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GEOTHERMAL RESOURCES AND EXPERIENCES IN APPLICATIONS IN TURKEY

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INTRODUCTION

Turkey is located on the Alpine-Himalayan orogenic belt, which have high geothermal potential. The first geothermal researches and investigations in Turkey started by MTA in 1960's. Upon this, 170 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. Around 1500 hot and mineralised natural springs and wells exist in Turkey. With the existing geothermal wells discharge water (2693 MWt) and springs (600 MWt), the proven geothermal capacity calculated by MTA is totally 3293 MWt (exhaust temperature is assumed to be 35 °C). The geothermal potential is estimated as 31,500 MWt (5,000,000 residences equivalence).

Most of the development is achieved in geothermal direct-use applications by 65,000 residences equivalence geothermal heating (750 MWt) including district heating, thermal facilities and 635,000 m^2 geothermal greenhouse heating. Main cities heated by geothermal energy as Izmir-Balcova, Narlidere, Afyon and Kirsehir City centers, Afyon-Sandikli, Kütahya-Simav,Ankara-Kizilcahamam, Kali-kesir-Gönen, Nevsehir–Kozakli, Manisa–Salihli, Agri-Diyadin, Denizli-Sarayköy and Balikesir-Edremit. 195 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of about 300,000 residences equivalence geothermal district heating has been completed.

By summing up all this geothermal utilisations in Turkey, the installed capacity is 1077 MWt for direct-use and 20.4 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant.

The district heating system applications have been started with large scale geothermal district heating systems in Turkey. This constitutes an important advantage of GDHS investments in Turkey in terms of technical and economical aspects.

The realization of the World Geothermal Congress 2005 in Antalya/Turkey, will benefit to the development and widening of geothermal applications in Turkey.

GEOTHERMAL RESOURCES IN TURKEY

In Turkey, more than 170 geothermal fields which can be useful at the economic scale and about 1200 hot and mineral water resources (spring discharge and reservoir temperature) which have the temperatures ranged from 20-242ºC, have been determined (Figure 1). These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions As a result of the geological, geophysical, geochemical surveys and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal resources in geothermal fields have been increased very seriously.

These manifestations are located mainly along the major grabens at the Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions (Figure 1).

With the existing springs (600MWt) and geothermal wells (2693MWt), the proven geothermal capacity calculated by MTA is 3293 MWt (discharge temperature is assumed to be 35 °C). The distributions of proven geothermal potential accordant to the geographic regions are given at Figure 2. The geothermal potential is estimated as 31,500 MWt. Up to now 500 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey (depths up to 2398m). The portion of the wells drilled by MTA in the total number of wells is 382. Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982.

There are some important geothermal possibilities have been discovered from existing oil exploration wells at southeastern Anatolia. The reservoir tem-

peratures are changing between 83- 138 °C at 2400-3850 m in the wells

As it will be considered, the number of geothermal production wells is too few if compared to the high geothermal potential of Turkey. Most of these wells have been drilled by MTA and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private (Akkus, 2002).

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

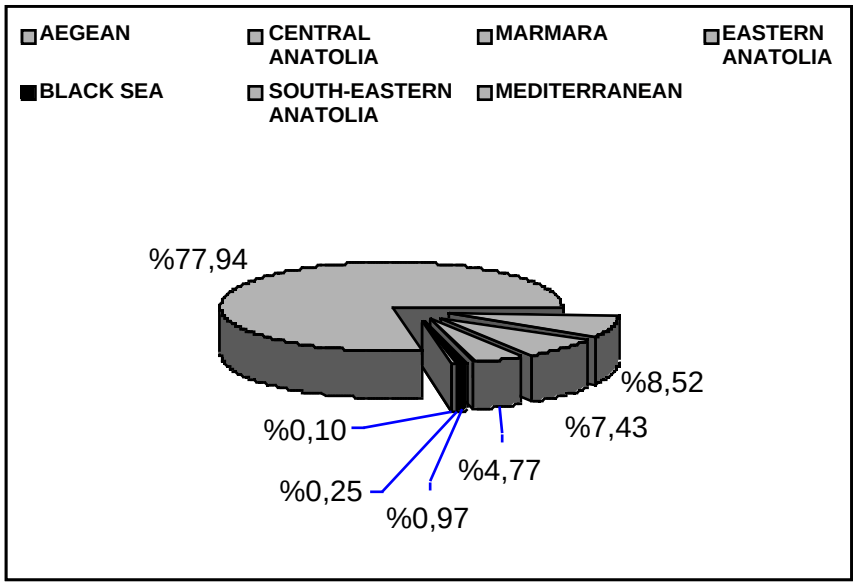

Fig. 2. Proven potential percentage for regions in Turkey

On the other hand, studies on Hot Dry Rock (HDR) systems which develop at zones included high temperature formations at shallow depths are continued very successfully. If the studies on the management of these systems will be economic, the geothermal potential of Turkey will grow up rapidly. From this point of view, especially in Central Anatolia the region of Acigol and the young volcanic fields of Eastern Anatolia are the positive fields.

PRESENT SITUATION OF GEOTHERMAL WELLS

Up to 2004, a total of about 500 geothermal exploration and production wells and 200 gradient wells have been drilled in Turkey. The portion of the wells

drilled by MTA in the total number of wells is 382. This makes a total geothermal well length as 151,557m (Table 3).

87 % of the wells drilled by MTA have been realised in Western Turkey, 11 % in Central Anatolian and 2 % in Eastern Turkey.

The temperature distribution obtained from the well outputs in Turkey is as follows:

Western Turkey:

Percentage (%)	Temperature (°C)
0,4	240-250
0,4	230-240
1,7	220-230
1,3	210-220
4,3	200-210
1,3	190-200
0,4	180-190
1,7	170-180
3,5	160-170
2,2	150-160
1,7	140-150
2,2	130-140
1,7	120-130
3,9	110-120
2,6	100-110
17,8	90-100
7,0	80-90
7,4	70-80
11,7	60-70
11,7	50-60
9,1	40-50
5,7	30-40

Central Anatolia:

Percentage (%)	Temperature (°C)
3,5	90-100
4,7	80-90
3,5	70-80
5,8	60-70
18,6	50-60
31,4	40-50
32,6	30-40

Eastern Turkey:

Percentage (%)	Temperature (°C)
3,0	100-110
6,1	80-90
12,1	70-80
9,1	60-70
15,2	50-60
36,4	40-50
18,2	30-40

Moreover, the first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982.

HIGH TEMPERATURE APPLICATIONS

First explorations regarding geothermal electricity generation was 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. Afterwards in 1984, the Kizildere Geothermal Power Plant was installed by TEK. (Turkish Electricity Authority, renamed as TEAS) with an installation capacity of 20.4 MWe (Table-1). This power plant generates an average of 12-15 MWe electricity annually (Figure. 3). The highest reservoir temperature in the Kizildere geothermal field is 242 °C (Simsek et al.2000).

A liquid CO_2 and dry ice production factory is integrated to this power plant which produces 120,000 tonnes of liquid carbon dioxide and dry ice annually.

One example to the high temperature city heating applications is Izmir GDHS fed from Balçova geothermal field. This system is the largest geothermal system in Turkey supplying 10.000 residences equivalence with heat (Balcova + Narlidere Towns). The system is extending to 15,000 residences. Moreover, additional 20.000 residences are planned.

A peaking station does not exist. Moreover, as all the wells are located in the city, there is no high transmission costs. The system has a property that adjusts the flowrates of geothermal and clean waters by frequency converter dependent of the outdoor temperature.

Table1: Capacities in Geothermal Utilization in Turkey (June 2004)

Geothermal Utilization	Capacity
District Heating	750 MWt
Balneological Utilization 195 Spa	327 MWt
Total Direct Use	1077 MWt
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

A power plant construction studies have been started at Germencik field (232 ºC).Geothermal fields which their reservoir temperatures over than 140 ºC are given below.

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.

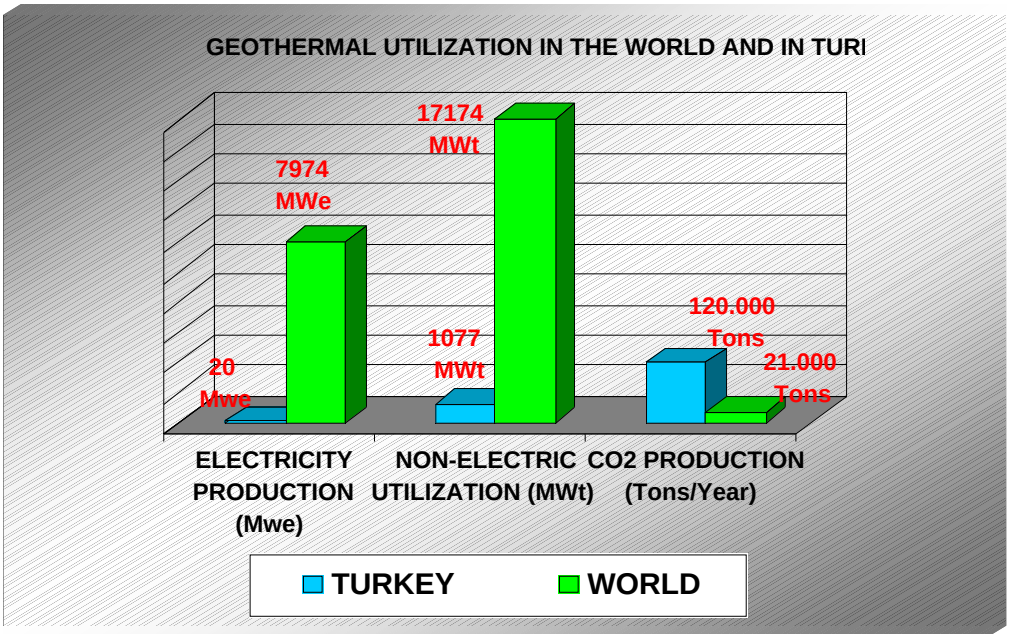

Figure 3. Installed capacities of geothermal applications in Turkey

LOW TEMPERATURE APPLICATIONS

The operational capacities of the city based geothermal district heating systems (GHDS) existing in Turkey are as the following: Gönen (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, 10.000 residences, ~ 115 °C), Sandikli (1998, 1600 residences, ~ 70 °C), Afyon (1996, 4000 residences, ~ 95 °C), Kozakli (1996, 1000 residences, ~ 90 °C), Izmir-Narlidere (1998, 1075 residences, ~ 98 °C), Diyadin (1999, 400 residences, ~70 °C), Salihli (2002, 3000 residences, ~94 °C), Edremit (2003, 500 residences, ~60 °C). Today, 40-45 °C temperatured geothermal waters are used for space heating in Turkey without heat-pump.

Most of the development is achieved in geothermal direct-use applications by 1077 MWt. 750 MWt (which equals to the heat requirement of 65000 residences equivalance[1]) of this potential is being utilized for geothermal heating including district heating, thermal tourism facilities heating and 635000 m^2 geothermal greenhouses heating. The remaining potential of 327 MWt of this potential is being utilized for balneological purposes (There exists 195 thermal facilities (Balneology) in Turkey).

Additionally, engineering design of more than 300,000 residences equivalence* geothermal district heating has been completed. By summing up all these geothermal utilizations, the geothermal installed capacity is 1077 MWt for direct-use and 20.4 MWe for electricity production in Turkey. Moreover, a liquid carbon dioxide and dry ice production factory (120.000 tons/year) is integrated to this electricity production power plant.

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

A total of 635.000 m^2 geothermal greenhouses exist in Turkey. In _anliurfa city nearly 106.000 m^2 geothermal greenhouses exist, where the yield obtained from the greenhouses is exported to Europe. Moreover in Dikili 190.000 m^2 geothermal greenhouse exist.

Geothermal district heating systems (GDHS) are the main geothermal utilization in Turkey, which have an important meaning to the Turkish citizens who are make use of this system, since, a clean environment and comfort has been provided to residences in more economic conditions. In the future wide spread applications have been expected. Engineering design of more than 150,000 residences equivalence geothermal district heating has been completed. A total of installed capacity is 1077 MWt (Figure 2). This capacity is equivalent of 800.000 tons oil annually.

Moreover, the district heating system applications have been started with large scale geothermal district heating systems 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 (ORME,2004).

The construction costs of power plants are 850-1250 USD/kW, by heating applications; it is 300 USD/kW in the conditions of Turkey. The geothermal heating cost per residence (including network and system, excluding radiator inside the house) is around 2000 USD, where these investments are paying themselves back in 5-8 years (Mertoglu et al., 2003).

The geothermal potential for electricity production according to today's commercial conditions is 500 MWe by the year 2010, this value is estimated as 2000 MWe (16 Billion kWh/year) in case of governmental support (ecologically driven as green power) could be received (like incentive).

With this geothermal potential Turkey can meet up to 5% of its total electricity demand and up to 30% of its total heat energy demand. In other words, if we take the weighted mean, Turkey can meet 14% of its energy (electricity+heat enegy) demand by means of geothermal.

The geothermal electricity production investment, the geothermal greenhouse and Balneolo-gical Cure House ((Therapy and Thermal Facilities, Thermal Tourism Complex) investments could be realized alone by private sector in Turkey.

In addition to these, big portion of geothermal potential in Turkey is suitable for heating purposes, geothermal district heating investments could be realized and operated with the cooperation of local governments, municipalities, people and private sector.

With integration of the geothermal district heating systems (GDHS) to the above mentioned electricity production, greenhouse heating and balneological applications (cascade use), the technical and economical aspects of the investment also becomes more favorable and convenient (TJD,2004).

In this case, the portion of 50-60 % of each geothermal district heating investment is financed by the consumers in advance and the GDHS's are constructed and the people are heated cheaper with geothermal energy (at least %50-70 cheaper than based on natural gas heating).

For this reason, 10-20% of the investment is put as own capital by the local government and municipality and 50-60% of the investment is financed by the consumers. So, it is important to use the loan for the rest 30-40% portion at the beginning of the investment. Since, at the very beginning of the GDHS investment, the geothermal field research and exploration studies have to be done, wells have to be drilled, feasibility reports and engineering designs have to be prepared and the construction to be started. In this way, the seriousness have to be shown to the consumers that they would be willing to give the financial support. For this reason, at least 30 % of the total investment is needed as pre finance.

In addition to that, the people are heated with environmentally benign and cheap geothermal energy; dependence to natural gas is decreased as well. This results with a commercially payback period of 5-8 years (It varies according to each investment) in investment and a payback period of 3 years in terms of natural gas equivalent foreign exchange savings.

With these investments, the clean and cheap geothermal energy is utilized and the living standard of the people is increased. Accordingly, people show their belief to the geothermal projects by financially supporting the geothermal investments. Therefore, there exists guaranteed demand (permanent customer)for geothermal heat production and distribution investments.

As mentioned before, the probable theoretical potential of Turkey is 31500 MWt, which means 5 million residences[i] could be heated geothermally if all potential is utilized for geothermal heating purpose.

RESULTS

Turkey have an important geothermal resources. As a result of the exploration and development studies, which have been done, an electrical power plant (20.4 MWe) was installed in Denizli-Kizildere field in 1984 where a liquid carbon dioxide and dry ice production factory is integrated to this power plant, with a capacity of 120000 ton/year and than important developments in applications of balneology (327 MWt), greenhouse and dwelling heating systems(750 MWt) has been installed (total 1077 MWt) in Turkey.

Main important items for research and development for the next period of geothermal resources in Turkey are given below;

- Existing fields should be managed and developed, new fields and deep reservoirs should be investigated.
- More geothermal wells should be drilled and the well risk should supported by the state.
- Determination of utilization possibilities of geothermal fields and planning of these fields in the form of integrated utilization and encouragement of the geothermal uses.
- More financing aids should be received and international cooperation should be developed for the geothermal development projects.
- To supply the required support about know-how transfer, education, finance and equipment necessities via realization of projects in common with international organizations,
- Turkish geothermal law should be finalized as soon as possible,

As a conclusion, geothermal energy in Turkey must be used as the main energy source at the regions where it is found, since it is very cheap, clean, sustainable and for the benefit of the mankind.

World Geothermal Congress 2005 in Antalya-Turkey, this activity is an important international success of geothermal development in Turkey.

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