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Geothermal Country Update Report of Turkey (2005-2010)

Orhan Mertoglu*, Sakir Simsek**, Hayrullah Dagistan***, Nilgun Bakir*, Nilgun Dogdu***

* Turkish Geothermal Association. – Ankara, tjd@jeotermaldernegi.org.tr

**Hacettepe University, Eng. Faculty, Geological (Hydrogeological) Eng.Dept. Beytepe, Ankara, ssimsek@hacettepe.edu.tr

*** General Directorate of Mineral Research and Exploration (MTA) – 06520, Ankara, dogdu@mta.gov.tr, Hayrullah@mta.gov.tr

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ABSTRACT

Turkey is located on the Alpine-Himalayan orogenic belt, which has high geothermal potential. The first geothermal research and investigations in Turkey were started by MTA in the 1960s. From this time, 186 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 1500 hot and mineralised natural springs and wells exist in Turkey. With the existing geothermal wells and spring discharge water, 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 (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 has been achieved in geothermal direct-use applications by 201,000 residences equivalence geothermal heating (1494 MWt) including district heating, thermal facilities and 2,300,000 m^2 geothermal greenhouse heating. A total of 260 spas in Turkey are used for balneological purposes (552 MWt). By summing up all these geothermal utilisations in Turkey, the installed capacity is 2084 MWt for direct-use (including heat pump applications totally 38 MWt) and 81.61 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to this power plant. About 7% of our total geothermal potential has been utilized so far. 550 MWe power production and 4000 MWt space heating is targeted for the year 2015. With the huge thermal tourism capacity potential of Turkey, the target is to increase the numbers of local curists (tourists in thermalism) to 15 million people and of foreign curists to 250,000 by the year 2015. Geothermal greenhouse heating has gained 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 six geothermal fields by MTA suitable for electricity generation in October 2008.

1. GEOTHERMAL POTENTIAL OF TURKEY

In Turkey, studies have determined more than 186 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 ranging from 20 to 242°C (Figure 1). These manifestations are located mainly along the major grabens (such as Buyuk Menderes, Gediz, Dikili-Bergama, Kucuk Menderes, Edremit Grabens) along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions. As a result of the geological, geophysical, geochemical surveys and the drillings carried out by General Directorate of Mineral Research and Exploration (MTA), the temperatures and the flow rates of thermal resources in geothermal fields have been increased very seriously (MTA, 2005, Dagistan, 2009). These manifestations are located mainly along the major grabens in Western Anatolia, along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions (Figure 1). With the existing springs (600MWt) and geothermal wells (3478 MWt), the proven geothermal capacity calculated by MTA is 4078 MWt (discharge temperature is assumed to be 35°C). The distribution of geothermal direct use in Turkey (August 2009) is shown in Figure 2. The geothermal potential is estimated as 31,500 MWt. The installed geothermal heat capacity is 2084 MWt for direct-use and 81.61 MWe for power production in Turkey, where a liquid carbon dioxide and dry ice production factory is integrated to the Kizildere power plant with a production capacity of 160,000 tons/year. Up to now around 800 geothermal exploratory and production wells and 220 gradient wells have been drilled in Turkey (depths up to 2432m in the AG-26 well in Germencik).

2. PRESENT SITUATION OF GEOTHERMAL WELLS

Between 2005-2009, a total of about 256 geothermal exploration and production wells for electricity production and direct use purposes (Table 6) and 150 gradient wells have been drilled in Turkey with a total depth of 127.1 km. Since 2000, the total number of the drilled geothermal wells for geothermal electricity and direct use applications is roughly 800 in Turkey. Especially in the Buyuk Menderes Graben and Gediz Graben geothermal systems new geothermal fields have been explored by MTA.

3. HIGH TEMPERATURE APPLICATIONS IN TURKEY

The first exploration regarding geothermal electricity generation was started in 1968 with the investigation of Denizli (Kizildere) geothermal field. In 1974 a pilot plant with a capacity of 0.5 MWe has been installed.

The Geothermal Electricity Power Plants (GEPP) present in Turkey are as follows:

1. Denizli-Kizildere GEPP: In 1984, the Kizildere Geothermal Power Plant was installed by TEK (Turkish Electricity Authority, renamed as TEAS) with an installation capacity of declared 20 MWe (Table-1). This power plant transfered (after privatization) to Zorlu in 2008 and generates an average of 12-15 MWe (as generator capacity) electricity annually. The reservoir temperature in the Kizildere geothermal field is 242°C. The reservoir that feeds the Kizildere Geothermal Power Plant contains 1.5 % non-condensable gases (Simsek, 2009).

A liquid CO2 and dry ice production factory is integrated to this power plant which produces 120,000 tonnes of liquid carbon dioxide and dry ice annually.

2. Aydin-Salavatli Dora-1 GEPP: In Aydın-Salavatlı, a 7.36 MWe installed capacity Binary Cycle Power Plant has been running since March 2006. 167°C temperature geothermal brine is used. A second 7.5 MWe install capacity Dora-2 GEPP is under construction.

3. Aydin-Germencik GEPP: The Gurmat plant has been running since April 2009 with an install capacity of the first stage as 47.4 MWe. The total installed capacity is aimed to reach 100 MWe. The geothermal brine temperature is 232°C.

4. Saraykoy GEPP: Waste geothermal water produced from the Kizildere Geothermal Power Plant at 140°C will be used in the Bereket plant. The total installed capacity of this plant is 6.85 MWe.

Geothermal fields in which the reservoir temperature is over 120ºC are given below.

1. Denizli-Kızıldere Field (242°C)
2. Aydın - Germencik -Omerbeyli Field (232°C)
3. Manisa –Salihli-Göbekli Field (182°C)
4. Canakkale- Tuzla Field (175°C)
5. Aydın-Salavatli Field (171°C)
6. Kütahya-Simav Field (162°C)
7. Manisa- Salihli-Caferbey Field (150°C)
8. Izmir- Seferihisar Field (153°C)
9. Izmir-Balcova Field (142°C)
10. Aydın-Yilmazköy Field (142°C)
11. Aydin-Sultanhisar (145°C)
12. Aydin Atca (125°C)
13. Manisa-Kavaklidere (213°C)
14. Aydin-Pamukoren (187°C)
15. Aydin Umurlu (155°C)
16. Aydin-Hidirbeyli (143°C)
17. Nazilli-Bozyurt-Guzelkoy (140°C)

4. LOW TEMPERATURE APPLICATIONS IN TURKEY

The operational capacities of the city based geothermal district heating systems (GHDS) existing in Turkey are as follows: Gönen (Commissioned: 1987, 3400 residences, geothermal water temperature is ~ 80°C), Simav (1991, 5000 residences, ~120°C), Kirsehir (1994, 1900 residences, ~57°C), Kizilcahamam (1995, 2500 residences, ~ 80°C), Izmir (1996, 30.000 residences, ~ 115°C), Sandikli (1998, 3600 residences, ~ 70°C), Afyon (1996, 4500 residences, ~ 95°C), Kozakli (1996, 1200 residences, ~ 90°C), Diyadin (1999, 400 residences, 70°C), Salihli (2002, 4100 residences, 94°C), Edremit (2003, 3900 residences, 60°C), Balikesir-Bigadic (2005, 1500 residences, 96°C), Yozgat – Sarikaya (2006, 600/2000 residences 60°C), Yozgat-Yerkoy (500/3000 residences, 60°C) and Yozgat-Sorgun (1008, 750 residences, 80°C). Today, 40-45°C temperature geothermal waters are used for space heating in Turkey without heat-pumps.

Most of the development is achieved in geothermal direct use applications to a total of 2084 MWt. 1494 MWt (which equals the heat requirement of 201,000 residences equivalance) of this is being utilized for geothermal heating including district heating, thermal tourism facilities heating and 2,300,000 m^2 geothermal greenhouse heating. The remaining 552 MWt of this potential is being utilized for balneological purposes. There exist 260 thermal facilities (balneology) in Turkey (TJD, 2009).

The first geothermal greenhouse heating application has been started with 2000 m^2 in 1973 in Denizli-Kizildere under the United Nations Development Programme (UNDP). 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 has been achieved. The major greenhouse applications heated geothermally are as follows:

Izmir-Dikili,Bergama : 1,000,000 m^2

Manisa-Salihli,Urganli : 305,000 m^2

Kutahya-Simav : 300,000 m^2

Denizli-Kizildere-Tosunlar : 200,000m^2

Sanliurfa-Karaali : 170,000 m^2

Izmir-Balcova : 100,000 m^2

12 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 number of local curists (tourists in thermalism) to 15 million people by the year 2015 (Mertoglu et al. 2006).

The foreign thermal curist number is planned to be reach 250,000 by year 2015.

The geothermal heat pump applications including Metro Meydan M1 Shopping Center/Istanbul (4.6 MWt) and Terme Maris Facility in Dalaman (0.2 MWt) have gained speed in Turkey. Totally, the total geothermal heat pump applications have reached an installed capacity of about 38 MWt (Form group, 2009). With the geothermal heat pump application, installed capacity the geothermal direct use capacity has reached 2084 MWt.

5. RELEASED GEOTHERMAL LAW

The Turkish Geothermal Law (Geothermal Resources and Natural Mineral Water Act, No. 5686) of Turkey has been released in June 2007 which was followed with the application regulations (number: 26727) released in December 2007. The geothermal law and its regulations provide solutions to the problems concerning legislative matters and obligations of the research and operation concession rights, technical responsibility, control and

protection of the geothermal areas. The geothermal law mainly covers;

- holding license by submitting the relevant project by a direct application,
- transferring the license to a third party, or receiving transferred licenses,
- repossessing of licensing of a geothermal area, which being released by any reason, by means of bidding,
- reinjection application to protect the reservoir parameters and environment.

The Law presents license and investment guarantees, by issuing of operating licenses to domestic and foreign companies, valid up to thirty (30) years in the initial phase, with consequent extensions possible for 10 + 10 years, in later phases.

The organisation of the World Geothermal Congress 2005 in Antalya/Turkey has mainly given rise to preparation of the geothermal law and its application regulations.

With the geothermal law, the geothermal applications like electricity production, geothermal field studies and especially direct use applications gained speed and increased 190% since 2005. Geothermal electricity production increased by 408%, which is a big step in the development of geothermal utilization in Turkey.

As a result, the geothermal law and its regulations aim to protect the geothermal system and its potential for the benefit of the investors. The geothermal law contains also some incentives like application of lower electricity tariffs in geothermal applications and the license owner may demand easement right in case of a contradiction with the owner of the private property right on the relevant geothermal field by applying to the Local Governorship of the area.

6. RESULTS

Being one of the richest countries in geothermal potential, Turkey's geothermal activities have been developed significantly in direct use (heating) and electricity production from 2005 to 2009.

The total installed electrical power production capacity has risen to a total of 81.61 MWe.

A liquid carbon dioxide and dry ice production factory is integrated to the Kizildere power plant, with a capacity of 160,000 ton/year. Also, important developments in applications of balneology (552 MWt), heating (residences, thermal facilities, greenhouses) (1494 MWt), and heat pump applications (38 MWt) have been installed (total 2084 MWt) in Turkey.

550 MWe power production and 4000 MWt heating and thermal facilities is aimed for the year 2015. With the huge thermal tourism capacity potential of Turkey, the target is to increase the numbers of local curists (tourists in thermalism) to 15 million people and of foreign curists to 250,000 by the year 2015.

The new Geothermal Law has been released in 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.

The 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 determination of characteristics and capacities of present field, providing the required support to MTA, Iller Bankasi, Universities and Private Organizations for their research, development and application projects.
- Geothermal activities are increased since the solution alternatives for waste water problem (as reinjection), with regard to the environment geothermal fields must be activated very rapidly.
- Scaling and corrosion problems which affect 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 or funds.
- 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, so 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/investors 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,
- Privatization of the existing geothermal district heating systems owned by the local governorships and municipalities would help to enhance and develop the existing geothermal district heating systems.

Geothermal energy in Turkey must be used as the main energy source at the regions where it is found, as it is very cheap, clean, and sustainable for the benefit of the mankind.

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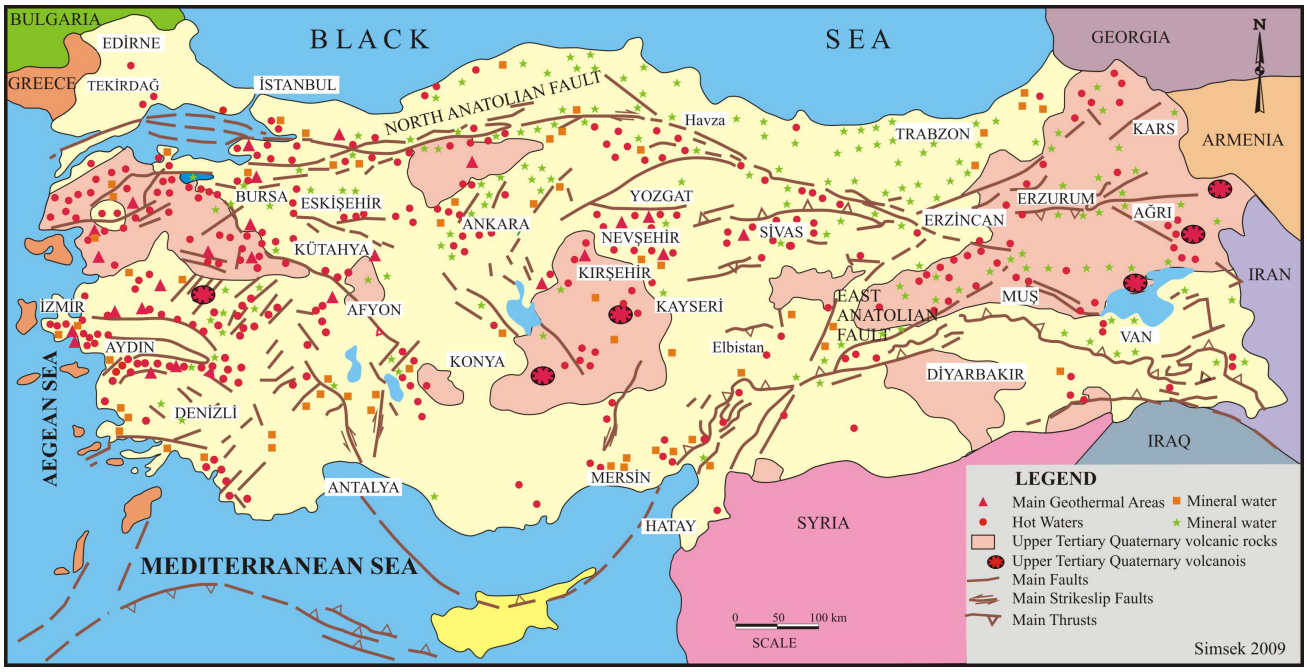

Figure 1: Main neotectonic lines and hot spring distribution of Turkey

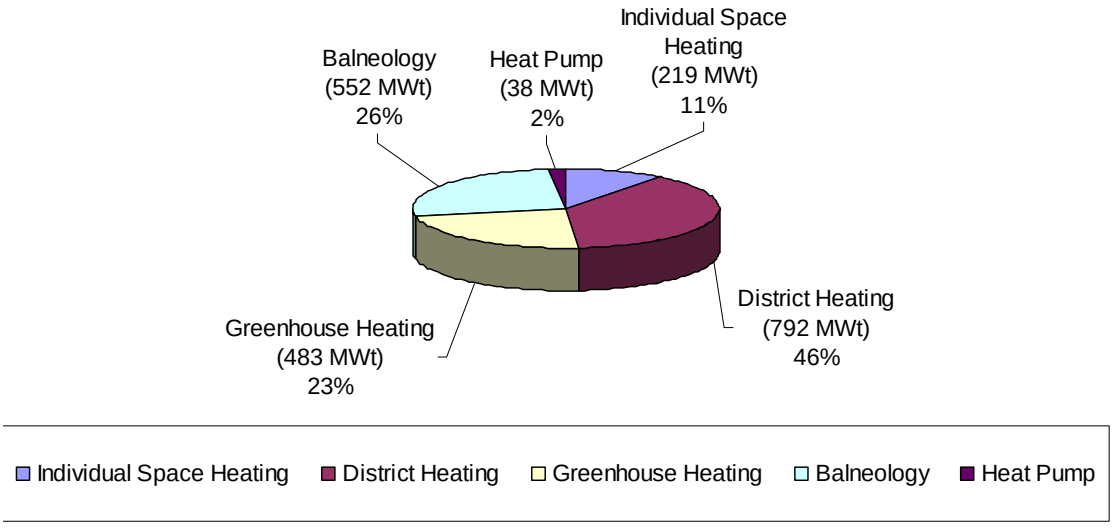

Figure 2: Geothermal Direct Use Distribution in Turkey

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels*		Hydro		Nuclear		Other Renewables**		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in July 2009	81,61	489,7	26774	154983	13830	50113			361,2		41046,8	
Under construction in December 2009	15	90			6564	23620			1100		7679	
Funds committed, but not yet under construction in December 2009	60	360	11020,5	53815	22260	79177			579,7		33340,5	
Total projected use by 2015	550	3000			23080	82095		31579	10.000		82066,3	

*coal, lignite, petroleum, natural gas
** wind, solar, biomass

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009

[1] N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

[2] 1F = Single Flash
2F = Double Flash
3F = Triple Flash
D = Dry Steam
B = Binary (Rankine Cycle)
H = Hybrid (explain)
O = Other (please specify)

[3] Data for 2009 if available, otherwise for 2008. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2009[3] GWh/yr	Total under Constr. or Planned MWe
Denizli	Kizildere (Saraykoy)	1987	1		1F	20	15	92,6	60
Aydin	Salavatli Dora-1	2006	1		B	7,36	6,5		7,5
Denizli	Bereket	2008	1		B	6,85	5		
Aydin	Guris/Gurmat Germencik	2009	1		2F	47,4	47,4		47,4
Aydin	Salavatli Dora-2		1		B				7,5
Canakkle	Tuzla		1		B				7,5
Total						81,61	73,9		129,9

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2009 (other than heat pumps)

[1] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.004184
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^{o}C) - outlet temp. (^{o}C)] x 0.1319
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization					Capacity[3]
		Flow Rate	Temperature (^{o}C)		Enthalpy[2] (kJ/kg)		
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)
Afyon (Omer-Gecek)	D, B	620	99				45
Afyon (Sandikli)	D, B	496	70				50
Agri (Diyadin)	D, B, G, O*	560	72				15
Ankara-Haymana	H, B	58	44				0,5
Ankara-Kizilcahamam	D, B, G	94	86				25
Ankara (Cubuk-Meliksah)	F, G	30	32-61				2
Aydin (Germencik)	G		100				0,1
Aydin (Salavatli)	B	94	155				4
Balikesir (Gonen)	D, B, G	131	80				32
Balikesir (Sindirgi)	G	176	98				0,4
Balikesir (Bigadiç)	D, B	103	96				25
Balikesir (Pamukcu)	H, B	35	58				2
Balikesir (Kepekler)	B	15	60				0,2
Balikesir (Edremit)	G	220	65				25
Balikesir (Gure)	D	21	55				0,01
Bolu (Karacasu)	D, B	85	44				4
Çanakkale (Kestanbol)	B, G	25	75				0,7
Denizli (Kızıldere)	G, O*	270	100				11,2
Denizli (Tekke Hamami)	B, G, O**	26	168				1,8
Denizli (Golemezli)	B, G	340	75				0,28
Eskisehir (Sakarilica)	B	29	55,5				0,05
Izmir (Balcova)	D, B, G	200	145				240
Izmir (Seferihisar)	G	50	153				1,06
Izmir (Dikili+Bergama)	G	115	165				200
Izmir (Cesme)	B	350	57				3
Kirsehir (Terme)	D, B	388	55				19
Kutahya (Simav)	D, B, G	476	162				39
Kutahya (Gediz)	H, B	112	97				1,5
Kutahya City Center	H	14	53				3
Manisa (Urganli)	G, B	120	62				54
Manisa (salihli)	D, B, G	237	100				40
Nevsehir (Kozakli)	D, B	250	93				20
Rize (Ayder)	H, B	42	55				0,29
Sakarya (Akyazi)	H, B	293	84				2
Sakarya (Kuzuluk)	H, B	271	84				30
Samsun (Havza)	H, B	143	56				0,1
Sivas (Sicak Cermik)	H, B	832	49				1
Tokat (Niksar)	G		32				0,14
Yalova (Termal)	H, B	20	49				0,5
Yalova (Armutlu)	H, B		75				30
Yozgat (Sorgun)	D, B	150	72				23
Yozgat (Sarıkaya)	D, B	168	60				24
Yozgat (Yerkoy)	D, B	60	60				31,5
TOTAL							

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	219	2417	0,35
District Heating [4]	792	7386,4	0,35
Air Conditioning (Cooling)			
Greenhouse Heating	483	9138	0,6
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	552	17408	1
Other Uses (specify)			
Subtotal	2046	36349,4	
Geothermal Heat Pumps	38	536,5	0,5
TOTAL	2084	36885,9	

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (balneology)	
Exploration[1]	(all)	12	60			31,2
Production	>150° C	17				9,5
	150-100° C	18	2			20,4
	<100° C		82		40	43,5
Injection	(all)	12	13			22,5
Total		59	157		40	127,1

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2005	70	32	20			32
2006	14	13	15			18
2007	12	4	6			10
2008	38	6	6	10		18
2009	45	10	7	5		41
Total	179	65	54	15		119

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	2,2					100
2000-2004	7,5	1,35	74		10	90
2005-2009	350	68	212	500	70	30