Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Geothermal Country Update Report of Turkey (2010-2015)

Orhan Mertoglu*, Sakir Simsek**, Nilgun Basarir*

* tjd@jeotermaldernegi.org.tr, **ssimsek@hacettepe.edu.tr

Keywords: geothermal, potential, utilization, EGC, Turkey

ABSTRACT

Being one of the richest countries in geothermal potential, a significant development was achieved in Turkey in geothermal electricity production and direct uses (district, greenhouse heating and thermal tourism) during last five years (2010-2015). Geothermal Law and its regulations accelerated the geothermal activities in Turkey. Especially, the feed in tariff application for electricity production and MTA's activities boosted this sector.

Since the 1960's, 227 geothermal fields have been discovered in Turkey. Geothermal direct-use applications have reached 2886.3 MWt geothermal heating including district heating (805 MWt), nearly 3 million m^2 greenhouse heating (612 MWt), thermal facilities, hotels etc heating 420 MWt, balneological use (1,005 MWt) and heat pump applications (42,8 MWt). Geothermal electricity production has reached 400 MWe (total of 17 geothermal power plants). Liquid carbon dioxide and dry ice production factories are integrated to the Kizildere and Salavatli geothermal power plants. Geothermal electricity production will be about 400 MWe (Aydin-Germencik, Aydin-Salavatli, Denizli-Kizildere, Aydin-Hidirbeyli, Canakkale-Tuzla, Aydın-Pamukören, Aydin-Gumuskoy and others) in December 2014.The geothermal power plants install capacity under construction is 165 MWe (Table 1).

With the existing geothermal wells and spring discharge water, the proven geothermal heat capacity calculated by MTA is totally 5,046 MWt (leaving temperature is assumed to be 35°C).

Most of the development has been achieved in electricity production and balneological utilizations in the last 5 years in Turkey. A total of 750 MWe power production and 4,000 MWt space heating is targeted for the year 2018 (TR Ministry of Development, 10th Development Plan 2014-2018). Thermal facilities heating and balneological use has gained speed especially in the last 2 years in Turkey. The issued geothermal law and incentives contributed to the increase in geothermal electricity production investments within Turkish private sector.

1. GEOTHERMAL POTENTIAL OF TURKEY

In Turkey, studies have identified more than 227 geothermal fields which can be useful at the economic scale and about 2,000 hot and mineral water resources (spring and well discharge and reservoir temperature) which have the temperatures ranging from 20 to 287°C. Up to now, nearly a total of 1,200 geothermal exploratory, production and reinjection wells have been drilled in Turkey (Simsek, 2014, Dagistan, 2014).

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 and in the Central and Eastern Anatolia volcanic regions.

The geothermal potential is estimated at 31,500 MWt up to 2010. Moreover, the updated calculations regarding the geothermal heat capacity potential of Turkey is concentrated at 60,000 MWt geothermal heat potential (Yilmazer, 2009, Satman, 2009, Turkish Geothermal Association, 2012).The installed geothermal heat capacity is 2,880 MWt for direct-use (including heat pumps) and 400 MWe for power production in Turkey, where liquid carbon dioxide and dry ice production factories are integrated to Kizildere and Salavatli power plants with a production capacity of 240,000 tons/year.

Total geothermal technical and economical electricity production potential (hydrothermal, 0-3 km) has been calculated as 2,000 MWe (16 Billion kWh/year) with the additional incentive for 15-20 years by 15 USDcent/kWh. The total geothermal theoretical electricity potential of Turkey (hydrothermal, 0-3 km) has been calculated as 4,500 MWe (TJD, 2013).

The targeted geothermal electricity production amount has been announced as 1,500 MWe for 2023 by the Turkish Government which is 100th Anniversary of Turkish Republic.

2. PRESENT SITUATION OF GEOTHERMAL WELLS

Between 2010-2015, a total of about 320 geothermal exploration, production and injection wells for electricity production and direct use purposes have been drilled in Turkey with a total depth of total 570 km drilled by MTA and the private sector in Turkey.

Especially in the Buyuk Menderes Graben and Gediz Graben geothermal systems, new geothermal fields have been explored by MTA and Turkish private Sector.

Nearly 80% of the geothermal exploration wells have been drilled in the Western Anatolia in Turkey.

3. LAWS AND REGULATIONS

The issue of the Law for the Use the Renewable Energy Resources for Electricity Production (No: 5346, Date: May 10, 2005) has started the acceleration in utilization of renewable energies (geothermal, hydro, wind, biomass and sun). The law gives the prices of electricity as incentives for different renewable energy resources. The produced geothermal electricity received a price of 10.5 USDcent/kWh.

Geothermal activities in Turkey is regulated by Law on Geothermal Resources and Natural Mineral Waters (No: 5686, Date: June 3, 2007) and its Implementation Regulation (No: 26727, Date: December 2007). The geothermal law and its regulations provide solutions to the problems concerning legislative matters and obligations of the exploration and production concession rights, technical responsibility, control and protection of the geothermal areas. The relevant authority is the Ministry of Energy and Natural Resources and the relevant head state entity is the Provincial Special Administration. There are two types of licenses described by law; namely prospecting license and operating license. The former enables its holder to carry out prospecting activities in a specific area based on the project notified to the Administration; the latter enables its holder to produce geothermal related-water, gas and steam and use them for energy production, heating or for industrial purposes (Parlaktuna et all, 2013).

The geothermal law covers geothermal activities in all aspects (exploration, drilling, production and utilization) since 2009.

4. HIGH TEMPERATURE APPLICATIONS IN TURKEY

As of December 2014, there exist 17 operating geothermal power plants at 9 geothermal fields in Turkey which have a total installed capacity of 400 MWe (Table 1 and Table 2).

These geothermal power plants are located in Denizli-Kizildere (Zorlu, 95.0 MWe), Aydin-Salavatli (Menderes, 34.45 MWe), Aydin-Germencik-1 (Gürmat, 47.4 MWe), Canakkale-Tuzla (Enda, 7.5 MWe), Aydin-Hidirbeyli (Maren, 92 MWe), Aydin-Pamukoren (Celikler, 45 MWe), Denizli-Kizildere (Bereket, 6.85 MWe), Manisa-Alasehir (Türkerler, 24 MWe), Aydin-Germencik-2 (Gürmat, 22,5 MWe), Aydin-Gümüskoy (BM, 6.6 MWe), Denizli-Gerali (Degirmenci, 2.52 MWe). Locations of power plants are shown in Figure 1 (Simsek, 2014).

165 MWe of installed capacity is under construction as of December 2014. Estimated total projected geothermal electricity use will be 1,077,3 MWe in the year 2020.

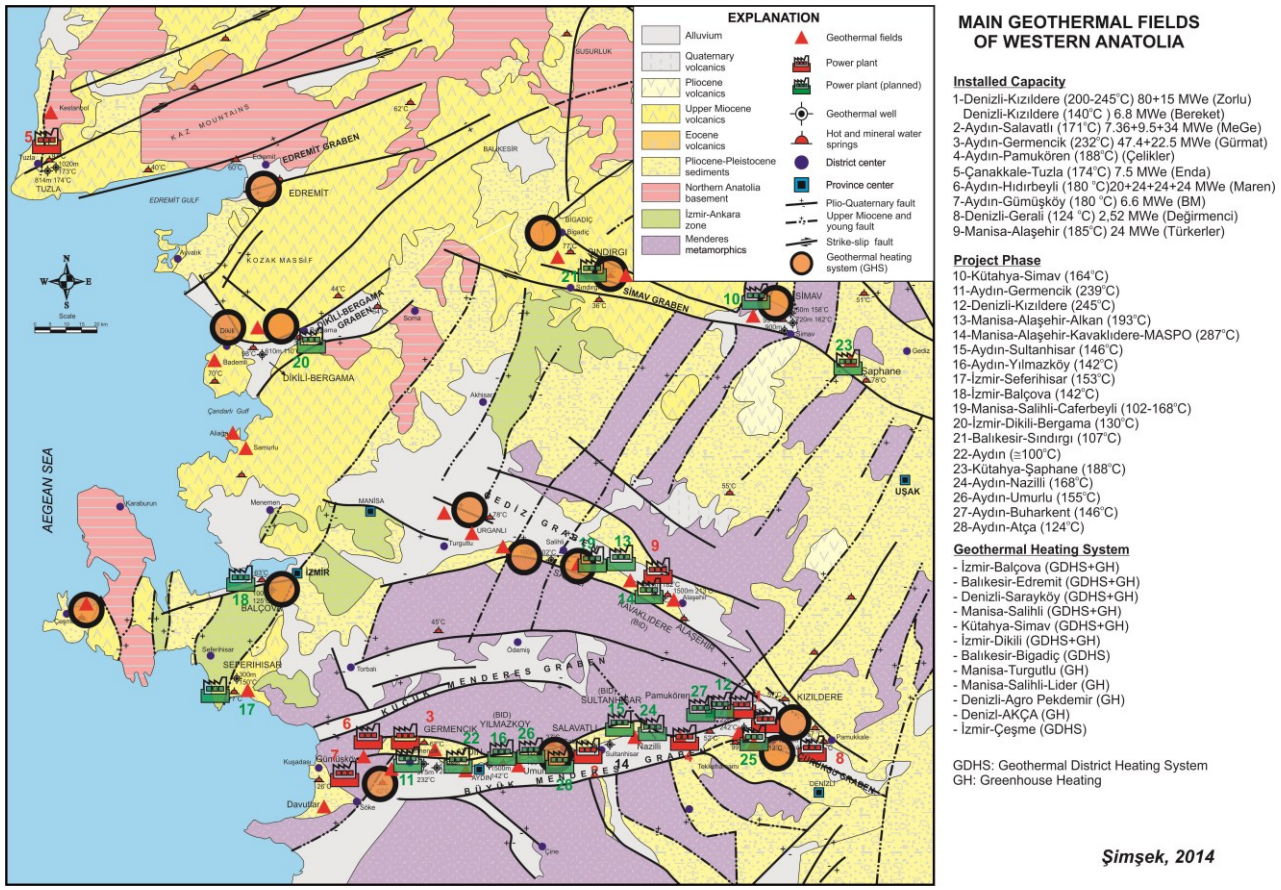

Figure 1. Main geothermal fields of Western Anatolia

5. 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, 3,400 residences), Simav (1991, 7,500 residences), Kirsehir (1994, 1,900 residences), Kizilcahamam (1995, 2,500 residences), Izmir (1996, 35,000 residences), Sandikli (1998, 6,000 residences), Afyon (1996, 8,000 residences), Kozakli (1996, 3,000 residences), Diyadin (1999, 570 residences), Salihli (2002, 7,292 residences), Edremit (2003, 4,881 residences), Balikesir-Bigadic (2005, 1,500 residences), Yozgat-Sorgun (2008, 1,500 residences), Izmir-Bergama (450 residences), Izmir-Dikili (1,160 residences) and Denizli-Saraykoy (2,200 residences). Today, as low as 40-45°C temperature geothermal waters are used for space heating in Turkey without heat pumps (Table 3).

As of December 2014, geothermal direct use applications have reached a total of install capacity of 2,886.3 MWt. This figure is composed of 805 MWt for district heating (equals to the heat requirement of nearly 90,000 residences equivalance in 16 cities), 420 MWt for individual space heating (mostly thermal facilities and hotels), 612 MWt for greenhouse heating (nearly 3 million m2), 1,005 MWt for balneological use (400 thermal facilities and spas), 1.5 MWt for agricultural drying (single application in Kirsehir) and the geothermal heat pump applications of 42.8 MWt (Figure 2) (Table 5).

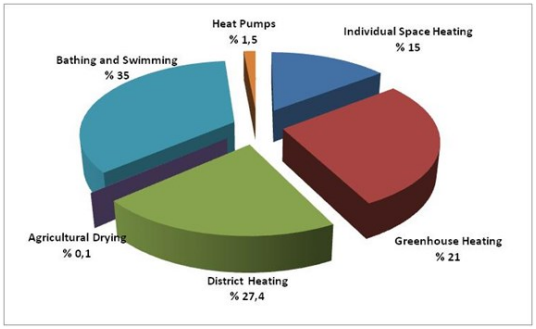

Figure 2: Geothermal Direct Use Distribution in Turkey (December 2014)

The geothermal greenhouse applications have reached ~3 million m^2 and due to the market satisfaction, the greenhouse investments slowed down in the last 1-2 years. Tomatoes are mostly grown in the greenhouses. The major markets are Russia (60%) and Europe (20%) and 10% of the yield is sold country wide. 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 : 310,000 m^2
- Denizli-Kizildere-Tosunlar : 200,000m^2
- Sanliurfa-Karaali : 474,000 m^2
- Izmir-Balcova : 100,000 m^2

16 million local and 10,000 foreign visitors are benefiting from balneological utilities in Turkey. Compared to greenhouse heating applications in Turkey, the thermal tourism and balneology investments have grown in the recent years and reached 1,005 MWt .

The geothermal heat pump applications including Metro Meydan M1 Shopping Center/Istanbul (4.6 MWt) and Terme Maris Facility in Dalaman (0.2 MWt), Titanic Hotel in Antalya (8 MWt), Antalya Terracity (12 MWt), Sabiha Gokcen Airport in Istanbul (1.9 MWt) residential heating (1.1 MWt) and others (13.2 MWt, like schools, office buildings etc.) have gained speed in Turkey. The total geothermal heat pump applications have reached an installed capacity of about 42.8 MWt (Table 4) (Cetin, and Paksoy, 2013). With the geothermal heat pump application, installed capacity for geothermal direct use capacity has reached 2,886.3 MWt.

6. RESULTS

The geothermal electricity applications started in 1984 and the geothermal direct use applications started in 1986 in Turkey. Geothermal district heating systems increased rapidly until the year 2000, but, geothermal electricity production aplications remained static at 15 MWe (Kizildere single flash power plant) until 2007. With the release of the geothermal law and the renewable energy law bringing incentives for the electricity production from the renewables, the Turkish private sector went in geothermal power production investments, whereas the geothermal electricity production has reached to 400 MWe since 2007. This can be recognised as a big success and expansion. The funds allocated by the Turkish Government, exploration activities of MTA (General Directorate of Mineral Research and Exploration of Turkey) and the tendering of the geothermal fields after 1-2 exploration wells drilled in each geothermal field took an important role in this expansion.

In addition, thermal tourism (balneology) investments have gained an expansion of nearly 20% in the last 1-2 years due to the increase in the awareness of the importance of thermal tourism and public health and to meet the vacation needs of the people during winter time.

Hereafter, Turkey shall give importance to geothermal district cooling. 70-80% of our hot geothermal resources are located in Western Anatolia and this area is extremely hot during the summer season and cooling is an important need. To utilize cooling geothermally would be important in terms of the environment and decrease the dependance to fosil fuels and foreign countries.

Our second aim could be to give emphasize on Enhanced Geothermal Systems, to discover its potential and to apply special incentives to EGS investments.

According to the estimations and calculations of Turkish Geothermal Association, the geothermal electricity production potential of Turkey could be an important amount if the purchase guarantee of the Turkish Government would be 20 years with a feed in tarif of 20 USDcent/kWh in the coming 25 years.

The targeted geothermal electricity production amount has been announced as 1,500 MWe for 2023 by the Turkish Government which is 100th Anniversary of Turkish Republic.

REFERENCES

Dagistan, H. Geothermal Resource Potential of Türkiye, Applications, Ssectorial Development and 2016 Projections, US-Turkey Geothermal Workshop, 21-22 October 2014, Ankara.

Mertoglu, O., Simsek, S., Dagistan, H., Bakir, N., Dogdu, N., Geothermal Country Update Report of Turkey (2005-2010), Proceedings World Geothermal Congress 2010, Bali-Indonesia

Korkmaz, E.D., Serpen, E., Satman, A., Turkey's Geothermal Energy Potential: Updated Results Proceedings, Thirty-Fifth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, February 1-3, 2010.

Yilmazer, S., Batı Anadolu'nun Olasi Jeotermal Potansiyelinin Belirlenmesi, Türkiye 11. Enerji Kongresi , Tepekule Kongre Merkezi, 2009, İzmir.

TJD, Geothermal Energy Development Report, Turkish Geothermal Association (TJD), 2012, Ankara.

TR Ministry of Development, 10th Development Plan (2014-2018), Geothermal Working Group Report, 2013, Ankara

Parlaktuna, M., Mertoglu, O., Simsek, S., Senturk, N., Paksoy, H., Basarir, N., Geothermal Country Update Report of Turkey (2010-2013), EGC2013, Pisa, Italy.

Simsek S. Main Geothermal fields of Western Anatolia, Jeotermal Çalışmalar artiyor. Yer Mühendisliği Blt. Sayı 2, 2014, , s,52-56, Istanbul.

TJD, Geothermal Energy Development Report, Turkish Geothermal Association (TJD), 2013 Ankara.

Cetin, A., and Paksoy, H., 2013, Shallow Geothermal Applications in Turkey, EGC2013, Pisa, Italy,

Yanmaz, Müslüm., 2014, Chairman of Geothermal Greenhouse Owners Union in Southeastern Anatolian Project Region, personal communication, Sanliurfa

STANDARD TABLES

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014	400	2660	38656		22749				2896		64732,2	
Under construction in December 2014	165	1100										
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020	1077,3	7172										

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2014

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

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

[3] Data for 2014 if available, otherwise for 2013. 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 2014[3] GWh/yr	Total under Constr. or Planned MWe
Denizli	Kizildere	1984/2003	2		1F, 2F, B	95	95	700	
Aydin	Dora1,2,3a	2006/2013	3		B	50,86	50,86	546	37
Aydin	Germencik	2009	1		2F	47,4	47,4	400	47,4
Çanakkale	Tuzla	2010	1		B	7,5	7,5	60	7,5
Aydin	Hidirbeyli	2011/2013	3		B	92	92	677	96
Aydin	Pamukoren	2013	1		B	45	45	360	
Denizli	Kizildere(b	2007	1		B	6,85	6,85	10,3	
Manisa	Alasehir	2014	1		B	24	24	250	
Aydın	Gümüşköy	2014	1		B	6,6	6,6	40	6,6
Denizli	Gerali	2014	1		B	2,52	2,52	17	
Aydin	Germencik	2014				22,5	22,5	187	25,3
Total						400,23	400,23	3247,3	219,8

* 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 2014 (other than heat pumps)

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

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

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)
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. (^oC) - outlet temp. (^oC)] 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

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)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet (aver.)	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Balcova+Narlidere (Izmir)	D		140				243			
Gonen	D		80				19			
Simav	D		137				72			
Kirsehir	D		56				20			
Kizilcahamam	D		75				28			
Afyon	D		95				102			
Kozakli	D		95				34			
Sandikli	D		75				65			
Diyadin	D		70				62			
Salihli	D		94				57			
Saraykoy	D		140				19			
Edremit	D		60				39			
Dikili	D		125				19			
Bergama	D		65				3			
Güre	D		65				4			
Sorgun	D		80				19			
TOTAL							805			

* Only city district heating systems including, houses, governmental buildings and universtities are included in this table.
Over 400 other direct use applications exit, which would be too much to be included in this list. The capacities about other direct use applications can be seen in table 5.

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2014

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected rejected to the ground in the cooling mode as this reduces the effect of global warming.

[1] Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

[2] Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

[3] Report the COP = (output thermal energy/input energy of compressor) for your climate

[4] Report the equivalent full load operating hours per year, or = capacity factor x 8760

[5] Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or Water Temp. (°C)[1]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load Hr/Year[4]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Istanbul Meydan Mall		4600		V			102,33	
Residential		1136.3					22,67	
Antalya Lara		2000		W			38,82	
Antalya Terracity		12000		W			242,65	
Titanic Hotel Antalya		8000		W			159,6	
Others (Schools, office buildings, etc.)		13208,7					356,12	
Sabiha Gokcen Airport		1855		O			38	
TOTAL		42800					960,19	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2014

[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)
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]	420	4635	0,35
District Heating [4]	805	8885	0,35
Air Conditioning (Cooling)			
Greenhouse Heating	612	11580	0,6
Fish Farming			
Animal Farming			
Agricultural Drying[5]	1,5	50	0,3
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	1005	19016	0,6
Other Uses (specify)			
Subtotal	2843,5	44166	
Geothermal Heat Pumps	42,8	960	0,7
TOTAL	2886,3	45126	

[4] Other than heat pumps; volume heating of curing houses, balneological therapy centers, hotels, motels, hot spring facilities, geothermal spas including sanitary hot water heating, thermal facilities, individual buildings, thermal vacation, therapy and recreation complexes

[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, 2010 TO DECEMBER 31, 2014 (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 (gradient)	
Exploration[1]	(all)					
Production	>150° C	130			20	323
	150-100° C			20	10	37
	<100° C		80		15	130
Injection	(all)	70	20			80
Total		200	100	20	45	570

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 Program
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	80	100	50	10		50
2011	100	140	60	15		60
2012	130	165	70	20		75
2013	140	195	80	25		85
2014	150	250	90	30		100
Total	600	850	350	100		370

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl.	Field Development Including Production	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
2010-2014	1250	750	300	2000	85	15