"An Overview on Geothermal Drilling and Projects in Turkey, 2013"

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ABSTRACT

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

Geothermal exploration in Turkey started in the early 1960s. The first use of geothermal energy resource for heating purpose in Turkey dates back to the central heating system of Gönen Park Hotel in 1964. The first geothermal well, which has a depth of 540 meters and a temperature of 198 °C, was drilled on high enthalpy fields for potential power production in 1968.

Taking into account of Turkey's potential, the current usage is still far below from the expected level. Turkey has enough reserves to fulfill the heat requirements of 1.2 million homes by means of geothermal heat power. Analysts set forth the potential of Turkey as more than 1000 MWe to 2000 MWe commercially viable megawatts of geothermal, an efficient source with minimal environmental impact. However, considerably promising and progressing increase of geothermal usage in Turkey has been remarked from last two decades in heating and after 2007 in power. Number of geothermal wells drilled between 1963 and 2012 is around 850-900.

The Turkish government has recently regulated the law of renewable energy, including geothermal energy, and has provided several incentives to encourage the market.

Turkey issued a geothermal energy resources law finally in June 2007, and the law was enacted a year later in June 2008. Besides the current geothermal law, new amendments on the renewable energy law have already helped the geothermal projects development with the purchasing warranty. Based on these recent developments in geothermal industry in Turkey, it is clear that geothermal energy will contribute significantly to Turkey's future energy supply.

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

After the effective date of code for geothermal law (2007), the number of geothermal power exploration and drilling projects has started to increase. However, significant increase in deep and high enthalpy well drilling in Turkey has been observed after 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 within; geothermal power - 10.5 US ¢/kWh for the first 10 years after the commencing of plants, purchase guaranty for the electricity generated.

This paper presents the information about geothermal projects development in Turkey. It is specially based on drilling activities, statistical investigation of drilling activities; their success, rig rates cost and average penetrating rates. The case histories of drilling in Menderes and Alaşehir/Gediz graben in Turkey are used to illustrate some of the concepts.

Almost 148.000 meters, 63 geothermal wells, were drilled by Turkish Petroleum International Company (TPIC) In Turkey by the end of March 2013 by TPIC.

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.

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. **(Figure 1)**

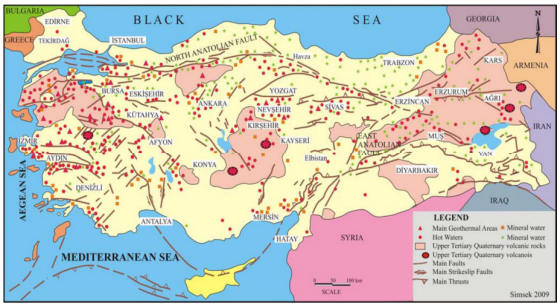


Figure 1 Main neotectonic lines and hot spring distribution of Turkey (Şimşek, 2009)

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 165 MWe for power production in Turkey. Up to now, around 945 geothermal exploration, production and re-injection wells and 320 gradient wells have been drilled in Turkey.

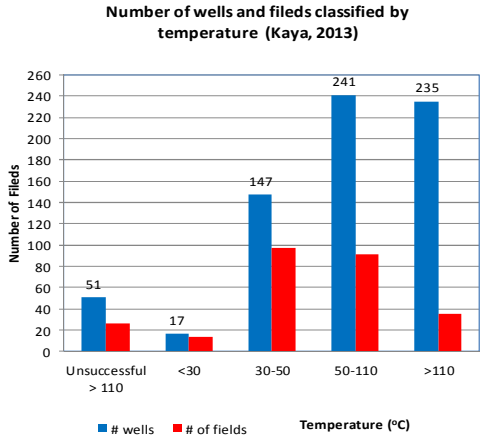


Fig 2 Number of geothermal fields and wells with temperature classification in Turkey (Kaya, 2012 revised)

After the date of geothermal law enacting at 2007, number of drilling wells which are for power generation has been increased significantly. More than 235 wells which are 110 °C and more have been drilled during last 4 years in 28 different geothermal fields. (Figure 2)

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

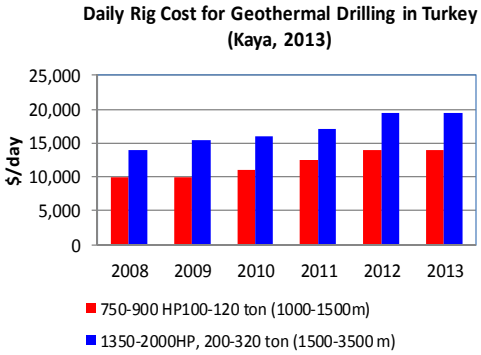


Figure 3 Average Rig Rate Cost for Drilling of Geothermal Wells in Turkey

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)

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. Compared to 2012, rig rate has not changed significantly in 2013

Number of active rigs for geothermal power projects is around 26 now for geothermal power projects which are located mainly Aegean Region of Turkey (March 2013).

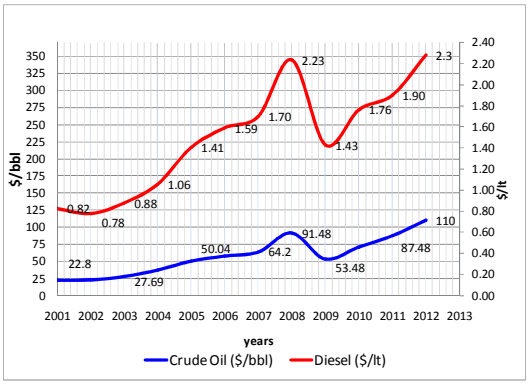


Figure 4 Comparison of rig rate, fuel, and crude oil cost chained vs. time (Kaya, 2013)

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 equipment 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.

Beside TPIC rigs, Turkish local drilling companies have been drilling geothermal wells mainly with American (NOV), Italian (Drillmec) , Romanian (Upetrom) rigs amd other name. Table 1

Table 1 Rig Count in Geothermal Drilling in Turkey, (Kaya, 2013)

Rig Count in Geothermal Power Projects in Turkey (march 2013) tkaya				
#	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	BORDRILL
6	MR8000	Manisa	4300 m/1080 HP	BORDRILL
7	Not Specified	Manisa	2000 m/1080 HP	BORDRILL
8	MR8000	Aydın	4300 m/1080 HP	MAREN
9	MR8000	Aydın	4300 m/1080 HP	MAREN
10	IDECO H44	Aydın	3000 m / 750 HP	POLMAK
11	F.CooperLTO750	Aydın	2500m/750 HP	AME
12	Wilson 75	Aydın	2500m/900 HP	AME
13	NAT 80 B	Aydın	3500 m/1000 HP	AME
14	F200	Aydın	4000 m/1350 HP	AME
15	Nat 32	Aydın	not specified	AME
16	BD125	Denizli	1600 HP	DEĞİRMENCİ
17	Gefco 185 K	Konya	2000m/600 HP	GM Müh
18	MR6000	İzmir	2000 m/540 HP	MTA
19	IDECO 202	Ağrı	3200m/620 HP	ARAR
20	IDECO H 44	Ankara	2700/912 HP	ARAR
21	Not Specified	Manisa	2000m/600 HP	Merty
22	Not Specified	Manisa	2000m/600 HP	Petrogaz
23	Not Specified	Simav	2000m/600 HP	Umran Boru
24	Not Specified	Aydın	2500 m/1000 HP	Viking
25	Not Specified	Aydın	2500 m/1000 HP	Viking
.+6	Domestic manufactued rigs			

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. 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 1500-2500-3500 MD Geothermal Wellin Aegean Region (Kaya,2013)

March 2013- tkaya	1500 m (30 days)	2500 (45 days)	3500 m (60 days)
Services	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	352,000
Mob & De-mob	200,000	300,000	300,000
Total Operating Cost (18.500$/day)	555,000	832,500	1,110,000
Mud Service	90,000	120,282	160,000
Cementing Service	120,000	180,783	220,000
Wireline logging	40,000	150,000	150,000
Acidizing	40,000	70,000	70,000
Well tests	35,000	40,000	40,000
Total Budget (%10 contingency)	1,778,000	2,823,405	3,422,400

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 5).

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 2011, GRC) 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

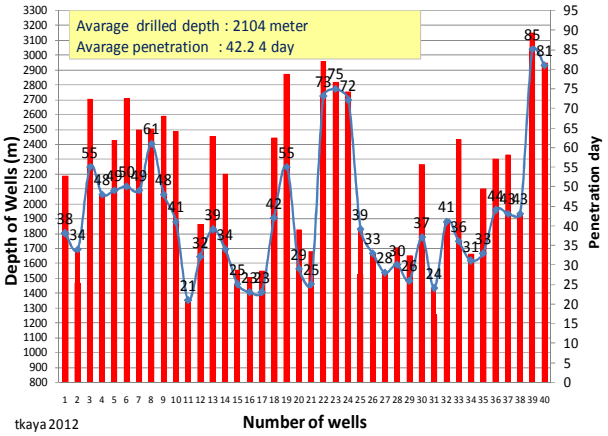


Figure 5 Depth and Penetration da of Geothermal Wells in Alaşehir and Menderes in Turkey (Kaya, 2012)

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. (Table 3)

Table 3 Drilling phases for Kenyan, Icelandic, Turkish Projects

Steps	Drilling Phases Drilling Size (")	Casing Size (")	Kenyan Wells Depth (m)	Iceland Wells Depth (m)	Alasehir Turkey W Depth (m)	Menderes Turkey W 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

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.

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

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

drilling when it is compared with other fields. Average drilling day will decrease by having more drilling experiences in Alaşehir.

5 WHY ARE SOME WELLS UNSUCCESS-FUL DRILLED IN GEOTHERMAL?

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 operator in main geothermal grabens which are Menderes and Alaşehir at below table 5. Almost 200 well's result has been listed ;

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

Reason drilled wells in Alaşehir, Menderes and other Graben (201 wells, March 2013) (Kaya, 2013)	Alaşehir	Menderes	Other Fields	Total
	40	132	31	203
encounters unexpected mechanical problems during drilling and is partly filled or bridged by drill cutting and/or casing collapse;	3	4	3	10
in adequate temperature;	0	8	4	12
too low a static pressure;	1	1		2
reservoir that is too "tight" (the productivity index is low) but high temperature	9	5	3	17
unacceptable chemical problems (such as, gassy, corrosive or scaling-prone fluids).	0	0		0
uncontrolled well, well head , casing cementing problem,	1	0		1
Total	14	18	10	42

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, current cases experiences support this theory. Cumulative percentage of successful wells increase with the number of drilled wells in the field. (Figure 6)

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.

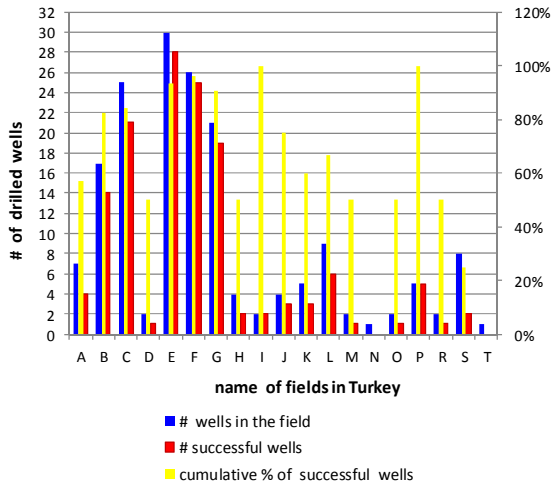


Figure 6 Evidence for the "learning curve" effect for geothermal drilling in Turkey (Kaya, 2013)

6 GEOTHERMAL DEVELOPMENT STAGES AND TIME IN TURKEY CASES;

If all goes well, geothermal development will take at least 4 years to commissioning from the time of securing resource rights.

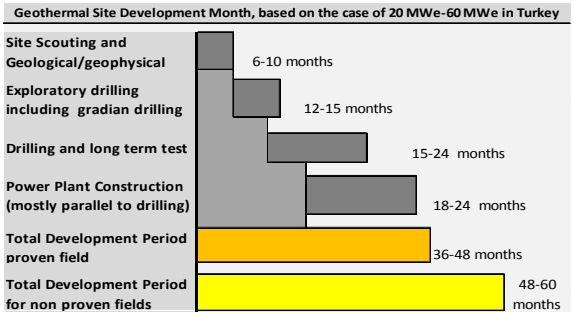


Figure 7 Geothermal Development Period for proven and non probven fields in Turkey (Kaya,2012)

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 7 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

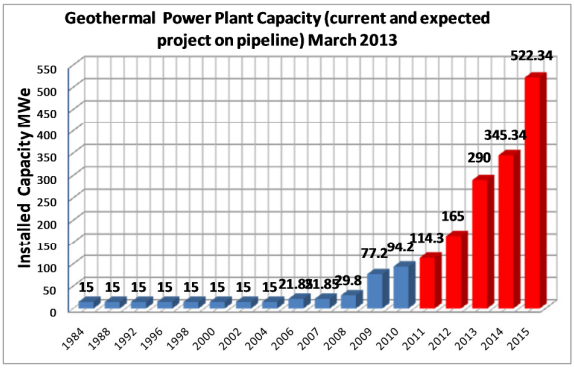


Figure 8 Geothermal Power capacity 1984-2015 in Installed Turkey projection (tkaya 2013) (2011-2015 Estimated)

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.

Geothermal installed capacity has been increasing rapidly over the years accounting for 50 % of the total installed capacity by Sept 2011. There are nine geothermal power plants which are under operation and eight power plant is under construction in Turkey. **(Table 6)**

Table 6 Name of geothermal power under operation and construction (May 2013), (Kaya, 2013)

	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
8	Sinem	Aydın-Germencik	23	Ormat
9	Deniz	Aydın-Germencik	23	Ormat
				Under Construction
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

8 LEGISLATION OF THE GEOTHERMAL LAW

The legislation of geothermal law in Turkey does not have a long history. 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.

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 of 2007.

Table 7 FIT 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	1.0	
Wind	7.3	Blade	0.8	11.0
		Generator and Power	1.0	
		Tower	0.6	
		Rotor and Nacel (all	1.3	
Geo-thermal	**10.5**	**Steam or Gas Turbine**	**1.3**	**13.2**
		Generator and Power	**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		22.5

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 MW by the end of 2023 (165 MW in 2013).

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. CONCLUSION

Today, Turkey uses only the 4% of its geothermal source potential, which is in very small amounts. However, the country can meet 13% of its total energy requirement if all of the potential sources are used. Since Turkey imports most of its energy need from other countries, sustainable sources that the country owns should be used more efficiently. Therefore, the great potential of the geothermal energy has a vital place in the future energy supply of Turkey. So that, the private sector should be encouraged and supported for these new investments by a professional drilling contractor company since only this sector is able to mobilize required funds and invest money for these kinds of projects.

REFERENCES

Kaya T, "Geothermal Project Development in Turkey - An Overview With Emphasis on Drilling" Proceeding of 2012 GRC Annual Meeting , Reno, NV, p. 159-164

Kaya T. and et all, 2011 "Experiences in Geothermal Deep Well Drilling of TPIC in Turkey, "GRC 2011" Proceeding of 2011 GRC Annual Meeting,San Diego CA, p. 173,181

Thomas Miyora Ong'au, 2011 "Controlled Directional Drilling in Kenya and Iceland (Time Analysis)" 2011 GRC Annual Meeting, San Diego CA, p. 207,214

Simsek, S., New Wide Development of Geothermal Power Production in Turkey, International Geothermal Days Slovakia 2009, CastaPapiernicka, Slovakia.

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