, before 1800 residences were geothermaly heated in the city center. With the use of geothermal district heating system, air pollution has been reduced in important amounts (Figure 2).

Due to geothermal district heating systems, the spaces used for storing the fuels and boilers have been emptied and could be used for more useful purposes.

Because of the high temperature, long mean time between the failures, low repair cost and availability of spare parts (most of them) as locally LSP system (line shaft pump) has been used in geothermal wells. In LSP system, filtered geothermal water has been used as a lubricant which is supplied to the line shaft bearings through the enclosing tube. Water lubrication system has been selected instead of oil lubrication system, because of the fact that, some of the geothermal brine is being used for balneological purposes after heating the supply water by means of heat exchangers (40-50°C).

Operational capacities of the existing city based geothermal district heating systems (GDHS) and their integrated geothermal applications in Turkey are as follows (Table 1):

City Name	Geoth. Heating Capacity (Res.Equiv.)	Integrated Geoth. Appl.	Year of Start up	Geoth. Water Temp. (°C)	Geoth. Heating Fee paid by the Resid. ($) (2002/2003 winter season)**
GONEN	3400	B, I	1987	80	27
SIMAV	3200	B, G	1991	120	26
KIRSEHIR	1800	B	1994	57	21
KIZILCAHAMAM	2500	B, G	1995	80	21
IZMIR-BALCOVA	11500	B	1996	137	19
AFYON*	4500	G	1996	95	25
KOZAKLI*	1000	G	1996	90	28
IZMIR-NARLIDERE	1500	-	1998	98	19
DIYADIN*	400	B	1999	70	n.d.***
SANDIKLI	2000/5000	B	2000	70	14
SALIHLI	2000/20.000	B	2002	94	15

*Table 1: Operational capacities of the existing city based GDHS and their integrated geothermal applications in Turkey (B: Balneology, I: Industrial Use, G: Greenhouse, *Construction is not realized by ORME, ** 1 $ = 1.650.000 TL, January 2003, *** not defined yet)*

3. GEOTHERMAL GREENHOUSE HEATING APPLICATIONS

The total area of greenhouses heated by geothermal energy is 565.000 m^2 (131 MWt) in Turkey. In Sanliurfa city 106.000 m^2 geothermal greenhouses exist, where the yield obtained from the greenhouses is exported to Europe [4].

The existing geothermal greenhouses in Turkey are as the following (Table 2):

LOCATION	AREA (m^2)	CAPACITY (MWt*)	LOCATION	AREA (m^2)	CAPACITY (MWt*)
Sanliurfa	106.000	24,5	Dikili	120.000	24
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

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

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 and will be realized with the received fund in year 2003.

4. THERMAL FACILITIES HEATING AND BALNEOLOGICAL APPLICATIONS IN TURKEY

The demand for balneological utilization of geothermal waters has been increased in the recent years in Turkey.

A possible producable potential amount of geothermal flowrate (~ 40°) has been estimated for the balneological use in Turkey, which is 50.000 l/s. This equals to the benefit of 8 million people/day from thermal waters in spa's in Turkey [4].

Turkey is one of the rare countries, where combining of 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 with 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 which are suitable for sea and thermal tourism combination are; Bodrum, Kusadasi, Datca and Edremit cities which are located at the Aegean and Mediterranean Sea's. Some of the spa & thermal curing centre applications in Turkey are as follows :

- Balcova Thermal Facilities are heated with 70 °C geothermal water
- Balcova Thermal Princess Hotel is heated with 125 °C geothermal water.
- Gediz spa & motel facilities are heated by 78°C geothermal water.
- Floor heating system was applied in Havza spa. Heated area is 1000 m^2 and geothermal water is 54°C.
- Rize Ayder thermal curing center is heated with a geothermal water of 54°C. Altitude of this facility is 1700 m above sea level.
- Two mosques in Haymana are heated by 43°C geothermal water. In this system operation cost is nearly zero. Since geothermal is producing in artesian mode, electricity cost does not exist.Due to the characteristics of geothermal fluid, scale and corrosion 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 Cermik Spa is heated by 46°C geothermal water. Area of heated space is 2100 m^2. In addition, geothermal water is used in sanitary hot tap water production and in greenhouses.
- Afyon Gazligol Spa facilities uses 68°C geothermal water for heating and curing purposes.
- Orucoglu Thermal Resort uses 48 °C geothermal water for heating and curing purposes.
- Cankiri-Cavundur Thermal Facility uses 56 °C geothermal water for heating and balneological purposes.
- Bolu-Karacasu Thermal Facilities uses 44 °C geothermal water for heating and balneological purposes.

The number of the local thermal curists is around 7 million and the number of the foreign thermal curists is around 10.000 in Turkey.

The turnover of Balçova Thermal Facilities is targeted as 5 million USD in 2002.

5. ELECTRICITY PRODUCTION

Because of it's relatively low installation and operational cost as well as being more environmental friendly, in comparison to the conventional thermic and hydraulic power plants geothermal electricity production is advantageous. At present, nine of the geothermal fields of Turkey are of high enthalpy and are appropriate for the geothermal-electric energy conversion by Binary Cycle or by Flashing Cycle . These fields are [4]:

1. Denizli-Kizildere	(242 °C)	
2. Aydin-Germencik-Omerbeyli	(232 °C)	
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3. Canakkale-Tuzla	(173 °C)	
4. Aydin-Salavatli	(171 °C)	economy is doubtfull
5. Kutahya-Simav	(162 °C)	at limited conditions
6. Manisa-Salihli-Caferbeyli	(155 °C)	
7. Izmir-Seferihisar	(153 °C)	

At present there is one operating geothermal power plant at Kizildere (Figure 3) and one geothermal power plant at Germencik (on the Aydin-Germencik geothermal field) is going to be constructed in a very near future.

Kizildere geothermal power plant was constructed by a consortium including GIE and ENEL of Italy between 1981-1984 and put into operation on February 1984.The installed capacity is 20.4 MWe and the generation capacity is 108 GWh. R-1 (2261 m) well drilled in 1997, produces from the third reservoir with a temperature of 242 °C and is connected to the system.

Figure 3: Kizildere Geothermal electricity production 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 turbine which drives an electric generator and a compressor.

The maximum operational capacity of the Kizildere Geothermal Power plant could have been increased by 10 % if the rejected hot brine from well head separators were flashed into dry steam at 122 °C and expanded in an atmospheric exhaust (back-pressure) turbine coupled with its own electric generator. Alternatively, by constructing a "Binary Cycle" unit, the rejected hot brine from the well head separators could have been utilized to increase the power plant's maximum operational capacity by 15 % [5]. Kizildere geothermal power plant is being operated by state-owned Electricity Company (TEAS) for the time being.

Germencik 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 power plant will consists of 4 Ormat Energy Converter Units. The installed capacity of the plant is 25 MWe at the beginning but it will be extended gradually to 100 MWe. The Power Unit operation is based on the principle of the Organic Rankine Cycle, in which geothermal steam and brine, serving as a heat source, flow through a shell-and-tube heat exchanger and evaporates an organic fluid. Consequently, the organic fluid vapour drives the High Pressure and Low Pressure turbines, which are coupled to the double shaft end generator producing electrical power. The vapour is condensed in an air cooled condenser. The total investment cost of this environmental friendly plant where the latest technology is used, amounts to US$ 46.700.000 [5].

6. MINERAL RECOVERY

Figure 5: Liquid CO_2 and Dry Ice production plan in Kizildere

Besides electricity generation, 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 for the beverage industry is produced (Figure 5).

LP and HP compressors maintains the vacuum conditions in the condenser and then extracts the CO_2 gas separated from the wet steam in the condenser. The condenser is a “direct contact jet type“ condenser which is cooled by the circulating geothermal water between condenser and cooling tower.

7. CONCLUSIONS

Only 3 % of our total geothermal potential has been utilized yet.

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$ net domestic value could be targeted.

For the further development and extension of the geothermal applications in Turkey, 15 % financial support of the Turkish Government would be appropriate.
31.500 MWt total geothermal heat potential is estimated in Turkey, which 500 MWe power production and 3500 MWt space heating is aimed for the year 2010.

With the huge thermal tourism capacity potential of Turkey, the target is to increase the local curist (tourists in thermalism) number to 30 million people until the year 2020. In this case, additional domestic economical activity of total 12 Billion USD will be created.

The foreign thermal curist number is targeted as 1 million until the year 2020.

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