

## Shallow Geothermal Application in Turkey

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### ABSTRACT

Exploiting geothermal resources of Turkey has become more important than ever. Within this context interest in shallow geothermal is increasing. Geothermal Heat Pump - GHP applications are seen in metropolitan areas and for large shopping malls. In addition to large buildings, increasing number of single family house applications, GHPs have been installed in some schools for demonstrative purposes. Recently, GHPs started to be considered for governmental buildings also. For proper design of GSHPs thermal properties of the ground has to be determined by in-situ Thermal Response Test – TRT. In some of the major GHP applications in Turkey TRT results have been used. Currently, there are no regulations and standards for applying GHPs in Turkey. This paper aims to present the potential for shallow geothermal applications and give examples from existing GHP systems in Turkey. Recommendations for exploiting the shallow geothermal potential more effectively are also given.

### 1. INTRODUCTION

Turkey is one of the rapid developing countries in the world. In 2010, Turkey was the 16th largest economy in the world and the 6th largest economy in Europe (IMF, 2011). Recently, Turkey had a population of 71.9 million with 1.8% growth rate. Annual income was approximately 9000 USD/capita in 2011, which is 3 times as much as in 2000. Additionally, due to population increase, economic and industrial development, energy consumption also rises every year. Industrial energy consumption showed nearly 6 times increase in 35 years and also residential energy consumption has increased 3 times in the last 35 years. Turkey had to import 77% of fossil fuel for its demands in 2009 (IEA, 2010).

In Turkey with more than 16 million buildings and 18,5 million households, share of buildings in total energy consumption is 35-40 % out of which 82 % is used for heating (www.eie.gov.tr). Fossil fuels used to meet significant part of the consumption lead to emission of greenhouse gases like NO<sub>x</sub> and CO<sub>2</sub>, which increases the global warming problem. Shallow geothermal systems are considered to be energy efficient and renewable for heating and cooling of buildings.

Heat pump technology is quite well known in Turkey, but shallow geothermal systems and geothermal heat pumps are new. Although the concept has been known and investigated experimentally (Babur, 1986 and Kara, 1999), the first applications of shallow geothermal systems were seen in early 2000.

This paper aims to give an overview of shallow geothermal applications in Turkey with recommendations for increasing number of successful applications

### 2. SHALLOW GEOTHERMAL SYSTEM

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 (SANNER, 2001). The following UTES systems are used for heating and/or cooling applications:

- Aquifer thermal energy storage (ATES)
- Borehole thermal energy storage (BTES)
- Cavern thermal energy storage (CTES)
- Foundation piles (energy piles)

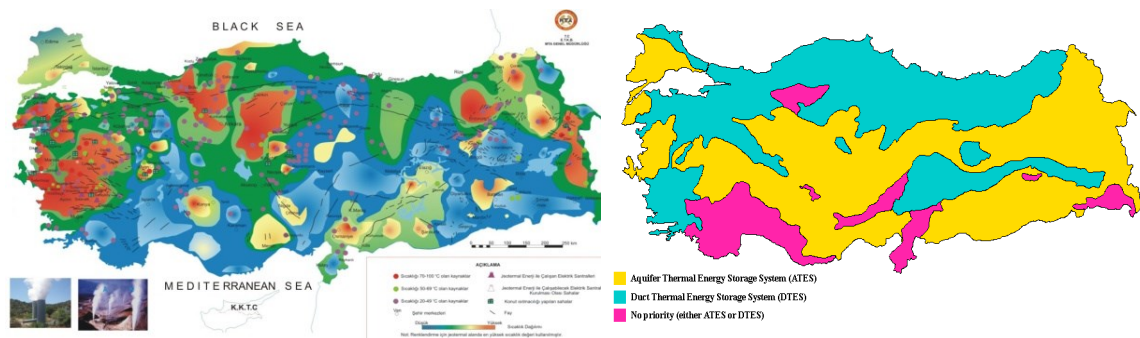
Two basic types of GHPs exist: (a) ground-coupled, and (b) water-source. Ground coupled ones are sometimes called ground source heat pumps – GSHPs. There are other names used for GHPs in different countries, which are influenced by local market drivers and legislative requirements.

### 3. SHALLOW GEOTHERMAL POTENTIAL

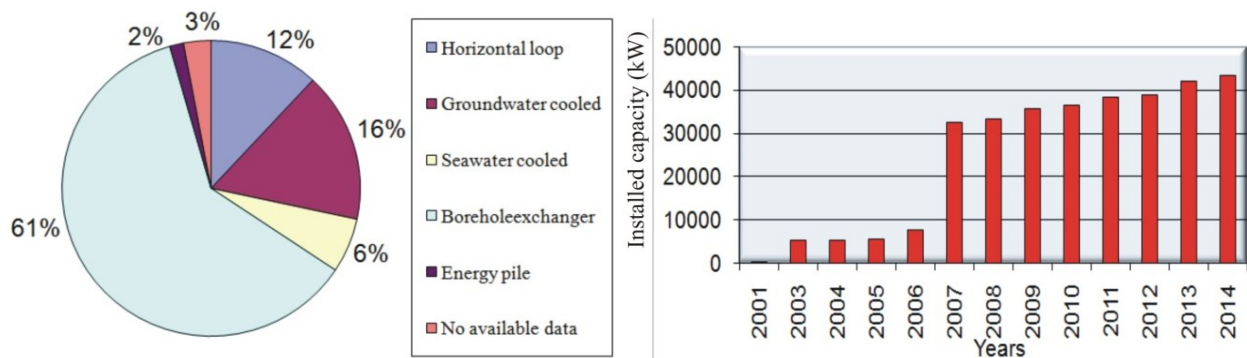
Turkey is situated in the Alps-Himalayan orogenic belt and young tectonism and volcanism is common. Turkey is the seventh in terms of technical geothermal potential and the fifth in terms of geothermal applications globally and the leading country in Europe. Geothermal fields in Turkey are mostly low and medium temperature. 95% of the known sources are suitable for heating and are situated in Western, North-Western and Middle Anatolia.

There are more than 600 hot water reservoirs with temperatures in the range of 25–103 °C (Figure 1). In regions, where natural geothermal resources are not available, shallow geothermal potential waits to be exploited. In a previous study, potential areas for

UTES applications were prepared using Geographic Information Systems – GIS. Relevant spatial information was overlapped to prepare the map shown in Figure 2. The colours on the map indicate potential areas for ATES and/or BTES: Blue for BTES, yellow for ATES and pink for ATES or BTES. Figure 1 gives a general potential, it is essential to determine the on-site geologic, hydrogeologic and climate conditions.



**Figure 1. Geological map and temperature distribution of geological resources of Turkey (MTA) (left), Map showing potential areas of UTES application, Blue for BTES, yellow for ATES and pink for ATES or BTES (Paksoy, 1999) (right).**



**Figure 2. Distribution of GSHP types (left) and installed capacity (right) in Turkey.**

#### 4. SHALLOW GEOTHERMAL APPLICATIONS

The first applications of shallow geothermal started in early 2000. There were about 24 units with a total installed capacity of 586 kW in 2001 (HEPBAŞLI et al., 2001). Total capacity is estimated to reach 38 MW (Formgroup, 2009) by 2009, covering a range of applications shopping malls, office buildings, hotels. The most common shallow geothermal application in Turkey is GSHPs. The number of GSHP companies has reached to eight. Four of these companies were established in 2009. 67 shallow geothermal systems have been installed by these companies since 2003. Figure 3 shows the breakdown of these installed systems of which 62% use borehole heat exchangers for ground coupling. There is an increasing trend in the installed capacity of GSHP reaching to 42 MWt as of 2013 (Figure 2).

The major components of the GSHP systems are exported, the cost varies depending on the change in foreign currency exchange rates. The installation cost of the system consisting of drilling of wells, borehole heat exchangers and collector pipes and connections is within the range of 1370 – 2280 Euro/kW (Iller Bank, 2013).

##### 4.1 Residential

The first residential geothermal heat pump system in the country was installed in a villa with a floor area of 276 m<sup>2</sup> in Istanbul, in 1998. The residential system consisted of a heating-only heat pump with a scroll compressor (15.6 kW heating) coupled to a 160-m borehole (Hepbasli et al., 2001). Several residential applications have been installed since then. Some examples from the more recent ones are given here:

GHP with a capacity of 156000 Btu/hr is installed in a villa in Zekariyakoy, Istanbul with a floor area of 305 m<sup>2</sup> for heating, cooling and hot water supply. Total depth of boreholes used for this application is 380 m (Korun, 2005).

In another villa application in Bolu with 2500 m<sup>2</sup>, 20 boreholes each with 120 m depth are used with 120 kW capacity GHP system (Akpınar, 2013).

The recreation center of 1300 m<sup>2</sup> for MESA Cengelkoy Houses in Istanbul uses GHP of 75 kW to meet part of the heating and cooling load of the building. 12 boreholes each at 125 m are used in the system. (Ustunalp and Pezukoğlu, 2013).

MERIDIEN residence building in Adana with 2940 m<sup>2</sup> floor area uses 17 boreholes coupled to a GHP of 160 kW (Dogalgeothermalenergy, 2013).

For a newly developed residential area in Zonguldak with 106 housing units and recreation center with 30000 m<sup>2</sup> living space, 720 kW capacity water to water GHP uses groundwater for heating, cooling, hot water production (Dogalgeothermalenergy, 2013).

For a villa application in Karamursel, Istanbul 1100m of horizontal slinky type ground coupling is used with GHP for heating and cooling of 150 m<sup>2</sup> space. Solar energy is also used as source of heating in this system decreases operational cost by 78% compared to conventional system working with LPG (Akpinar, 2013).

#### 4.2 Shopping malls

The first larger scale applications of GHPs started to be installed for shopping malls. The first one in Antalya Laura shopping mall, uses groundwater at 17°C. The 2 MW GHP system operating at COP of 5 consumes 50% less electricity compared to the other shopping malls in Antalya (Korun,2005).

In a more recent shopping mall GHP application in Antalya groundwater is also used. Terracity shopping mall with an area of 12000m<sup>2</sup> is one of the largest open GHP systems with capacity of 12 MW. (Korun,2013).

One of the largest GHPs of Europe with 900 kW capacity and total depth of 18327 m boreholes is installed for Meydan shopping mall in Istanbul (Korun et. al., 2009).

#### 4.3 Office Buildings

The administration building of industry technology park - Ostim in Ankara is designed as a green building. In addition to cogeneration and PVs, a 12 kW GHP is used with two 100 m boreholes for heating and cooling of 2500 m<sup>2</sup> space (Kilicaslan, 2013).

For the ESER office building in Ankara, five boreholes of 120 m each are coupled to a 60 kW GHP. This building also uses 6126 kW PVs and 1kW wind turbine installed on the roof of the building.

The heating and cooling of Simsek print office building in Istanbul of 1200 m<sup>2</sup> uses 60 kW GHP with 6 boreholes at 125 m each (Dogalgeothermalenergy, 2013).

For the administrative building of Karavil cement plant of 2050 m<sup>2</sup>, a GHP of 80 kW and seven boreholes each at 125 m depth are used (Dogalgeothermalenergy, 2013).

Euroflora flower and decoration center with 3000 m<sup>2</sup> uses slinky type ground coupling with 90 kW GHP to meet part of the heating and cooling load (Akpinar, 2013).

#### 4.4 Hotels

For Gallipoli Hotel in Çanakkale with 8000 m piping is used for ground coupling of 250 kW GHP (Formgroup, 2009).

For Pine Beach Hotel in Antalya with 2192 m<sup>2</sup> space, 12 boreholes at 130 m each are coupled to 120 kW GHP (Dogalgeothermalenerji, 2013).

Titanik hotel in Belek, Antalya is using river water as a source for cooling with a 8 MW system (Formgroup, 2013).

For Heaven Beach Hotel in Manavgat-Antalya, groundwater is used. Depth of wells are between 8 and 10 meter with 180 m<sup>3</sup>/h yield. With 1100 kW capacity and COP 8.5 GHP is used in this project supported by Tubitak (Erkmen, 2014).

#### 4.5 Schools

The first application in schools is for Ankara University Baştem Schools-ANKU High School with 3500 m<sup>2</sup> area. GHP with capacity of 180 kW uses 18 boreholes at 25 m depth each. (Dogalgeothermalenergy, 2013).

#### 4.6 Istanbul Sabiha Gokcen Airport

For maintenance building of aviation Services – HABOM at Sabiha Gokcen Airport, one of the largest energy piles GHP project in the world is realized. With 1855 kW capacity it will be the largest GHP in Turkey when it starts operation in 2013. System uses 1584 energy piles each at 20 m depth and total piping length including horizontal connection pipes of 275 km. (Ozkok, 2011).

#### 4.7 Hospitals

There are no hospital GHP applications in operation so far. For Cukurova University Balcali Hospital a feasibility study for an ATES system has been done. The system was designed to use Seyhan lake water and groundwater from 6 warm and 6 cold wells (PAKSOY et al., 1997) The annual energy conservation was calculated to be 3250 MWh electricity and 1000 m<sup>3</sup> Fuel-Oil.

#### 4.8 Greenhouses

Geothermal resources for greenhouse heating is used with an increasing trend reaching an area of 2,811,000 m<sup>2</sup> by 2012 (GEKA, 2012). The use of shallow geothermal systems in greenhouses is at demonstration phase.

ATES demonstration plant for a research greenhouse of 360 m<sup>2</sup> at Cukurova University is the first application in greenhouses in Turkey and Mediterranean climate. The system uses two wells at 90 m with a groundwater flow of 10 L/s. The results show that 60% of the energy used for heating is conserved and the investment cost was paid back in less than two years (Turgut et al., 2008).

### 5. THERMAL RESPONSE TEST

Thermal response test (TRT) is used to determine the thermal properties of the ground in designing BTES and GHP systems. It is an in-situ test that is a pre-requisite of BTES application in many countries. The results from TRT are used for optimum design of

BTES system, which leads to more economic and safer application. TRT is carried out by Cukurova University in Turkey for commercial and research projects (Paksoy et al., 2010). Table 1 shows the location where TRT has been used. For especially larger systems it is essential to carry out TRT.

## 6. FUTURE OPPORTUNITIES

There are a number of developments in Turkey that may lead to boost of GHP applications

### 6.1 Urban development plan

For the next 10 years, a major urban development plan is proposed to renovate almost one-third of the building stock in Turkey. The price tag for this effort is considered to be as high as 500 billion USD. This is a huge potential for applications of shallow geothermal systems for more energy efficient solutions of the new buildings.

**Table 2: Thermal response tests done in Turkey.**

Site	Year	Number of boreholes	Purpose
Adana	2000-2001	1	Research
Hadımköy, Istanbul	2001	1	Commercial
Beykoz, Istanbul	2001	1	Commercial
Umraniye, Istanbul	2007	5	Commercial
Elazığ	2007	1	Research
Ankara	2008	1	Commercial
Samsun	2009	1	Commercial
Mugla	2009	1	Commercial

### 6.2 Buildings Energy Performance Legislation

Buildings Energy Performance Legislation that is in action according to the Law of 5627 Energy Efficiency dated 18 April 2007, Article no 7, the new and existing buildings need to have an Energy Identity Document (EKB). EKB, which must be required by all buildings to get a construction permit as of 1 January 2011, contains “information on minimum energy demand and consumption classification of the building, insulation properties and efficiency of heating and/or cooling systems” ([www.eie.gov.tr](http://www.eie.gov.tr)). The Building Energy Performance Code prepared as part of European Union accession enforces this situation.

In this document, energy classification is given as A-G and the new buildings are expected to have energy consumption and CO<sub>2</sub> emissions of higher than D class. Using renewable energy resources, energy efficiency and conservation have been more important than ever for our country where more than 70% of the energy demand is met by import. Shallow geothermal systems can be one of the solutions for buildings to be able to get EKB document.

### 6.3 Green building movement

Green building certification (LEED, BREEM) for buildings started to receive interest among some commercial projects recently. Use of renewable technologies as part of greenbuildings not only gives a positive market image for the company, but also by consuming less energy brings economic and environmental benefits. Green marketing policy of some companies. Some recent shallow geothermal projects like ESER and OSTIM buildings in Ankara have received LEED certification. Among the planned buildings, there is growing interest for using shallow geothermal systems. The annex building for the Ministry of Environment and Urbanization and headquarters of Bank of Provinces in Istanbul are among the governmental buildings which plan to use geothermal heat pump systems.

## 7. BARRIERS

There are no GHP manufacturers in Turkey. The piping materials used in ground heat exchangers are also imported. This situation increases the initial investment of the systems. In countries where a boost in shallow geothermal applications is seen, incentives, rebates or other types of governmental support are given.

The drilling sector in Turkey developed for water wells and geothermal applications can be insufficient in terms of expertise and equipments for shallow geothermal boreholes.

There is lack of awareness in shallow geothermal systems and their benefits in society. The number of educated experts to design, construct and maintain these systems is still limited.

Recent large projects that are among the largest in the world, like Meydan shopping mall and HABOM Sabiha Gokcen Airport indicate that Turkish companies have the knowledge and started to gain experience to develop such project.

## 8. CONCLUSIONS

The number of shallow geothermal applications has increased from 24 in 2001 to 132 in 2014 with a total 42 MWt capacity. This shows that there is growing interest, but not at a desired level. The larger projects that have been built recently show that the trust and awareness in these systems are increasing. For a boost in shallow geothermal applications in Turkey the following recommendations can be given:

- New laws and legislations that considers shallow geothermal among the renewable energy applications are needed.

- Planning and realizing financial incentives for these systems should be done.
- Local production of GHP and pipes should be encouraged.
- Education activities to increase number of experts for design, construction and installation of these systems are necessary.
- Information dissemination activities to increase the awareness on the benefits of these systems in public and also decision makers.
- For quality assurance, technical success and economic design of shallow geothermal systems TRT must be used as a standard pre-design tool.

Turkey is very rich in geothermal resources. Some of these resources can be exploited more efficiently if they are used together with shallow geothermal systems, such as using waste heat from balneology applications in medium enthalpy fields.

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