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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 from 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 CO_2 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) allowed 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 emphasis to the geothermal exploration-studies, drilling 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 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 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).

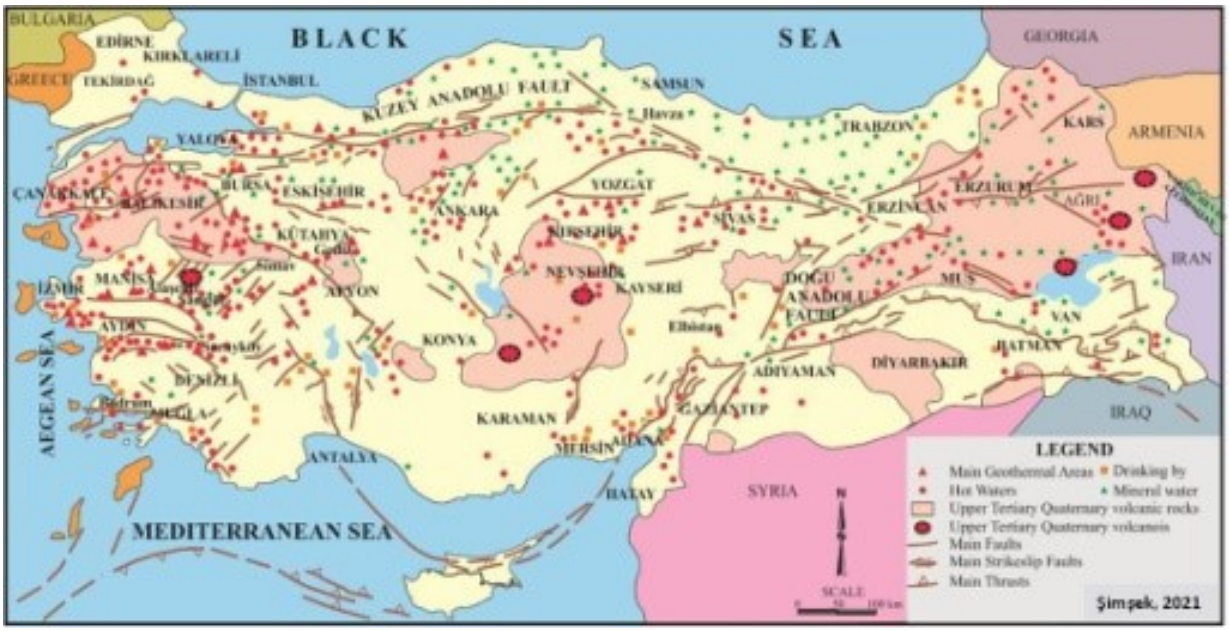

Figure 1: Distribution of geothermal resources in Türkiye

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 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 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 residual geothermal fluid from the geothermal power plant is used in greenhouse heating and in some of the urban heating developments, 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. They include customs duty exemption, Value Added Tax (VAT) exemption, permission for credit allocation, etc.

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

2. GEOTHERMAL APPLICATIONS IN TÜRKİYE

Geothermal electricity development in Türkiye started in 1984, and geothermal direct use applications started in 1986.

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

(Figure 2), has been calculated as approximately a total 91 billion TL per year. 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 rapidly the exploration, development, and investment in the geothermal fields. Most of the established power plants are binary cycle power plants. The annual production factor is around a net 70-75% on average.

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, able to operate at high temperatures (150 - 200 °C), are currently in operation.

Some examples to low-temperature applications in Türkiye are the following. In Kırşehir, a district heating equivalent to 1900 residences has been develped using 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 heated 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, but developments have been started 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, a total of 200 million juvenile fish is produced in this facility. Production is sold both in the domestic market and European countries.

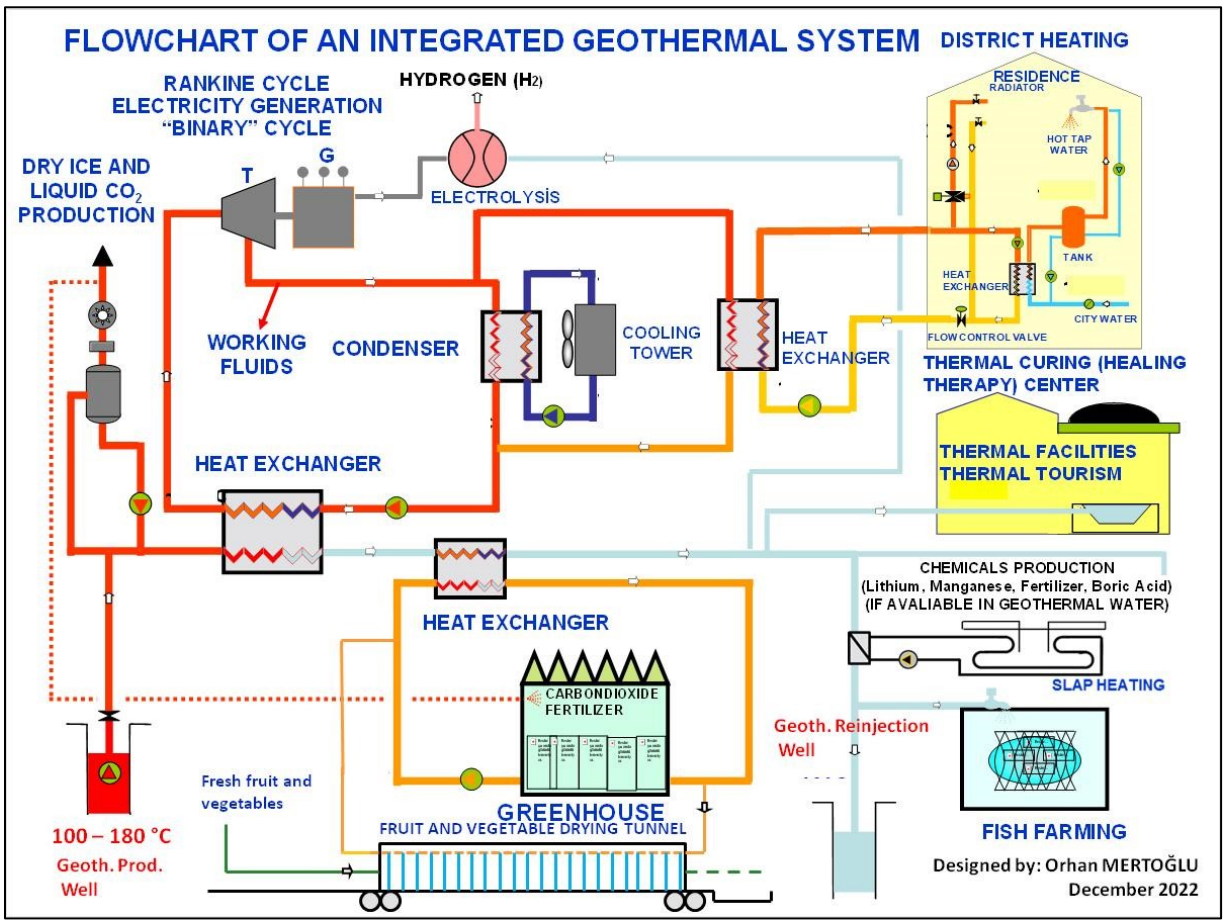

Figure 2: Flowchart of an integrated geothermal system (Mertoglu, 2022)

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.

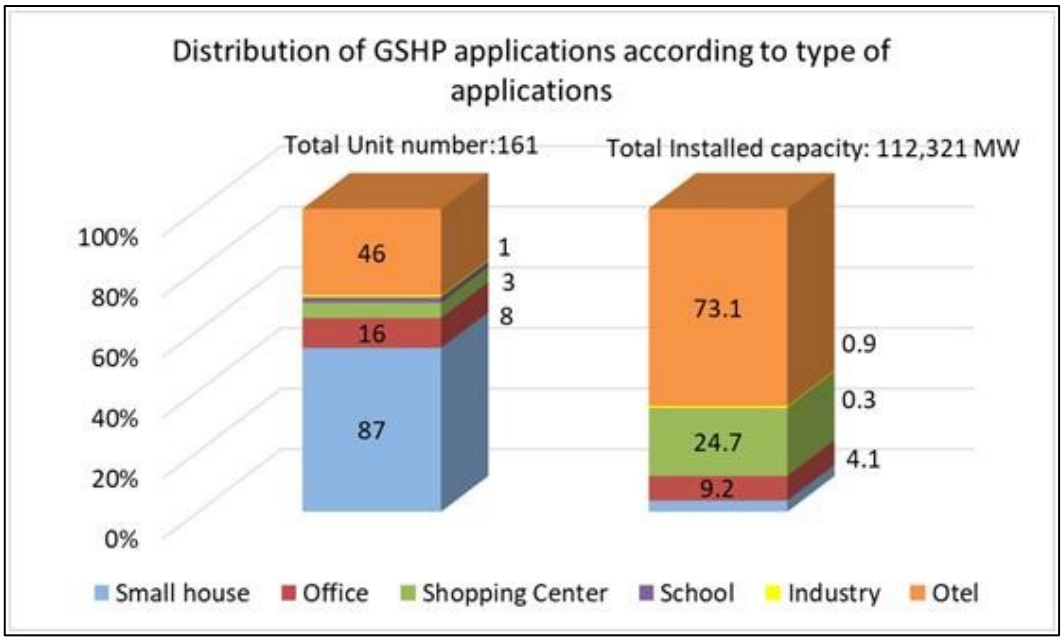

Figure 3: Distribution of GSHP applications according to the type of applications

There are more than 70 HDR/EGS projects in the world, with some pilot, demostration and pre-commercial applications already in operation (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 intrusives and geothermal heat.

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

c) Thinning of the earth's crust in certain places with temperature reaching 300 °C at 3000 m depth, and even 450-500 °C is expected at depth of 5000 m.

CO_2 (as NCG) is gradually decreasing in geothermal fields during long exploitation periods. 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

The geothermal heat potential of Türkiye has been re-calculated to 107.000 MWt, the technical and economical hydrothermal power potential is 9000 MWe (at 0-6 km depth; 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 depth)	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

The Strategy Committee of the Türkiye Ministry of Energy and Natural Resources and the Turkish Geothermal Association have made some action plan suggestions to the Government of Türkiye that will accelerate the development of geothermal applications. Main suggestions of this action plan are as follows:

1. Project to determinate the potential production of critical raw minerals, as lithium, boric acid, fertilizer, hydrogen etc., from geothermal resources.

2. Project to define the potential geothermal district heating places.

3. Project to assess potential places for geothermal greenhouse applications.

4. Research project on 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, the action plan presents important suggestions regarding the FIT schemes for geothermal applications:

1. For geothermal power generation plants the current FIT base price (54 kurus/kWh) shall be increased to 11 TL cents/kWh for a period of 10 years, subject to the main elements. The local machinery incentive should be increased by 25%.

2. 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 in Türkiye 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. The saved natural gas 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 (at 100 m^2/house).

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

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

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

The risk insurance system (Risk Share Mechanism) is online and was implemented by the World Bank and TKYB (Bank). It has been partially successful to lower the geological risk (mining risk) that may arise during the drilling of deep exploration wells, which is high in geothermal exploration.

In some geothermal fields, the concentration of H_2S (Hydrogen Sulfide) depending on the type and technology of the power plant becomes relevant in terms of the environment and the reaction of the public. H_2S level is not the same in all fields, but 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 must 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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