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# Geothermal applications in Turkey: the technology and economics

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**ABSTRACT**

There have been 140 geothermal field discoveries since 1960's in Turkey, in which, 133 of them are smtable for geothermal direct use applications and the rest for power generation Geothermal energy is mostly utilized in direct use (beahng of residences, greenhouses, thermal facilities) and for balneological purposes in Turkey The installed capacities of the city based geothermal district heahng systems existing in Turkey are as the following GONEN (4500 residences, geothermal water temperature is - 80°C), SIMAV (6500 residences, ~120°C), KIRSEHIR (1800 residences, ~57°C), KIZILCAHAMAM (2250 residences, - 80°C), IZMIR-BALCOVA (15 000 residences, ~125°C), SANDIKLI (5000 residences, –70 "C), AFYON (4000 residences, ~95°C), KOZAKLI (700 residences, ~90°C), NARLIDERE (5000 residences, - 98°C)

Besides the geothermal direct use applicahons in Turkey, one geothermal power plant with 20 4 MWe installed capacity in Denizli-Kizildere and one geothermal liqmd $CO_2$ and dry ice production factory (40 000 tons/year) integrated to Kizildere geothermal power plant exist in Turkey Chemical inhibitors and smtable material selection, the negative effects such as scaling and corrosion depending on the chemical composition of geothermal fluid are minimized The cost per residence connected to the geothermal district beating system in Turkey, is around 1500-2500 USD (network and system included, the radiator installahon in the houses excluded)

**KEYWORDS**

Turkey, direct use, power generation, technology, economy

## Geothermal direct use applications

Today, 50.000 residences equivalency is being heated geothermally (350 MWt) in Turkey. The number of geothermal beating systems are 38 (including city based district heating systems as mentioned below, thermal facility and greenhouses heating systems). Moreover, with the balneological utilization of geothermal waters in 190 spas in Turkey (285 MWt), the geothermal direct use capacity is totally 635 MWt. The engineering designs of over 150.000 residences equivalency geothermal district heating systems have been completed by ORME Geothermal Inc.

Heating of 50.000 residences equivalency geothermally in Turkey lead to elimination of nearly 500.000 tons/year carbondioxide from the atmosphere which equals also to the removal of nearly 300.000 cars from the traffic (in January as peak in the heating season).

District heating systems in Turkey has been realized firstly by means of geothermal energy. For this reason there was no need to change the previous installed heating network and the district heating systems has been installed directly according to the geothermal design parameters which has brought technical and economical advantages. Another fact is if there would exist any other previous district heating system, it would be rather difficult to come to todays geothermal district heating development in Turkey.

Annually 23 % increament of residence connection to geothermal district heating systems has been achieved since 1983 in Turkey in average as seen in Figure 1.

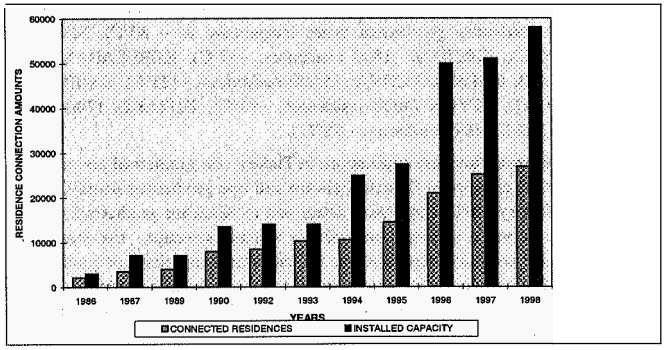


***Figure 1: Residence connection rates to the geothermal heating systems in Turkey according to the years***

The important properties of some of the geothermal district heating systems in Turkey are as the following :

**Kizilcahamam Project (2250 residences, 18 MWt)**

Due to the Kizilcahamam geography, there exist very frequent elevation differences. For this reason two heat centers and substations were built in Kizilcahamam geothermal district heating system. Four geothermal production wells exist in Kizilcahamam. 3 of them are equipped with downhole pumps and the other well has artesian production. Total production of the wells is 60 kg/s.

**Kirsehir Project (1800 residences, 20 MWt)**

Kirsehir geothermal district heating system, where 57 °C temperatured geothermal fluid is used (without heat pump), has been realized very economically. This system includes peaking system, which is used for maximum two weeks in a year during the peak load time. The reinjection pipes, some part of the city network return pipes are not insulated. The total cost of 1 kWh heat in Kirsehir geothermal district heating system is only 0.65 cent.

**Sandikli Project (5000 residences, 42 MWt)**

The geothermal water transportation pipeline of Sandikli geothermal district heating system is 9318 m and the heat center is located in 92 m higher elevation than the geothermal wells. Downhole pumps for geothermal production is used, where the dynamic level is approximately 20 m. With the used technology maximum 2 °C temperature loss exist during this long transportation fiberglass pipeline. The flowrate in Sandikli will be tripled in the near future, which will reduce the heat loss to less than 1 °C. The geothermal fluid is produced by downhole pump, whereas the downhole pumps are working with the frequency converters. 1000 residences equivalency are heated now in Sandikli geothermally and the house connections to the system are continuing.

**Cesme Project (1100 residences equivalency, 10 MWt)**

In Cesme, thermal tourism and geothermal heating has been integrated and the very salty and corrosive geothermal water (TDS is around 36.000 ppm, where 20.000 ppm is Cl) will be transported by single pipe and given directly to the hotels and residences, where small heat exchangers at each building will be used. This has brought an important economy to the investment.

**Izmir-Balcova Project (15.000 residences, 100 MWt)**

In Balcova geothermal district heating system (Figure 2), variable speed driver are used in every downhole and supply pump. This leads to a very less electricity cost of heating. 1 Million kcal/h requires 26 kWh electricity which costs only 2,5 USD. In order to produce geothermal fluid with a temperature between 105-140 "C, LSP systems (Lineshaft pump) have been used in 6 wells. For each well, $N_2$ (Nitrogen) gas line is used for monitoring the dynamic levels. There are special chemical injection system to prevent the scaling problem ($CaCO_3$) in each geothermal well. In the Balcova geothermal district heating system city

network, special chemical inhibitor is used to prevent corrosion. Moreover, by a 125 "C geothermal water + vapor + gas production, separator with condenser is used to separate the gas and by the aid of additional condensation settings nearly all the vapor is getting condensed which steam exhaust is prevented. If the 24 hour daily average temperature is 9 "C, the energy amount per residence (100 $m^2$) will be 2900-3000 kcal/h. In this case the total geothermal production amount is 87 kg/sec. with an average temperature of 125 °C. 85 % of the geothermal water is reinjected and the rest is supplied to the thermal facilities for balneological purposes. Except the geothermal wells with LSP pumps, there are downhole heat exchanger system which supply energy to the Balcova Thermal Hotel (ORME Geothermal Inc. 1996).

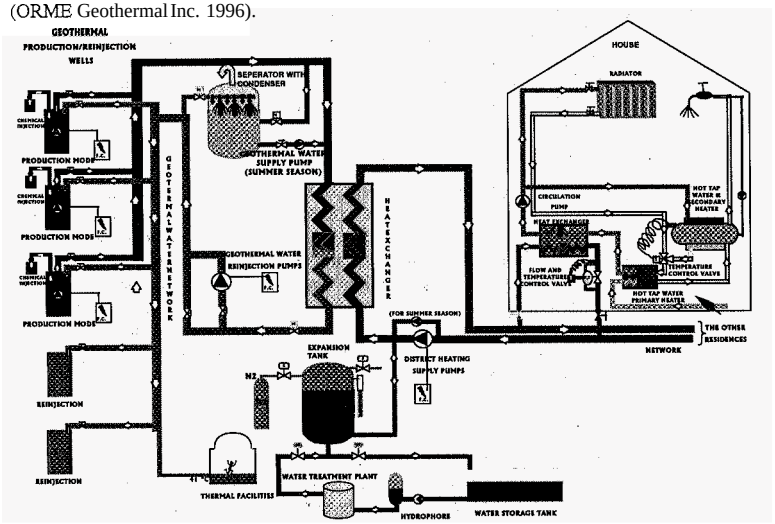


***Figure 2: Izmir - Balcova Geothermal District Heating System***

Besides these geothermal district heating applications there exist many other geothermal heating systems in Turkey. Some of these are : Dokuz Eyliil University Hospital and Campus (1100 residences equivalency), Balcova Thermal Facilities and Thermal Princess Hotel (total 1800r.e.), Afyon Orucoglu Thermal Resort (500r.e.) etc.

Geothermal district heating systems under construction with their total heating capacities are as the following : Salihli (7000 residences), Cesme (9000 residences), Sandikli (5000 residences), Kizilcahamam (2250 residences), Narlidere (5000 residences), Balcova (the 3rd stage, 15.000 residences) and Balýkesir (BALPAS) Thermal Facility (300 residences equivalency).

## Geothermal power generation

First explorations regarding geothermal electricity generation have started in 1968 with the investigation of Kizildere geothermal field. In 1974 a pilot plant with a capacity of 0,5 MWe has been installed. After seeing this successful and beneficial pilot application, in 1984, the Kizildere Single Flash Geothermal Power Plant was installed by T.E.K. (Turkish Electricity Establishment, new named as TEAS) with 20 MWe capacity. But, due to some operation problems the average production amount changes between 12-15 MWe.

The reservoir temperature in Kizildere geothermal field has been revised to 241 °C during reinjection well drilling in 1997, which is now the highest encountered temperature in Turkey after Germencik geothermal field (232 "C).

Other geothermal fields which have high temperatures are : Aydin-Germencik geothermal field (reservoir temperature : 232 °C) Canakkale -Tuzla geothermal field (rt : 173 °C), Aydin-Salavatli geothermal field (rt : 171 "C), Kiitahya-Simav geothermal field (rt: 162 "C), Izmir-Seferihisar geothermal field (rt: 150 °C).

Moreover, according to the prepared feasibility reports, the geothermal power generation capacity in Aydin - Germencik geothermal field is reported as 100 MWe.

## Other geothermal applications

The reservoir which feeds the Kizildere Geothermal Power Plant contains 1,5 % non-condensable gases. The amount of these gases at the separation pressure in the single flash plant is 15 % in weight.

Annual 40.000 tons of liquid carbondioxide and dry ice production exist in the integrated factory to the Kizildere geothermal power plant. This factory **runs** with full capacity during the summer season and with 50 % capacity during the winter season, which supplies 50 % of the $CO_2$ demand of Turkey which is the single application in the world.

## Projections regarding geothermal applications

The theoretical geothermal potential of Turkey has been estimated by MTA and Turkish Geothermal Association as 31500 MWt, which is equal to geothermal heating of 5.000.000 residences in Turkey. The proven geothermal capacity calculated by MTA is 2420 MWt (exhaust temperature is assumed to be 35 °C). According todays technical and economical availability of the geothermal fields, 500.000 residences could he heated until the year 2010.

The estimated projections regarding geothermal utilization capacities in Turkey are given in Table 1 (acc. to Turkish Geothermal Association and ORME Geothermal Inc.) :

| Years | Power Prod. (MWe) | Heating (Residences Equivalency) | Spa/Others (MWt) |
|---|---|---|---|
| **2000** | 45 | 60.000 (420 MWt) | *300* |
| **2010** | *500* | 500.000 *(3500* MWt) | 895 |

## Technology

The geothermal water transportation and city distribution network pipelines buried directly into the soil are resistant against corrosion (economic life is *30* years) with very low friction resistance and very high heat insulation affects the development and the first investment cost positively.

The heat loads of the consumer are determined according to the experimental results which brings a more real approach to the system and not according to the theoretical evaluations.

In the heating circuit, the temperature difference interval is maximum and constant and the flowate is variable that the electricity and geothermal fluid consumption is minimized and maximum energy transportation has been achieved.

Production and circuit pumps are working with variable speed driver by means of the frequency converters depending on the outside temperature. Use of the frequency converters decreases the electricity consumption as 40% - *65%* and so decreases the operation costs.

Against scaling 3-5 ppm chemical inhibitor is used and corrosion effects has been minimized by using fiber glass pipe material, stainless steel and titanium heat exchangers. In four applications in Turkey (Rize-Ayder, Sivas Sicak Cermik, Afyon-Orucoglu Thermal Facilities and Haymana Mosque Heating) the geothermal fluid has been used as low as 40-45 "C (without heat pumps). Moreover, in Haymana mosque heating, due to the suitable chemical properties and conditions of the geothermal water, no chemical inhibitors, no pumps and no heat exchangers are used. Haymana mosque heating (slab heating) bas been running since 1988 without any operation costs.

Heat pump applications have a wide utilization area around the world which is not the case in Turkey. In conditions of Turkey, it is not economical to use heat pumps due to the high electricity costs and low real interest applications. When these conditions will be changed the heat pump utilization will be economical in Turkey.

## Economy

The cost per residence connected to the geothermal district beating system is around 2000 USD (network and system included, the radiator installation in the houses excluded). The payback periods of geothermal district heating system investments in Turkey is around 5-10

years. The construction costs of heating applications is 300-350 USD/kWh (installed capacity) in the conditions of Turkey.

About 30-50 % of the investment have been paid by the consumers as a connection subscription fee like cash in capital by taking the heating fees for two years in advance. As a result of this, the geothermal district heating system investments are getting more economical.

The pay back periods of geothermal district heating system investments in Turkey is around 5-10 years. The residences connected to the geothermal district heating system are paying 20-25 USD/month heating fee. Geothermal district heating distribution networks have been designed and constructed according to the geothermal system parameters which brings great advantage to geothermal district heating system investments in terms of technical and economical aspects.

Geothermal heating cost is only 117 if compared to the heating with natural gas in the conditions of Turkey.

Heating of 500.000 residences geothermally in Turkey (3500 MWt) brings 1,5 Million tons fuel-oil economy (370 Million USD). If we think to the development and utilization of the total theoretical and target geothermal potential which is 31500 MWt in city heating, power production, greenhouse and thermal facilities heating, use in balneology and industry will bring over 20 Billion USD net domestic value added per year (Table 2).

***Table 2: Heating Costs in Turkey (April 1999, 1USD = 393.000 TL)***

| Heating Categories | cents/1000 kcal |
|---|---|
| Geothermal based heating | 0,23 - 0,42 |
| Natural gas based heating | 2,9 |
| Fuel-oil based heating | 3 |
| Coal based heating | 4,4 |
| Electricity based heating | 9,6 |

Ref.: Intern. Energy Technol. and Inst. Periodical 1999

## Conclusion

The district heating system mentality has been settled in Turkey by means of geothermal district heating systems, where as previously lignite heating (furnace) was accustomed for heating. For this reason it has brought technical and economical advantages to the geothermal district heating system applications which has resulted in development rise of geothermal district heating system investments in Turkey. Moreover the people were

introduced to a higher living standard by means of geothennal district heating systems. People show a very high demand to geothermal district heating systems is Turkey. The people prefer to buy or rent geothermally heated residences, that the rent or selling price **of** these houses increase **3-4** times **like** the houses connected to Izmir-Balcova geothermal district heating system.

But there are also some points which should be improved **for** the development of geothermal applications in Turkey. These points could be summarized as follows : Turkish geothermal law should be finalized as soon as possible, more geothermal wells should be drilled and the well risk should be taken by the state, a control mechanism should work and more financing aids should be received for the geothermal development projects in Turkey.

## References

International Energy Technology **and** Installation Periodical **1999.** Comparison Table **of** Fuel Prices **for** Residence Heating, Vol. **37,** Istanbul.

ORME Geothermal Inc. 1996. Balcova Geothermal District Heating System Feasibility Report, Ankara.