Geothermal Country Update Report of Turkey (2010-2013)

Mahmut Parlaktuna[1] Orhan Mertoglu[2], Sakir Simsek[3], Halime Paksoy[4], Nilgun Basarir[2]

[1]Middle East Technical Univ., Petroleum and Natural Gas Engineering Dept., 06800 Ankara-Turkey
[2]Turkish Geothermal Association, Hosdere Cad. No: 190/12, Çankaya-Ankara
[3]Hacettepe University, Engineering Faculty, Geological Eng., Dept., 06532 Beytepe, Ankara - Turkey
[4]Çukurova University, 01130 Balcalı Adana-Turkey
mahmut@metu.edu.tr

Keywords: Geothermics, geothermal energy, Turkey, geothermal update, electricity, direct use, projections

ABSTRACT

Laws and regulations released by the Grand National Assembly of Turkey regarding the use of Renewable Energy sources and Geothermal Energy boosted the activities on the utilization of geothermal energy in Turkey in the last five years. More than 250 geothermal fields were discovered in Turkey and about 95% of them are low to medium enthalpy fields mainly suitable for direct use applications. Although the geothermal energy potential of Turkey was historically estimated as 31,500 MW_t and recently increased to 60,000 MW_t, the proven potential by drilling activities (4209 MW_t) and natural discharges (600 MW_t) is only 4809 MW_t. As of today, 58 % of the proven capacity (2705 MW_t) is utilized for geothermal heating, including residence heating (805 MW_t), greenhouse heating (612 MW_t), thermal facilities heating (380 MW_t), balneological use (870 MW_t) and heat pump application (38 MW_t). The most remarkable change in the activities took place in the exploration of geothermal resources for electricity production. Current installed capacity is 162.2 MW_e and it is expected to become above 300 MW_e by the end of 2013.

1. LAWS AND REGULATIONS

The Grand National Assembly of Turkey (TBMM) released The Law to Use the Renewable Energy Resources for Electricity Production (No: 5346, Date: May 10, 2005) in order to activate the use of renewable resources (hydro, wind, geothermal, biomass and sun). The law is aiming to extend the use of renewable resources for electricity production, to utilize these sources in a reliable, economical and high-quality manner, to increase the resource diversity and to decrease the greenhouse gas emissions. The law is amended by December 29, 2010 giving the prices of electricity as incentives for different renewable energy resources (Table 1). As observed, electricity produced from geothermal resources has got a higher price than from hydro and wind.

Table 1: Price of electricity in Turkey from renewable resources

Renewable energy	Price (USD-cent/kWh)
Hydro	7.3
Wind	7.3
Geothermal	10.5
Biomass	13.3
Sun	13.3

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.

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

2. GEOTHERMAL POTENTIAL OF TURKEY

Turkey is located on the seismically active Mediterranean Earthquake Belt. The active tectonics of Turkey results from the continental collision of the African and Eurasian plates, as expressed by collisional intra-continental convergence and tectonic-escape-related deformation (Bozkurt, 2001). The neotectonic framework of Turkey is outlined by three major structures: namely the North Anatolian Fault Zone (NAFZ), East Anatolian Fault Zone (EAFZ), and the Aegean-Cyprian Arc - a convergent plate boundary

where the African plate to the south is subducting beneath the Anatolian plate to the north. The continuum of deformation along the NAFZ and EAFZ and the westward extrusion of Anatolia have been accommodated through the internal deformation of Anatolia. Consequently, four distinct neotectonic provinces have been generated: the East Anatolian, the North Anatolian, the Central Anatolian and the West Anatolian extensional provinces (Bozkurt, 2001).

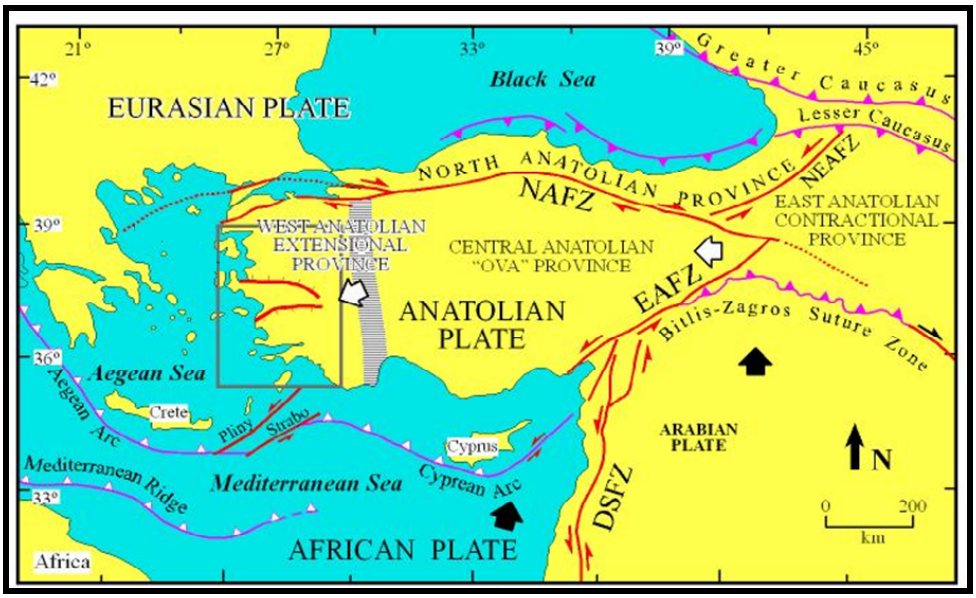

Figure 1: Simplified tectonic map of Turkey showing major noetectonic structures. DSFZ: Dead Sea Fault Zone, EAFZ: East Anatolian Fault Zone, NAFZ: North Anatolian Fault Zone, NEAFZ: Northeast Anatolian Fault Zone (Bozkurt, 2001)

Majority of natural springs as well as geothermal fields of Turkey are located along the major grabens situated in West Anatolian extensional province (Buyuk Menderes, Gediz, Dikili-Bergama, Kucuk Menderes and Edremit Grabens), along the Northern Anatolian Fault Zone, Central and Eastern Anatolia volcanic regions (Figure 2).

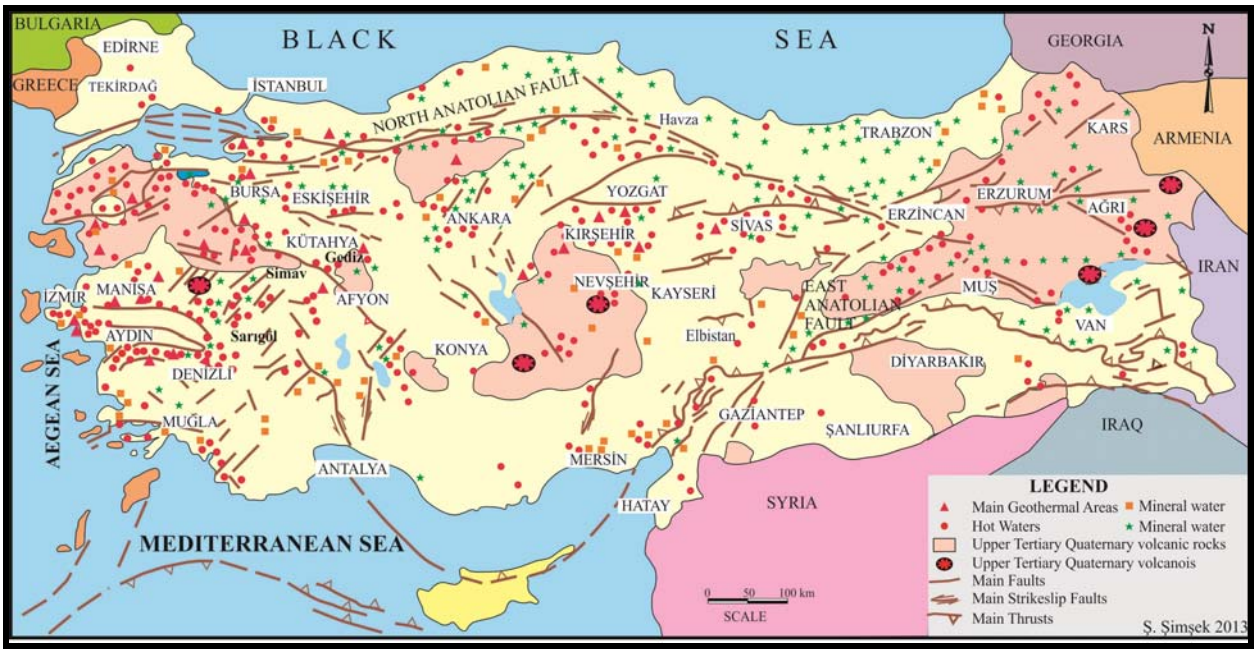

Figure 2: Main neotectonic lines and hot spring distribution of Turkey (Modified after Şimşek, 2009).

Although there are more than 250 localities in Turkey having geothermal manifestations only about half of them were tested by drilling. This brings an extra uncertainty on the prediction of Turkey's geothermal energy potential. Historically the potential of Turkey was reported as 31,500 MW_t in many publications and recently increased to 60,000 MWt (Yılmazer, 2009) which is also included in the 10th Development Plan of the Turkish Republic Ministry of Development, Geothermal Commission Report (2014-2018) (TGA, 2013). A recent study based on Monte-Carlo simulation evaluated 55 potential geothermal fields of Turkey and reported 23,566 MW_t recoverable thermal power based on 15 °C reference temperature (Korkmaz et al., 2010). Among these 55 fields 17 of them having temperatures higher than 100 °C were considered as suitable for electric power generation and Monte Carlo simulation results showed a potential of 710 MW_e proven power generation potential (Korkmaz et al., 2010).

Another study by General Directorate of Mineral Research and Exploration of Turkey (MTA) estimated the proven direct heat application of Turkey as 4809 MW_t by taking into account the natural springs (600 MW_t) and geothermal wells (4209 MW_t) based on a discharge temperature of 35 °C (Dagistan, 2012).

3. DRILLING ACTIVITIES

The ultimate activity of any exploration study for geothermal energy is the drilling of wellbores to bring the energy to the surface. The total number of drilled geothermal wells for geothermal electricity and direct use applications is about 1200 in Turkey since 1960's. About one-third of these wellbores were drilled in the last four years aiming both high-enthalpy and low to medium enthalpy resources. More than 235 wells having temperatures higher than 110 °C were drilled during last 4 years in 28 different geothermal fields mainly in the Buyuk Menderes Graben and Gediz Graben geothermal systems (Kaya, 2012). 31 drilling rigs with different capacities owned by drilling contractors took part in the drilling of those wellbores. The average rig on time of those wellbores with average depth of 2100 m is 42 days (Kaya, 2012).

3. ELECTRICITY PRODUCTION

Kizildere geothermal field was the first field utilized for electricity production in Turkey. Electricity production from Kizildere goes back 1974 where a 0.5 MW_e pilot plant was used to supply electricity for the neighboring three villages. Commercial size power production in Kizildere started in 1984 with an installed capacity of 15 MW_e. Kizildere remained the only producer till 2006 (22 years) after which there exist new additions almost every year. A list of the installed Geothermal Electricity Power Plants in Turkey is presented in Table 2. Installed capacity has increased with an increasing trend within the period of 2009 – 2013. It is expected that four more power plants will be in operation by the end of 2013 with a total installed capacity of 150.2 MW_e (Table 3). Finally, Table 4 lists the projects received license from Energy Market Regulatory Authority (EMRA) of Turkey. If all these projects are realized the total installed capacity will reach a value of 642.8 MW_e (162.2 MW_e already in operation, additional 150.2 MW_e expected by the end of 2013 and 330.4 MW_e received license).

Table 2: Installed geothermal power plants

Field, Province	Owner	Type*	Year	Installed Capacity (MW_e)
Kizildere, Denizli	ZORLU	F	1984	15
Salavatlı (DORA-I), Aydin	MENDERES	B	2006	7.95
Kizildere, Denizli	BEREKET**	B	2007	6.85
Germencik, Aydin	GÜRMAT	F	2009	47.4
Tuzla, Çanakkale	ENDA	B	2010	7.5
Salavatlı (DORA-II), Aydin	MENDERES	B	2010	9.5
Hıdırbeyli (IREM), Aydin	MAREN	B	2011	20
Hıdırbeyli (SINEM), Aydin	MAREN	B	2012	24
Hıdırbeyli (DENIZ), Aydin	MAREN	B	2012	24
TOTAL				**162.2**

* F = Flash,
B = Binary

**Not in operation since 2008

,**Table 3: Geothermal power plants expected to be in operation by the end of 2013**

Field, Province	Owner	Type*	Capacity (MW_e)	Field, Province
Kizildere (Phase-2), Denizli	ZORLU	F	60	Kizildere (Phase-2), Denizli
Kizildere (Phase-2), Denizli	ZORLU	B	15	Kizildere (Phase-2), Denizli
Pamukören, Aydin	ÇELİKLER	B	45	Pamukören, Aydin
Gümüşköy, Aydin	BM	B	13.2	Gümüşköy, Aydin
Salavatlı (DORA-III), Aydin	MENDERES	B	17	Salavatlı (DORA-III), Aydin
TOTAL				**150.2**

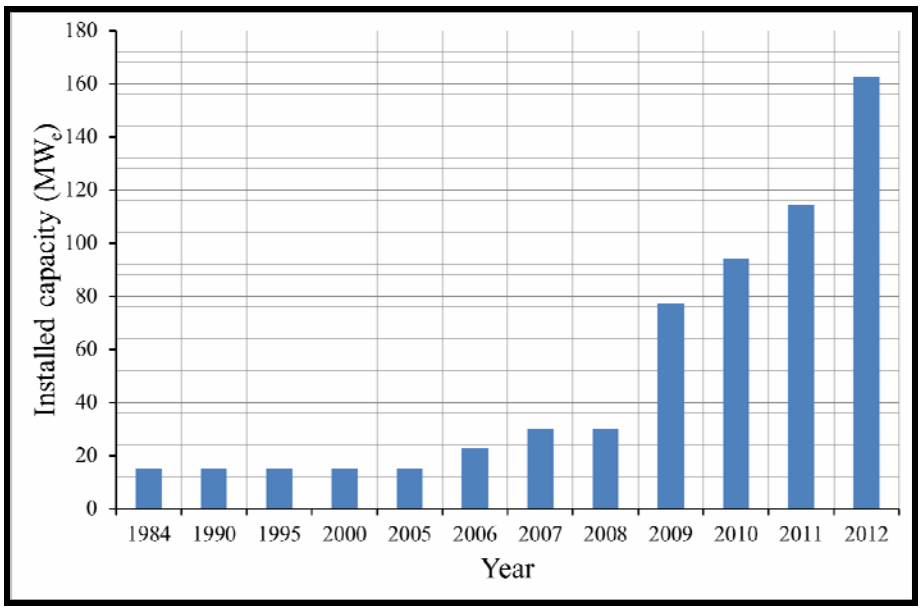

Figure 3: Installed capacity change by time

Table 4: Geothermal power plants projects received license from EMRA

Field, Province	Owner	(MWe)
Babadere, Çanakkale	MTN	3
Manisa	SANKO	15
Sarıkız, Manisa	TURKERLER	10
Alaşehir, Manisa	TURKERLER	24
Alaşehir, Manisa	ZORLU	30
Merkez, Manisa	KEN KIPAS	24
Nazilli, Aydin	KIPER	20
Sultanhisar, Aydin	ÇELİKLER	9.9
Atça, Aydin	ALRES	9.5
Umurlu, Aydin	KARKEY	5
Germencik, Aydin	BURÇ	163
Salavatlı (DORA-IV), Aydin	MENDERES	17
TOTAL		**330.4**

4. DIRECT USE

Space heating is the main type of direct use of geothermal energy in Turkey. Among the three different type of space heating applications, geothermal district heating system (GDHS) has the highest proportion with a capacity of 805 MW_t. There are 16 provinces (mainly in western and central Anatolia) in Turkey utilizing geothermal fluid for residential heating. Gönen was the first town having the GDHS in 1987. Properties of important GDHS are listed in Table 5 (Mertoglu et al. 2010). Almost half of the current capacity is in Balçova field of Izmir. One important observation is that there isn't any new GDHS project after 2008 opposite to the case for electricity production.

Table 5: Important GDHS projects of Turkey

Town, Province	Year	Current capacity (RE*)
Gönen, Balıkesir	1987	3400
Simav, Kütahya	1991	7500
Kırşehir, Kırşehir	1994	1900
Kızılcahamam, Ankara	1995	2500
Balçova, İzmir	1996	35000
Afyon, Afyon	1996	8000
Kozaklı, Nevşehir	1996	3000
Sandıklı, Afyon	1998	6000
Diyadin, Ağrı	1999	570
Salihli, Manisa	2002	7292
Sarayköy, Denizli	2002	2200
Edremit, Balıkesir	2003	4881
Bigadiç, Balıkesir	2005	1500
Sorgun, Yozgat	2008	750
Bergama, İzmir	2008	450
Dikili, İzmir	2008	1160
TOTAL		**86853****

*RE = Residence equivalent, 1 RE = 100 m^2 heated space

** There are other district heating systems with 2590 RE install capacity whereas the heating systems are not operational due to different reasons and are not included into the list.

Greenhouse heating is the second rank space heating application by geothermal energy in Turkey. The first geothermal greenhouse heating application was started in Denizli-Kizildere under the United Nations Development Programme (UNDP) in an area of 2000 m^2 in 1973. Since then, there exists ever increasing trend in the greenhouse heating by geothermal energy reaching an area of 2,811,000 m^2 by 2012 (GEKA, 2012). Majority of the heated area lies in 6 provinces of western Anatolia, but there exists a unique application in southeastern Anatolia (Sanliurfa) with

an area of 367,000 m^2 (Figure 4). Total installed capacity of greenhouse heating is 612 MW_t.

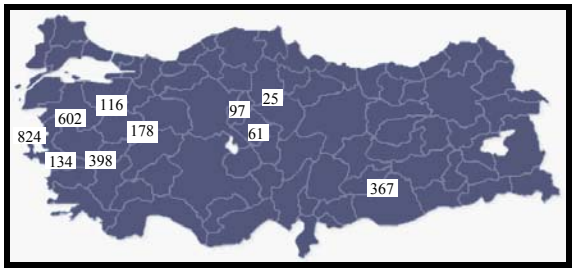

Figure 4: Area of greenhouses heated by geothermal (1000 m^2)

Turkey is well known with its "Hamam-Turkish Bath" culture since Roman-Ottoman periods. People in Anatolia have used natural springs for bathing, recreation and curing purposes for centuries. Among several localities, Hierapolis in Denizli-Pamukkale, Agamennon in Balçova-İzmir and Kükürtlü Kaplıca in Bursa were well known. This tradition is still continuing in Turkey but in a modernized fashion. Thermal facilities in luxury (5 stars) complexes serve their visitors the relaxing atmosphere of geothermal fluid. There are about 190 establishments of this kind in 46 provinces of Turkey. 12 of these establishments have the licenses from Ministry of Health as curing centers and received tourism investment certificate from Ministry of Culture and Tourism. Their bed capacity is 2347. On the other hand, there exist 30 firms with tourism licenses whose total bed capacity is 8567. As the third category, 156 small enterprises received their licenses from local authorities. Their bed capacity is around 16000 (Ministry of Health, 2013). Thermal facility heating and balneology applications have reached capacities of 380 MW_t and 870 MW_t, respectively. The target is to reach 15 million local and 250 thousand international visitors of thermal facilities by the year 2015 (Mertoglu et al. 2010).

Distribution of direct heat use of geothermal energy in Turkey is shown in Figure 5.

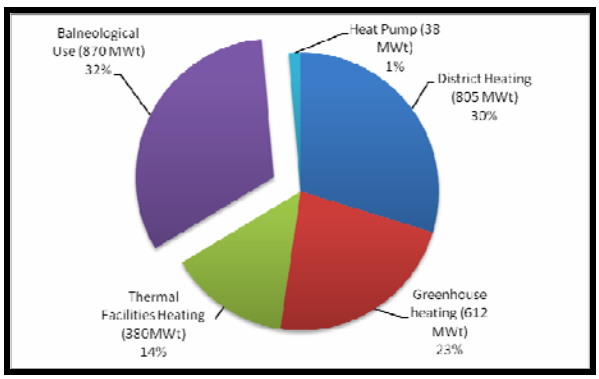

Figure 5: Distribution of Geothermal Direct Use in Turkey

Dry-ice and liquid carbon dioxide is the side product of Denizli – Kizildere geothermal field. Carbon dioxide produced along with hot geothermal fluid is separated and converted into liquid carbon dioxide or dry ice in a factory next to power plant. The factory produces 23,000 tons liquid CO_2 annually (70 % of Turkey's consumption) which is mainly used in carbonated beverages, greenhouses and cooling – preservation processes of the food. The company produces 1,150 tons of dry-ice mainly for cooling purposes (LINDE, 2013).

5. SHALLOW GEOTHERMAL

Shallow geothermal energy - heat in the Earth's uppermost strata (up to 400 metres) and in the groundwater – can be utilized for space heating and cooling through geothermal heat pumps (GHP) and underground thermal energy storage (UTES) systems. The number of such applications started to increase in Turkey following the trend in global market. The total installed capacity of applications for residential and office buildings, shopping malls, and hotels has reached to 38 MW_t in 2009 (Form group, 2009). Most of the larger systems, including Metro Meydan M1 Shopping Center/Istanbul (0.9 MW_t) and Terme Maris Facility in Dalaman (0.2 MW_t) use borehole heat exchangers. Terracity shopping mall in Antalya with a cooling capacity of 12 MW uses heat pumps and groundwater at 17°C (Korun, 2012). For the HABOM project at Sabiha Gokcen Airport 1584 energy piles are used. This system with an installed capacity of 1855 kW is one of the largest energy pile applications in the world (Özkök, 2011)

6. PROJECTIONS

Turkish Geothermal Association recently prepared a report including the projections on the use of geothermal energy by 2018 (Table 6) (TJD, 2013). If these projections are achieved, it is estimated that 300,000 direct and indirect employments can be created.

Table 6: Estimated projections of geothermal applications for the year 2018

Use	Projection
Electricity Production	750 MW_e
Heating (residences, hotels, thermal facilities etc.)	4000 MW_t
Greenhouse heating	2040 MW_t (6,000,000 m^2)
Drying	500 MW_t
Balneology	1100 MW_t 400 spa, thermal facility
Cooling	300 MW_t
Aquaculture + others	400 MW_t
Total direct use	**8340 MW_t**

The report also emphasizes on some important issues to strengthen the geothermal energy use in Turkey.

- Some of recently drilled wellbores encountered with very high temperatures (as high as 287 °C) but low permeability. Enhanced Geothermal Systems (EGS) applications in these fields should be studied with governmental and international support.
- Incentives applied for electricity production from geothermal energy accelerated the activities within this area. Similar incentives should be given to geothermal district heating investments, since this application lost its acceleration within last 5 years.
- Integrated use of geothermal energy (electricity generation, district heating, thermal and balneological use) should be encouraged.
- Turkey should benefit its unique geography which brings sea/sun/cultural tourism together.
- Some of the existing geothermal district heating systems owned by the local governorships and municipalities have difficulties to sustain the systems. Privatization of these facilities would help to enhance and develop the existing geothermal district heating systems.

7. CONCLUSIONS

Being one of the richest countries in geothermal potential, a significant development was achieved in Turkey both in electricity production and direct use of geothermal energy in the period of 2009 to 2013. The following headlines can be listed:

- Geothermal Law and its regulations accelerated the geothermal activity in Turkey. Especially monetary incentives given for electricity production boosted this sector.
- The total installed capacity for electricity is reached to a value of 162.2 MW_e with an increasing rate within last four years. It is expected to be over 300 MW_e by the end of 2013.
- As of today, the capacity of direct heat applications of geothermal energy is 2705 MW_t including residence heating (805 MW_t), greenhouse heating (612 MW_t), thermal facilities heating (380 MW_t), balneological use (870 MW_t) and heat pump application (38 MW_t).

REFERENCES

Bozkurt, E.: Neotectonics of Turkey-a synthesis, *Geodinamica Acta*, **14**, Paris, (2001), 3-30.

Dagistan, H.: Türkiye'de Jeotermal Kaynak Potansiyeli, Uygulamalar, Sektörel Gelisim ve 2015 Projeksiyonu, *Türkiye'de Jeotermal Kaynaklar Arama ve Uygulama Sempozyumu*, (2012), Istanbul (in Turkish).

Form Group,: Metro-Meydan M1 Shopping Center Heat Pump Applications, www.formgroup.com, (2009).

GEKA,: A Report on the Determination of Difficulties to Utilize Geothermal Energy of Greenhouse Heating, (2012) (in Turkish).

Kaya T,: Geothermal Project Development in Turkey - An Overview with Emphasis on Drilling, *Proceedings 2012 GRC Annual Meeting*, Reno, NV, (2012), 159-164

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

Korun, T.: Terracity Shopping Center: Commercial Heat Pump Applications in Turkey, *European Heat Pump Newsletter*, **4**, December (2012).

LINDE,: http://www.habergazete.com/haber-detay/1/13864/Turkiyenin-Gidalarini-Jeotermal-Koruyor-2013-03-05.html (retrieved on March 31, 2013) (in Turkish).

Mertoglu, O., Simsek, Ş., Dagistan, H., Bakir, N., Dogdu, N.: Geothermal Country Update Report of Turkey (2005-2010), *Proceedings of the World Geothermal Congress 2010*, Bali-Indonesia, (2010) paper #0119.

Ministry of Health,: http://www.saglikturizmi.gov.tr/en/83-thermal-hotels-with-tourism-licence.html (retrieved on March 31, 2013)

Özkök, B., HABOM (Havacılık Bakım, Onarım ve Modifikasyon Merkezi) ve BMW Dünyası Binaları, *Tesisat Dergisi*, No:186, June (2011).

Simsek, S.: New Wide Development of Geothermal Power Production in Turkey, *International Geothermal Days Slovakia*, Casta Papiernicka, Slovakia, (2009).

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

Yılmazer, S.: Batı Anadolu'nun Olası Jeotermal Potansiyeli'nin belirlenmesi, *Proceedings of 11th Energy Congress of Turkey*, İzmir, Turkey, (2009) (in Turkish).

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	
	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (MW_e)	Production (GWh_e/yr)	Capacity (%)	Production (%)
In operation end of 2012	162.2	950	57072	239100	0.3	0.4
Under construction end of 2012	150.2					
Total projected by 2015	642.8	3750	71200	324860	0.9	1.1

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name	Year commis s.	No of units	Status	Type	Total inst. Capacity (MW_e)	Total run-ning cap. (MW_e)	2012 product. (GWh_e/y)
Denizli	Kizildere	1984	1	O	1F	15		
Aydin	DORA-1	2006	1	O	B-ORC	7.95		
Denizli	BEREKET	2007	1	N	B-ORC	6.85		
Aydin	Germencik	2009	1	O	2F	47.4		
Çanakkale	Tuzla	2010	1	O	B-ORC	7.5		
Aydin	DORA-II	2010	1	O	B-ORC	9.5		
Aydin	IREM	2011	1	O	B-ORC	20		
Aydin	SINEM	2012	1	O	B-ORC	24		
Aydin	DENIZ	2012	1	O	B-ORC	24		
total						**162.2**		**950**

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)
R	Retired	2F	Double Flash	O	Other

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 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)
In operation end of 2012	805		612		1250	
Under construction end of 2012						
Total projected by 2015	1500		1500		1500	

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

Locality	Plant Name	Year com mis	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	2012 geo-thermal heat prod. (GWh_{th}/y)	Geother. share in total prod. (%)
Balikesir	Gönen	1987	No	No				100
Kütahya	Simav	1991						
Kirsehir	Kirsehir	1994						
Ankara	Kizilcahamam	1995						
İzmir	Balcova	1996			160			
Afyon	Afjet	1996						
Nevsehir	Kozakli	1996						
Afyon	Sandikli	1998						
Agri	Diyadin	1999						
Manisa	Salihli	2002						
Denizli	Sarayköy	2002	Yes					
Balikesir	Edremit	2003	No					
Balikesir	Bigadic	2005						
Yozgat	Sorgun	2008						
Izmir	Bergama	2008						
Izmir	Dikili	2008						
total					**805**			

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

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2012	132	38		3	2.8	
Projected by 2015	150	45				

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	190	1000*	200	1500
Geothermal direct uses	40	7000**	60	12000
Shallow geothermal	7.5		20	
total	**237.5**	**8000**	**280**	**13500**

*Includes drilling and service company activities, **Includes central heating applications, thermal tourism and greenhouse heating

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D			
Financial Incentives – Investment		LIL	
Financial Incentives – Operation/Production	FIT		
Information activities – promotion for the public	Yes		
Information activities – geological information	Governmental institutes, universities and private sector continuously produce and disseminate geological information for geothermal energy		
Education/Training – Academic	Several universities have undergraduate and graduate programs on geothermal energy.		
Education/Training – Vocational	There are vocational education programs on energy, drilling and renewable energy sources		

Key for financial incentives:					
DIS	Direct investment support	RC	Risk coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota