GEOTHERMAL DEVELOPMENT POTENTIAL IN TURKEY

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SUMMARY - Turkey is located in the Mediterranean Sector of the Alpine-Himalayan Tectonic Belt which has an important geothermal potential. In Turkey, there are approximately 170 geothermal fields with temperatures ranging from 20 to **240** °C at economic depth, associated with about 1000 thermal springs. Research and drillings carried out by General Directorate of MTA has significantly increased the proven potential of these thermal resources. As a result of the exploration and development studies, a pilot electrical power plant **(20.4** MWe) was installed in Denizli-Kizildere field in 1984. In addition, important developments have been made in direct use applications of geothermal energy, with a total installed capacity of 867 MWt, consisting of greenhouses (a total of about 500000m^2 floor space), space heating for about 57000 dwelling units, and balneological utilization at 195 spas. These utilization schemes are operated by governorships, municipalities and their companies, and private sector. Since the geothermal sources are considered clean, cheap and renewable, there are expectations for more widespread applications all around the country in the near future.

1. INTRODUCTION

Turkey is located in the Mediterranean Sector of the Alpine-Himalayan Tectonic Belt. This young belt has an important geothermal potential. Geothermal fields are associated with the graben systems of Western Anatolia, the widespread volcanism and tectonism of Central and Eastern Anatolia and the right lateral and strike slip North Anatolian Fault Zone. These zones are the controlling factors for the distribution of thermal- and mineral water resources.

In Turkey, there are approximately 170 geothermal fields with temperatures ranging from **20** to **240** °C at economic depth, associated with about 1000 thermal springs (Figure 1). Research and drillings carried out by General Directorate of MTA has significantly increased the proven potential of these thermal resources. (Kocak, 1990, Simsek, 2001).

As a result of the exploration and development studies, a pilot electrical power plant **(20.4** MWe) was installed in Denizli-Kizildere field in 1984. In addition, important developments have been made in direct use of geothermal energy with a total installed capacity of 867 MWt, which includes greenhouses and dwelling heating systems. Since

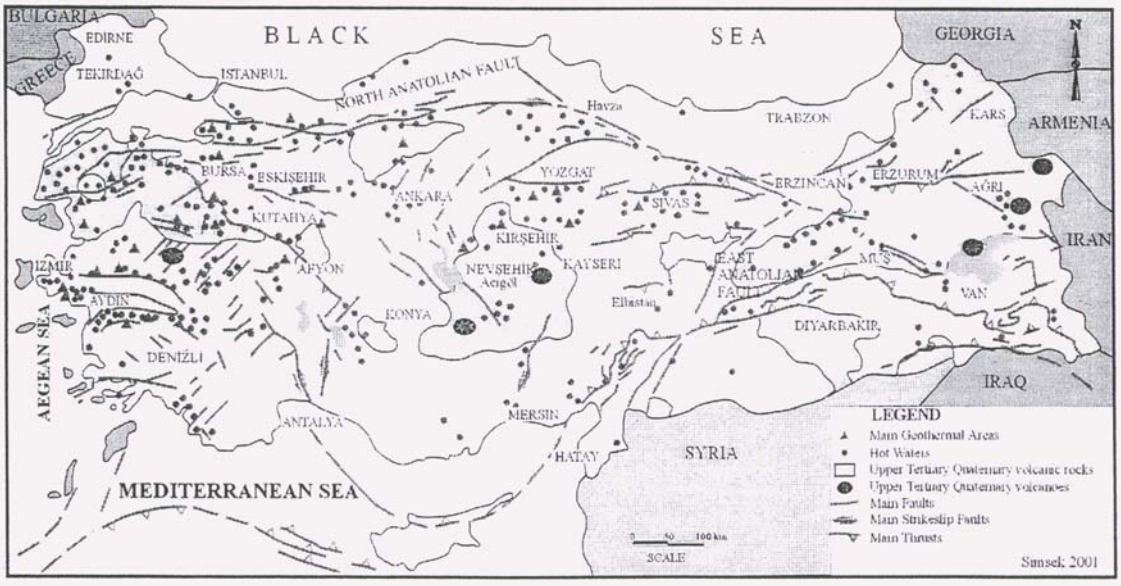

Figure 1: Main neotectonic lines and hot spring distribution of Turkey

the geothermal sources are considered clean, cheap and renewable there are expectations for more widespread applications all around the country in the near future. In this paper, the expectations contained in the commission report prepared by State Planning Organization (SPO-DPT) regarding geothermal development activities in Turkey between 2001 and 2005, will be discussed.

2. GEOTHERMAL POTENTIAL OF TURKEY

Geothermal research and investigations in Turkey were started by MTA in 1960's. A total of 170 geothermal fields were discovered; about 95% of them are low-medium enthalpy fields, which are mostly suitable for direct-use applications. About 1000 hot and mineralized natural springs exist in Turkey. These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, and at the central and eastern Anatolia volcanic regions. With the existing geothermal wells and springs, the proven geothermal capacity calculated by MTA is 2600 MWt (discharge temperature is assumed to be 40 °C). The geothermal potential is estimated at 31,500 MWt. At present about 400 geothermal exploratory and production wells and 200 gradient wells have been drilled in Turkey (maximum depth 2398m). The number of wells drilled by MTA is 342 (Akkus, 2002). The first geothermal well was drilled in 1963 and the number of the wells increased sharply after 1982.

Some important geothermal potential were discovered fiom existing oil exploration wells at southeastern Anatolia. In this area the reservoir temperatures are between 83 °C and 138 °C at 2400-3850 m depths.

The number of geothermal production wells in Turkey is too few with respect to the high geothermal potential of the country. Most of these wells were drilled by MTA and were financed by the Governorships, Municipalities and their companies (66.2%), MTA (16.5%), and private sector (11.7 %).

Studies on Hot Dry Rock (HDR) systems, which develop at regions containing high temperature formations at shallow depths, are being continued with promising results. If the studies show that these systems can be managed economically, the geothermal potential of Turkey will increase sharply. The Central Anatolia in the region of Acigol and the young volcanic fields of Eastern Anatolia are promising areas for HDR developments.

3. HIGH TEMPERATURE FIELDS AND THEIR UTILIZATIONS

The first exploration with the purpose of geothermal electricity generation was started in 1968 with the investigation of Kizildere Geothermal Field by MTA and UNDP. In 1974 a pilot plant with a capacity of 0.5 MWe was installed. In 1984, the Kizildere Geothermal Power Plant was built by TEK. (Turkish Electricity Establishment, renamed as EUAS) with an installation capacity of 20.4 MWe. The reservoir temperature in the Kizildere geothermal field is 200-242°C. The reservoir fluid which feeds the Kizildere Geothermal Power Plant contains 1.5 *Yo* non-condensable gases. The amount of these gases at the separation pressure in the single **flash** plant is 15 *Yo* by weight. A liquid CO_2 and *dry* ice production factory is integrated to this power plant, which produces 120,000 tones of liquid carbon dioxide and *dry* ice annually since 1987 (Table 1).

Another power plant construction studies was started at Germencik field (232 °C) in 2001 (Table 2). Some others high enthalpy geothermal fields are Çanakkale-Tuzla (173 °C), Aydin-Salavatli (171 "C) and Kutahya-Simav (162 "C).

Table 1: Capacities in Geothermal Utilization in Turkey (August 2002)

Geothermal Utilization	Capacity
District Heating	540 MWt
Balneological Utilization 195 Spa	327 MWt
Total Direct Use	867 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

4. LOW TEMPERATURE FIELDS AND THEIR UTILIZATIONSS

The operational capacities of geothermal district heating systems utilizing low temperature fields in Turkey are: Gonen (Commissioned: 1987, 3400 residences, geothermal water temperature is –80 "C), Simav (1991, 3200 residences, –120 "C), Kirsehir (1994, 1800 residences, –57 "C), Kizilcahamam (1995,2500 residences, –80 °C), Izmir (1996, 11.500 residences, –115 "C), Sandikli (1998, 1600 residences, –70 "C), Afyon (1996, 4500 residences, –95 °C), Kozakli (1996, 1000 residences, -90 "C), Izmir-Narlidere (1998, 1500 residences, –98 °C), Salihli (1500 residences), Diyadin (1999, 400 residences, –70 °C). At present, geothermal waters of 40-45 °C temperatures are used for space heating in Turkey without any heat pump.

Geothermal district heating systems (GDHS) are the main geothermal utilization in Turkey. They have an important meaning to the Turkish citizens, since the systems provide, economically, clean environment and comfort. More widespread applications of GDHS are expected in the future (Table 3).

The geothermal direct-use development has achieved 57.000 residences equivalence geothermal heating (540 MWt) including district heating, some thermal facilities and approximately 500.000 m^2 geothermal greenhouse heating. **A** total of 195 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of more than 150,000 residences equivalence geothermal district heating has been completed. The total of installed capacity is **867** MWt (Figure 2). This capacity is equivalent to an annual oil consumption of 700.000 tons.

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

An annual average of 23% increment of residential connection to GDHS has been achieved since **1983** in Turkey.

The construction costs of power plants are 850-1250 USD/kW. For heating applications it is 300 USD/kW for the conditions of Turkey. The geothermal heating cost per residence (including network and system, but excluding radiator inside the house) is around 2000 USD, and these investments are paying themselves back in ***5-8*** years (Mertoglu et al., 2000).

For the year 2010 the geothermal heating capacity has been estimated at 3500 MWt, power production at 500 MWe, and balneological utilization at 895 MWt. For the year 2020 the geothermal heating capacity has been estimated at 8300 MWt, power production at 1000 MWe and balneological utilization at 2300 MWt (Table 3).

Table 2: Utilization of Geothermal Energy for Electric Power Generation as of August 2002

Locality	Power Plant Name	Year Commis.	No. Of Units	Status	Type of Unit	Total Installed Capacity MWe	Annual Energy Produced 2000 GWh/yr	Total planned MWe
Denizli – Kizildere	Kizildere Power Plant	1984	1	Presently Operated	Single Flash	20.4	91.8	
Aydin	Germencik							25 MWe, planned

Table **3** : Geothermal utilization projections of geothermal energy in Turkey

Years	Power Prod. (MWe)	Heating (Residences Equivalency)	Spa/Others (MWt)
2010	**500**	**500.000** (3500 MWt)	895
2020	1000	1.250.000 (8300 MWt)	2300

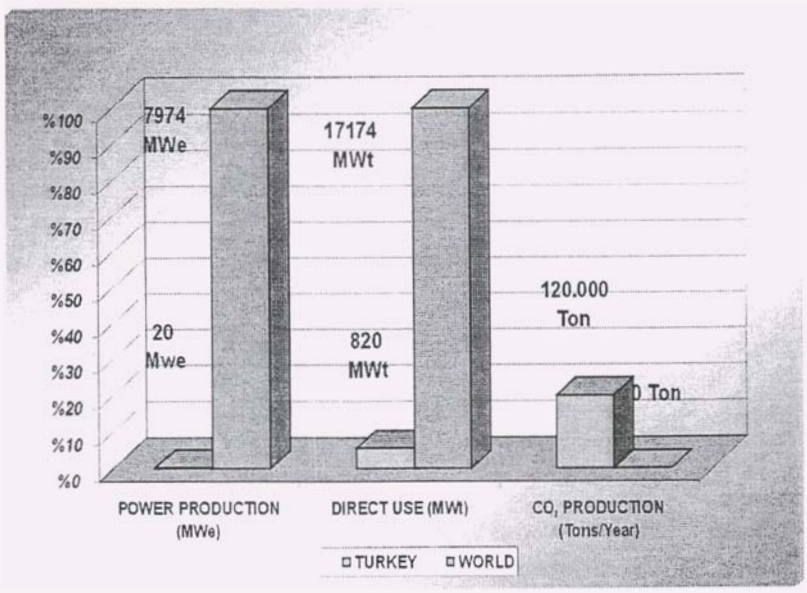

Figure 2. Geothermal energy utilization in Turkey and in the World

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

5. EXPECTATIONS CONCERNED IN THE 8th FIVE YEARS PLANNING PERIOD (2001-2005)

According to the scope of the report prepared for State Planning Organization (SPO-DPT), it is thought that an important part of geothermal energy potential will be run next years in Turkey. According to the 8th Development Program for Five Years (8. BYKP) (2001-2005), the aims which are expected to realize are as follows (Simsek et al. 2000):

1) Installation of electricity power plant of 185 MWe and usage of geothermal energy with integrated installations of 2890 MWt for heating.
2) Exploration programms for new fields, and for the determination of characteristics and capacities of presently known fields, which will also provide supports to MTA, Universities and Private Organizations for their research, development and application projects.
3) Selection of new type power plants with high efficiency and a suitability for the technology of the heating systems currently used (e.g. new type binary cycle systems).
4) To follow the world developments of geothermal energy, to attract specialists who have the required background and to support their experimentation and reputation in this sector.
5) Since the solution alternatives for waste water problem have progressed (e.g reenjection), with regard to environmental issue, geothermal resources must be developed rapidly.
6) Scaling and corrosion problems which affect the management of geothermal utilizations, have been solved by the injection of chemical inhibitors. It is necessary to develop the geothermal resources and to accelerate the investments in this sector.
7) To provide the required supports related to transfers of knowledge, education, finance and equipment necessities, via realization of projects in common with international organizations.
8) To provide the validity of related legislations as soon as possible.
9) Determination of utilization possibilities of geothermal resources in the form of integrated utilizations and encouragement of geothermal usages.
10) To encourage the electrical utilization investments and to accelerate the explorations and priorities by way of Build-Operate-Transfer (BOT) and to increase the attempts for entering the geothermal sector.
11) To encourage the international organizations to invest in this sector.

6. RESULTS

The installed capacities of geothermal utilizations in Turkey are 867 MWt for direct-use and 20.4 MWe for electricity generation. A liquid carbon dioxide and dry

ice production factory is integrated to the electricity power plant, with a capacity to produce 120000 ton/year of carbon dioxides.

The district heating system was established earlier in Turkey using lignite for heating in furnaces. The introduction of geothermal district heating systems has increased the living standard people. There are very high demands for geothermal district heating systems in Turkey. People prefer to buy or rent geothermally heated residences and this causes an increase of the renting or selling prices of these houses, up to **3-4** times in comparison to the other houses.

There are some points that are important for the development of geothermal applications in Turkey These points are summarized in the following: Turkish geothermal law should be finalized as soon as possible; more geothermal wells should be drilled and the state should provide supports to reduce the drilling risks; a control mechanism should be made to work; more financial aids should be sought; and international cooperation should be developed for the geothermal development projects in Turkey.

As a conclusion, geothermal resources in Turkey must be used as the main energy sources at the regions where they are located, because geothermal energy is cheap, clean, sustainable and good for the benefits of the mankind.

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