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NEW WIDE DEVELOPMENT OF GEOTHERMAL POWER PRODUCTION IN TURKEY

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ABSTRACT

Turkey is located on the Alpine-Himalayan orogenic belt, which have high geothermal potential. The first geothermal investigations in Turkey started by MTA in 1960's. Upon this, 185 geothermal fields have been discovered by MTA. Around 1500 hot and mineralised natural springs and wells exist in Turkey. For electricity production total installed capacity reached up to 82.25 MWe in 2009. With the existing geothermal wells discharge water (3300 MWt) and springs (600 MWt), the proven geothermal capacity calculated by MTA is totally 4078 MWt (exhaust temperature is assumed to be 35 °C). The geothermal potential is estimated as 31 500 MWt. Most of the development is achieved in geothermal direct-use applications by 122.000 residences equivalence geothermal heating (1025 MWt) including district heating, thermal facilities and nearly 1.579 000 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, Balikesir-Gönen, Edremit, Nevsehir–Kozakli, Manisa–Salihli, Agri-Diyadin, Denizli-Sarayköy, Yozgat-Sarikaya, Yozgat-Yerkoy and Yozgat-Sorgun. 200 spas in Turkey are used for balneological purposes (340 MWt). By summing up all this geothermal utilisations in Turkey, the installed capacity is 1342 MWt for direct-use, a liquid carbon dioxide and dry ice production factory (ann. capacity 160.000 tons). The district heating system applications have been started with large scale geothermal district heating systems in Turkey. Only 6 % of total geothermal potential has been utilized yet. 550 MWe power production and 4000 MWt space heating is aimed for the year 2010-2013. 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 and the foreign curist number to 250.000 until the year 2010-2013. The geothermal greenhouse heating gained a speed especially in the last 3 years in Turkey. The geothermal law has been released in June 2007 which contributed to the realization of privatization of Kizildere geothermal power plant and tendering of 6 fields for electricity production and 13 fields for heating and thermal applications by MTA suitable for electricity generation in October 2008 and 2009.

INTRODUCTION

Turkey, one of the richest country in the World, has a high geothermal potential as a result of its suitable geological situation. It is located on the Alpine-Himalayan orogenic belt and has extensional tectonics (horst and graben systems) and young volcanism. Four main geothermal provinces consider in Turkey, namely the Western Anatolia horst-graben system, the Northern Anatolian Fault zone and the areas affected by upper Tertiary recent volcanic activity localised mainly in Central and Eastern Anatolia (Fig.1). The highest measured tempe-

ratures observed in Western Anatolia graben systems (Fig.2).

The first geothermal researches and investigations in Turkey started by General Directorate of Mineral Research and Exploration (MTA) in 1960's. Up to now, 185 geothermal fields have been discovered and 500 wells have been drilled by MTA.

In Turkey, geothermal energy is used in various applications such as heating (residences, thermal Facilities), electricity generation, Industrial processes, thermal tourism and balnelogy. 95% of geothermal fields are low-medium enthalpy fields, which are suitable mostly for direct-use applications (district heating, greenhouse heating, thermal facilities and balneology) (Table 2,3)[1]. The installed heat capacity is 1365 MWt for direct-use and 82.25 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to the Kizildere power plant. The total production is 104.6GWh/yr (Table 3).

Geothermal capacity calculated by MTA is totally 4078 MWt (exhaust temperature is assumed to be 35 °C). The geothermal potential is estimated as 31,500 MWt (5.000.000 residences equivalence). This figure means also that 30 % of the total residences in Turkey could be heated by geothermal energy [2].

Only 6 % of our total geothermal potential has been utilized yet. For the further development and extension of the geothermal applications in Turkey, 20 % financial support of the Turkish Government would be appropriate. 550 MWe power production and 4000 MWt space heating is aimed for the year 2010-2013. With the huge thermal tourism capacity potential of Turkey, the target is to increase the local curist (tourists in thermalism) number to 30 million people until the year 2020. The foreign thermal curist number is targeted as 1 million until the year 2020.

1. GEOTHERMAL POTENTIAL OF TURKEY

In Turkey, more than 185 geothermal fields which can be useful at the economic scale and about 1500 hot and mineral water resources (spring discharge and reservoir temperature) which have the temperatures ranged from 20-242 °C, have been determined. 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 (Fig. 1). As a result of the geological, geophysical, geochemical surveys and the drillings carried out by MTA, the temperatures and the flow rates of thermal resources in geothermal fields have been increased very seriously [1].

Up to now 500 geothermal explanatory and production wells and 200 gradient wells have been drilled in Turkey Geothermal wells of totally 212250 m in depth have been drilled by MTA, from these wells proven geothermal heat capacity is about 31500 MWt [3]. The first geothermal well was drilled in 1963 and the number of the wells drilled increase after 1982. 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 (total number of wells is around 400) and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private.

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.

There are some important geothermal possibilities have been discovered from existing oil exploration wells at southeastern Anatolia. The reservoir temperatures are changing between 83-138 °C at 2400-3850 m in the wells. 87 of the wells drilled by MTA have been realised in Western Turkey, 11 % in Central Anatolia and 2 % in Eastern Turkey.

Fig 1. Main neotectonic lines and hot spring distribution of Turkey

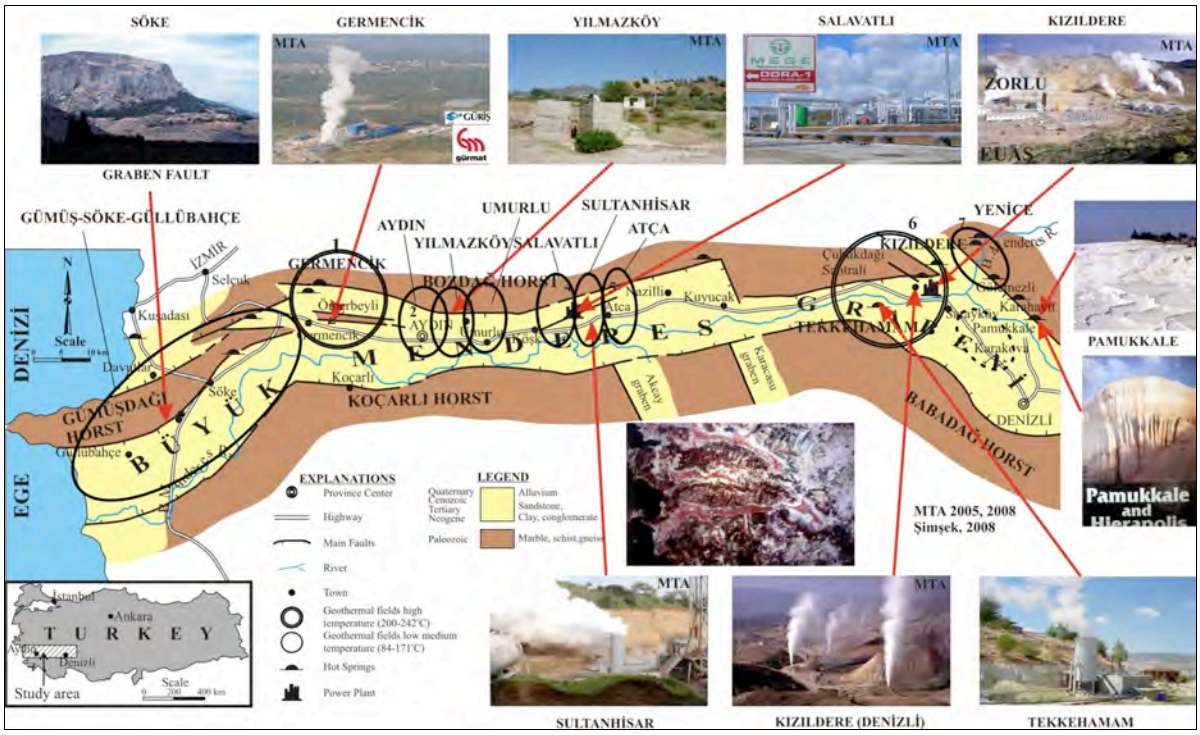

Figure 2. Main geothermal fields of Buyuk Menderes Graben (**Ş**im**ş**ek, 2009)

2. HIGH TEMPERATURE APPLICATIONS IN TURKEY

First explorations regarding geothermal electricity generation was started in 1968 with the investigation of Kizildere geothermal Field at Buyuk Menderes Graben (Fig.2). 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 T.E.K. (Turkish Electricity Authority, renamed as TEAS) with an installation capacity of 20 We. This power plant transferred to Zorlu Energy and generates an average of 12-15 MWe current capacity (Fig.3). The reservoir temperature in the Kizildere geothermal field is 242°C [4].

The reservoir which feeds the Kizildere Geothermal Power Plant (20MWe) and Bereket Energy Binary Cycle GPP (6.85 MWe) is using of waste water at about 140°C. A liquid CO2

and dry ice production factory is integrated to this power plant which produces 160,000 tonnes of liquid carbon dioxide and dry ice annually (Fig.3).

A power plant have been started at Aydin-Salavatli field in 2006 with capacity 8.0 MWe. Thus, the installed capacity of electricity production between 2005 and 2009 increased from 20 MWe to 82.25 MWe MWe, about 422%. Also, the year 2013 goals for electricity production is 565 MWe (Table 2)[3].

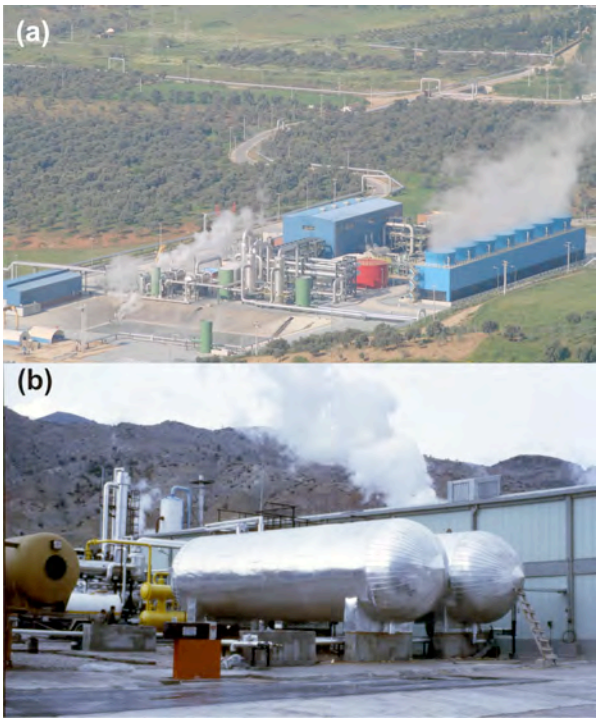

Figure 3. a) Aydin-Germencik geothermal power plant b) Denizli-Kızıldere carbon dioxide plant

Geothermal Power Plants (GPP) in Turkey.

- Denizli – Kızıldere Zorlu GPP 20 MWe in operation since 1984
- Aydin-Salavatli Dora-1 GPP 8 MWe in operation since 2006
- Aydin-Germencik Gürmat GPP 47,4 MWe Denizli- Kızıldere Bereket GPP 6,85 MWe

Licenced (giving by Ministry of Energy and Naturel Resources and EPDK and Under construction.

- Çanakkale-Tuzla ENDA (TJEAS) GPP 7,5 Mwe

The all fields of reservoir temperatures over than 130 ºC on present situation are listed below Table 1.

3. LOW TEMPERATURE APPLICATIONS IN TURKEY

Table1. Present situation for geothermal electricity production in Turkey [3]

Geothermal Field Name	**Temp. (°C)**	**Status**
Denizli-Kizildere	200-242	Running 15 and 5 Mw installed capacity, the field tendered
Aydin-Germencik	200-232	47,4 Mw installed power plant under construction planned to generate in February 2009
Manisa-Alasehir-Kavaklidere	213	Under tender by MTA
Manisa-Salihli-Gobekli	182	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 tender by MTA
Aydin-Hidirbeyli	143	Tender 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

Most of the development is achieved in geothermal direct use applications by 104574 residences equivalence geothermal heating

(1342 MWt) including district heating, thermal facilities and 1579000 m2 geothermal greenhouse heating (Table 2, 3). Main city centers heated by geothermal energy as Izmir-Balcova, Narlidere, Afyon, Kirsehir and Afyon-Sandikli, Kutahya -Simav, Ankara-Kizilcahamam, Balikesir-Gonen, Nevsehir-Kozakli, Manisa-Salihli, Agri-Diyadin, Denizli-Saraykoy, Balikesir-Edremit, Bigadic. As a result of latest investigations, wells drilled for heating application in Yozgat-Sarıkaya, Sorgun, Yerköy fields (Fig.4) and these fields are being heated with geothermal energy. The total direct use increased from 1131 to 1342 between 2005-2008 [3]. The target is to increase heating facilities to 2150 MWe till 2013.

In addition to these, big portion of geothermal potential in Turkey is suitable for heating purposes, geothermal district heating invest-ments could be realized and operated with the cooperation of local governments, municipa-lities, people and private sector [5].

There is a huge thermal tourism potential in Turkey. 215 spas are used for balneological purposes (402 MWt). 10 million local and 10.000 foreign visitors are benefiting from balneological Utilities in Turkey [2]. Also the thermal tourism facility investments have gained speed in the recent years. Combining thermal tourism with the sea/sun/cultural tourism brings important economical development to the region and country. A possible producable potential amount of geothermal flowrate (~40°) has been estimated for the balneological use in Turkey, which is 50.000 l/s. This equals to the benefit of 8 million people/day from thermal waters in spa's in Turkey. The target is to increase the local curist (tourists in thermalism) number to 15 million people and the foreign curist number to 250.000 until the year 2013 [2].

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.

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.

4. GEOTHERMAL LAW OF TURKEY

The geothermal law (Geothermal Resources and Natural Mineral Water Act, No. 5686) has been released on 13th June, 2007 and designed in accordance with the Turkish Trade Law. The new geothermal law resolves the problems regarding legislation, and offers this rich potential, which could not be appraised for long years, to the interest of domestic and foreign investors.

The Law presents license and investment guarantees, by the issues of operating licenses to the domestic and foreign companies, valid up to thirty (30) years in the initial phase, with consequent extensions possible for ten (10) years, in later phases. The new geothermal law, No. 5686, has been prepared in an approach to preserve the geothermal system and potential, and to watch the benefit of the investor. With the long-term license validity and investment assurance provided to the foreign entrepreneurs, it is aimed to put these invaluable domestic resources to the beneficiation of humankind, through all the possible geothermal-related investment areas.

RESULTS

Being one of the richest countries in geothermal potential, Turkey's geothermal activity have been developed mostly to district heating

Table 2. Comparison of Geothermal Direct Use Applications for the years 2005 and 2008 [3].

Applications	2005	2009	Increasment (%)	2013 targets
Heating (Residences+Thermal Facilities+ Greenhouse)	804 MWt	940 MWt	16	2150 MWt

Thermal Tourism Applications	327 MWt	402 MWt	22	300 Thermal
Total Direct Use	**1131 MWt**	**1342 MWt**	**19**	**4000 MWt**
Mineral Production (CO_2)	160000ton/year	160000ton/year	-	
Electricity production (installed capasity)	20 MWe	82.25 MWe	411	565 MWe
Proven capacity of existing geothermal wells and natural	3293 MWt	4078 MWt	23	

Figure 4. Drilled wells for geothermal heating applications in Yozgat.

Table 3. Geothermal district heating systems in Turkey.

Location	**Geoth. Heated Residences**	**Start-up**	**Geoth. Water temp. (°C)**	**Investor**
9 Eylul Unv. Campus	2500	1983	115-60	Governorship, University Rectorate
Gonen	3400	1987	80	Mainly Municipality Inc.
Simav	7500	1991	137	Municipality
Kırsehir	1800	1994	57	Governorship (mainly) + Municipality Inc.
Kızılcahamam	2750	1995	80	Mainly Municipality Inc.
Balçova	15000	1996	137	Mainly Governorship Ltd. Company
Afyon	5000	1996	95	Governorship (mainly) + Municipality Inc.
Kozaklı	2000	1996	90	Mainly Municipality Inc.
Narlıdere	1500	1998	125	Mainly Governorship Ltd. Company
Sandıklı	4000/5000	1998	70	Mainly Municipality Inc.
Diyadin	540	1999	70	Mainly Governorship Inc.

Salihli	6700/24000	2002	94	Municipality
Saraykoy	2100/5000	2002	140	Mainly Municipality Inc.
Edremit	3200/7500	2003	60	Municipality + Private Sector Inc.
Bigadic	1860/3000	2005	96	Municipality
Yozgat-Sarıkaya	250/2000	2006	50,5	Governorship + Municipality+ Private Sector cooperation is planned
Yozgat-Sorgun	1350		80	Municipality
Yozgat-Yerköy	500/3.000 Under construction		55-60	Governorship + Municipality+ Private Sector cooperation is planned
zmir-Bergama	400			Municipality
Thermal Facilities and 1579000 m^2 greenhouse heating (Sanlıurfa, Dikili, Balçova, …)				Investment in the field= Governorship Greenhouse investment= Private Sector

systems between 2000-2009.

A total of installed electrical power production capacity rised up to total 82.25 MWe (Denizli-Kizildere-20 MWe and Aydin-Salavatli 8.0 MWe in Turkey. Utilization of the discharge water of Kızıldere-Sarayköy Geothermal Power Plant - 6,85 MWe, Aydin-Germencik Power Plant 47.4 MWe and Çanakkale-Tuzla Geothermal Power Plant 7,5 MWe (under consturaction).

A liquid carbon dioxide and dry ice production factory is integrated to this power plant, with a capacity of 160 000 ton/year and than important developments in applications of balneology (402 MWt), greenhouse and dwelling heating systems (940 MWt) has been installed (total 1342 MWt) in Turkey.

65 MWe power production and 4000 MWt heating and thermal facilities is aimed for the year 2013. 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 and the foreign curist number to 250.000 until the year 2013.

The district heating system was established earlier in Turkey using lignite for heating in furnaces. Moreover the people were introduced to a higher living standard by means of geothermal district heating systems. People show a very high demand for geothermal district heating systems is Turkey. The people prefer to buy or rent geothermally heated residences and this causes an increment of the renting or selling prices of these houses 3-4 times in comparison to the other houses.

The new geothermal law has been released in 13 June 2007. The law resolves the some of the problems regarding legislation, and offers this rich potential, which could not be appraised for long years, to the interest of domestic and foreign investors.

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

* New fields should be investigated,
• Deep and high temperature reservoirs should be searched,
• Exploration of new fields, and for determination of characteristics and capacities of present field, providing the required support to MTA, Universities and Private Organizations for their research, development and application projects.
• Geothermal activities are increased since the solution alternatives for waste water problem (as reenjection), with regard to the environment geothermal fields must be activated very rapidly.
• Scaling and corrosion problems which effect the management of geothermal energy, have been solved by the injection of the chemical inhibitor. Consequently, it is necessary to activate the fields and to accelerate the investments at this sector.
• 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 (electricity generation, district heating, thermal and

balneological applications) and encouragement of the geothermal uses.

- 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.
- Thermal tourism and balneological utilization with the sea/sun/cultural tourism brings important economical development to the region and country.
- 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,

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, and sustainable for the benefit of the mankind.

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