Geothermal Project Development in Turkey — An Overview With Emphasis on Drilling

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Keywords

Turkey, geothermal drilling, cost of geothermal drilling, time analysis, geothermal risk, geothermal energy law

ABSTRACT

Turkey, a net oil and gas importer, has recently attracted considerable private investments in renewable energy, including hydro, wind and geothermal.

Geothermal exploration in Turkey started in the early 1960s. The first use of geothermal resources dates back to the central heating system of the Gönen Park Hotel in 1964. The first geothermal well in a high enthalpy field for potential power production was drilled in 1968; it had a depth of 540 m and a temperature of 198 °C.

Turkey has enough geothermal reserves to satisfy the heat requirements of 1.2 million homes. Analysts estimated the country's potential to be between 1000 MWe and 2000 MWe.

Considering the size of Turkey's geothermal resources, the current development of this clean and renewable resource is still far below an expected level. However during the last two decades, there has been a remarkable increase in the use of geothermal for heating purposes and for electricity generation, which started in 2007. Since 1963, between 850 and 900 geothermal wells have been drilled.

The Turkish Government has recently enacted the Renewable Energy Law, which includes geothermal, and has introduced several incentives to promote the renewable energy market.

Turkey issued the Geothermal Energy Resources Law in June 2007, which was enacted a year later, in June 2008. Besides the current Geothermal Law, new amendments to the Renewable Energy Law have already helped the implementation of geothermal with a purchase warranty. Based on recent industry developments, it is clear that geothermal will contribute significantly to Turkey's future energy supply.

The Geothermal Energy Law regulates geothermal resources, natural mineral water resources and geothermal-related gases in terms of ownership rights, licenses, and their assignment and transfer.

After 2007, when the Geothermal Law became effective, the number of geothermal exploration and drilling projects has grown in Turkey. A significant increase in deep and high-enthalpy well drilling has been observed after the Renewable Energy Law No. 6094 (the "Amending Law") came into effect on 8 January 2011. The Amending Law introduced further USD Fixed Price incentives to encourage investments; i.e., for geothermal power: 10.5 US¢/kWh for the first 10 years after the plants came on line and a, purchase warranty for the electricity that was generated.

This paper reviews geothermal project development in Turkey, with emphasis on drilling activities, particularly on drilling statistics, success rates, rig costs and average penetrating rates. The case histories of the Menderes and Alaşehir/Gediz graben drilling activities are used to illustrate some of the concepts.

Forty eight geothermal wells have been drilled by the Turkish Petroleum International Company (TPIC), which was established in 1988 as a subsidiary of the Turkish Petroleum Corporation (TPAO) to operate in all branches of the oil industry, comprising mainly exploration, drilling, field development, production, transportation, refining, crude oil and oil products trading and distribution. Besides the oil well drilling services, TPIC has conducted geothermal drilling activities and is very active in geothermal services (work over, cementing, well testing, wire line services, directional drilling etc.). TPIC should have successfully completed almost 120,000 m of geothermal well drilling by the end of May 2012. (Kaya 2011)

1. Introduction

Turkey has a unique geographic position at the crossroads between Europe and Asia. It is located on an active tectonic, orogenetic belt, the Alpine-Himalaya Orogen with young faults and active volcanism. The exact reason of Turkey's substantial geothermal resource potential is the perfect location of Turkey (on the ring of fire). Many earthquakes occur each year in different parts of Turkey. It should be noted that 90% of the world's earthquakes and 89% of the world's largest earthquakes occur along the Ring of Fire.

Figure 1. Main neotectonic lines and hot spring distribution of Turkey (Şimşek, 2009).

In Turkey, studies show that more than 186 geothermal fields may be of commercial scale and about 1500 hot and mineral water resources (spring discharge and reservoir temperature) with temperatures ranging from 20 to 287.3°C

With the existing springs (600 MWt) and geothermal wells (3478 MWt), the proven geothermal capacity calculated by MTA (General Directorate of Mineral Research and Exploration) is 4078 MWt (discharge temperature is assumed as 35°C). The estimated geothermal potential is estimated as 31,500 MWt. The installed geothermal heat capacity is 2084 MWt for direct-use (650 Residences heating, 850 Greenhouse heating, 550 thermal facilities, rest is others) and 114 MWe for power production in Turkey. Up to now, around 900 geothermal exploration, production and re-injection wells and 300 gradient wells have been drilled in Turkey. After the date of Geothermal Law enacting at 2007, number of drilling wells which are for power generation has been increased significantly. More than 100 wells which are 110 ºC and more have been drilled during last 3 years in 28 different geothermal fields.

Since 2007, beside state exploration company, MTA, which has been drilling geothermal wells for only exploration and production

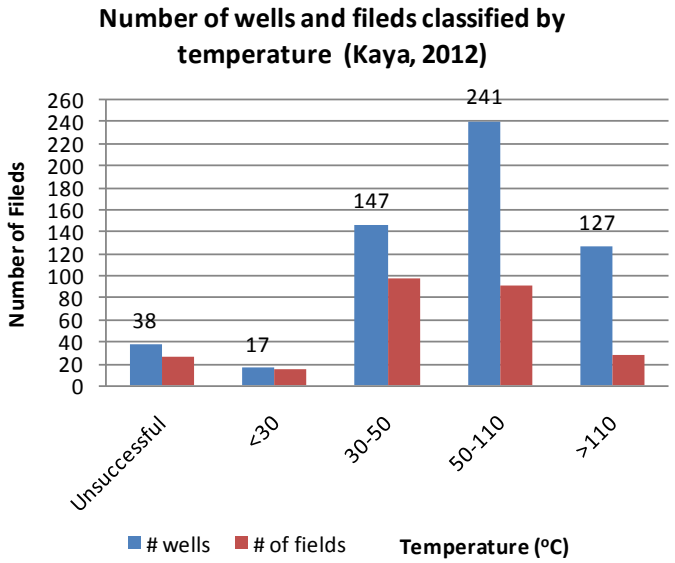

Figure 2. Number of geothermal fields and wells with temperature classification in Turkey.

purposes and since 1960's for power generation, some oil drilling expertise company has started to drill geothermal well.

After that date, concept of the drilling in geothermal industry has started to shape in Turkey. Also, daily rate cost, having services from different companies like, cementing, mud and directional have started.

2. Geothermal Drilling Costs for Power Projects

As the case with world geothermal power projects, geothermal power plant production and injection well installation costs are major parts of investment in Turkey. Exploration, production and injection well installation costs can be 25-30% for a high-grade to 50-60% or more for the investment which have a low-grade/ low permeability geothermal fields.

Turkey's current geothermal drilling operations are being executed under drilling service contract structures which are predominantly "unit time rate" like in New Zealand, Kenya and Indonesia. It is also a possible turnkey by TPIC. In contrast with the contract environments currently adopted in recent geothermal drilling operations which are predominantly "meter-rate and 'turnkey' in Iceland. Meter-rate and turnkey are used for direct use drilling in Turkey.

In this part of study, major effects for the geothermal well construction in Turkey are examined. Thus, the need to update information on two well construction cost drivers which are rig rate and fuel is considered. Indices show that how costs have changed with time. The current daily rate cost of 750-900HP rig is 14.000-16.000, 1350-2000HP rigs is $18.000.

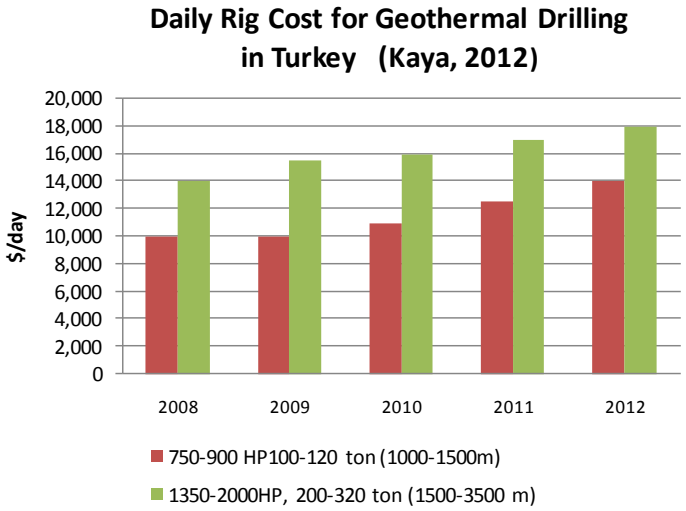

Figure 3. Average Rig Rate Cost for Geothermal Drilling in Turkey (May 2012) (Kaya, 2012).

Rig rate and fuel cost are just one part of well construction costs. Besides the drilling rig rate and fuel cost, other major costs of well construction include steel, cement, rental items cementing, mud services, and labor. However, because of limited rig availability and having high oil price, these two major factors are much more effective on drilling cost.

Number of active rigs for geothermal power projects is around 16 now for geothermal power projects which are located mainly Aegean Region of Turkey (May 2012).

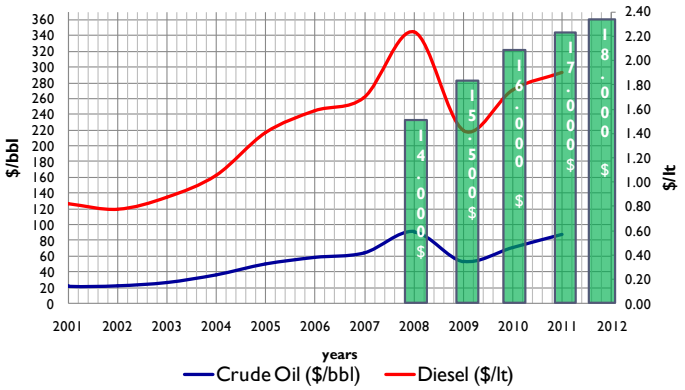

Figure 4. Comparison of rig rate, fuel, and crude oil cost chained vs. time (Kaya, 2012).

Drilling contractor costs including labor and drilling materials continue to rise and thus the rig daily rates are forced to increase. The drilling business continues to be in a state of flux as indicated by the shift from drilling oil. High services and material price level of oil drilling continue to increase in geothermal drilling. The expectation of drilling contractors is that rig daily rates will continue to rise in the immediate future and are unlikely to go down as long as oil prices remain high in geothermal high temperature and deep well drilling in Turkey.

3. Typical Capacity of Drilling Rigs for Deep Geothermal Drilling Including TPIC Rig Inventory

The equipments used by TPIC are the products of well-known firms in the world. The current drilling rigs are from the National Oil Varco (NOV), Upetrom and Drillmec, IDECO IRI. All of TPIC Romanian type rigs are modified with respect to the western standards. All of our workover rigs are mobile type, and produced by the Ideco-IRI.

Table 1. Rig Count in Geothermal Drilling in Turkey (Kaya, 2012).

Drilling Rigs in Geothermal Power Projects in Turkey (May 2012)				
#	Rig	Place	Capacity (w/ 4 1/2" DP)	Company
1	F-320/5	Denizli	6210 m/2000 HP	TPIC
2	F 200/11	Aydın	4000 m/1350 HP	TPIC
3	F200/10	Manisa	4000 m/1350 HP	TPIC
4	IRI 100/1	Aydın	425 HP/W.OWER	TPIC
5	MR8000	Manisa	4300 m/1080 HP	MAPEK
6	MR8000	Aydın	4300 m/1080 HP	MAREN
7	IDECO H44	Aydın	3000 m / 750 HP	POLMAK
8	F. Cooper LTO-	Aydın	2500m/750 HP	AME
9	Wilson 75	Aydın	2500m/900 HP	AME
10	NAT 80 B	Aydın	3500 m/1000 HP	AME
11	F200	Aydın	4000 m/1350 HP	AME
12	BD125	Denizli	1600 HP	DEĞİRMENCİ
13	Gefco 185 K	Konya	2000m/600 HP	GM Müh
14	MR6000	İzmir	2000 m/540 HP	MTA
15	Not Specified	Manisa	2000m/600 HP	Merty
16	Not Specified	Manisa	2000m/600 HP	Petrogaz

Beside TPIC rigs, Turkish local drilling companies have been drilling geothermal wells mainly with American (NOV), Italian (Drillmec) , Romanian (Upetrom) rigs amd other name.

The cost of high temperature and deep geothermal well drilling is generally higher than oil and natural gas well drilling.

Dealing with high temperatures and deviation as well as unexpected problems are the main reasons that increase the cost. High temperature and deviation can also affect drill string, wellhead and surface equipment's performance. However, shallow depth geothermal drilling cost (around 1000-1200 m) is cheaper than oil drilling in Turkey. Because of availability of more suitable rigs for low pressure and temperature material, cost saving in shallow drilling is possible.

The approximate cost and cost parameters of a 30, 45, and 60-days well from spud to release date are shown in Table 2 and Figure 5. Rig rental cost including mobilization and demobilization and fuel cost is more than 50 % of well cost. It may be 55-60% for some wells.

Table 2. Cost of a Planned 1500-2500-3200 MD Geothermal Well in Aegean Region (Kaya,2012).

May 2011	1500 m	2500 m	3200 m
SERVICES (30/45 /60 DAYs WELL DRILLING)	Price (USD)	Price (USD)	Price (USD)
Land Acqusition and permission	40,000	50,000	50,000
Pre-Spud Services, waste handling	80,000	120,400	120,400
Material Purchase (casing, bit, welhead etc.)	350,000	607,440	850,000
Fuel	228,000	352,000	475,000
Mob & De-mob	200,000	300,000	300,000
Total Operating Cost (17.500$/day)	525,000	790,000	1,050,000
Mud Service	90,000	120,282	160,000
Cementing Service	120,000	180,783	220,000
Wireline logging	50,000	150,000	150,000
Acidizing	39,739	39,739	39,739
Well tests	35,000	40,000	40,000
Total Budget (%10 contingency)	1,757,739	2,750,644	3,332,139

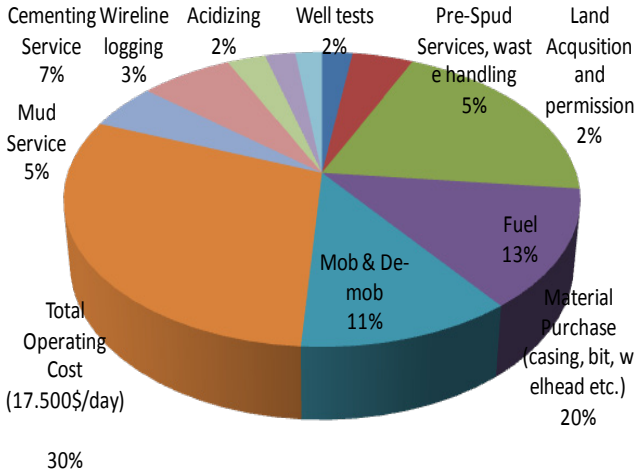

Figure 5. Average Percentages of Cost Parameters of a Planned.

4. Penetration Rate of Geothermal Drilling in Turkey and Comparison of Directional Drilling in Kenya and Iceland

According to TPIC drilling experiences in Menderes and Alaşehir graben, mostly metamorphic, schist, limestone, sandstone and marble formations, average penetration rate in is 45-50 days for 2000-2500 meters for both directional and vertical production wells, and more than 70 days for the 2800-3000 meters exploration wells.

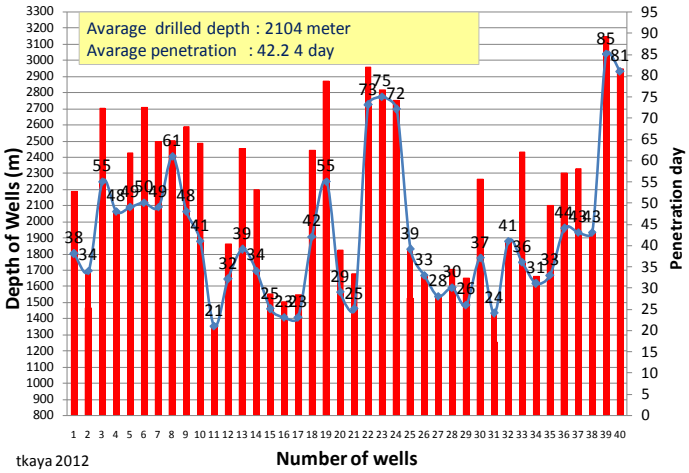

Figure 6. Depth and Penetration da of Geothermal Wells in Alasehir and Menderes in Turkey (Kaya, 2012).

The two casing designs used are typical of geothermal wells drilled worldwide, either: a) Regular Diameter wells with 9 5/8" production casing, b) Large Diameter wells with 13 3/8" production casing. For both there are three cemented casing strings with roughly to the following depths: surface to 90 m, anchor to 300-400 m and production casing to 800-1800 m and then there is a slotted liner which is 800-1200 meter to total depth.

The drilling histories of 12 wells from Olkaria Kenya, 14, Wells from Hengil, Field, Iceland were analyzed (Miyora Ong'au, 2011) for comparison with 12 wells from Alasehir and Menderes Fields, Turkey.

All of the wells from Olkaria and Hengilwere directionally drilled. Their used casing and bit sizes were the same with the vertically and directionally drilled wells in Turkey. The wells compared in this study have also the same casing design; regular diameter wells with 9 -5/8"production casing.

Different types of formations are encountered during drilling. Some formations become unstable either during drilling or sometime later. This may cause fragments of the formation to fall into the hole and around the drill collars or the bit.

Table 3. Drilling phases for Kenyan, Icelandic, Turkish Projects.

Drilling Phases			Kenyan Wells	Iceland Wells	Alasehir Turkey W	Menderes Turkey W
Steps	Drilling Size (")	Casing Size (")	Depth (m)	Depth (m)	Depth (m)	Depth (m)
0	26	20	0-60	0-90	0-90	0-100
1	17 1/2	13 3/8	60-300	90-300	90-600	100-700
2	12 1/4	9 5/8	300-1000	300-800	600-2000	700-1700
3	8 1/2	7	1000-2800	800-2300	2000-3100	1700-2700

Formation in Kenya: Hard volcanic rock and tuff layers;

Formation in Iceland: Volcanic system is composed of crater rows and a large fissure swarm like Kenya

Formation in Turkey: Calcareous sedimentary or metamorphic rock; metamorphic, shist, limestone, sand stone and marble

Performance of rig, company, selected material and many other reasons have been affecting the penetration rate and total drilling time. The Table 4 shows importance of lessons learned and having experience in one field. Alasehir field has less drilling when it is compared with other fields. Average drilling day will decrease by having more drilling experiences in Alaşehir.

Table 4. Drilling phases with Penetration Rate and Average days of geothermal drilling for Kenyan, Iceland, Turkey.

Avarage Drilling	Kenya Wells	Iceland Wells	Alasehir Turkey W	Menderes Turkey W
Avarg. Depth(m)	2829	2378	2923	2076
Avarg.Days	57	41	77	41
Penetration(mpd)	49.6	58.0	38.0	50.6

5. Why Are Some Wells Unsuccessful Drilled in Geothermal (Observed by TPIC)?

In geothermal fields, a "dry hole" is a rarity; all geothermal wells flow to some extent. However, a geothermal well may be deemed unsuccessful for one or more reasons discussed/observed by TPIC in two main geothermal graben which are Mendere and Alaşehir at below Table 5. Forty-three well's data has been evaluated.

Table 5. Reasons for Unsuccessful Geothermal Well Drilling in Turkey (Kaya, 2012).

Reason drilled wells in Ataşehir and Menderes Graben (95,000 meter, January 2012) (Kaya, 2012)	Alaşehir (7 wells)	Menderes (37 Wells)
encounters unexpected mechanical problems during drilling and is partly filled or bridged by drill cutting and/or casing collapse;	1	1
in adequate temperature;	0	4
too low a static pressure;		1
reservoir that is too "tight" (the productivity index is low)	2	0
unacceptable chemical problems (such as, gassy, corrosive or scaling-prone	0	0

It is expected that well drilling becomes more successful with more wells drilled in a field. Each drilled well helps to refine knowledge of the size and location of the resource, TPIC experiences support this theory. Cumulative percentage of successful wells increase with the number of drilled wells in the field.

Success on the first well appears to be about 50:50, on average cumulative success rate rises rapidly in the first few wells. The cumulative success rate continues to rise as later wells are consistently more successful.

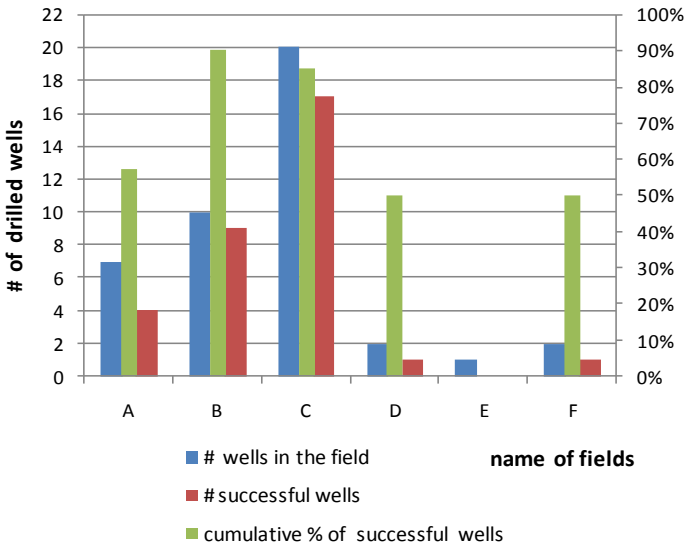

Figure 7. Evidence for the "learning curve" effect for geothermal drilling in Turkey (Kaya, 2012).

6. Geothermal Development Stages and Time in Turkey Cases

If all goes well, geothermal development will take at least four years to commissioning from the time of securing resource rights.

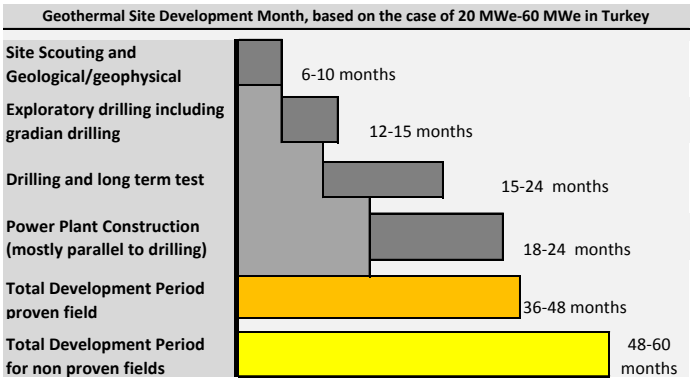

Figure 8. Geothermal Development Period for proven and non probven fields in Turkey (Kaya,2012).

A typical geothermal project can be divided into five different stages. Because of having plenty of several condition, a concrete time estimate for each stage is not easy as it is strongly dependent on local condition and national legal requirements and availability of services and supplies e.g. well head, drilling turbine.

Geothermal site development period has been predicated on current local condition, permission, legislation, rig availability, drilling period, material procurement in Turkey. As for that current and completed implementing projects, it is common for geothermal power projects in Turkey to take four to five years. Figure 8 shows a typical project time line and activity at different development stage of a geothermal power project in Turkey.

It takes four full years to get power on line for small power plant while it takes minimum 5-6 full years from decision till one sells power from a large plant. We would then have the same 20 MW on line in three years.

7. Current and Projected Geothermal Power Plant

Although the utilization of geothermal energy has increased dramatically in Turkey since then, taking into account of Turkey's potential, the current usage is still far behind from the expected level. The total installed capacity in Turkey geothermal power plant is given in Figure 8 and Table 6. For reaching the forecasting of 2015, based on an accurate accounting of all the existing projects which has been observing by TPIC at an executive stage, a clear change is observed after 2007.

The first exploration regarding the 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. Turkey has been producing 15 MWe capacity since 1984 to 2007. It has been operated 50% capacity because of scaling problem in the wells, after privatization of the Kızıldere Power Plant, it has been operated 80-90% capacity since 2008.

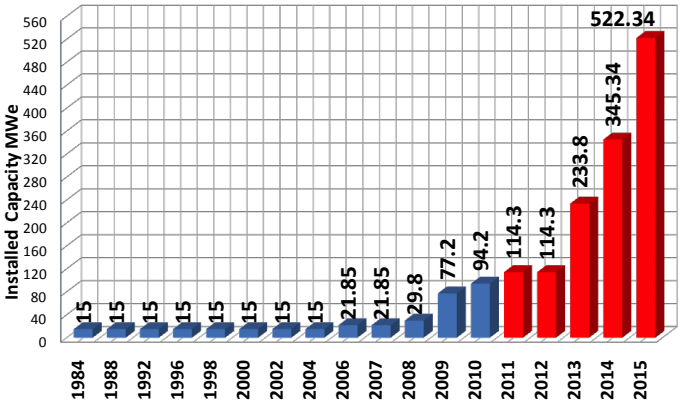

Figure 9. Geothermal Power capacity 1984-2015 in Installed Turkey projection (Kaya, 2012) (2011-2015 Estimated).

Table 6. Geothermal power plants under operation and construction in Turkey, as of May 2012 (Kaya, 2012).

	Name of Power Plant	Place	Installed Capacity (MWe)	Technology Provider
				Under Operation
1	Kızıldere	Denizli-Sarayköy	15	Ansaldo
2	Dora-1	Aydın-Salavatlı	8	Ormat
3	Bereket	Denizli-Sarayköy	7	Ormat
4	Germencik	Aydın-Germencik	47	Mitsubishi
5	Tuzla	Çanakkale Tuzla	8	Ormat
6	Dora-2	Aydın-Salavatlı	12	Ormat
7	Irem	Aydın-Germencik	20	Ormat
				Under Construction
8	Sinem	Aydın-Germencik	23	Ormat
9	Deniz	Aydın-Germencik	23	Ormat
10	Pamukoren	Aydın-Pamukören	45	Atlas Copco
11	Gumuskoy	Aydın-Germencik	7	TAS
12	Dora 3U1	Aydın-Salavatlı	15	Ormat
13	Alasehir	Manisa-Alasehir	24	Ormat
14	Dora 3U2	Aydın-Salavatlı	20	Ormat
15	Kızıldere-2	Denizli Sarayköy	75	Fuji-TAS

Geothermal installed capacity has been increasing rapidly over the years accounting for 50 % of the total installed capacity by Sept 2011. There are seven geothermal power plants which are under operation and eight power plant is under construction in Turkey.

8. Legislation of the Geothermal Law

Geothermal legislation does not have a long history in Turkey. The market-based policies for renewable energy sources had been first introduced in 1984. It is replaced by the Electricity Market Law (Law No. 4628) with financial incentives in 2001. Another existing law with relevance to the use of renewable energy sources is the Law on Utilization of Renewable Energy Resources for the purpose of Generating Electrical Energy (Law No. 5346, dated May 10, 2005). The main objective of this law is to promote the use of renewable energy sources for generating electricity. An alteration has been made with this law on the 29th of December, 2010. According to the alteration, the price of electricity produced in geothermal changed from 5.5 € ¢/kWh to 10.5 US ¢/kWh for the production facilities based on geothermal energy.

Table 7. FIT, Feed-In Tariffs (for Renewable Energy in Turkey).

Power Plant Type	FIT ($)	Dometic Manufacturing	Additional Local Content ($cent/kW	Max FIT ($cent/kWh)
Hydro	7.3	Turbine	1.3	9.6
		Generator and Power Electronics	1.0	
Wind	7.3	Blade	0.8	11.0
		Generator and Power Electronics	1.0	
		Tower	0.6	
		Rotor and Nacel (all mechanic)	1.3	
Geothermal	**10.5**	**Steam or Gas Turbine**	**1.3**	**13.2**
		Generator and Power Electronics	**0.7**	
		Steam Injector or Vacuum Pump	**0.7**	
Biomass	13.3	Equipments		18.9
Solar	13.3	Fotovoltaik Equipments		20.0
		Concentrated olar Power Equipmen		22.5

Another promotion was made with the law on Geothermal Resources and Natural Mineral Water (Law No. 5686) to attract private investors. The governing regulations relevant to the law (Law No. 5686, dated July 03, 2007) has been brought into force on 11 December 2007.

Today, the importance of electricity generation from renewable energy sources has been understood and an awareness of its importance has been gained in Turkey. Accordingly, some long-term plans were made by the Government and the main objectives were declared as:

- The amount of electricity generation from renewable energy sources shall be increased to at least 30 percent of total electricity generation by the end of 2023 (0.08 % in 2007).
- The installed capacity of geothermal facilities shall be raised to 600 MWe by the end of 2023 (114 MWe in 2012).

According to current progressing in geothermal project development in Turkey, the target number is 600 MWe for year if 2023 has started to be updated.

9. Conclusions

Presently, Turkey uses only 4% of its geothermal resource potential. The country could satisfy 13% of its total energy requirements if all of its geothermal potential is developed. Since Turkey imports most of the energy it needs, its indigenous renewable sources should be used more efficiently. Therefore, geothermal energy has a vital role in Turkey's energy future. The private sector (including the drilling companies) should be supported and encouraged by the Turkish Government to invest in the development of the country's low- and high-enthalpy geothermal resources.

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