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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 1962. Upon this, 227 geothermal fields have been discovered by MTA. The geothermal potential of Turkey is estimated (theoretically) at 31.500 MWt.

After the year 2008, 55 new geothermal areas have been explored and the number of the geothermal areas raised from 172 to 227 and 9 of them are suitable for power production; (Aydın-Sultanhisar (146 °C), Aydın-Bozköy-Çamur (146 °C), Aydın-Atça (124°C), Aydın-Umurlu (150°C), Aydın-Nazilli-Bozyurt (127°C), Aydın Pamukören (188 °C) Kütahya -Şaphane (181°C), Manisa-Alaşehir-Kavaklıdere (287 °C), Aydın-Buharkent (147 °C)) , and the others are suitable for heating and thermal tourism.

The number of exploration wells drilled by MTA are now 578 and the total depth is 332,000 m. The total proven geothermal capacity of the wells conducted by MTA is 5000 MWt and together with the private sectors drillings, approximately 8000 MWt proven capacity has been reached. Sixteen geothermal fields which are located in western Turkey and discovered by MTA are suitable for geothermal power production and 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 2013-2014, geothermal research and exploration increased, and the installed electricity capacity reached to 317.4 MWe.

No. 5686 "Law on Geothermal Resources and Mineral Waters" was enacted in 2006 and by this law, geothermal fields, discovered by the MTA are transferred to investors through a tender process. Since 2008, the geothermal fields within the framework of this law have been started to be tendered by the MTA and from that time, 91 geothermal fields (16 of them are suitable power generation) were tendered to the private sector for about 545 million US dollars.

In addition to research and exploration activities, MTA provide scientific and technical support to the geothermal appliers, in order to protect the existing renewability of geothermal areas and ensure sustainable production of them to increase geothermal potential by investigating the deep extensions of currently known geothermal systems.

1. INTRODUCTION

In Turkey, geothermal resource prospection was initiated by MTA (General Directorate of Mineral Research and Exploration of Turkey) in 1962. Until now, 578 wells, with a total depth of 332,000 m, have been drilled and 227 geothermal fields have been discovered by MTA.

The geothermal potential of Turkey is estimated (theoretically) at 31,500 MWt. The total proven geothermal capacity of the wells together with the springs is 5000 MWt, of which 2130 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).

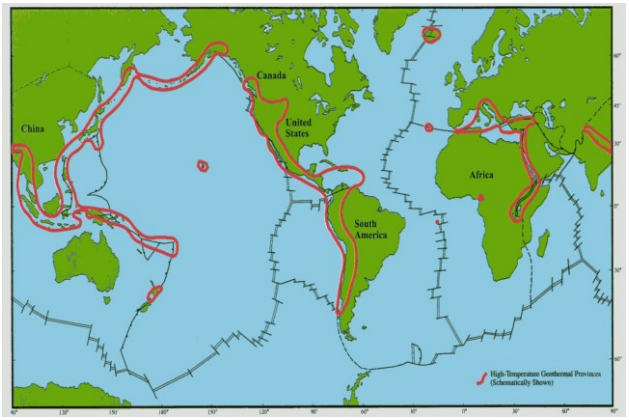

Figure 1. Geothermal Belts in the world.(Dickson and Fanelli, 2004).

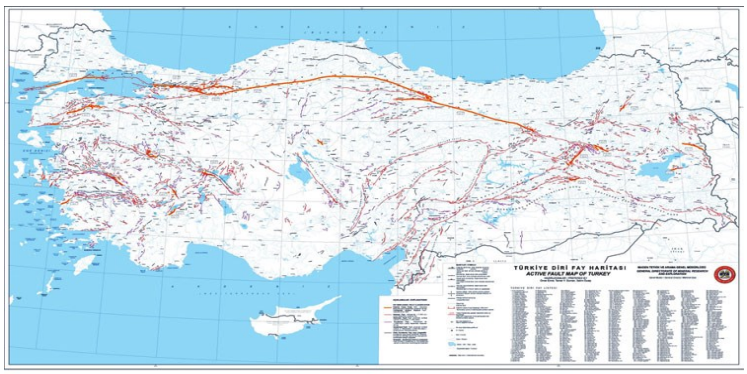

Figure 2. Active fault map of Turkey (Emre Ö. et. al, (2012)).

3. GEOTHERMAL POTENTIALS OF TURKEY

Turkey holds a significant potential for geothermal energy exploitation. 227 geothermal fields in Turkey contain geothermal fluids with a temperature higher than 40°C.

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 172 in 2005 (Lund et al. 2005) to 227 in 2014. After the year 2008, 55 new geothermal areas have been explored and the number of the geothermal areas raised from 172 to 227 and 9 of them are suitable for power production; (Aydın-Sultanhisar (146 °C), Aydın-Bozköy-Çamur (146 °C), Aydın-Atça (124°C), Aydın-Umurlu (150°C), Aydın-Nazilli-Bozyurt (127°C), Aydın Pamukören (188 °C) Kütahya -Şaphane (181°C), Manisa-Alaşehir-Kavaklıdere (287 °C), Aydın-Buharkent (147 °C)), and the others are suitable for heating and thermal tourism.

5 of the newly discovered geothermal sites are suitable for electricity production. These are Aydin-Umurlu (150 °C), Aydin-Sultanhisar (146 °C), Aydin-Bozkoy (143 °C), Aydin-Atca (124 °C) and Aydin-Pamukoren (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 5000 MWt (calculated by the MTA, General Directorate of Mineral Research and Exploration of Turkey).

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	89563Re equivalence (806 MWt)
Greenhouse heating	3130 decare (544 MWt)
Balneology	350 thermal facilities (630 Mwt)

4.1. Indirect Applications

In Turkey, there are 25 geothermal fields discovered by MTA, which are suitable for geothermal power production. When all the fields are developed, the total installed capacity will reach about 1000 MWe electricity. The present situation for geothermal electricity production in Turkey is presented below, in Table 2. This installed capacity estimation (1000 MWe) refers to licensed projects under project phase taken from EMRA (Energy Market Regulatory Authority) (total 713 MWe) and other newly discovered geothermal fields. This estimation also includes projected hot dry rock systems that will be implemented in the near future.

First geothermal electricity production in Turkey started in Kizildere Geothermal Field by MTA in 1974 with a pilot plant with an 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 95 MWe. A liquid CO_2 and dry ice production factory is integrated with this power plant which produces 120,000 tons of liquid carbon dioxide and dry ice annually.

In Aydin-Salavatli, there is nearly 34.45 MWe installed capacity with a geothermal brine temperature of 167 °C. In the field, for an additional 9.4 MWe of installed capacity, new production and reinjection wells are completed.

In Germencik geothermal field which was discovered by MTA in 1988, a 47.4 MWe installed capacity geothermal power plant started to be contracted by GURMAT A.S. in 2007 after drilling new production wells and completing required tests. The construction of power plant was completed by the end of 2008 and the power plant is now running at full capacity. The brine temperature is 232 °C.

4.2. Direct Applications

The direct-use applications include district heating in seventeen sites (67,700 residence equivalence, 608 MWt), green house heating (1,579,000 m^2, 292 MWt), and 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 started in 1973 in Denizli-Kizildere (2000 m^2). Since then, geothermal greenhouse heating applications have gained a rapid increase in terms of investment especially in recent years. 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 2015 projections, is presented in Table 4.

4.2.3. Balneological Utilization and Thermal Tourism

Approximately 10 million local and 10,000 foreign visitors have taken advantage of balneological utilities in Turkey. For that reason, the thermal tourism facility investments have increased significantly in recent years. It is projected to reach 1.000.000 thermal bed capacity with integrated use of geothermal energy sources. With these investments, 400 certified thermal tourism facilities and 250.000 jobs with a total income of 5 billion US$ is expected from thermal tourism in the future.

Table 2. Geothermal fields suitable for electricity production

Geothermal Field Name	Temp. (°C)	Status
Denizli-Kizildere	200-242	Explored by MTA and tendered. Running 15+60+20 =95 MWe and 6.85 MWe installed capacity.
Aydın-Germencik (J-553)	239	Tendered by MTA, 162.5 Mwe under project phase
Aydin-Germencik (Gürmat)	200-232	47.4 MWe power plant operated by the Gurmat Inc., 22.6 MWe in project phase
İzmir-Balcova	136	House heating and thermal applications + 7.5 MWe Small GPP possibility
Balıkesir-Sındırgı Hisaralan	116	Tendered by the MTA
Aydın-Buharkent	145	Tendered by the MTA, the project phase
Izmir-Dikili	130	Greenhouse heating +7.5 Mw BCPP or small GPP possibility
Aydın-Germencik-Gümüşköy	178	13.2 MWe running
Canakkale-Tuzla	174	7.5 MWe power plant in operation
Aydin-Salavatli	171	7.95 Mwe + 9.5 + 17 MWe three plants running , 17 MWe Dora-4 under constraction
Kutahya-Simav	162	Housing-greenhouse heating, and thermal applications +Up to 7.5 MW BCPP or small JES
Izmir-Seferihisar	153	BCPP 3.2 MWe, and additional drilling stage of the project continues
Manisa-Salihli-Caferbeyli	150	tendered by the MTA, 15 MWe in project phase
Aydin-Sultanhisar	145	tendered by the MTA, 9.9 MWe in project phase
Aydin-Yilmazkoy	142	tendered by the MTA, Project phase
Aydin-Bozköy-Çamur	143	tendered by the MTA, 68 MWe running
Aydin-Atca	124	tendered by the MTA, 9.5 Mw phase of the project
Manisa-Alasehir Kavaklidere	287	tendered by the MTA at project phase
Aydın-Pamukören	188	tendered by the MTA, 45 MWe running
Aydın-Umurlu	155	tendered by the MTA,4.85 MWe in the project phase
Aydın-Nazilli-Bozyurt	127	tendered by the MTA, the project phase
Kütahya-Şaphane	181	tendered by the MTA, the project phase
TOTAL LICENCED : 713 MWe		RUNNING INSTALLED CAPACITY : 317.4 MWe
TECHNICAL AND ECONOMIC POTENTIAL : 750 MWe		

Table 3. Existing situation in geothermal house heating systems in Turkey.

Place Name	Number of Residential Equivalence (RE) heated	Geoth.water temp(^{o}C)	Investor
İzmir-Balçova+Narlıdere	34100	125-145	Provincial and Municipal Administration Equal Weighted Joint Stock Company
Gönen	2500	80	Weighted Municipal Corporation
Simav	7500	167	Municipality
Kırşehir	1800	57	Special Provincial Administration of the Municipal Corporation Weighted
Kızılcahamam	2500	80	Weighted Municipal Corporation
Afyon	8000	95	Special Provincial Administration of the Municipal Corporation Weighted
Kozaklı	3000	90	Weighted Municipal Corporation
Sandıklı	6000	70	Weighted Municipal Corporation
Diyadin	690	70	Special Provincial Administration
Salihli	7292	94	Municipality
Sarayköy	2200	140	Weighted Municipal Corporation
Edremit	4881	60	Municipality+Private Sector Company
Bigadiç	1950	96	Municipality
Sarıkaya	550 (not operated)	50	Special Provincial Administration + Municipality+ Private Sector
Yozgat-Sorgun	1500 (not operated)	80	Municipality
Yerköy	1500 (not operated)	55-60	Special Provincial Administration + Municipality+ Private Sector
Güre	650	55	Municipality
İzmir – Dikili	2500	99	Municipality
İzmir – Bergama	450	60	Municipality
19 districts with 89563 RE heating			

Table 4. Geothermal greenhouse heating in Turkey.

Geothermal Field	The current Greenhouse Area (decare)	Approximate Power (MWt)	2015 Projections Expected (decare)	2015 Projections Expected (MWt)
İzmir-Dikili	1000	196	1000-1200	193,3
Denizli-Yenicekent	53	10,5	100	20
Denizli- Sarayköy	152	30	400-500	100
Manisa-Salihli	250	49	400	108,4
Manisa-Urganlı	20	3,5	70	12,3
Kütahya-Simav-Eynal	310	61	350	70,0
Aydın-Gümüşköy-Salavatlı	134	12	100-150	25,0
Afyon	50	10	500	98,0
Afyon-Sandıklı	128	25,6	200	39,2
Nevşehir-Kozaklı	67	13	20	3,9
Urfa	170	33	80	16,4
İzmir-Balçova	17	3	100	19,4
Kırşehir-Mahmutlu	100	9,8	200	38,7
İzmir-Aliağa-Samurlu	Tendered		200	40,0
İzmir-Dikili-Hasanağa	Tendered		100-200	48,6
Balıkesir-Balya	Tendered		50	9,8
Denizli-Gölemezli	424	33,3	150-600	106,3
Kızılcahamam	0,5	0,1	-	
Bergama	80	15,6	100	19,4
Aydın-Çiftlik	Tendered		100-300	54
Aydın-Kuyucak	Tendered		100-300	54
Aydın-İsabeyli	Tendered		100-300	54
Yozgat – Sorgun	15 (47*)	9	50	9,8
Yozgat – Sarıkaya	97*	19		
Yozgat - Yerköy	10*	2		
Yozgat - Boğazlıyan	56	11		
TOTALLY	3130	543	6080	1150

* : Projected by alloted geothermal water - project phase

5. SIGNIFICANT IMPROVEMENTS INCREASING INVESTMENTS GROWTH IN GEOTHERMAL SECTOR

5.1. Increase in exploration - research amount and budget

Since 2005, exploration and drilling surveys of MTA in geothermal sector rapidly increased. The research surveys for drilling budget has reached 15 million dollars annually and this budget is continously increasing. On the other hand three new geothermal drilling rigs were purchased. One of these rigs has 3000 m drilling and the other two 2000 m drilling capacity.

5.2. Privatization of Geothermal Areas

No. 5686 "Law on Geothermal Resources and Mineral Waters" gives rights to MTA to tender discovered geothermal sites, discovered by MTA.

Since 2008, the geothermal fields within the framework of this law have been started to be tendered by the MTA; from that time 91 geothermal fields (16 of them are suitable power generation) were tendered to private sector.

5.3. Legal Regulations Related to Geothermal

5.3.1. Renewable Energy Resources Law for the Purpose of Generating Electricity (Law No:5346) (Gazette No : 25819)

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.

It is guaranteed purchased for a price that will not be below Turkish Lira corresponding to at least 10.5 US Dollar Cent/kWh during 10 years. The regulation provides incentives for RES generation facilities:

- Pay only 1% of the total licensing fee.
- Exemption from annual license fees for the first eight years following the facility completion date.
- May purchase electricity from private sector wholesale companies on the condition not to exceed the annual average generation amounts.
- Priority for system connection.

5.3.2. Law on Geothermal Resources and Natural Mineral Water (Law No:5686) (Gazette No : 26551)

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, 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.

6. NEW TARGETS OF MTA FOR GEOTHERMAL SURVEYS

MTA targets to provide scientific and technical support to the geothermal appliers, in order to protect the existing renewability property of geothermal areas and ensure sustainable production of them. For that reason and to increase geothermal potential by investigating the deep extensions of currently known geothermal systems, MTA projects to survey hot dry rock systems in the future (Fig. 4).

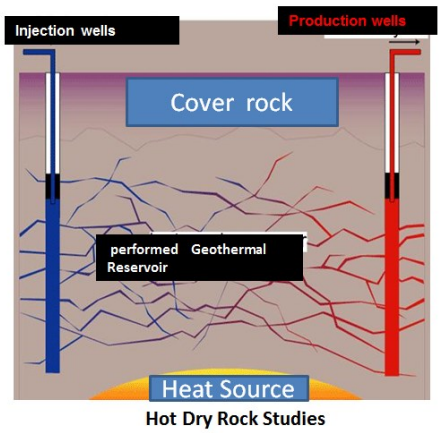

Fig 4. Hot-Dry rock systems

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 227 in 2014. Turkey holds a significant potential for geothermal energy exploitation. 227 geothermal fields containing geothermal fluid with more than 40°C temperature exist in Turkey.

There have been some problems during geothermal exploration and applications related with legal aspects. The Law on Geothermal Resources and Natural Mineral Water solve most of those 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 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. On the other hand MTA projects to survey hot-dry rock systems in Turkey to advance geothermal potential of Turkey.

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