Present status and future development possibilities of Aydın-Denizli Geothermal Province

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Abstract

Aydın-Denizli Province (Büyük Menderes Graben) is one of the most developed regions in Western Anatolia for geothermal energy research. The geothermal system is controlled by the active graben faults in the region. The reservoir rocks in the geothermal field are limestone in a Neogene and marbles and quartziteschist in Paleozoic basement complex. Nowadays six main geothermal fields have been defined along the Büyük Menderes Graben by MTA. The first electric power plant of 20 MWe capacity has been installed in the Kızıldere (Denizli) geothermal field (212-242ºC). Geothermal energy investigations have been carried out in the Germencık-Aydın (232 ºC), Salavatlı- Aydın (171ºC), Yilmazköy- Aydın (142ºC) and Ilıcabasi- Aydın (101ºC), Gölemezli (75-88ºC) and Yenice (36-63ºC) fields in Denizli. Geothermal potentials have been planned for generation of electricity, district and greenhouse heating, cooling, industrial, balneological and touristic purposes in the region.

Keywords: *geothermal exploration, Utilization, Büyük Menderes Graben, Aydın, Denizli.*

1 Introduction

Investigations of new energy resources are nowadays based on development cost and impact on the environment. The MTA General Directorate conducted the first geothermal investigation in Turkey in the Aydın-Denizli Geothermal Province (Büyük Menderes Graben). About 30 hot water springs are known in that area with temperature ranging between 26-101ºC (MTA, 1996). A MTA–UNDP geothermal project began in Kızıldere in 1965. It included geology, geophysics and geochemical studies, and was followed by the first drilling (KD-1) into a (198ºC) geothermal reservoir in 1968. This exploration and the drilling of 120 gradient and 40 exploration production wells, showed the important geothermal energy potential in the Aydın-Denizli Geothermal Province.

In 1982 the second highest reservoir temperature in Turkey was found by drilling in Germencik (OB-2, 232ºC). This reservoir may be suitable for generation of electricity. Prefeasibility studies are still going on for this region. Exploration wells were drilled in the Salavatlı field in 1988 (AS-2, 171ºC), in the Ilıcabası field in 1989, in the Yılmazköy field in 1999 (YK- 1, 142ºC) and in the Yenice and Gölemezli field in 2001-2002 (Figure 1).

Following the exploration, the geothermal fluids (steam+hot water+gas) discharging from the geothermal wells in Büyük Menderes Graben were considered suitable for electricity production. The first economical pilot power plant of acapacity of 20 MWe, was installed in Kızıldere by TEAS (Turkish Electricity Authority) in 1984. The separated water is used for heating of greenhouses, and the gases are used to produce CO_2. An additional feasibility study for district heating has been made. The geothermal resources in the area are considered important for the economy and beneficial to the environment.

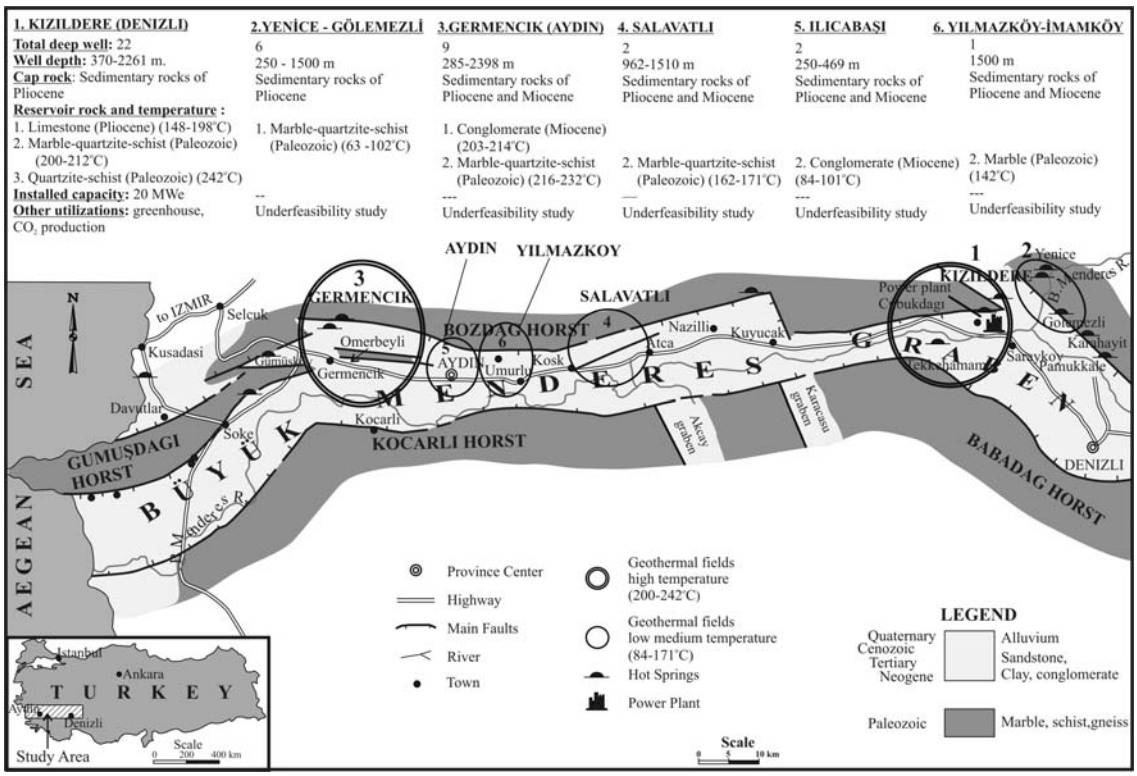

Figure 1: Main geothermal fields of Aydın – Denizli Geothermal Province.

2 Methods applied for exploration and development

Geological, hydrogeological, geophysical (gravity, resistivity, seismic) and geochemical studies have been carried out in Aydın- Denizli province (MTA, 1996). Temperature gradient wells and deep wells have also been drilled. Various tests and pre-feasibility studies have been carried out. To start with the hot spring areas were evaluated with the aid of geological and hydrogeological surveys. It was determined that the hot springs are mainly concentrated on the northern fault zone in Büyük Menderes Graben (Simsek et al., 1984; Simsek, 2003).

Hyperthermal springs and fumerole in the region are associtated with large (1000 m) asymetric slip faults). The fumeroles at Tekkehamam, Germencik and Kizildere are all at boiling temperature. In order to define burried structure and step fault mechanism, Bouger and second derivative maps were prepared by Özgüler et al. 1984. Resistivity studies were conducted within the graben. Low resistivity values (2-10 ohm.m) were found in Denizli (Kızıldere, Tekkehamam, Buldan, Yenice, Gölemezli, and Karakova) and Aydın (Germencik, Ömerbeyli, Bozköy, and Salavatlı). The resistivity anomalies converge toward the main fault and diverge toward to the centre of the graben. Geochemical analyses were carried out to find general characteristics of geothermal fluid (Simsek, 1984; Simsek et al.2000). The results of analyses show that geothermal waters in the Aydin region are mainly of the Na-Ca-HCO_3 type and Na-Ca-HCO_3-SO_4 type in the Denizli region. Reservoir temperature was estimated by Na-K, Na-K-Ca, SiO_2 geothermometers and mixing models. The results were confirmed through drilling. For example, in Denizli the estimated temperature was 200-250°C and the measured temperature in the wells was 212ºC. A third reservoir was discovered in 1998 with a temperature of 242ºC.

Tritium content of the geothermal waters in Kızıldere, Aydın and Germencik indicates that residence time of recharging water in the geothermal system is more than 50 years while at the Pamukkale and Söke region the thermal waters appear to be

younger. There is a clear $\delta^{18}O$ shift from MMWL in Kızıldere, Aydın and Germencik high temperature fields (Simsek et al. 2000).

About 130 geothermal gradient wells have been drilled in the Aydın – Denizli Geothermal province ranging in depth between 50-150 m. Temperature gradient of 2-4ºC/10 m is an indication of a promising area. Following temperature gradient wells, a total of 22 deep wells were drilled in Kızıldere, 9 in Germencik, 2 deep wells in Salavatlı field, a deep well in Yılmazköy, 2 shallow wells in Aydın, 4 wells in Tekkehamam and 3 wells in Yenice. Up to the year 2003, seven fields were explored by drilling.

3 Geothermal fields

The following geothermal fields have been explored by drilling in Aydın-Denizli:

In Denizli: 1-Kızıldere , 2- Yenice - Gölemezli,

In Aydin: 3-Germencik- Ömerbeyli, 4-Salavatli, 5-Yilmazköy- Imamköy, 6-Ilıcabasi

Other important geothermal fields are the Tekkehamam, Buldan, Karakova and Karahayit- Pamukkale fields in Denizli region and Germencik Camur- Bozköy-Alangüllü, Nazilli Basen (Güvendik-Gedik-Nazilli) and Söke fields in Aydın region.

3.1 The Kizildere geothermal field

The geology, geophysics (gravity, resistivity, seismic), geochemistry and gradient drilling were carried out from 1965 to 1968. After that, the first deep well, 590 m deep, was drilled in order to proof the reservoir. The reservoir temperature is 198ºC. Up to now 20 deep wells ranging in depth from 370 m to 1241 m have been drilled. The field has three aquifers. The rock type of the first aquifer (170-198 ºC) is Pliocene limestone and the second aquifer (200-212ºC) is in Paleozoic marbles-quarzites. The third aquifer was discovered in 1998, at 2261 m depth with a temperature of 242ºC. At Kızıldere the power plant is operated with annual generation capacity of 140* 10^6 kWh. But due to environmental constrains the average production is limited to 90* 10^6 kWh. This capacity is equal to 36.000 tonne fuel oil saving per year. The remaining fluid capacity is about 100 MWt (275 l/s). If this energy were used for house heating during the six months heating season, 36.000 tonne fuel oil would be saved per year. Beside this the water could be used to heat greenhouses (10.000 m^2). Now prefeasibility study is beeing made for district heating in Denizli city. Because of high content of noncondensable gases in the steam, a factory started operation in 1985 producing 120.000 tonnes of CO_2 annually. The geothermal fluid could also be used in drying and washing of textile products, cooling, tourist and balneological purposes.

Tekkehamam geothermal field is located 5 km south of Kızıldere geothermal field. In Tekkehamam, 2 deep wells have been drilled by MTA (TH-1: 116ºC and TH-2: 147ºC). In the last 2 years, 4 shallow wells have been drilled by private sector reaching temperatures up to 125ºC (Karamanderesi, 2003 personal communication).

3.2 The Yenice-Gölemezli geothermal field

These fields are located at the northern flank of the Cürüksu graben. In Gölemezli 2 wells were drilled in 2001-2002 by MTA. Production temperatures are 88ºC (102ºC in reservoir) - 75ºC and flow rates are 15 l/s-140 l/s respectively. Three exploration wells were drilled in 2002 in the Yenice geothermal field reaching 54 m, 238 m and 250 m. The flowrates are 20 l/s, 100 l/s, 40 l/s and temperatures are 53ºC, 63ºC and

36,5-38ºC respectively. In both these fields district heating, greenhouse heating and balneological utilization is possible.

3.3 The Germencik geothermal field

The Aydın – Germencik field, which is the second economical geothermal field for generation of electricity, was discovered by MTA. This area is located west of Büyük Menderes Graben about 40 km from Aegean Sea. Geothermal studies started in 1967. After detailed geological, geochemical, geomorphological and geophysical studies, the first exploration well was drilled to a depth of 1002 m (Gülay and Gürsoy 1984, Simsek 1984). The temperature of first and second aquifer was 203 ºC. A total of 9 exploration wells have been drilled up to now ranging in depth from 285 to 2398 m. The temperature of the first and second aquifers was 203-214ºC and 216-232ºC (MTA, 1996). These aquifers are located in Miocene conglomerates and Paleozoic marbles respectively. The deepest well in Turkey, OB-7, reaches a depth of 2398 m (227ºC). The Germencik field like the Kızıldere field covers a large area, and is therefore promising for exploitation. After well tests, the potential of the field, the type of power plant, and the other possible uses will be studied. Due to high temperature and steam ratio the geothermal fluid will primerly be used for generation of electricity. Integrated utilization, like greenhouse and district heating, drying, canning, textile industries, production of chemicals in addition to touristic and healt resorts seems to be profitable.

3.4 The Salavatlı geothermal field

This field is placed close to the central part of the Büyük Menderes Graben and at the same distance from the Kızıldere and Germencik fields. The exploration wells of 1510 m and 962 m depth were drilled in 1987 and 1988 (Karamanderesi et al.1989). The reservoir consists of Paleozoic marbles. Their temperature is 162ºC and 171ºC. Each of the wells has a capacity of 300 tone/h. It is expected that it will be used for generation of electricity (?), district heating of Nazilli, Sultanhisar Atca and Kösk city centers heating and greenhouse heating, industrial applications, touristic and balneological utilisation.

3.5 The Ilıcabası geothermal field

The Ilıcabası geothermal field is located in the city center of Aydın. District heating in the city center of Aydın, greenhouse heating and balneological utilizations seem to be the ideal utilisation of the Ilıcabası geothermal field. Exploration wells were drilled in 1989 to a depth of 250-469 m. The aquifers are located in Miocene conglomerate with temperature ranging from 84 to 101ºC. The well capacities are 2-7 l/s (MTA, 1996). According to hydrogeology and chemical geothermometers temperature higher than 100ºC is expected at an economic depth in the second aquifer (marble-schist).

3.6 The Yılmazköy and Imamköy fields

The Yılmazköy and Imamköy geothermal fields are located 3 km and 6 km east of the city center of Aydın respectively. An exploration well was drilled at Yılmazköy in 1999 to a depth of 1500 m. The aquifer is located in Paleozoic marble-schist with a temperature of 142ºC. The well capacity is 20 l/s. It is expected that district heating in the city center of Aydın and greenhouse heating, cooling and balneological utilization will be possible from both fields.

4 Geothermal energy utilization possibilities

From a regional point of view, there are many possibilities for the utilization of geothermal energy. In some fields, electrical and non-electrical utitlization of geothermal energy is common.

a) **Electricity production**: Reservoir fluid with temperature higher than 180°C is necessary for economic generation of electricity. Kızıldere and Germencik fields seem to be promising for electricity production. Other possible fields for electricity production are Salavatli and Tekkehamam.

b) **District heating and cooling**: The geothermal resources in Germencik, Bozköy, Aydın, Yılmazköy, Salavatlı, Kızıldere, Yenice and Gölemezli areas can be used for district and greenhouse heating. There are also possibilities of using geothermal energy for house heating in Aydın, Sultanhisar, Atca, Nazilli, Söke, Sarayköy, some parts of Denizli city. Some local residents in other towns may be covenient for district heating. At present there are greenhouse heating (10.000 m^2) applications in Kızıldere and Tekkehamam. If the power plant in Kızıldere operates at full capacity, 100 MWt can be obtained from waste fluid. Sarayköy town and some parts of Denizli city could be heated by this energy.

c) Industrial usage of geothermal energy:

- **Textile industry**: The geothermal energy could be utilized both in whitening processes and for washing of textiles. Therefore, there is a considerable demand and requirement especially in Aydın and Denizli regions.
- **Drying process**: Geothermal energy is suitable for the drying processes of figs, grapes, tobacco and wood. The utilization of geothermal energy is of great interest for high potential export products. These products could be dried in the factories using geothermal energy and billions of Turkish liras would be saved. When these products are dried in the open air there is a considerable loss of the product.
- **Refregiration (cooling) plants**: There are many hot springs with temperature higher than 80°C in the region. The geothermal energy could be used for cooling plants for agricultural products and residents.
- **Canning and pasteurising**: Geothermal energy could be used in canning of fresh vegetables and pasteurising milk processes.

d) **Production of chemical substances**: The steam in high temperature geothermal fields is high in the non-condensable gasses, especially CO_2. CO_2 can therefore be produced from the steam. In the Kızıldere field a factory started production in 1986 with a capacity of 120.000 tonnes /year.

e) **Touristic and balneological applications**: Many historical cities (like Pamukkale-Hierapolis and Magnesia) along the graben were located close to hot springs. During the historical periods the hot water was used for bathing or as health centers. From a social and economical point of view, these places and nearby sites could be developed in a modern way.

5 Results

As a result of geological, geophysical, geochemical and isotopic surveys end exploration and development studies in Aydın-Denizli geothermal province, many fields were discovered. These are Kızıldere, Tekkehamam, Gölemezli, Yenice, Buldan areas in Denizli and Germencik, Ömerbeyli, Bozköy, Yılmazköy, Imamköy, Salavatlı and Ilıcabası areas in Aydın. Generation of electricity and production of CO_2

has been started. Pre-feasibility study is being made for district heating in Sarayköy and Denizli city centers. The geothermal fluid with the second highest reservoir temperature (OB-2, 232ºC) in Turkey was found in Germencik. This field seem to be suitable for generation of electricity.

The Salavatlı, Ilıcabası, Yılmazköy, Imamköy, Yenice, Gölemezli and Tekkehamam fields can be used mainly for district heating and some industrial applications as the measured reservoir temperature as 63-171ºC. Electrical and non-electrical use of geothermal energy in Aydın and Denizli will be profitable from a social, economical and environmental point of view.

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