Geothermal Country Update for Türkiye - 2023

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ABSTRACT

Due to its complex geology and active tectonic features, Türkiye has a high geothermal (hydrothermal and EGS) potential distributed throughout the country with different temperature intervals.

The utilization of geothermal resources in Türkiye has made great progress in the last 20 years. From 2005 to the end of 2022, the installed geothermal power capacity was increased by about 20 MWe to 1717 MWe. Geothermal direct use capacity has reached 5323 MWt, including 1528 MWt for space heating, 1230 MWt for greenhouse heating (5293 da), 1763 MWt for thermal-balneological utilization in tourism (23 million people annually), 680 MWt for geothermal heating of thermal tourism facilities, 9.5 MWt for drying, 0.35 MWt for cooling, 112.3 MWt for geothermal heat pumps (geothermal ground source) and 400.000 tons/year for geothermal production of liquid CO2 and dry ice. Projections for 2030 are for 3000 MWe (24 billion kWh/year) of electricity generation and 10,550 MWt of direct geothermal use, with geothermal heating accounting for the largest share at 5000 MWt. Our country's target for 2030 is 12,000 da of geothermal greenhouse applications. The additional investment required to achieve these uses for power generation and direct use is nearly $9.17 billion.

Organizing of the World Geothermal Congress 2005 in Antalya (joint organisation of IGA-TGA (Turkish Geothermal Association)) caused to understand the importance of geothermal very well by State of the Republic of Türkiye, MTA (General Directorate of Mineral Research and Exploration, State establishment), private sector, enacting the geothermal law and the geothermal incentive law in Türkiye and MTA started to give more emphasize to the geothermal exploration-studies, drilled 1-2 wells/concession area and transferred (similar to leasing and renting) the geothermal field to the private sector. Thanks to this method and the feed in tariff and applied incentives, Türkiye became the 4th country in geothermal power install capacity in the World.

Since most Turkish geothermal power plants are binary ORC plants with air-cooled condensers, production efficiency decreases due to high ambient temperatures in summer. To compensate for this, solar hybrid plants have been projected, and in a few months, solar panels will be installed and integrated into geothermal power plants to compensate for the decrease in electricity production. In this way, the production factor and profitability will increase, and renewable solar and geothermal energies will be integrated together. In the next 10 years, integrated geothermal use as district heating, greenhouse heating, drying, and other applications (mineral recovery) will also be given special emphasis and are planned to be expanded.

Given the great potential of Enhanced Geothermal System (EGS) and Hot Dry Rock (HDR) resources, apart from geothermal hydrothermal resources, it is recommended that the initial EGS/HDR implementation be carried out by the Turkish government institutions (such as MTA) and then the private sector invest further with special incentives.

1. INTRODUCTION

Due to the effect of extension tectonism, the western part of Türkiye is the most geothermally active. By the end of 2022, up to 460 geothermal fields with an outlet temperature of at least 30 °C have been explored (Figure 1)Due to the effect of extensional tectonism, the western part of Türkiye has the most abundant geothermal activity. As of end 2022, the explored geothermal fields has reached up to 460 with an discharge temperature of min. 30 °C (Figure 1).

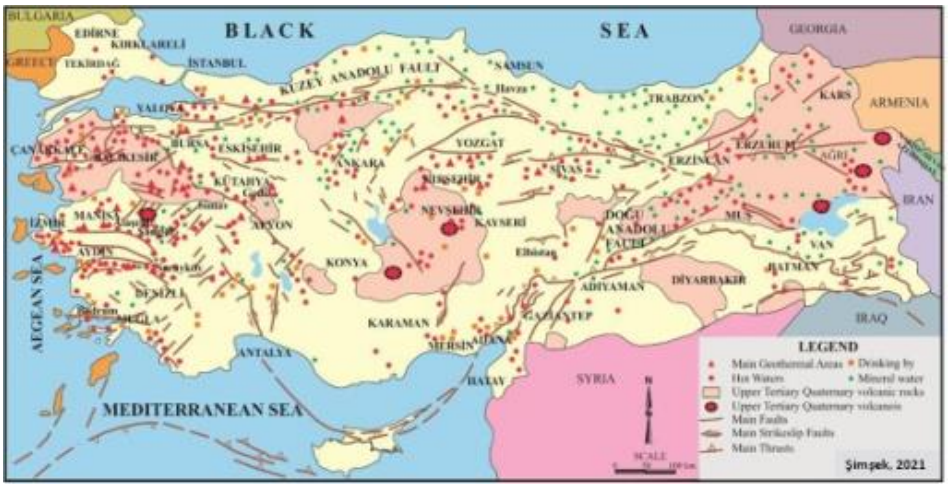

Figure 1: Distribution of geothermal resources in Türkiye

A total of 1663 geothermal exploration and 1835 operating licences belong to the private sector, local governors and municipalities, and individuals in Türkiye

Up to 341 °C in Nigde province-Central Anatolia has been measured at 3845 m depth recently. The deepest geothermal well has reached up to 4792 m at Denizli-Tekkehamam geothermal field. Faults accommodating the deep circulation of hydrothermal fluids of mostly meteoric origin are the primary means by which of geothermal systems are controlled in this region. In the last 10-15 years, under the framework of energy resource diversification, the investment of geothermal energy applications rapidly increased. This can be remarkably seen especially in geothermal electricity production and geothermal greenhouse applications. Moreover, some small drying and cooling applications have been added to the geothermal utilisation range in the country. Nearly 50% of the geothermal fields are used for thermal facilities, geothermal spas, and balneological use, which is followed by geothermal heating (36%) and the rest is used mostly for geothermal electricity production (14%).

The underground resources are subject to the public ownership in Türkiye. This means that geothermal springs and natural mineral waters are under the government's control and disposal.

A total of 66 geothermal power plants is to date running in Türkiye. Some of the existing geothermal power plants in Türkiye provide exemplary investments and geothermal brine, and heat supply for integrated uses. In Çanakkale-Babadere, Aydın-Ortaklar, Aydın-Germencik, Salavatlı and Denizli-Sarayköy, the geothermal fluid from the geothermal power plant is used in greenhouse heating and in some of the urban heatings, before reinjected back to the reservoir.

There is an incentive system implemented by the Ministry of Industry and Technology for geothermal investments of a certain size. Customs duty exemption, Value Added Tax (VAT) exemption, permission for credit allocation, etc. incentives are applied.

More than 15 countries in the world apply geothermal incentives (FIT-feed in the description). The lowest incentive applied in the world is in Türkiye. As of July 2021, it is approximately 6.5-8.6 $ cents/kWh. 10 years purchase guarantee is applied by the Ministry of Energy and EPDK (EMRA).

2. GEOTHERMAL APPLICATIONS IN TÜRKİYE

The geothermal electricity applications started in 1984 and the geothermal direct use applications started in 1986 in Türkiye.

The share of geothermal in electricity generation in Türkiye is between 3.2-3.6% per year. The economic activity contribution created by geothermal to the Turkish National Economy with electricity generation, geothermal central heating, greenhouse heating, liquid food grade carbon dioxide production, thermal tourism and others has been calculated as approximately a total 91 Billion TL per year (Figure 2). The total (direct/indirect) employment in the sector is 240,000 people. The present city-based geothermal district heating systems and their capacities can be seen in Table 1.

With the transferring of the geothermal fields to the private sector via bidding by the MTA, the private and public sectors realized the exploration, development, and investment in the geothermal fields rapidly. Most of the established power plants are Binary cycle power plants. The annual production factor is around a net 70-75% on average.

TIn our study, the amount of CO_2 (as NCG) in geothermal power plants in Türkiye has decreased by 50-70% in the last 15 years. Therefore, the use of downhole pumps, submersible pumps and pumps resistant to high temperatures has become essential. More than 140 ESP are running, permissible for high temperatures (150 - 200 °C).

Some examples to low-temperature applications in Türkiye: In Kırşehir, 1900 residences equivalence district heating have been realized with geothermal water at 57°C since 1994. In Haymana, floor heating is applied at a mosque by using 42°C geothermal water. Since 1992, Afyon-Oruçoglu Thermal Resort facilities have been heated by floor heating with 48°C geothermal water. In addition, Bolu-Karacasu Thermal Facilities have been partially at 44°C since 2001, Rize-Ayder Cure Center at 55°C, Hatay-Kumlu Thermal Facilities at 37°C with floor heating, Sivas-Hot Çermik Thermal Springs at 46°C and Samsun- Havza Thermal Facilities are heated with geothermal water at 54°C.

One of the applications where geothermal is least evaluated in Türkiye is aquaculture, and developments have been started and achieved in this regard in recent years. For example, larval/juvenile fish farming with geothermal water at a temperature of 26-29 °C in Aydın Söke has made a significant progress in recent years. Annually total 200 million juvenile fish is produced in this facility. Sales are made to the domestic market and mainly to European countries.

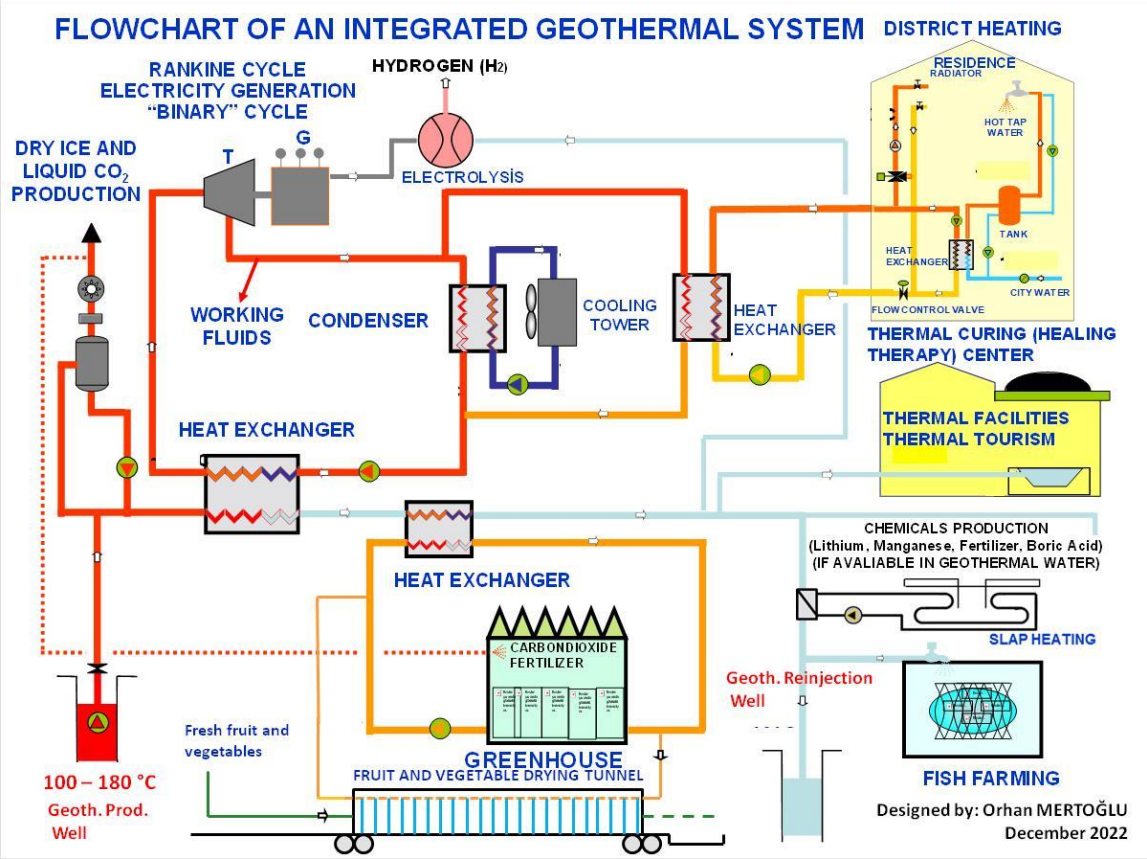

Figure 2: Flowchart of an integrated geothermal system (Mertoglu, 2022)

Ground source heat pump systems (GSHP) have been implemented in different types as horizontal, vertical, groundwater and sea sources. Ground source systems started with horizontal applications in the early 2000's with a capacity of 586 kW. With the increasing interest in renewable energy in 2018, new applications in shopping centers, schools and public buildings were implemented. Cezeri Renewable Energy High School and Land Registry cadastre building are examples of applications in this period. The number of installed systems reached to 161 in 2021 with a total installed capacity of 112,321 MWt.

The installed capacity of applications on open systems including sea, lake, groundwater, and geothermal wastewater sources is 104 MWt. This corresponds to 92 % of the total capacity. Closed systems consisting of horizontal, vertical and energy pile applications have a total capacity of 8.3 MWt and these constitute 7.4 % of the installed capacity (Figure 3).

Table 1: Geothermal city heating systems in Türkiye

City Name	Residences Equivalence (RE) heated (1 RE= 100 m^2)	Geothermal water temperature (°C)	Greenhouse heating ---------- Thermal water supply for the spas + ---------- +	Distance between City and the geothermal field (km.)	Investor/Company
Balçova + Narlıdere	38500	140	+ ---------- +	3	Local Governorship and Municipality equal partnership Inc.
Gönen	3400	80	+ ---------- +	2	Mainly Municipality Inc.
Simav	18600	125	+ ---------- +	5	Municipality + Municipality Inc.
Kırşehir	1900	57	+ ---------- +	1	Mainly Governorship + Municipality Inc.
zılcahamam	2500	70	+ ---------- +	2	Mainly Municipality Inc.
Afyon	30000	95	+ ---------- +	15	Mainly Governorship + Municipality Inc.
Kozaklı	4100	90	+ ---------- +	2	Mainly Municipality Inc.
Sandıklı	30000	75	+ ---------- +	10	Mainly Municipality Inc.
Diyadin	970	70	+ ----------	5	Mainly Local Governorship Inc.
Salihli	10067	94	---------- +	6	Municipality
Sarayköy	5000	95		10	Mainly Municipality Inc. Private sector Inc. is the Investor and operator
Edremit	5500	60	+ ---------- +	4	Municipality+ Private Sector Inc.
Bigadiç	1500	96		18	Municipality
Güre	1400	98	---------- +		Gürcag Foundation +Municipality
Dikili	2000	125	+ ---------- +	10	Municipality Inc.
Bergama	850	70		8	Municipality Inc.
Sorgun	1500	80	+ ---------- +	2	Municipality
Sındırgı	4000	98	---------- +	12	Municipality + Private Sector Inc.

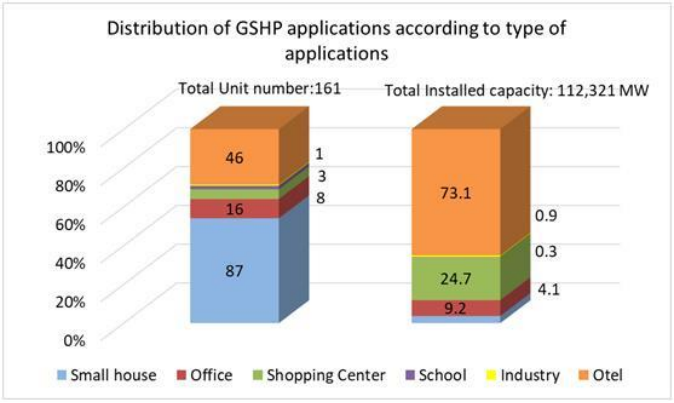

Figure 3: Distribution of GSHP applications according to the type of applications

There are more than 70 HDR/EGS projects in the world. The technological developments regarding EGS systems continue and commercial applications started already (e.g. Landau, Rittershoffen, etc.). One of the countries closest to commercial practice in EGS/HDR applications is Türkiye. The relevant reasons for that can be listed as the following:

a) The presence of large granite-granodiorite and geothermal heat

b) Decrease in the number of evaluable hydrothermal geothermal fields,

c) Thinning of the earths crust is certain places and that the temperature reaches 300 °C at 3000 m depths, and even 450-500 °C is expected towards 5000 m

CO_2 (as NCG) is gradually decreasing in geothermal fields during a long exploitation period. It is carried out with technical and economical abatement studies regarding the presence of H_2S emissions in some fields. We have gained experience regarding CO_2 injection into the reservoir. Technical, economical, and environmental aspects are under evaluation.

3. GEOTHERMAL POTENTIAL OF TÜRKİYE

As the geothermal heat potential of Türkiye has been re-calculated to 107.000 MWt, the technical and economical hydrothermal power potential is 9000 MWe (0-6 km; 11 $ cent/kWh and 10 years purchase guarantee; 72 billion kWh/year) and the technical and economical EGS potential is 272.000 MWe according to maximum 21 $ cent/kWh and 20 years purchase guarantee (Table 2).

Table 2: Geothermal potential values of Türkiye

Hydrothermal geothermal probable theoretical heat potential of Türkiye (Excluding EGS/HDR)	: 107.000 MWt
Total geothermal electricity potential of Türkiye (Hydrothermal resources) (0-4 km)	: 9000 MWe (72 Billion kWh/Year) technical, economical potential (11 $ cent/kWh based on 10-year purchase guarantee)
Geothermal (Hydrothermal) electricity production target of Türkiye for 2030	: 3000 MWe (24 Billion kWh/Year), supported by the state (10.5 $cent/kWh based on a 10-year purchase guarantee)

EGS/HDR (Enhanced Geothermal Systems/Hot Dry Rock) Electricity Generation (3-5 km)	
i) Technical Potential	: Minimum 400.000 Mwe
ii) Technical Economical Potential	272.000 MWe, supported by the state (up to $21 cent/kWh and 20 years purchase guarantee)
iii) EGS/HDR geothermal electricity generation technical economical potential of Türkiye	- 40.000 MWe (based on $14 cent/kWh and 15-year purchase guarantee) - 20.000 MWe (based on $12 cents/kWh and a 15-year purchase guarantee)

4. GEOTHERMAL ACTION PLAN

As the Strategy Committee of the Türkiye Ministry of Energy and Natural Resources and Turkish Geothermal Association, it has been made some action plan suggestions to the Government of Türkiye that will accelerate the development of geothermal applications. It can be expressed our action plan suggestions as follows:

1. Project for determination of potential production of critical raw minerals, Lithium, Boric Acid, Fertilizer, Hydrogen etc. from geothermal resources.

2. Project of determination of potential geothermal district heating places.

3. Project of determining potential places for geothermal greenhouse applications.

4. Research project of the Hot Dry Rock (HDR)/Enhanced Geothermal Systems (EGS) potential in Türkiye.

5. Research Project about technology and economy properties of elimination of Hydrogen Sulfide (H_2S) discharged from geothermal power plants in Türkiye.

Beside of these suggestions, in order to increase the future share of geothermal heating and electricity generation applications in Türkiye, we made important suggestions regarding the feed-in tariffs of geothermal applications:

1. Our feed-in-tariff suggestions for geothermal power generation plants: The current feed-in-tariff base price (54 kurus/kWh) shall be implemented in geothermal electricity generation plants in Türkiye (for a period of 10 years) at 11 $ cents/kWh equivalence in Turkish Lira's, subject to the main elements. The local machinery incentive should be increased by 25%.

2. Our feed-in-tariff suggestions for geothermal district heating/cooling systems: This incentive; based on a technical and economic feasibility report, 25% of the investment should be given to companies belonging to the Municipalities or Local Governorships (YIKOB) owning more than 51% share as a grant for the equity capital of geothermal district heating/cooling investments by the Türkiye Ministry of Treasury and Finance, Ministry of Energy and Natural Resources, Ministry of Interior, the Bank of Provinces (Iller Bank), Local Governorships. In this case, the investing company will cover the rest by means of public participation and loans.

5. CONCLUSIONS

Since WGC2020, geothermal direct-use applications have increased by 39% and geothermal electricity production increased by 3,25%.

Today, geothermal district heating costs in heating applications in Türkiye are 60-70% cheaper than natural gas. In other words, it is for the benefit of the people, and the natural gas to be saved should be used in electricity production and industry because our geothermal heat potential is around 107.000 MWt, that is, it is large enough to potentially heat 13 million houses. Most of these geothermal potential fields are more suitable for heating as an aspect of technical and economical point of view that could result in 1 Million houses (100 m^2/house).

In order for the EGS/HDR potential to be partially put into production; The government of the Republic of Türkiye needs to make the first good example application and provide additional incentives (long-term and high feed in tariff purchase guarantee) for HDR/EGS applications.

One of Europe's largest heat pump applications is located in Istanbul and one in Ankara. In addition, the heating and cooling of places such as shopping malls, villas, etc. in different regions of the country are done by heat pumps. In the near future GSHP application will be extended.

Approximately 3.5% of Türkiye's electricity consumption was met from geothermal power plants. Therefore, geothermal resources, which are domestic, renewable and cheap, have made significant contributions to the country both in electricity generation and heating.

The risk insurance system (Risk Share Mechanism) is online by the World Bank and TKYB (Bank) was implemented and partially successful, against the geological risk (mining risk) that may arise during the drilling of deep wells that carry a great risk in geothermal exploration.

In some geothermal fields, the status of H_2S (Hydrogen Sulfide) depending on the type and technology of the power plant gains importance in terms of the environment and the reaction of the public. H_2S level is not the same in all fields. It differs from field to field. There are techniques for the elimination of H_2S from power plants in geothermal fields. For the implementation of these techniques the state has to procure additional incentives.

It is expected that EGS/HDR projects will start in 2023-2024 in Türkiye, depending on technological developments and incentive practices.

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