Geothermal Energy Use, Country Update for Turkey

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Keywords: Geothermal, potential, country update, Turkey

Abstract

Since the 1960's, 230 geothermal fields have been discovered in Turkey. Geothermal direct-use applications have reached 3262,3 MWt geothermal heating including district heating (1033 MWt), 3,93 million m^2 greenhouse heating (760 MWt), thermal facilities, hotels etc heating 420 MWt, balneological use (1,005 MWt), agricultural drying (1,5 MWt) and heat pump applications (42,8 MWt). Geothermal electricity production is 650 MWe (Aydin-Germencik, Aydin-Salavatli, Denizli-Kizildere, Aydin-Hidirbeyli, Canakkale-Tuzla, Aydın-Pamukören, Aydin-Gumuskoy and others) as of April 2016. Liquid carbon dioxide and dry ice production factories are integrated to the Kizildere and Salavatli geothermal power plants. With the existing geothermal wells and spring discharge water, the proven geothermal heat capacity calculated by MTA is totally 8000 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 4 years in Turkey. Geothermal electricity production increased by 380% and balneological use by 116% between 2013 - 2016. 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).

The issued geothermal law and incentives contributed to the increase in geothermal electricity production investments within Turkish private sector. Beside of the hydrothermal system utilization, Turkey shall give emphasize on EGS systems for future projections.

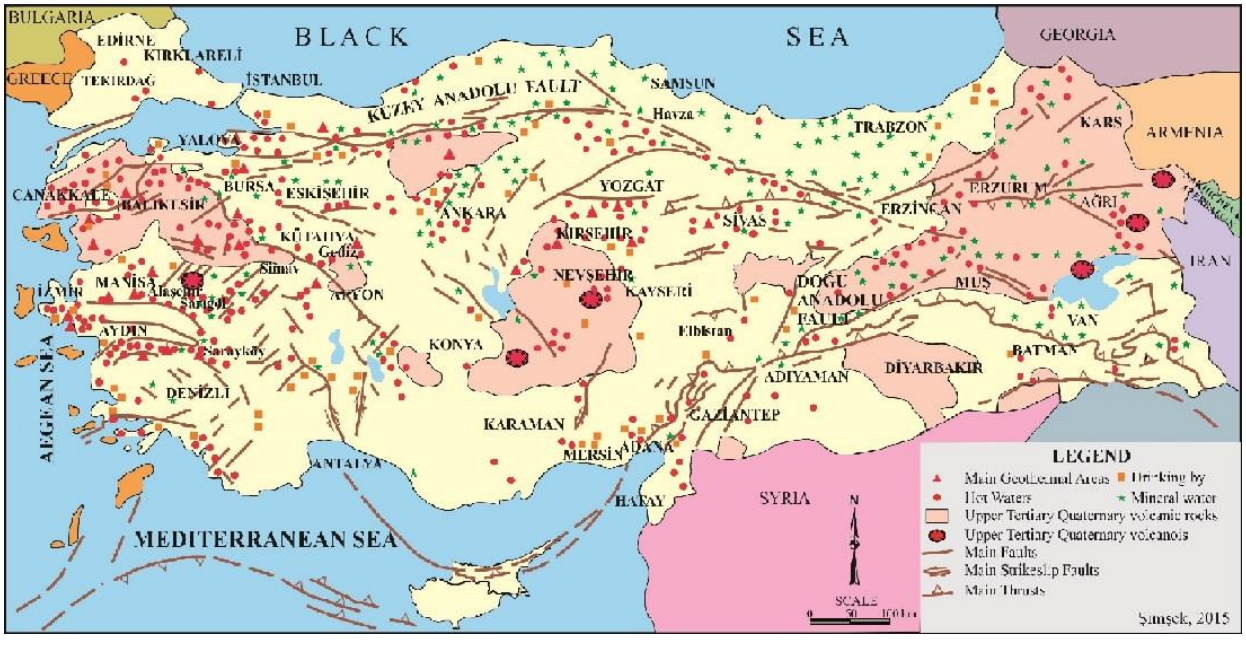

Figure 1: Distribution of the Main Geothermal Areas and Natural Discharges in Turkey

1. GEOTHERMAL POTENTIAL OF TURKEY

In Turkey, studies have identified more than 230 geothermal fields by MTA (General Directorate of Mineral Research and Exploration of Turkey) which can be useful at the economic scale and about 2000 hot and mineral water resources (spring and well discharge and reservoir temperature) which have the temperatures ranging from 20 to 287°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 and in the Central and Eastern Anatolia volcanic regions (Figure 2).

Up to now, a total of 1441 geothermal exploratory, production and reinjection wells have been drilled in Turkey by MTA and the private sector in Turkey (MTA private communication, 2016). Until the end of 2015, MTA has tendered 142 geothermal fields (including wells) to private sector

The geothermal potential is estimated as 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 3262,3 MWt for direct-use (including heat pumps) and 650 MWe for power production in Turkey, where liquid carbon dioxide and dry ice production factories are integrated to the 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 2000 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 4500 MWe (TJD, 2013).

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 USD cent/kWh (Mertoglu at all, 2015).

2. PRESENT SITUATION OF GEOTHERMAL WELLS

A total of about 1441 (600 by MTA and 841 by private sector) geothermal exploration, production and injection wells for electricity production and direct use purposes have been drilled in Turkey with a total depth of 1.048.449m.

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

Nearly 85 % of the geothermal exploration wells have been drilled in the Western Anatolia region 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 solar). 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 April 2016, there exist 30 operating geothermal power plants at 15 geothermal fields in Turkey which have a total installed capacity of 650 MWe (Figure 2, Table 1).

The number of geothermal electricity production licenses in Turkey is 31 and has reached 838,9 MWe install capacity. The number of geothermal electricity preliminary licenses is 28 and has reached 437,9 MWe install capacity. It makes totally 1276,8 MWe.

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, 3400 residences, geothermal water temperature is ~ 80°C), Simav (1991, 12000 residences, ~120°C), Kirsehir (1994, 1900 residences, ~57°C), Kizilcahamam (1995, 2500 residences, ~ 80°C), Izmir (1996, 35.000 residences, ~ 115-142°C), Sandikli

(1998, 11000 residences, ~ 70°C), Afyon (1996, 14000 residences, ~ 95°C), Kozakli (1996, 3000 residences, ~ 90°C), Diyadin (1999, 570 residences, 70°C), Salihli (2002, 8500 residences, 94°C), Edremit (2003, 6000 residences, 60°C), Balikesir-Bigadic (2005, 1500 residences, 96°C), Yozgat-Sorgun (2008, 1500 residences, 80°C), Izmir-Bergama (450 residences), Izmir-Dikili (2000 residences) and Denizli-Saraykoy (2500 residences). Today, as low as 40-45°C temperature geothermal waters are used for space heating in Turkey without heatpumps (Table 3).

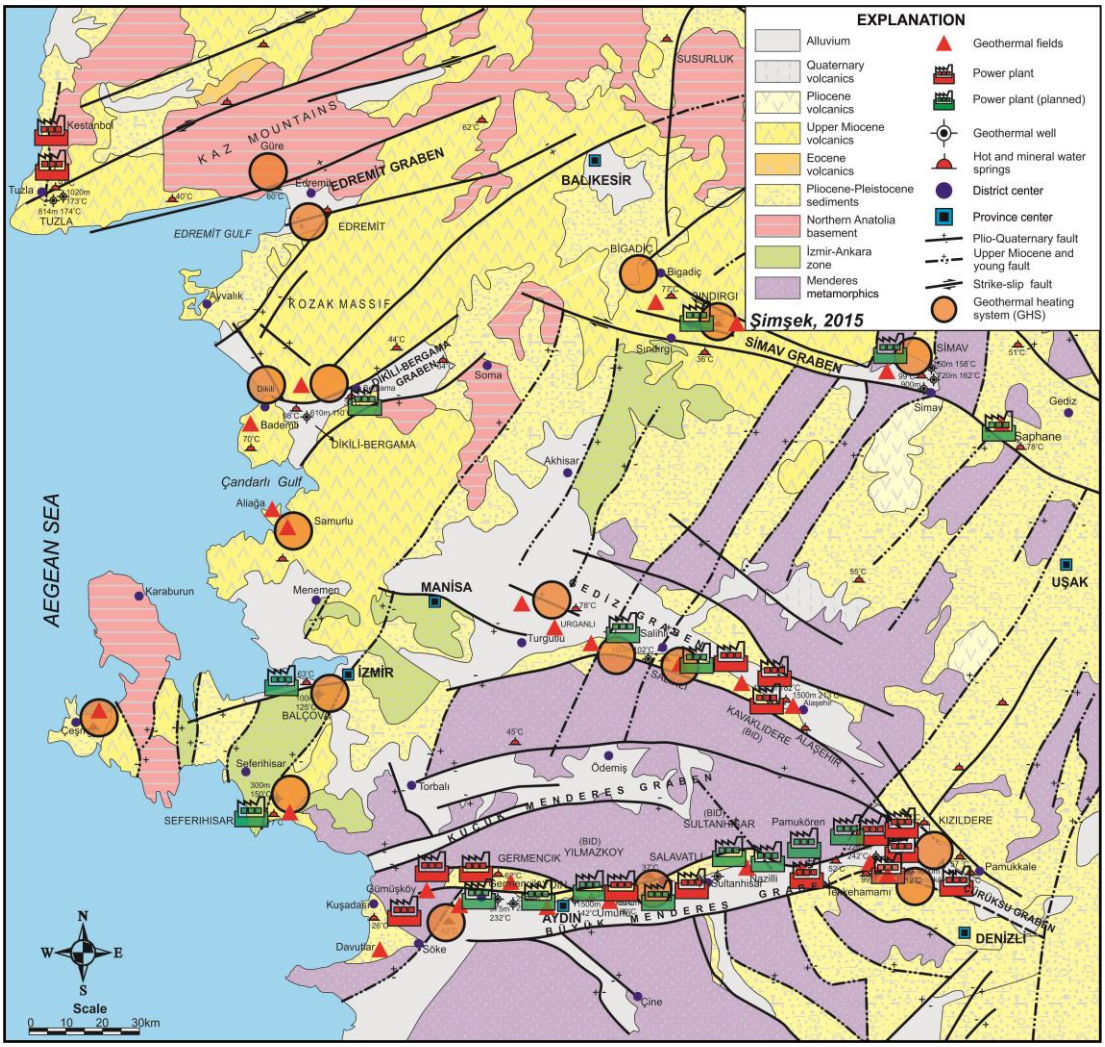

Figure 2: Main geothermal fields and geothermal applications Western Anatolia of Turkey.

As of April 2016, geothermal direct use applications have reached a total of install capacity of 3262,3 MWt. This figure is composed of 1033 MWt district heating of (equals to the heat requirement of nearly 115.000 residences equivalance in 17 cities), 420 MWt individual space heating (mostly thermal facilities and hotels), 760 MWt greenhouse heating (3,93 million m^2), 1005 MWt balneological use (400 thermal facilities and spas), 1,5 MWt agricultural drying (single application in Kirsehir) and the geothermal heat pump applications of 42,8 MWt (Table D1).

The geothermal greenhouse applications have reached to 3,93 million m^2 and due to the market satisfaction, the greenhouse investments slowed down in last 1-2 y years. The major greenhouse applications heated geothermally are as follows:

Izmir-Dikili,Bergama : 1,200,000 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 : 200,000 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 1005 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 İstanbul (1,9 MWt) residential heating (1,1 MWt) and others (13,2 MWt, like schools, Office buildings etc.) have gained speed in Turkey. Totally, 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 has reached 3262,3 MWt Table 1, Table C.

Table1: Geothermal Direct use capacities in Turkey

UTILIZATION	CAPACITY
GEOTHERMAL DISTRICT HEATING (CITY, RESIDENCES)	115000 residences equivalence (1033 MWt)
GREENHOUSE HEATING	3,93 Million m2 (760 MWt)
HEATING OF THERMAL FACILITIES, SPAS, THERMAL HOTELS AND TIME-SHARE FACILITIES	46.400 residences equivalence (420 MWt)
THE HEAT ENERGY OF THERMAL WATER USE IN HOTELS, SPAS AND TIME-SHARE FACILITIES	400 Spas (1005 MWt) (18,5 Million guests/annual)
AGRICULTURAL DRYING	1,5 MWt
GEOTHERMAL HEAT PUMP	42,8 MWt
TOTAL HEAT USE	**3262,3 MWt (313.000 Residences Equivalence)**
TOTAL ELECTRICITY PRODUCTION	**650 MWe** (Aydın-Germencik, Denizli-Sarayköy, Aydın Salavatlı, Aydın-Hıdırbeyli, Çanakkale-Tuzla, Aydın Pamukören, Aydın-Gümüşköy)
CARBONDIOKSITE PRODUCTION	240.000 Tons/year

6. CONCLUSIONS

The geothermal electricity applications started in 1984 and the geothermal direct use applications started in 1986 in Turkey. Geothermal district heating system applications increased rapidly until the year 2000, but, geothermal electricity production applications 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 650 MWe since 2007. This can be recognised as big success and expansion. The funds allocated by the Turkish Government, exploration activities of MTA and the tendering of the geothermal fields after 1-2 exploration wells drilled in each geothermal field took an important role in this expansion.

Our second aim could be to give emphasize on Enhanced Geothermal Systems (EGS), 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 coming 25 years.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country		Share of geothermal in total electric power generation	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2015 *	650,22	5273,8	74626,7			
Under construction end of 2015	96,22	780,42				
Total projected by 2018	537,24	4357,44				
Total expected by 2020	1283,7	10.411,66				
In case information on geothermal licenses is available in your country, please specify here the number of licenses in force in 2015 (indicate exploration/exploitation, if applicable):						

* If 2014 numbers need to be used, please identify such numbers using an asterisk

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis-sioned	No of units **	Status	Type	Total capacity installed (MW_e)	Total capacity running (MW_e)	2015 pro-duction * (GWh_e/y)
Denizli	Kızıldere (Zorlu)	1984/2003	2	O	1F,2F+ B	95	95	700
Aydın	Dora 1,2,3 (MeGe)	2006/2013	3	O	B	51,45	51,45	546
Aydın	Germencik (Gürmat)	2009	1	O	2F	47,4	47,4	400
Çanakkale	Tuzla (Enda)	2010	1	O	B	7,5	7,5	60
Aydın	Hıdırbeyli (Maren)	2011/2013	4	O	B	92	92	677
Aydın	Pamukören (Çelikler)	2013	2	O	B	45	45	360
Denizli	Kızıldere (Bereket)	2007	1	O	B	6,85	6,85	10,3
Manisa	Alaşehir (Türkerler)	2014	1	O	B	24	24	250
Aydın	Gümüşköy (BM)	2014	2	O	B	13,2	13,2	80
Denizli	Gerali (Değirmenci)	2014	1	O	B	2,52	2,52	17
Aydın	Germencik (Gürmat)	2014	1	O	B	22,5	22,5	187

Denizli	Tosunlar (Akça)	2015	1	O	B	3,5	3,5	23,6
Aydın	Pamukören (Çelikler)	2015	2	O	B	45	45	394,9
Aydın	Germencik (Gürmat)	2015	3	O	2(B)+2 F	92,4	92,4	678
Manisa	Alaşehir (Zorlu)	2015	1	O	B	45	45	360
Çanakkale	Ayvacik	2016	1	O	B	7,2	7,2	55
Aydın	Umurlu (Kar-Key)	2016	1	O	B	12	12	125
Denizli	Tekkehamam (Greeneco)	2016	1	O	B	12,8	12,8	120
Manisa	Alaşehir-Kemaliye (Enerjeo)	2016	1	O	B	24,9	24,9	230
Total						650,22	650,22	5273,8

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
		2F	Double Flash	O	Other
R	Retired				

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** In case the plant applies re-injection, please indicate with (RI) in this column after number of power generation units

Explanation to tables C, D1 and D2: ‘Geothermal distric1t heating or distrBict cooling’ (Geothermal DH plants) is defined as the use of one or more production fields as sour1ces of heat to supBply thermal energy through a network to multiple buildings or sites, for the use of space or process h3eating or cooling, including associated domestic hot water supply. If greenhouses, spas or any other category is among the consumers supplied from such network, it should be counted as district heating and not within the category of the individual consumer. In case heat pumps are applied in any part of such a network, the also should be reported as district heating and not as geothermal heat pumps. An exception is for distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings; systems of this kind should be reported in table E. For table D2, please give information on large systems only (>500 MW_{th}); installations with geothermal source temperatures <25 °C and depth <400 m should be reported in table E.

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry***		Geothermal heat for individual buildings		Geothermal heat in balneology and other **	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015 *	1033		804,3		420		1005	
Under construction end 2015								
Total projected by 2018	4000		2540				1100	
Total expected by 2020								

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Note: spas and pool are difficult to estimate and are often over-estimated. For calculations of energy use in the pools, be sure to use the inflow and outflow temperature and not the spring or well temperature (unless it is the same as the inflow temperature) for calculating the energy parameters, as some pool need to have the geothermal water cooled before using it in the pools.

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Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commissioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 production * (GW_{th}/y)	Geoth. share in total prod. (%)
Izmir	Balçova+Narlidere	1983	N	N	243			
Balikesir	Gönen	1987	N	N	19			
Kütahya	Simav	1991	N	N	92			
Kırşehir	Kırşehir	1994	N	N	20			
Ankara	Kızılcahamam	1995	N	N	28			
Afyon	Afyon	1996	N	N	127,5			
Nevşehir	Kozaklı	1996	N	N	34			
Afyon	Sandikli	1998	N	N	119			

Agri	Diyadin	1999	N	N	62			
Manisa	Salihli	2002	N	N	57			
Denizli	Sarayköy	2002	N	N	19			
Balikesir	Edremit	2003	N	N	39			
Balikesir	Bigadiç	2005	N	N	7			
Izmir	Dikili	2009	N	N	19			
Izmir	Bergama	2009	N	N	3			
Yozgat	Sorgun	2008	N	N	19			
Kütahya	Sındırgı	2015	N	N	7			
Others					118,5			
Total					1033			

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

*** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Table D2: Existing geothermal direct use other than DH, individual sites

Locality	Plant Name	Year commis-sioned	Cooling **	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GWh_{th}/y)	Geoth. share in total prod. (%)
add	lines	as					
total							

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Explanation to table E: 'Shallow geothermal' installations are considered as not exceeding a depth of 400 m and (natural) geothermal source temperatures of 25 °C. Installations with geothermal source temperatures >25 °C and depth >400 m should be reported in table D1 or D2, respectively. Distribution networks from shallow geothermal sources supplying low-temperature water to heat pumps in individual buildings are not considered geothermal DH *sensu strictu*, and should be reported in table E also.

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015 *		42,8				
Projected total by 2018						

* If 2014 numbers need to be used, please identify such numbers using an asterisk

Table F: Investment and Employment in geothermal energy

	in 2015 *		Expected in 2018	
	Expenditures ** (million €)	Personnel *** (number)	Expenditures ** (million €)	Personnel *** (number)
Geothermal electric power	200	350	1500	
Geothermal direct uses	75	200	1000	
Shallow geothermal				
total	**275**	**550**	**2500**	

* If 2014 numbers need to be used, please identify such numbers using an asterisk

** Expenditures in installation, operation and maintenance, decommissioning

*** Personnel, only direct jobs: Direct jobs – associated with core activities of the geothermal industry – include "jobs created in the manufacturing, delivery, construction, installation, project management and operation and maintenance of the different components of the technology, or power plant, under consideration". For instance, in the geothermal sector, employment created to manufacture or operate turbines is measured as direct jobs.

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D			
Financial Incentives – Investment			
Financial Incentives – Operation/Production	10,5 USDcent/kWh	-	-
Information activities – promotion for the public			
Information activities – geological information			
Education/Training – Academic			
Education/Training – Vocational			

Key for financial incentives:					
DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)