CURRENT STATUS AND FUTURE DIRECTIONS OF GEOTHERMAL HEAT PUMPS IN TURKEY

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ABSTRACT

Ground-source or geothermal heat pumps (GHPs) are attractive alternative to conventional heating and cooling systems owing to their higher energy utilization efficiency. In this regard, GHPs have had the largest growth since 1995, almost 59% or 9.7 annually in the United States and Europe. The installed capacity is 6,850 MW_t and annual energy use is 23,214 TJ/yr in 26 countries. The actual number of installed units is around 500,000. The utilization of GHPs in residential buildings is new in Turkey, although they have been in use for years in developed countries. In other words, GHPs have been put on the Turkish market for about three years. There are no Turkish GHPs' manufacturers yet. It is estimated that 43 units are presently installed in Turkey, representing a total capacity of 527 kW. Considering the ongoing installations, the total installed capacity will reach 3,763 kW in this year, with a total of 282 units. The majority of the installations are in the Marmara region of Turkey (in Istanbul). High-income earners also prefer these systems. The current status of GHPs in Turkey is discussed and two case studies are described, of which the first one relates to the University of Ege, Izmir, Turkey while the second one includes a commercial application, which replaced a furnace.

GHPS APPLICATIONS IN TURKEY

In Turkey, the concept of the ground-source (or geothermal) heat pumps (GSHPs), in general heat pumps, is not new. However, the utilization of GSHPs in residential buildings is new in Turkey, although they have been in use for years in developed countries and the performance of the components is well documented. The first residential geothermal heat pump system in the country was installed in a villa with a floor area of 276 m^2 in Istanbul, in 1998; while, the first experimental study was carried out in the Mechanical Engineering Department, METU (Middle East Technical University) in Ankara, in 1986 (for more detail see Babur, 1986; Hepbasli and Gunerhan, 2000). The residential system consisted of a heating-only heat pump with a scroll compressor (15.6 kW heating) coupled to a 160-m (525-ft) vertical 1 ¼ inch U-bend ground coupling. The representative firm of Swedish GSHPs' manufacturer imported the heat pump itself and its relevant ground coupling materials and this system has been successfully operated since its installation.

In this context, the studies carried out on GHPs in Turkey can be divided into three groups (for more detail, see Hepbasli and Gunerhan, 2000); a) university studies, b) case studies (heat pump industry), and c) standardization studies.

University Studies

University studies on GSHPs can be classified into two categories: theoretical and experimental. Up to date, only three experimental studies were carried out by Babur (1986), Kara (1999) or Kara and Yuksel (2000) and Hepbasli (2000). Table 1 shows the main characteristics of GHP systems installed at the three different universities. The theoretical studies performed were described elsewhere (Hepbasli and Gunerhan, 2000).

Table 1. Main characteristics of GHPs installed at the Turkish Universities as of January 2001 (Babur, 1986; Kara, 1999, 2000; Hepbasli, 2000)

Name of University	Year built	System type	HP cap. kW
Middle East Technical University (Ankara)	1986	A single pipe-horizontal heat pump system for the heating only with R-12; 10 m of ground coil at 1.5 m depth with a spacing of 0.6 m; COP: 1.1 to 1.3.	0.95
Ataturk University (Erzurum)	1999	A water-to-water geothermal heat pump system for the heating only with R-22; an actual COP value of 2.8; Geothermal water inlet/outlet temp. 35/30 ºC at a flow rate of 1,100 L/h	7.02
Ege University (Izmir)	2000	A GSHP system for both heating and cooling with a vertical-single U-bend heat exchanger; 4 ½ inch of a bore diameter with a boring depth of 50 m	5.2

Heat Pump Industry (Market)

GSHP systems installed so far in Turkey are few in numbers. There are not any Turkish GSHPs' manufacturers yet. Currently, there are three companies, of which one is the pioneer of GSHPs in Turkey (Firm D) and has installed many systems. The remainder deals with water-loop heat pump systems imported from the USA (Firm A; Firm C), excluding one (Firm B). Besides these, the others are trying to introduce GSHPs into the Turkish market nowadays. In order to

determine the number of GSHPs installed, information from 16 case studies was collected on residential and commercial systems from Turkish GSHP sellers (and also contractors) throughout Turkey. "Firm A" installed in 1998 a water-loop heat pump system (WLHPS) at Kaya Building consisting of 12 storeys in 1998 which was the biggest one in Turkey and is still active. Based on the data given by the "Firm B," six projects have been implemented for building heating ranging from an air-conditioned floor area of 650 m^2 to 24,900 m^2 by means of GSHPs. Two of them were completed in 1999 and the remaining is in progress. In fact, no reliable data were obtained from "Firm B" and it is heard that this firm went bankrupt. Besides these, no data was obtained from "Firm C." Therefore, only data given by the "Firm D," which is at present the single one in the installation of GSHPs in Turkey, were taken into account. The distribution of GHP systems installed by "Firm D" so far amounts to 16 vertical and 5 horizontal closed-loop systems, with 275 vertical ones in progress. In 1998 when the first installation was began, two GHP systems with a total capacity of 26 kW were completed, representing a total floor area of 596 m^2. These systems have had the largest growth since the beginning of the year 2000. Today, the installed capacity is 527 kW while the number of installed units is 23, totaling 43 units with the equivalent number of 12 kW. The 12 kW equivalent is used as typical of homes in the United States and some western European countries (Lund and Freeston, 2000). The size of individual units is in the range 9 to 46 kW and 38 to 46 for residential and commercial uses, respectively. Considering the ongoing installations, the total installed capacity will be 3,763 kW, with a total of 282 units ranging from 7.3 to 46.2 kW for both residential and commercial uses. In addition, by taking into account the new works, which are at the design stage, with a total 130 villas ranging from 120 to 310 m^2 of floor areas, it is estimated that the installed capacity will reach about 5 MW. Of the GHP systems installed up to date, 80% were vertical ground-coupled GHP systems while about half was designed for both heating and cooling. The diameter of U-bend tubes was 1 ¼ inches for the both applications. The heating and cooling loads were approximately 80 and 95 W/m^2, respectively. The majority of the installations are in the Marmara region (in the province of Istanbul).

Standardization Studies

Turkish standards relating to heat pumps are few in numbers. Up to date, 14 standards were issued on heat pumps by TSI (Turkish Standards Institution), of which only two contained the water to water type heat pumps (Hepbasli and Gunerhan, 2000). This means that standardization studies are also new in Turkey.

CASE STUDIES

In the following, the two case studies will be described. Of these, the first one relates to the University of Ege, Izmir, Turkey while the second one includes a commercial application, which replaced a furnace.

Case Study 1: Ege University

The water (ground)-to-water type heat pump (GSHP) system was connected to a 64-m^2 classroom of the Solar Energy Institute Building (SEIB) at the University of Ege, Izmir, Turkey. The building constructed in 1986 uses passive solar techniques and hence it was well insulated. It has three floors and a total floor area of 3,000 m^2. The GSHP system mainly consisted of three separate circuits, which are called the ground coupling circuit (brine circuit or water-antifreeze solution circuit), the refrigerant circuit (or a reversible vapor compression cycle) and fan-coil circuit (water circuit). The system was commissioned in July 2000. Performance tests still continue. From the measurements, the specific heat extraction rate was found to be 84.4 W per meter of borehole length, while the COP for cooling was about 3.1.

Case Study 2: Office Building

The building, located in Izmir, has 49 offices. The heating and cooling loads of the structure are 259 and 294 kW, respectively. The building was formerly designed for the heating only and hence heated by a 406-kW oil-fired hot water generator through fan-coils. The GSHP system replaced this hot water generator in June 2000 and has operated since that time. It was designed for both heating and cooling. No performance data were obtained from the installer. The measurement devices were missing in order to monitor the performance of the system.

CONCLUSIONS

The importance of energy as an essential ingredient in economic growth as well as in any strategy for improving the quality of life human beings is well established. In this context, energy, which can be defined as money and even cash from the viewpoint of energy efficiency, is the mainstay of the modern society. So, GHPs are attractive alternative to conventional heating and cooling systems. GSHPs are receiving increasing interest in Turkey. The technology is well established with over 500,000 units installed worldwide. The soil type and moisture content on the performance of GSHP have recently been reported by some investigators (Morino and Oka, 1994; Leong *et al*., 1998; Allan, 2000). However, in Turkey, this cost reduction factor, which can be achieved by decreasing the necessary ground loop length with the optimal selection of the backfill material, is not taken into account in the design. Besides these, for the successful development of GHPs in Turkey, the other issues given elsewhere (Hepbasli and Gunerhan, 2000) should be taken into account.

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GHPs Installations with Conventional Horizontal Ground Loop in Turkey as of January 2001

Situation of Application	City of Region	Building Type/No. of Buildings	Total Floor Area (m^3)	No. of HP Units (type)	Total Pipe Length (m)	HP Capacity (kW)	Total HP Capacity (kW)	Total Equiv. Number of 12 kW Units
Completed	Istanbul/ Marmara	Villa / 2	1,400 + 400 = 1,800	2 / (HC)	1,690 + 600 = 2,290	38 and 15	53.0	
	Ankara/ Central Anatolian	Villa / 1	525	1 / (H)	850	46.2	46.2	
	Bolu/ Black Sea	Bungalow / 1	240	1 / (H)	420	9.0	9.0	10
	Mersin/ Mediterrean	Villa / 1	435	1 / (H)	600	15.0	15.0	
TOTAL		5	3,000	(2HC 3 H)	4,160		123.2	

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Firm A, Form Inc.

Firm B, Ente Avrasya Inc.

Firm C, TEBA Inc.

Firm D, Yesil Cizgi Inc.

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