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Geothermal Explorations and Investigations by MTA in Turkey

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ABSTRACT

First geothermal exploration & investigations in Turkey started by MTA (General Directorate of Mineral Research and Exploration of Turkey) in 1960. Upon this, 187 geothermal fields have been discovered by MTA.

The geothermal potential of Turkey is estimated (theoretically) as 31.500 Mwt. The number of wells were drilled by MTA are now 470 the total depth is 212,250 m. the proven geothermal capacity of the wells totally is 3,478 Mwt. Fifteen geothermal fields, all in western Turkey, discovered by MTA are suitable for geothermal power production & they need to be developed. The main uses of geothermal energy in Turkey cover a wide range of applications, such as space heating and domestic hot water supply, greenhouse heating, swimming and balneology, industrial processes and electricity generation.

Based upon the current status, the majority of geothermal applications in Turkey have been realized in district heating systems. In 2008 geothermal researches and explorations increasingly completed about eleven wells with the total depth 16,500 m in ten geothermal fields and the proven geothermal capacity is 150 Mwt as MTA activities.

Law on Geothermal Resources and Natural Mineral Water and its regulation has been enacted on 13 June 2007 with contribution of MTA. The purpose of this law is to set forth the procedures and principles regarding effective exploration, research, development, production and protection of geothermal and natural mineral water resources, holding rights on these resources and devolution of the rights, economic utilization of the resources in a compatible way to the environment, and abandonment of these resources.

1. INTRODUCTION

In Turkey, geothermal resource prospection was initiated by MTA (General Directorate of Mineral Research and Exploration of Turkey) in 1962. Up to now, 470 wells, having a total depth of 212,250 m, have been drilled and 187 geothermal fields have been discovered by MTA.

The geothermal potential of Turkey is estimated (theoretically) as 31,500 Mwt. The total proven geothermal capacity of the wells together with the springs is 4,078 Mwt, of which 1,342 Mwt is directly used.

2. GENERAL TECTONIC AND VOLCANIC FEATURES OF TURKEY

Turkey has a unique geographic position at the crossroads between Europe and Asia. It is located on an active tectonic, orogenetic belt, the Alpine-Himalaya Orogen with young faults and active volcanism which is the reason for Turkey's substantial geothermal resources.

Turkey's geographic position along geothermal belts in the world is shown in Figure 1. Most of the geothermal energy potential is located in the Aegean and Central Anatolian region (Fig.2).

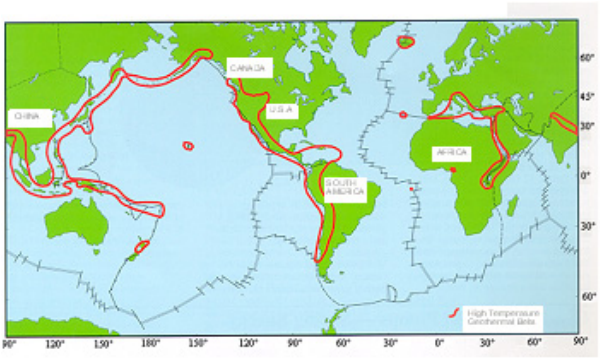

Figure 1: Geothermal belts in the world

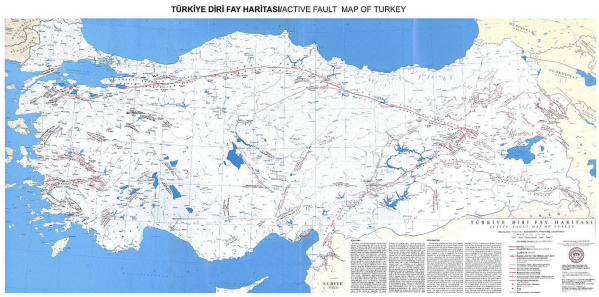

Figure 2: Active Fault Map of Turkey

3. GEOTHERMAL POTENTIALS OF TURKEY

Turkey holds a significant potential for geothermal energy exploitation. 187 geothermal fields that contain geothermal fluid with more than 40°C temperature exist in Turkey.

Sources that contain high temperature geothermal fluid exist mostly in western Turkey because of grabens that are formed as a result of recent tectonic activities. Low- and moderate- temperature sources exist in Middle- and Eastern-Anatolia because of volcanism and fault formations and in the north, along North Anatolian Fault Zone (Figure 3).

Figure 3: Distribution of hot springs and major geothermal fields in Turkey

The number of geothermal fields discovered by MTA increased from 170 in 2005 (Lund et al. 2005) to 187 in 2008. Among those geothermal sites, 5 of the newly discovered geothermal sites are suitable for electricity production. These are Aydın-Umurlu (150 °C), Aydın-Sultanhisar (146 °C), Aydın-Bozköy (143 °C), Aydın-Atça (124 °C) and Aydın-Pamukören (188 °C) geothermal fields. The total geothermal potential in Turkey is estimated to be about 31,500 MWt. With an assumed exhaust temperature of 35 °C, the proven geothermal capacity of the existing wells and springs in Turkey is about 4078 MWt (calculated by the MTA, General Directorate of Mineral Research and Exploration of Turkey). In 2008, geothermal researches and explorations were increasingly completed by MTA in distinct sites. Geothermal wells of totally 16,500 m in depth have been drilled by MTA, from these wells in this year proven geothermal heat capacity is about 150 Mwt (Fig. 4)

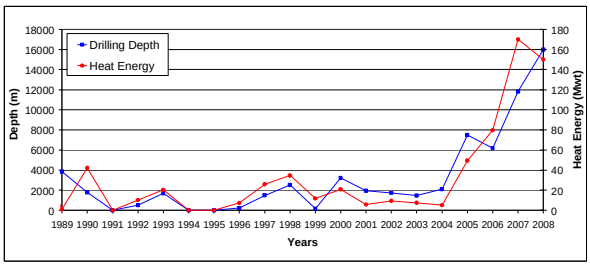

Figure 4: Drilling depth and heat energy produced by MTA projects

MTA, while continuing to prospecting deeper fluid circulating geothermal fields, plans to identify sites in the future years where hot rocks having insufficient porosity and permeability with high temperatures exist, and by determining their physical and chemical parameters, plans to perform mapping and inventory studies beginning from the year 2009.

When the geothermal energy studies performed until now and the geological structure and heat flow maps are examined, the possibility of the existence of potential sites with high temperature hot dry docks can be seen. For these studies, young volcanic sites and sites where crust thins and plate boundaries intersect can be selected as target areas. For example, sites such as the Nemrut volcanism field, Alaşehir Kavaklıdere, Kızılcahamam, Nevşehir Acıgöl, Aksaray, Konya Ilgın, Kütahya-Şaphane and Çanakkale are the ones that will be considered the first in this respect.

In these studies, provinces lying at depths of 2500-3000 m with high temperatures will be identified, and information related to the feasibility of heat gain will be generated by determining parameters such as heat conduction of hot rocks at depth and the physical and chemical properties of the rock.

4. GEOTHERMAL APPLICATIONS IN TURKEY

Turkey is one of the 10 richest countries in terms of geothermal potential in the world. Geothermal energy is a clean, proven and reliable resource for supplying the needs of a sustainable society and helping to improve the environment in Turkey. The main uses of geothermal energy in Turkey cover a wide range of applications, such as space heating and domestic hot water supply, greenhouse heating, swimming and balneology, industrial processes and electricity generation.

Based upon the current status, the majority of geothermal applications in Turkey have been realized in district heating systems. The current geothermal situation in Turkey is given in Table 1. The geothermal applications in Turkey can be divided as Indirect and Direct applications.

Table 1. Current Geothermal Situation in Turkey .

EVALUATIONS	CAPACITY
Geothermal District Heating (City, Greenhouses Thermal facilities etc.)	104.574 Residences Equivalence (940 Mwt)
Balneology	215 thermal facilities (402 Mwt) (10 million people per year)
Total Direct Utilization	1342 Mwt

4.1. Indirect Applications

In Turkey, there are 17 geothermal fields discovered by MTA, which are suitable for geothermal power production. When all the fields are developed, the total installed capacity will reach to about 600 Mw electricity**.** The present situation for geothermal electricity production in Turkey is presented below, in Table 2.

First geothermal electricity production in Turkey started in Kizildere Geothermal Field by MTA in 1974 a pilot plant with a installed capacity of 0.5 MWe. Afterwards in 1984, the Kizildere Geothermal Power Plant was installed by TEK (Turkish Electricity Establishment, renamed as TEAS) with a total installation capacity of 20,4 MWe, today its installed capacity is 15 Mwe. This power plant generates an average of 12-15 MWe electricity (9 wells are productive). The reservoir which feeds the Kizildere Geothermal Power Plant has a temperature of 242°C and contains 1,5% noncondensable gases. The amount of these gases at the separation pressure in the single flash plant is 15% in weight. A liquid CO2 and dry ice production factory is integrated to this power plant which produces 120,000 tons of liquid carbon dioxide and dry ice annually. The Kızıldere field was privatized in 2008 and its installed capacity will be increased (TEAŞ, 2007).

Again, in Aydın-Salavatlı, nearly 7,4 MWe install capacity Binary Cycle Power Plant, which is the first private owned plant, is running since March 2006. 167 °C temperatured geothermal brine is used. In the field, for the additional 9.4 MW installed capacity projects, new production and reinjection wells are completed.

In Germencik geothermal field which was discovered by MTA in 1988, 47,4 MW installed capacity geothermal power plant started to be contracted by GURMAT A.Ş. in

2007 after drilling new production wells and completing required tests. The construction of power plant has been completed at the end of 2008 and the power plant started to product development cycle and now it is running with the total installed capacity. The brine temperature is 232 °C.

Table 2. Present situation for geothermal electricity Production in Turkey.

Geothermal Field Name	Temp. (°C)	Status
Denizli-Kizildere	200-242	Running 15 and 5 Mw installed capacity, the field tendered
Aydin-Germencik	200-232	Running 47,4 Mw installed power plant
Manisa-Alasehir-Kavaklidere	213	Under tender by MTA
Canakkale-Tuzla	174	7,5 Mw at project phase additional drilling goes on
Aydin-Salavatli	171	7,4 Mw installed capacity BCP plant is running and 9,5 Mw at project phase
Kutahya-Simav	162	Direct application
Izmir-Seferihisar	153	3,2 Mw at project phase additional drilling goes on
Manisa-Salihli-Caferbey	150	Under tender by MTA
Aydin-Sultanhisar	145	Under tender by MTA
Aydin-Yilmazkoy	142	will be tendered by MTA
Aydin-Hidirbeyli	143	Tendered by MTA
Aydin-Atca	124	Under tender by MTA
Aydın -Umurlu	155	tendered
Izmir-Balcova	136	Direct usage
Izmir-Dikili	130	Direct usage
Pamukören	188-200	under development

4.2. Direct Applications

The direct-use applications include; district heating in seventeen sites (67700 residence equivalence, 608 Mwt), green house heating (1579000 m^2, 292 MWt), Thermal facilities & balneological purposes (215 spas, 402 MWt). The total direct use increased from 1131 Mwt in 2005 to 1342 Mwt in 2009.

4.2.1. Geothermal House Heating

The existing situation in geothermal house heating systems in Turkey is given in Table 3. As can be seen from the table, a total of 17 sites in Turkey are being heated with geothermal energy.

4.2.2 Geothermal Greenhouse Heating Applications

The first geothermal greenhouse heating application has been started with 2000 m^2 in 1973 in Denizli-Kizildere. Since then, geothermal greenhouse heating applications have gained a rapid increase in terms of investment especially in the recent years. Especially in the last 2-3 years, this development is achieved. The major greenhouse applications heated geothermally are located in the Aegean region (Dikili, Salihli, Simav). The current situation of greenhouse heating in Turkey, together with the 2013 projections, is presented in Table 4.

Table 3. Existing Situation in Geothermal House Heating Systems in Turkey.

Location	Geothermal residence equivalence/ installed capacity	Temp. of Geoth. Water (°C)	Investor
Dokuz Eylül Unv. Campus+ Balcova + Narlidere (1983)*	24000	125–145	Equal partnership of Governorship and Municipality Inc. (Dokuz Eylül Unv:Governorship + University Rectorate)
Gonen (1987)*	3000	80	Mainly Municipality Inc.
Simav (1991)*	7500	137	Municipality
Kirsehir (1994)*	1,8	57	Local Governorship (Mainly) + Municipality Inc.
K.hamam (1995)*	2,75	80	Mainly Municipality Inc.
Afyon (1996)*	5	95	Local Governorship (Mainly) Municipality Inc.
Kozakli (1996)*	2000	90	Mainly Municipality Inc.
Sandikli (1998)*	4000/5.000	70	Mainly Municipality Inc.
Diyadin (1999)*	540	70	Mainly Local Governorship Inc.
Salihli (2002)*	6700/24.000	94	Municipality
Saraykoy (2002)*	2.100/5.000	140	Mainly Municipality Inc.
Edremit (2003)*	3200/7.500	60	Municipality+Private Sector Inc.
Bigadic (2005)*	1860/3.000	96	Municipality
Sarikaya (2006)*	250/2.000	50	Governorship + Municipality+ Private Sector
Yerköy	500/3.000Under construction	55-60	Governorship + Municipality+ Private Sector
Yozgat-Sorgun	1350	80	Municipality
Bergama-İzmir	400		Municipality
Balıkesir-Güre	1000		Municipality

Table 4. Existing Situation and 2013 Projections in Greenhouse Heating in Turkey.

Place	Greenhouse Area (decare)	Estimated Power (MWt)	2013 Projections Estimated (Decare)	2013 Projections Estimated (Mwt)
İzmir-Dikili	700	137	1000	193,3
Denizli-Yenicekent	26	5	100	20,0
Denizli- Sarayköy	30	5,87	400	78,4
Manisa-Salihli	250	49	400	78,4
Manisa-Urganlı	20	3,5	70	12,3
Kütahya-Simav	275	40	350	70,0
Aydın-Gümüşköy	60	9	100	15,0
Afyon-Sandıklı	40	7,83	200	39,2
Afyon-Merkez			500	98,0
Nevşehir-Kozaklı	5	0,97	20	3,9
Urfa	40	8,2	80	16,4
İzmir-Balçova	43	8,52	100	19,4
Kızılcahamam	0.5	0,1	-	-
Bergama	80	15,67	100	19,4
Yozgat-Sorgun	10	1,95	50	9,8
Kırşehir-Mahmutlu	Will be tendered by MTA		200	38,7
İzmir-Aliağa-Samurlu	Will be tendered by MTA		200	40,0
Manisa-Kula	Will be tendered by MTA		100	19,6
Balıkesir-Balya	Will be tendered by MTA		50	9,8
Denizli-Gölemezli			150	26,3
Total	**1579**	**292**	**4000**	**800.0**

In the near future it is expected that greenhouse heating will increase to 800 MWt according to 2013 projections

4.2.3. Balneological Utilization and Thermal Tourism

10 million local and **10.000 foreign visitors** are benefiting from balneological Utilities in Turkey. Also the thermal tourism facility investments have gained speed in the recent years. With the huge thermal tourism capacity potential of Turkey, the target is to increase the local curist (tourists in thermalism) number to **15 million people** until the year 2013. The foreign thermal curist number is planned to be achieved as 250.000 in year 2013.

The comparison of geothermal utilization between 2005 and 2008 is presented in Table 5. As can be seen from the table, an increasing trend is dominant regarding all sectors of geothermal utilization. The heating facilities, covering heating of houses, thermal facilities and greenhouse heating, increased from 804 MWt to 940 MWt, showing an increase of about 16%. Balneological utilization, on the other hand, increased about 22 %. The total installed direct use capacity became 1342 MWt in 2008.

The annual production amount of CO_2 remained the same throughout the years. The installed capacity of electricity production, on the other hand, increased from 15 Mwe to 27.4 Mwe.

5. NEW LEGISLATIVE REGULATIONS CONCERNING GEOTHERMAL RESOURCES

5.1. Renewable Energy Resources Law for the Purpose of generating Electricity (Law No. 5346, Date of Approval: 18/5/2005)

Within the scope of this law, Renewable energy resources (RES) are wind, solar, geothermal, biomass, biogas, wave, current and tidal energy resources suitable for the electricity generation together with hydraulic generation plants, either canal or run of river type or with a reservoir area of less than fifteen square kilometers.

Table 5. Comparison of Geothermal Utilization Between 2005 and 2008 in Turkey.

Utilization (Install Capacity)		2005	2008	Increment (%)
Heating (Houses + Greenhouse + Thermal facilities)		804 MWt	940 MWt	16
Balneological Utilization		327 MWt	402 MWt	22
Total Direct Use		**1131 MWt**	**1342 MWt**	**19**
Mineral Production CO2		120000 ton/yıl	120000 ton/yıl	
Electricity Production	**Install Capacity**	**15 Mwe**	**27.4 Mwe**	**35**
The proven capacity of drilled geothermal wells and natural discharges		3293 MWt	4078 MWt	23

5.2. Law on Geothermal Resources and Natural Mineral Water (Law No. 5686, Date of Approval: 3/6/2007)

The purpose of this law is to set forth the procedures and principles regarding effective exploration, research, development, production and protection of geothermal and natural mineral water resources, holding rights on these resources and devolution of the rights, economic utilization of the resources in a compatible way to the environment, and abandonment of these resources.

This law encompasses the procedures, principles, and sanctions on holding and devolving the rights on the resources; abandonment of the resources: tendering, terminating, and supervising resource utilization; and protection of the resource and accumulation reservoir during exploration and operation periods of detected or to be detected geothermal and natural mineral water resources and geothermal gases.

In the law advantages for geothermal appliers are:

- After the enforcement date of this law, rent, mesne profits shall not be taken for the activities in the places of private ownership of treasury and places under the adjudication and management of the State.

- Companies that make geothermal resource distribution and production shall be considered as industrial and waste treatment organizations. In accordance with this assessment they shall benefit from first of all electric tariffs and all the other incentives and rights that are granted to the industrial organizations and waste treatment organizations.

The Main principles of the law are (Durak, 2009):

- Geothermal resources and natural mineral waters are under the authority and possession of the State and are not subject to the property of land where they are found. Geothermal activities cannot be run without a license. The exploration license period covers a period of 3 years and can be extended for additional 1 year.

- In actions subject to this law; protection of geothermal system, no waste of the resource and protection of environment are basic principles and before the actions for operation, protection area study of the resource by the license holder is obligatory. Otherwise, actions shall be stopped. Reports of protection area study, after taking the opinion of MTA, requires the approval of the Administration.

- Reinjection of the waste water is essential. If it is not possible for technical reasons, the waste water can be discharged within the limits of environmental rules. Reinjection of the waste water is essential. If it is not possible for technical reasons, the waste water can be discharged within the limits of environmental rules. The exploitation license holders are responsible for obtaining the required permissions from the related institutions. The exploitation license holders are required to apply for the permissions within 3 months and shall be obtained in 2 years. Otherwise the license is cancelled.

- The activities are audited by the Administration. If the Administration requires, MTA can also audit, if needed.

- The exploration and exploitation licenses can be transferred

- MTA carries out its research of geothermal and natural mineral water resources upon a license obtained pursuant to the provisions of the Law with exemption from the license fee and compensation.

- MTA can carry out any kind of scientific and technical survey anywhere, including the viable license areas, without requirement of the license.

CONCLUSION

The main uses of geothermal energy in Turkey cover a wide range of applications, such as space heating and domestic hot water supply, greenhouse heating, swimming and balneology, industrial processes and electricity generation.

The number of geothermal fields discovered by MTA increased from 170 in 2005 (Lund et al. 2005) to 187 in 2009. Turkey holds a significant potential for geothermal energy exploitation. 187 geothermal fields that contain geothermal fluid with more than 40°C temperature exist in Turkey.

There have been some problems during the geothermal exploration and applications related with regal aspects. The Law on Geothermal Resources and Natural Mineral Water solve most of that problems.

MTA is ready to cooperate with foreign colleagues, such as the Research and Development institutes in studies concerning the research and development of both existing geothermal fields and fields under exploration. In order to benefit from the geothermal potential in a sustainable manner, more geothermal wells should be drilled for extending geothermal applications throughout the country.

In order to benefit efficiently from the geothermal potential in a sustainable manner;- more geothermal wells (production and re-injections) should be drilled for developing present geothermal fields throughout the country, and new financing mechanisms are needed to promote investment which will support the development of geothermal energy in the country.

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