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GEOTHERMAL ENERGY UTILISATION DEVELOPMENT IN TURKEY -PRESENT GEOTHERMAL SITUATION AND PROJECTIONS-

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ABSTRACT

Turkey is located on the Alpine-Himalayan orogenic belt, which constitutes the major factor in having high geothermal potential.

The first geothermal researches and investigations in Turkey started by MTA in 1960's. Upon this, 170 geothermal fields have been discovered by MTA, where 95% of them are low-medium enthalpy fields, which are suitable mostly for direct-use applications. Around 1000 hot and mineralised natural self-flowing springs exist in Turkey. With the eisting geothermal wells and springs, the proven geothermal capacity calculated by MTA is 2600 MWt (exhaust temperature is assumed to be 40 °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.

Turkey is the 7th richest country in the world in geothermal potential. Most of the development is achieved in geothermal direct-use applications by 51,600 residences equivalence geothermal heating (493 MWt) including district heating, thermal facilities and 454,470 m^2 geothermal greenhouse heating. 194 spas in Turkey are used for balneological purposes (327 MWt). Engineering design of more than 150,000 residences equivalence geothermal district heating has been completed.

By summing up all this geothermal utilisations in Turkey, the installed capacity is 820 MWt for direct-use and 20.4 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant (Table-1,2).

Distribution of the geothermal resources in Turkey according to their temperatures is shown in Figure 1.

Geothermal district heating systems (GDHS) are the main geothermal utilisation in Turkey, which have an important meaning to the Turkish citizens who are make use of this system, since, a clean environment and comfort has been provided to residences in more economic conditions.

Moreover, the district heating system applications have been started with large scale geothermal district heating systems in Turkey, whereas, the geothermal district heating distribution networks have been designed according to the geothermal district heating system parameters. This constitutes an important advantage of GDHS investments in Turkey in terms of technical and economical aspects.

1. PRESENT SITUATION OF GEOTHERMAL WELLS

Up to now 400 geothermal production wells and 300 gradient wells have been drilled in Turkey. The portion of the wells drilled by MTA in the total number of wells is 305. This makes a total geothermal well length as 119,240.85 m (Table 3).

87 % of the wells drilled by MTA have been realised in Western Turkey, 11 % in Middle Anatolian and 2 % in Eastern Turkey (Figure 2).

The temperature distribution obtained from the well outputs in Turkey is as follows (Akkus et al., 1998):

Western Turkey:

Percentage (%)	Temperature (°C)
1	240-250
2	230-240
2	220-230
5	200-210
11	190-200
5	170-180
2	130-140
7	110-120
3	100-110
21	90-100
5	80-90
8	70-80
7	60-70
9	50-60
7	40-50
5	30-40

Middle Anatolian:

Percentage (%)	Temperature (°C)
5	90-100
4	80-90
4	70-80
4	60-70
17	50-60
34	40-50
32	30-40

Eastern Turkey:

Percentage (%)	Temperature (°C)
6	160-170
6	80-90
6	70-80
16	60-70
16	50-60
38	40-50
11	30-40

Moreover, the first geothermal well were 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 and financed by the Governorships, Municipalities and their companies, which constitutes 66.2 % and followed by MTA with 16.5 % and 11.7 % Private (Figure 3).

2. PRESENT SITUATION OF GEOTHERMAL APPLICATIONS

The operational capacities of the city based geothermal district heating systems existing in Turkey are as the following: Gönen (Commissioned: 1987, 3400 residences, geothermal water temperature is ~ 80 °C), Simav (1991, 3200 residences, ~120 °C), Kirsehir (1994, 1800 residences, ~ 57 °C), Kizilcahamam (1995, 2500 residences, ~ 80 °C), Izmir (1996, 10.000 residences, ~ 115 °C), Sandikli (1998, 1600 residences, ~ 70 °C), Afyon (1996, 4000 residences, ~ 95 °C), Kozakli (1996, 1000 residences, ~ 90 °C), Izmir-Narlidere (1998, 1075 residences, ~ 98 °C), Diyadin (1999, 400 residences, ~70 °C). Today, 40-45 °C temperatured geothermal waters are used for space heating in Turkey without heat-pump.

Energy amount from utilization of Geothermal Energy in Turkey for Direct Heat as of 31 December 1999 is 6862.94 TJ/yr (Table-4).

Annually average of 23 % increment of residential connection to GDHS has been achieved since 1983 in Turkey (Figure 4).

The construction costs of power plants are 850-1250 USD/kW, by heating applications; it is 300 USD/kW in the conditions of Turkey. The geothermal heating cost per residence (including network and system, excluding radiator inside the house) is around 2000 USD, where these investments are paying themselves back in 5-8 years.

For the year 2010 the geothermal heating capacity has been estimated as 3500 MWt, power production as 500 MWe, Balneological utilization as 895 MWt. For the year 2020 the geothermal heating capacity has been estimated as 8300 MWt, power production as 1000 MWe and balneological utilization as 2300 MWt (Table-5).

The professional personnel to geothermal activities, restricted to personnel with a University degrees has been calculated as total 120 for the year 1999 (Table-6)

Total investments done in geothermal for the period 1995-1999 is 10 Million USD for research and development, including surface exploration and exploration drilling + Field development, including production drilling and surface equipment. Total investment done for direct and electrical utilization is 15 Million USD for the period 1995-1999 (Table 9).

Japan Government has supplied a donation of 700.000 USD to Japan private sector for preparation pre-feasibility studies for Izmir, Balikesir and Manisa GDHS.

2. 1. LOW TEMPERATURE APPLICATIONS IN TURKEY

There is one low temperature large-scale city heating application in Turkey, which is Kirsehir GDHS.

Kirsehir is a city in middle Anatolian region that shows a terrestrial climate. According to TS 2164, the outdoor design temperature is - 12 °C. The system uses 54/57°C geothermal water from artesian wells located within Kirsehir City. The wells are close to the heat plant, thus the investment cost of the transportation line was kept minimum. The discharge temperature is 40°C.

Kirsehir City distribution network comprises pre-insulated fibreglass pipes. In the return line noninsulated pipe were used to obtain investment economy. Due to characteristics of fibreglass pipe, no heat expansion joints were used. Pipes are kept between two fixed concrete blocks and expansion is stored as stress in the pipes. Branching is done using steel tees. From this connection fibreglass pipe is laid up to the house entries.

Temperature loss in these pipes is minimum. In larger dimensions, DN 300 and above, it is about 0.1 °C/km. In small dimension pipes, it is about 0.5 °C/km.

The equipment used in building stations is self operated temperature and flow control valves, circulating pumps, pressure and temperature gauges.

Heating circulation pumps are divided into three stages. These are low, medium and high flowrate pumps. The outdoor average temperature determines which pumps operate. But, supply and return temperatures are always kept the same.

The geothermal water in Kirsehir is corrosive and causes scaling. To minimise the scaling problems, scale inhibitor is injected to the wells. To protect against corrosion, fibreglass pipes and titanium plate heat exchangers are used. The system was commissioned partially in 1993 and completed in 1994 with a capacity of 1800 residence equivalence and 18 MWt. The system also has a peaking station.

Some of the other low temperature geothermal applications (spa & thermal curing facilities and small heating systems) are as follows (ORME Brochure,1999) :

* Gediz spa & motel facilities are heated by 78°C geothermal fluid since November 1987.
* Floor heating system is applied in Havza spa by 54°C geothermal water.
* Rize Ayder thermal curing centre is heated with a geothermal water of 54°C at an elevation of 1700 m above sea level.
* Two mosques in Haymana are heated by 43°C geothermal water. In this system operation cost is zero. Since geothermal fluid is produced artesian, electricity cost does not exist. Due to the characteristics of geothermal fluid, scale inhibitor is not used. Floor heating system is fed by geothermal water directly and plastic pipes were used. If all these benefits are added up, with a small investment cost, the heating system operates free of charge.

* Sivas Sicak Çermik Spa is heated by 46°C geothermal water.
* Afyon Gazligöl Spa facilities uses 68°C geothermal water for heating and curing purposes.
* Another thermal curing centre using low temperature geothermal water is Oruçoglu Thermal Resort. Geothermal water temperature is 48°C.

Heat pump applications have a wide utilisation area around the world, which is not the case in Turkey. In Turkey, it is not economical to use heat pumps due to the high electricity costs and low interest. When these conditions will be changed the heat pump utilisation will be economical in Turkey.

2.2. HIGH TEMPERATURE APPLICATIONS IN TURKEY

First explorations regarding geothermal electricity generation was started in 1968 with the investigation of Kizildere geothermal Field. 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 Establishment, renamed as TEAS) with an installation capacity of 20.4 MWe. This power plant generates an average of 12-15 MWe electricity annually. The reservoir temperature in the Kizildere geothermal field is 242 °C. The reservoir which feeds the Kizildere Geothermal Power Plant contains 1,5 % non-condensable gases. The amount of these gases at the separation pressure in the single flash plant is 15 % in weight.

A liquid CO_2 and dry ice production factory is integrated to this power plant which produces 120,000 tonnes of liquid carbon dioxide and dry ice annually.

One example to the high temperature city heating applications is Izmir GDHS fed from Balçova geothermal field. This system is the largest geothermal system in Turkey supplying 10.000 residences equivalence with heat (Balçova + Narlidere Towns). The system is extending to 15,000 residences. Moreover, additional 20.000 residences are planned.

We use two types of LSP (USA origin Lineshaft Pumps) deep well pumps in Turkey. For the shallow wells, the local manufactured pumps are installed (installation depths are about 70 – 80 m). For the deep wells, Icelandic design deep well pumps (Installation depths are about 150 – 200 m, 40-45 kg/sec. capacity and operating temperature is 150 °C [4] (Figure 3).

By utilising deep well pumps in Balcova, a large-scale GDHS could be realised. Before the application of deep well pump downhole heat exchangers were used in this geothermal field and a total of 6 MWt was produced from 9 shallow wells. To date, we produce 100 MWt from 3 shallow and 7 deep wells by means of downhole pumps.

In order to prevent scaling of calcite, scale inhibitor which has European Specification ISO 9002, is being injected into the well below the pump by using special chemical injection line.

A peaking station does not exist. Moreover, as all the wells are located in the city, there is no high transmission costs. The system has a property that adjusts the flowrates of geothermal and clean waters by frequency converter dependent of the outdoor temperature.

Some of the other high enthalpy geothermal fields of Turkey are Aydin-Germencik (200-232 °C), Denizli-Kizildere (200-242 °C), Çanakkale-Tuzla (173 °C), Aydin-Salavatli (171 °C) and Kütahya-Simav (162 °C).

It has been estimated that the Aydin-Germencik geothermal field would have 100 MWe power production capacity.

RESULTS

Being one of the richest countries in geothermal potential, Turkey's geothermal developments have been limited mostly to district heating systems.

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.

But there are some points, which should be improved for the development of geothermal applications in Turkey. These points could be summarised as follows: Turkish geothermal law should be finalised as soon as possible, more geothermal wells should be drilled and the well risk should be taken by the state, a control mechanism should work and more financing aids should be received for the geothermal development projects in Turkey.

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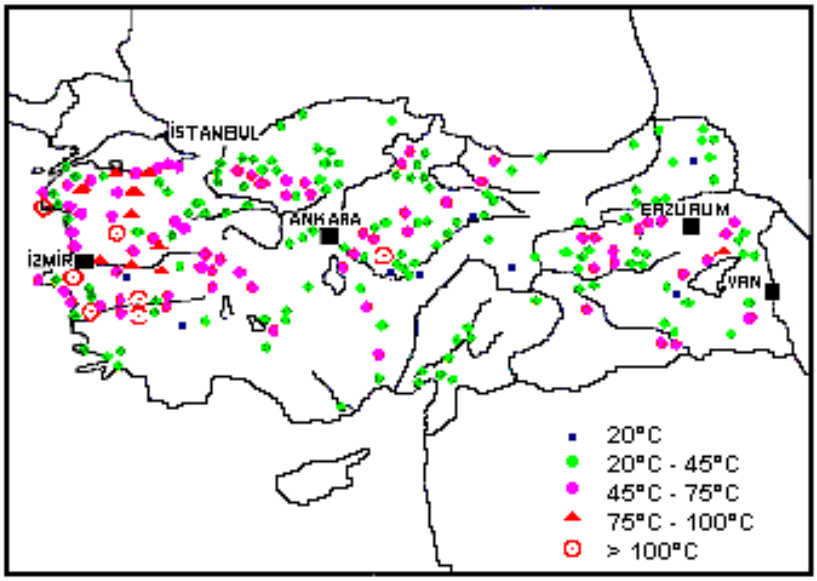

Figure 1 : Distribution of geothermal temperature records in Turkey

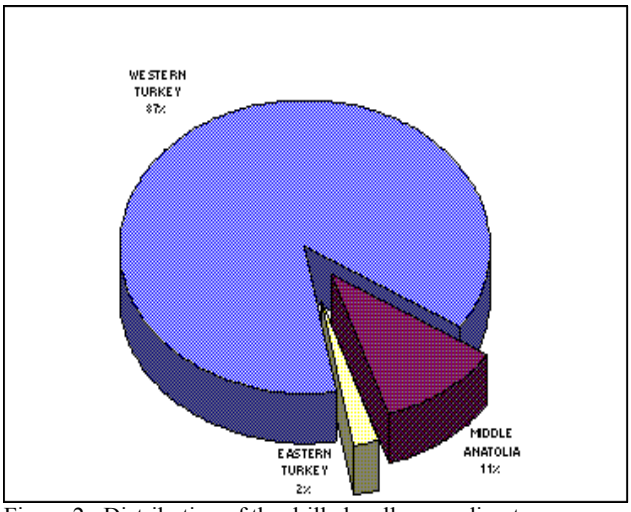

Figure 2 : Distribution of the drilled wells according to western, middle and eastern parts of Turkey.

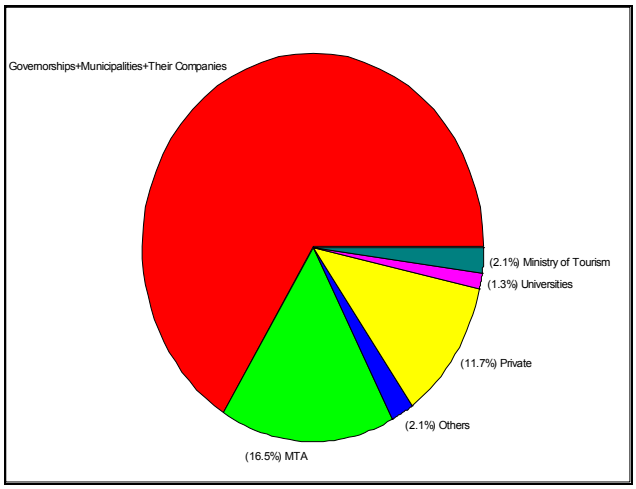

Figure 3 : Distribution of the financiers of the existing geothermal production wells in Turkey.

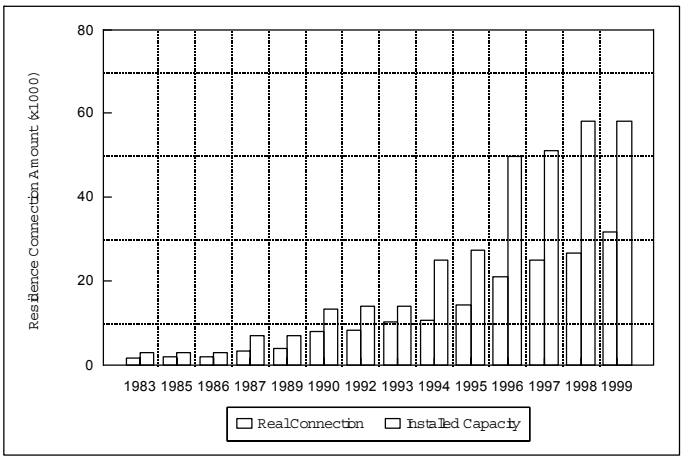

Figure 4 : Geothermal district heating residence connection amounts in Turkey.

Table-1: Categories in Geothermal Utilization in Turkey

Geothermal Utilization Categories	**Capacity**
District Heating	493 MWt
Balneological Utilization	327 MWt
Total Direct Use	**820 MWt**
Power Production	20.4 MWe
Carbon dioxide production	120.000 tons/yr

Table-2 : Summary Table of Geothermal Direct Heat Uses as of 31 December 1999

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr)	Capacity Factor
Space Heating (residences + thermal facilities)	392	4327	0.35
Greenhouse Heating	101	1115	0.35
Bathing and Swimming	327	10,314	1
TOTAL	820	15756	0.60

Table 3 : Distribution of geothermal wells drilled by MTA according to the years

Years	Number of Wells	Depth (m)	MTA Project	Paid
1960-1965	8	852.5	8	-
1965-1970	13	7869.5	13	-
1970-1975	16	7484.7	16	-
1975-1980	8	3597.1	7	1
1980-1985	49	24101.75	29	20
1985-1990	73	27211.4	11	62
1990-1995	65	18188.9	7	58
1995-1998	69	31752.7	7	62
1998-1999	4	3027.6	1	6
TOTAL	305	119,240.85	99	209

Table-4: Utilization of Geothermal Energy for Direct Heat as of 31 December 1999
(H : Spece Heating, B : Balneology, I : Industrial use, G . Greenhouse heating)

Locality	Type	Capacity (MWt)	Energy (TJ/yr)	Capacity Factor
GÖNEN	H, B, I	32	353.3	0.35
SIMAV	H, B	25	276	0.35
KIRSEHIR	H,	18	198.7	0.35
KIZILCAHAMAM	H	25	276	0.35
IZMIR	H	90.4	998	0.35
SANDIKLI	H	45	496.8	0.35
AFYON	H	40	441.6	0.35
KOZAKLI	H	11..2	123.64	0.35
DIYADIN	H	6.3	695.5	0.35
IZMIR MEDICAL FACULTY, HOSPITAL, CAMPUS	H	21.7	239.6	0.35
BOLU	H	8	88.32	0.35
BALCOVA THERMAL FACILITY & THERMAL PRINCESS HOTEL	H, B	13.6	150.1	0.35
AFYON-ORUCOGLU	H, B	5.7	62.9	0.35
GEDIZ	H, B	0.64	7.07	0.35
AFYON- GAZLIGÖL	H, B	5	55.2	0.35
RIZE-AYDER	H, B	0.29	3.2	0.35
KUZULUK	H, B	20	220.8	0.35
AFYON-ÖMER	H, B	2.5	27.6	0.35
SALIHLI	H, B	0.37	4.09	0.35
HAYMANA	H, B	0.1	1.1	0.35
HAVZA	H, B	0.07	0.77	0.35
BALIKESIR- HISARKÖY	H, B	0.12	1.33	0.35
KIZILCAHAMAM	H, B	1	11	0.35
ESKISEHIR-SAKARIILICA	H, B	0.05	0.55	0.35
SIVAS-SICAKCERMIK	H, B	0.6	6.62	0.35
AFYON- BOLVADIN	H, B	1.5	16.6	0.35
SIMAV	H, B	3.6	39.7	0.35
KIZILCAHAMAM	H, B	0.25	2.76	0.35
KIZILCAHAMAM	H, B	3	33.12	0.35
KOZAKLI	H	2.5	27.6	0.35
ALANGULLU	H, B	0.7	7.73	0.35

GÖLEMEZLI	H, B	0.08	0.88	0.35
SANDIKLI	H, B	2.4	26.5	0.35
RESADIYE	H, B	0.1	1.1	0.35
AMASYA	H, B	2	22.1	0.35
AYAS	H, B	2	22.1	0.35
PAMUKCU	H, B	2	22.1	0.35
URFA	G	15	283.9	0.6
SIMAV	G	33	624.5	0.6
SINDIRGI	G	0.4	7.6	0.6
AFYON	G	1.5	28.4	0.6
KIZILDERE	G	2.4	45.4	0.6
BALCOVA	G	17.6	333	0.6
KESTANBOL	G	0.4	7.6	0.6
SARAYKENT	G	0.6	11.35	0.6
TEKKEHAMAM	G	1.8	34	0.6
YALOVA	G	0.12	2.27	0.6
KOZAKLI	G	1.2	22.7	0.6
DIKILI	G	2	35.2	0.6
GOLEMEZLI	G	0.2	3.52	0.6
SEFERIHISAR	G	1.06	18.7	0.6
BERGAMA	G	0.4	7.6	0.6
GERMENCIK	G	0.1	1.9	0.6
EDREMIT	G	9.9	187,36	0.6
EZINE	G	0.3	5.7	0.6
NIKSAR	G	0.14	2.65	0.6
KIZILCAHAMAM	G	1.45	27.44	0.6
GEDIZ	G	2.1	39.74	0.6
CANAKKALE-TUZLA	G	9	170.33	0.6
TOTAL		**493.44**	**6862.94**	

Table-5 : Geothermal utilization projections of geothermal energy in Turkey

Years	**Power Prod. (MWe)**	**Heating** (Residences Equivalency)	**Spa/Others (MWt)**
2010	500	500.000 (3500 MWt)	895
2020	1000	1.250.000 (8300 MWt)	2300

Table-6: Allocation of Professional Personnel to Geothermal Activities (Restricted to personnel with a University degrees)

Year	**Professional Person-Years of Effort**				
	Government	**Public Utilities**	**Universities**	**Paid Foreign Consultants**	**Private Industry**
1999	60	20	10	-	30
Total	**120**				

Table 7 : Present and Planned Production of Electricity (First Energy Council of Turkey, 1998)

	Geothermal		**Fossil Fuels**		**Hydro**	
	Capacity (MWe)	**Gross Production (GWh/yr)**	**Capacity (MWe)**	**Gross Prod. (GWh/yr)**	**Capacity (MWe)**	**Gross Prod. (GWh/yr)**
In operation in January 2000	20,4	152.4	11,312 (1996)	54,387 (1996)	10,103 (1997)	39,816 (1997)
Total Projected use by 2005	185	1338	27,607		17,981	

Table-8: Utilization of Geothermal Energy for Electric Power Generation as of 31 December 1999

Locality	**Power Plant Name**	**Year Commis.**	**No. Of Units**	**Status**	**Type of Unit**	**Total Installed Capacity MWe**	**Annual Energy Produced 1999 GWh/yr**	**Total planned MWe**
Denizli - Kizildere	Kizildere PowerPlant	1984	1	Presently Operated	Single Flash	20.4	91.8	-
Aydin	Germencik							25 MWe, 1st stage (for the year 2000)

Table 9 : Total Investments in Geothermal in US$

Period	**Research & Development Incl. Surface Explor. And Exploration Drilling And Field development Incl. Orıduction Drilling & Surface Equipment**	**Utilization Direct & Elektrical**	**Funding Type**
1995 - 1999	10 Million USD	15 Million USD	Japan Government has supplied a donation of 700.000 USD to Japan Private sector for preparation pre-feasibility studies for Izmir, Balikesir and Manisa GDHS.