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# 2010 PRESENT STATUS OF GEOTHERMAL ENERGY IN TURKEY

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## ABSTRACT

The present (2010) installed geothermal power generation capacity in Turkey is about 100 MWe, while that of direct use installations is around 795 MWt.

Direct use of geothermal energy in Turkey has focused mainly on district heating. The first of these systems came on line at the low-temperature Gönen field in 1987. During 1991-2006 period other 19 district heating systems were installed.

Based on these recent projects it is clear that geothermal energy will contribute significantly to Turkey's future energy supply. In spite of the complex legal issues related to the development of Turkey's geothermal resources, their use is expected to increase in the future, particularly for electricity generation and for greenhouse heating. In this study we will examine the present status, economics, trends and legislative aspects of Turkish geothermal energy resources and projects.

## INTRODUCTION

It is expected that the worldwide use of fossil fuels is going to decline in this century, and that geothermal energy will contribute in the replacement of those fossil fuels. Even now, the recent rise of oil and gas prices has made the development of the geothermal resources of Turkey more feasible.

In the recent years, among the renewable energy alternatives, geothermal energy in world and our country has become very attractive. The reason for this interest is features of geothermal energy in direct and indirect use. It is unfortunate that geothermal energy in direct use can only be utilized locally. But, firing fossil fuels at 1500$^{o}$C, and using the generated heat at only 50-60$^{o}$C is obviously a thermodynamic waste. Therefore, utilization of low grade geothermal energy resources fills an important gap in this area. On the other hand, although indirect use of geothermal energy with relatively low temperatures seems inefficient with respect to fossil fuel fired energy sources, it has an advantage of base-load power generation with respect to other renewable such as wind, solar, etc.

Geological studies indicate that the most important geothermal systems of Turkey are located in the major grabens of the Menderes Metamorphic Massif, while those that are associated with local volcanism are more common in the central and eastern parts of the country (Fig.1).

Geothermal exploration in Turkey started in the early 1960s. At first, the work was focused on high-enthalpy fields for potential power production; Kızıldere was discovered in 1968. The Balçova and Seferihisar, two medium-temperature geothermal fields, were found and studied in the 1960s and 1970s, respectively. A second high-enthalpy system, Germencik, and various other medium-enthalpy fields, such as Salavatli-Sultanhisar and Simav, were discovered in the 1980s. Turkey's low- and medium-temperature resources have yet to be thoroughly explored and evaluated. With proper exploration methods and investments, some might be shown to contain higher-enthalpy fluids; geochemical data seem to support such a hypothesis.

While the state is gradually withdrawing from power generation utility business, private sector has shown substantial interest in investing for geothermal energy. The advantage of geothermal energy in power generation has lead former textile producers to the energy investments.

In this study, while living through these developments by the end of 2009, we would like to

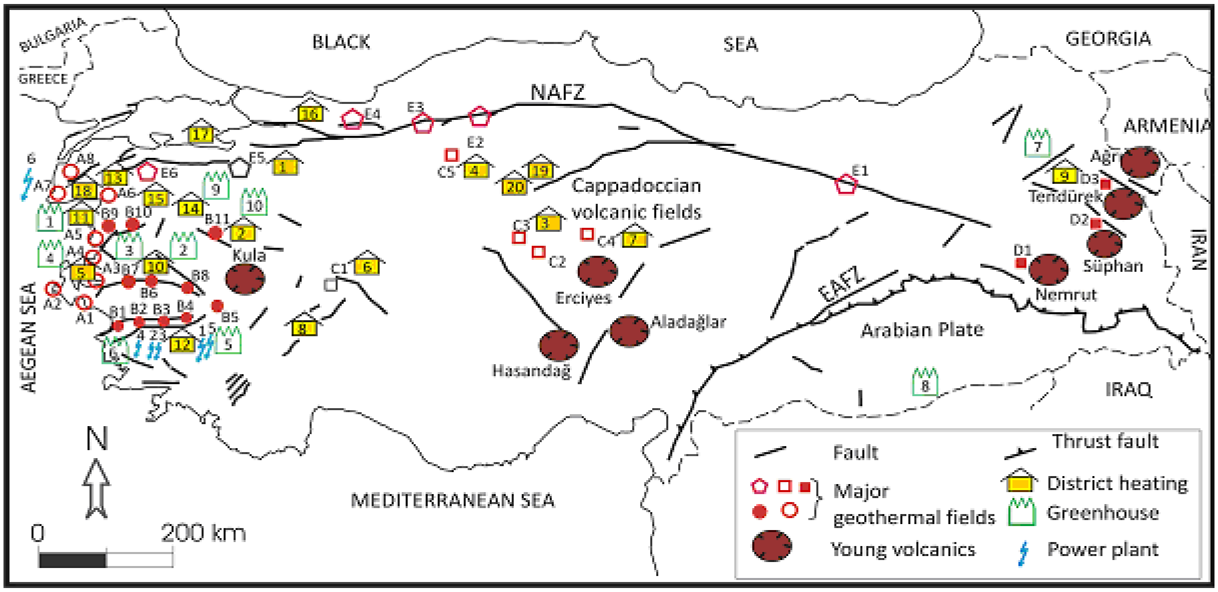


*Figure 1: Locations of major geothermal fields, district heating and greenhouse installations and young volcanoes (updated from Serpen et al, 2009a).*

reflect the true present status of geothermal energy industry in our country without exaggerations. For today, our aim is to maintain level of interest momentum built and keep the high enthusiasm by providing correct information whereabouts of geothermal energy in our country. Otherwise, there is a real risk of losing interest of investors after providing exaggerations and non-existent occurrences.

## SOME GEOLOGICAL ASPECTS AND REGIONAL DISTRIBUTION OF TURKEY'S GEOTHERMAL RESOURCES

Turkey is located at the central part of the Alpine-Himalayan Mountain Belt that began developing by the closing/shrinking of the Tethys Ocean in the Late Mesozoic. High mountain ridges were formed at the northern and southern sides of Anatolia, while some pre-Cambrian-Paleozoic metamorphic shields (i.e. Menderes and Central Anatolian Massifs) remained at its center. One of these Massifs, the Menderes Metamorphic Massif (Fig.2) has been studied in great detail. Its recent tectonics is thought to be responsible for its the present high heat flow and the location of many medium-to-high enthalpy geothermal systems in western Anatolia.

The westward movement of the Anatolian Sub-plate under the influence of the northward push of the Afro-Arabian Plate, particularly in Southeastern Anatolia, resulted in extensional crustal stresses in Eastern and Central Anatolia, where these forces lead to the development of vast volcanic fields between the Miocene and the Recent periods. There are several hydrothermal manifestations and some signs of high heat flow at these volcanic fields; but these prospects have not been studied well yet.

Finally, the northern boundary of the westward moving Anatolian Sub-plate, the Northern Anatolian Fault Zone (NAFZ) provides several deep channels for the infiltration and circulation waters within its up to 17 km deep brittle deformation zones, explaining the presence of several low-enthalpy hydrothermal systems, there.

The geothermal systems in Turkey (Fig. 1) are located mainly following recent and regional structural lines and are more frequent in regions of recent tectonism and Tertiary volcanism and/or metamorphism. However, while these systems differ radically between regions, substantial similarities tend to exist among systems of a given region. This zonation also defines the suitability of conditions for the existence of possible deep geothermal resources. Following division of some known geothermal fields and occurrences are made on the basis of both geographical distribution and some geoscientific aspects of those geothermal resources.

*Aegean Coastal Belt:* Seferihisar, Çeşme, Balçova, Aliağa, Dikili-Bademli, Edremit, Tuzla and Kestanbol.

*Menderes Metamorphic Massif and Western Anatolian grabens:* Germencik, Aydın Yılmazköy-İmamköy, Serçeköy-Umurlu, Salavatlı-Sultanhisar, Pamukören, Kızıldere, Yenice, Gölemezli geothermal systems in Büyük Menderes Graben. Salihli-Kurşunlu, Caferebeyli and Sart, Turgutlu-Urganlı and Alaşehir-Kavaklıdere geothermal systems in Gediz Graben. Dikili-Kaynarca and Bergama geothermal

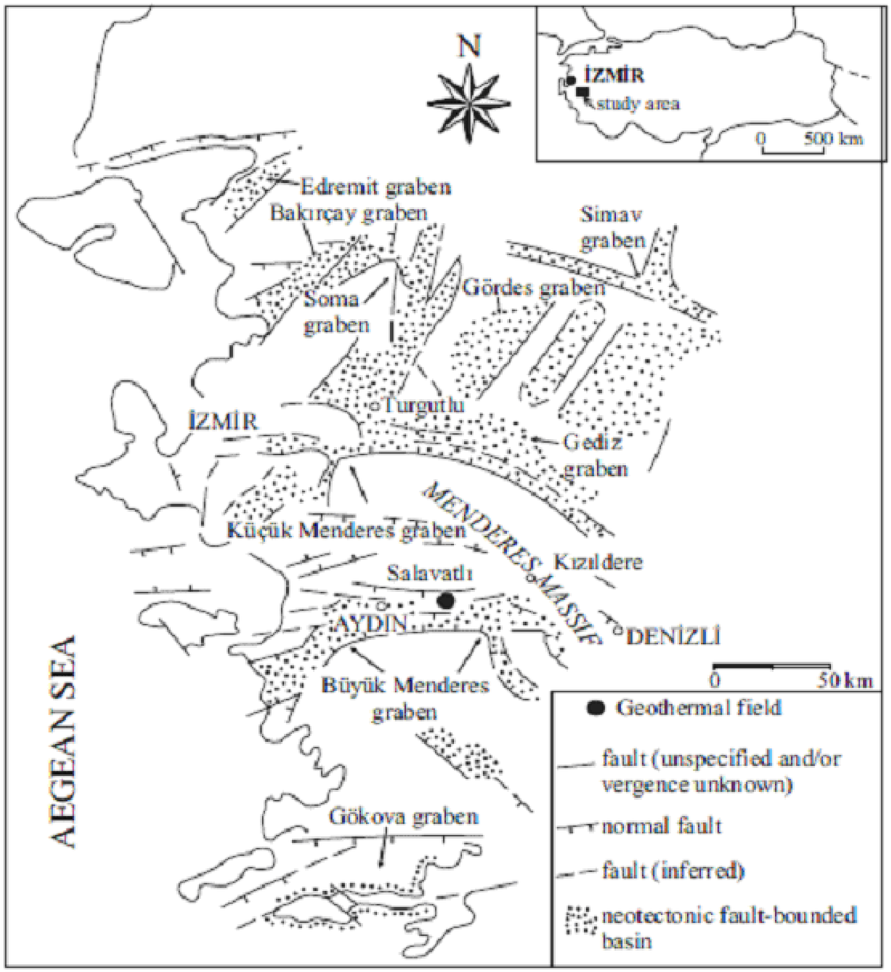


*Figure 2: Geological setting of Aegean Coastal Belt Menderes Massif (updated from Sepen et al., 2009a).*

systems in Dikili-Bergama Graben, and Simav, Şaphane and Gediz-Abide geothermal systems in Simav Graben. These geothermal systems are all in the same geological environment (JICA, 1986; Serpen vd., 2009).

*Central Anatolian geothermal fields:* Afyon, Kapadokya, Kırşehir, Kozaklı, Kızılcahamam.

*Eastern Anatolian geothermal systems:* Nemrut Caldera, Erciş-Zilan ve Diyadin.

*Geothermal Fields Formed in the North Anatolian Fault Zone:* Erzincan, Çerkeş, Bolu, Adapazarı-Akyazı, Bursa Çekirge-Kükürtlü, Gönen

## UTILIZATION OF TURKEY'S GEOTHERMAL RESOURCES

Utilization of geothermal energy started in 1984 after installation of Kizildere geothermal power plant, following a long exploration and testing period. Direct utilization of geothermal energy began in 1987 with Gönen district heating system. In the following sections both direct and indirect use of geothermal energy developments will be reported.

## Direct Use of Geothermal Energy in Turkey

Direct use of geothermal energy in our country are concentrated in the following areas : (1) district heating, (2) greenhouse heating, (3) balneology. Utilization of geothermal energy in these sectors is reported as follows:

### *District Heating:*

As mentioned before district heating in Turkey started in 1987 heating 1500 households. Later the system was expanded to 2500 subscribers. As seen in Table 1, by 2007, Turkey had 20 district heating systems working with geothermal energy. Of these district heating systems, one in Saraykoy is heated by the waste heat coming from bottoming binary power plant in Kızıldere. Table 1 shows that low temperature geothermal resources are mostly used in district heating with the exception of Balçova and Simav, which have medium grade resources that could also have been used for power generation purpose.

About 6 million square meter space are heated by district heating with a capacity of 395 $MW_t$.

*Table 1. Turkey's District Heating Systems (updated from Serpen et al., 2009a).*

| District Heating | Year | $T_{in}$, °C | $T_{out}$ °C | $Q_{max}$ kg/s | Capacity $MW_t$ | Equivalent Area, 100 $m^2$ |
|---|---|---|---|---|---|---|
| Gönen-Balikesir | 1987 | 67 | 45 | 200 | 18.4 | 2500 |
| Simav-Kütahya | 1991 | 100 | 50 | 175 | 36.6 | 6000 |
| Kirsehir | 1994 | 54 | 49 | 270 | 5.6 | 1800 |
| Kizilcahamam-Ankara | 1995 | 70 | 42 | 150 | 17.6 | 2600 |
| Balçova-Izmir | 1996 | 118 | 60 | 320 | 77.7 | 21500 |
| Afyon | 1996 | 90 | 45 | 180 | 33.9 | 5000 |
| Kozaklı-Nevsehir | 1996 | 98 | 52 | 100 | 19.2 | 1500 |
| Sandikli-Afyon | 1998 | 70 | 42 | 250 | 29.3 | 4000 |
| Diyadin-Ağrı | 1998 | 65 | 55 | 200 | 8.4 | 400 |
| Salihli-Manisa | 2002 | 80 | 40 | 150 | 25.1 | 4000 |
| Dikili-Izmir | 2008 | 120 | 60 | 40 | 10.0 | 150 |
| Sarayköy-Denizli | 2002 | 125 | 60 | 100 | 27.2 | 2500 |
| Edremit-Çanakkale | 2004 | 60 | 45 | 270 | 16.9 | 2740 |
| Bigadiç-Balikesir | 2006 | 80 | 50 | 80 | 10.0 | 1000 |
| Bergama-Izmir | 2006 | 62 | 40 | 100 | 10.0 | 200 |
| Kuzuluk-Sakarya | 1994 | 80 | 40 | 25 | 11.2 | 500 |
| Armutlu-Yalova | 2000 | 78 | 40 | 30 | 4.8 | 250 |
| Güre-Balikesir | 2006 | 62 | 52 | 200 | 8.5 | 300 |
| Sorgun-Yozgat | 2007 | 75 | 50 | 200 | 20.9 | 1500 |
| Yerköy-Yozgat | 2007 | 60 | 40 | 40 | 3.3 | 500 |
| Total | | | | | 394.6 | 58940 |

***Greenhouse Heating***

Heating greenhouses with geothermal energy has recently become very popular in Turkey. Table 2 shows important greenhouse sites and areas heated by geothermal fluids, and their estimated capacities. Majority of these greenhouse areas are situated in Western Anatolia and their areas are expanding very fast. Greenhouses are heated 1500-2000 hour per year and their main produces are tomatoes and Californian peppers.

Geothermal resources with moderate and high enthalpy in our country have high $CO_2$ content (1-2.5% by weight of geothermal fluid) and this gas is also used to accelerate the growth of greenhouse produces. It is necessary to inject 1000-2000 ppm of $CO_2$ into greenhouse atmosphere and greenhouses consume 4000 ton/year $CO_2$ per hectare. In other words, $CO_2$ obtained from geothermal resources are used for greenhouses.

As seen in Table 2, 2104 decare greenhouse area are heated by geothermal energy with 207.4 $MW_t$ direct heat capacity.

*Table 2. Greenhouse Heating in Turkey (Serpen, et al., 2009b).*

| Place | Capacity ($MW_t$) | Area (decare) |
|---|---|---|
| Dikili-İzmir | 83.7 | 775 |
| Salihli-Manisa | 22.6 | 350 |
| Turgulu-Manisa | 15.4 | 110 |
| Balçova-İzmir | 10.5 | 100 |
| Kızıldere-Denizli | 40 | 357 |
| Gümüşköy-Aydın | 2.5 | 50 |
| Diyadin-Ağrı | 3.1 | 2.4 |
| Karacaali-Urfa | 25 | 170 |
| Sındırgı-Balıkesir | 3.0 | 200 |
| Simav-Kütahya | 17 | 100 |
| Total | 207.4 | 2104.4 |

***Balneological Use***

Health-Spa tourism is very fast developing sector in Turkey, and 4 million people are visiting Hot Spring sites. Majority of facilities in those sites cannot be said in good shape, but, improving them in future will attract more people, especially, foreign tourists helping to obtain substantial income.

In Turkey, there are important Healt Spa sites, such as Balçova, Afyon, Çeşme, Gönen and Kizilcahamam, and besides, balneological services could also be provided for residences in Akyazi-Adapazari and Armutlu-Yalova. In Çeşme 42 km long-pipe line is installed to supply thermal water for 18 Hotels. About 60 Hotels with 10000 bed capacity will be connected to this pipeline and then Çeşme might become most important balneological center. For the time being thermal capacity in Çeşme is around 20.9 $MW_t$.

Other popular Health Spa center is being developed in Afyon area, and nowadays 3 big Hotels with health therapy centers are being built. A 15 km long hot water pipeline is also being built in this region.

Direct use capacity for balneological utilization is estimated around 250 $MW_t$. Total Turkey's direct-use capacity (with district heating, greenhouse heating and balneological uses) is about 850 $MW_t$. On the other hand, the world geothermal community exaggerates direct application figures for Turkey by indicating more than twicefold figures, as can be noted from the figures presented in this study (Serpen, 2006).

## Indirect Use Geothermal Energy in Turkey

*Table 3. Geothermal Power Plants of Turkey (Serpen et al., 2009b).*

| Geothermal Power Plants | Start-up Date | Installed Power (MWe) | Resource Temp. (°C) |
|---|---|---|---|
| Dora-I Salavatli | 2006 | 7.35 | 172 |
| Dora-II Salavatli | 2010 | 11.1 | 174 |
| Ömerbeyli | 2009 | 47.4 | 232 |
| Bereket | 2007 | 7.5 | 145 |
| Tuzla-Çanakkale | 2010 | 7.5 | 171 |
| Kızıldere-Denizli | 1984 | 17.8 | 243 |
| Total | | 97.85 | |

Total installed power generation capacity has reached to 100 $MW_e$ by the beginning of 2010. Among power plants indicated in Table 3, Dora II will be commissioned in early February/2010. Next year another 17.5 $MW_e$ power plant in Hidirbeyli would be commissioned. All these activities have indicated that power generation capacity in the last 4 years has increased fourfold, a fact that was not foreseen by the international geothermal community in WGC2005 geothermal update.

In a speech given on the worldwide status of geothermal energy during the closing ceremony of WGC2005, Salavatli-Sultanhisar geothermal power plant was not mentioned, and was not even shown in 2010 projections (Serpen, 2006).

## INDUSTRIAL PRODUCTS

Medium and high enthalpy geothermal fields of Turkey contain 1-2.5% of $CO_2$ by weight of fluid. Taking advantage of that fact 40000 tons/year of capacity $CO_2$ plant was initially installed in Kizildere field with $CO_2$ supply from Kizildere power plant. With increasing $CO_2$ demand, another 40000 tons/year of capacity $CO_2$ plant was later installed at the same site. Another $CO_2$ plant, 40000 tons/year, has recently been installed in Salavatli-Sultanhisar field as an integrated utilization, and $CO_2$ production from geothermal resources has reached 120000 tons per year. Turkey has met almost all $CO_2$ needs from geothermal since long time, and actually more than 50% of $CO_2$ is being produced from geothermal resources (Serpen, et al., 2009a).

From Çanakkale-Tuzla geothermal field 100 ton/h of industrial salt, NaCl has been produced for 20 years. Three tons/day $CuSO_4$ has been producing in the same field, after declining salt prices in the last 3 years.

## GEOTHERMAL ENERGY TRENDS FOR TURKEY

Unlike the world trend in geothermal energy, utilization of heat pumps and development of enhanced geothermal systems have not developed in Turkey. No enhanced geothermal system has been identified yet, and heat pump utilization is very limited due to its high capital costs. Carbon credit's exchange may not be feasible given the high $CO_2$ content of most of Turkey's medium and high enthalpy geothermal resources. However, somehow carbon credit trading in geothermal power generation has already started.

Greenhouse heating using geothermal energy is very popular lately. This sort of heated greenhouse areas has substantially increased from 809 decare in 2006 (Serpen, 2006) to 2104 decare this year creating a threefold increment.

District heating projects has been stalled for the following reasons: (1) no geothermal resource close to towns available anymore, (2) hard competition from natural gas industry despite high natural gas costs, (3) disappointments with geothermal district heating systems because of lack of heat supply in some of them and (4) weak economics of such projects due to high heating costs.

## ECONOMICS OF GEOTHERMAL ENERGY IN TURKEY

Power generation seemed marginally profitable with the levelized cost of electricity around 5 cents/kWh in 2003. Electricity cost has changed between 5 and 12 cents/kWh since then, and last year's average was 9.5 cents/kWh. Because of high oil prices and recent energy shortages in Turkey electricity prices have tended to increase. A recent study by Sener and Aksoy, (2007) has found cost of electricity around 5.7 cents/kWh for Turkey. The payout time for this type of investments reaches 7 to 8 years.

As for district heating economy, a stochastic study has also been conducted by Kaygan, (2008) for district heating systems (several of them already installed). They do not seem to be profitable with actual low fixed rate heat tariffs. Several of them are studied, and not a single one of them resulted in a profitable business. Other studies, such as conceptual planning of the extension of Balçova district heating system (Toksoy et al., 2005) have also resulted in negative NPV with actual tariffs.

## GEOTHERMAL LEGISLATION IN TURKEY

Turkey issued a geothermal energy resources law finally in June/2007, and the law was enacted a year later in June/2008.

After 2.5 years of implementation of highly criticized Geothermal Energy Resources Law and Regulations have created substantial chaotic circumstances in legal, administrative, economic and technical areas. After beginning of application of new geothermal legislation, numerous lawsuits at various categories have been brought at different levels of courts, and most of them are still going on.

Three-headed administration (Local Government-Mining Authority and Mineral Research Institution) has created contradictions and disagreements between different administrative levels. Sometimes unlawful applications occur. Numerous geothermal fields are closed to exploration and development. A market for licenses has been created. The geothermal fields have dangerously been divided. There is no transparency in operations, and information gathering and distribution channels are not well functioning; and technical and state supports are nonexistent.

There are important problems in bidding preparation and management. License transfer contracts have caused some injustice and biased actions. Identification of blocked neighboring areas to geothermal fields has created injustice and illegal acts.

Geothermal resource protection area reports for the surroundings geothermal fields have not being approved, and therefore, controls for the fields can not be implemented. Technical responsibility subject is blurred and there is a future uncertainty.

Resource is being damaged in the fields that are divided, uncontrolled, and responsibilities are not openly and correctly distributed. Pressures and temperatures of the reservoirs are declining and the sustainability of the resources is in grave danger.

## CURRENT GEOTHERMAL ACTIVITIES IN TURKEY

Current geothermal activities are very much alive in Turkey. Ten years ago geothermal activities were virtually nonexistent.

Exploration activities such as different types of geophysical surveying (resistivity, MT, CSAMT, active seismic, magnetic, etc.), geological and geochemical surveying are proceeding in at least 6 geothermal areas. And all of these activities are carried out by private sector. State also contributes in some geothermal areas by means of Mineral and Research Authority, MTA. It should be remembered that all these activities were sparked by the development of Salavatlı-Sultanhisar field and installation of a binary plant. The first and last power plant had been installed 20 years ago in 1984 in Kizildere.

Field development activities such as drilling and testing are going on in three areas. On the other hand, three other companies are about starting development stage. MTA also is drilling in some other prospects.

On the other hand, Turkish State using MTA did a bidding last year to sell development rights for 30 years about 10 geothermal fields. Since these fields were low enthalpy ones, only one of them was sold. This year MTA is also bidding 16 field of which three could be used for power generation.

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