GEOTHERMAL HEAT PUMPS - AN OVERVIEW

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Geothermal heat pumps (ground-source heat pumps) (GHP or GSHP) are used in two basic modes: ground coupled (vertical and horizontal)--closed loop, or groundwater types - open loop (Figures 1 and 2). These have been described extensively in a previous Geo-Heat Center Bulletin (Vol 18, No. 2 - April 1997) and in more detail in "An Information Survival Kit for the Prospective Geothermal Heat Pump Owner" by Kevin Rafferty--both of which are available on our website: <geoheat.oit.edu>.

The installation and use of geothermal heat pumps worldwide have had a large increase over the past ten years with almost a 10% annual increase during this time. Most of this growth has occurred in the United States and Europe, though interest is developing in other countries such as Japan and Turkey. The present worldwide installed capacity is 6,875 MWt and the annual energy use is 23,287 TJ/yr (22,088 billion Btu/yr or 6,453 GWh/yr) at the beginning of 2000 in 27 countries (Table 1). The actual number of installed units is around 500,000, but the data are incomplete. The equivalent number of 12 kW units installed is slightly over 570,000. The 12 kW (3.4 tons) equivalent is used as typical of homes in the United States and some western European countries. The size of individual units, however, range from 5.5 kW (Poland and Sweden) for residential use to large units of over 150 kW (Germany and the United States) for commercial and institutional installations.

In the United States, most units are sized for the peak cooling load and are oversized for heating (except in the northern states) and, thus, are estimated to average only 1,000 full-load heating hours per year (capacity factor of 0.11). In

Table 1. Worldwide Geothermal Heat Pump Installations in 2000

Country	MWt	TJ/yr	GWh/yr	Actual #	Equiv. # (12 kW)
Australia	24	57.6	16.0	2,000	2,000
Austria	228	1,094	303.9	19,000	19,000
Bulgaria	13.3	162	45.0	16	1,108
Canada	360	891	247.5	30,000	30,000
Czech Republic	8.0	38.2	10.6	390	663
Denmark	3	20.8	5.8	250	250
Finland	80.5	484	134.5	10,000	6,708
France	48	255	70.8	120	4,000
Germany	344	1,149	319.2	18,000	28,667
Greece	0.4	3.1	0.9	3	33
Hungary	3.8	20.2	5.6	317	317
Iceland	4	20	5.6	3	333
Italy	1.2	6.4	1.8	100	100
Japan	3.9	64	17.8	323	323
Lithuania	21	598.8	166.3	13	1,750
Netherlands	10.8	57.4	15.9	900	900
Norway	6	31.9	8.9	500	500
Russia	1.2	11.5	3.2	100	100
Poland	26.2	108.3	30.1	4,000	2,183
Serbia	6	40	11.1	500	500
Slovak Republic	1.4	12.1	3.4	8	117
Slovenia	2.6	46.8	13.0	63	217
Sweden	377	4,128	1,146.8	55,000	31,417
Switzerland	500	1,980	550.0	21,000	41,667
Turkey	0.5	4.0	1.1	23	43
UK	0.6	2.7	0.8	49	53
USA	4,800	12,000	3,333.6	350,000	400,000
TOTAL	6,875.4	23,286.9	6,453.1	512,678	572,949

Europe, most units are sized for the heating load and are often designed to provide just the base load with peaking by fossil fuel. As a result, these units may operate from 2,000 to 6,000 full-load hours per years (capacity factor of 0.23 to 0.68). Unless the actual number of full-load hours were known, a value of 2,200 hours was used for energy output (TJ/yr) based on data for several of the European countries. As an example, Finland has approximately 10,000 units installed, 70% horizontal installation, where the ground temperature is around 10°C (50°F).

Since performance of heat pumps is described in the papers in this Bulletin, several definitions are appropriate. Heating performance is defined by the index called COP (Coefficient of Performance), which is the heating affect produced by the unit (in Btu/hr) divided by the energy equivalent of the electrical input (in Btu/hr) resulting in a dimensionless number. Cooling performance is defined by an index called EER (Energy Efficiency Ratio), which (in the U.S.) is the cooling affect produced by the unit (in Btu/hr) divided by the electrical input (in watts) resulting in units of Btu/watt‡hr.

The energy reported for heat pumps should be reduced from the installed capacity based on a COP (coefficient of performance) of 3.0, which allows for one unit of energy input (usually electricity) to three units of energy output. Thus, the geothermal component is 67% of the energy output. Newer units have COPs in the 4 to 5 range which increases the geothermal use to 75% to 80% of rated capacity.

In the United States, geothermal heat pump installations have steadily increased over the past 10 years with an annual growth rate of about 12%, mostly in the mid-western and eastern states from North Dakota to Florida. At the end of 1999, there are an estimated 400,000 units installed, with 45,000 installed annually. Today these figures are 450,000 and 50,000 respectively. Of these, 46% are vertical closed loop, 38% horizontal closed loop and 15% open loop systems. Projections for the future are that the growth rate will increase about 12% annually, so that by 2010 an estimated 140,000 new units would be installed in that year, thus, adding almost one million units for a total of about 1.5 million units. Over 600 schools have installed these units for heating and cooling, especially in Texas. Using a COP of 3.0 and 1,000 full-load hours per year in the heating mode, the 450,000 equivalent 12 kW (3.4 ton) units remove approximately 12,900 TJ/yr (12,250 billion Btu/yr) from the ground. The cooling mode energy is not considered geothermal, since this rejects heat to the ground; however, the cooling mode does replace other forms of energy and is, thus, considered in fossil fuel and greenhouse gases emission savings. It should be noted at this point, that in the United States, heat pumps are rated on tonnage (i.e., one ton of cooling power--produced by a ton of ice) is equal to 12,000 Btu/hr or 3.51 kW.

One of the recent converts to this form of energy savings is **President George W. Bush**, who recently installed a geothermal heat pump on his Texas ranch during the election campaign. Howard Newton, a consultant on the job, overheard the then President-elect explaining to Vice President-elect Dick Cheney and General Colin Powell that geothermal heat is "**environmentally hip"** (Julie V. Iovine, *The New York Times*, January 4, 2001). The unit total is 14 tons (49 kW) broken into five separate systems with desuperheater. The vertical closed loop installation cuts his heating and cooling cost by 40%.

Figure 1. Ground-coupled (closed-loop) types.

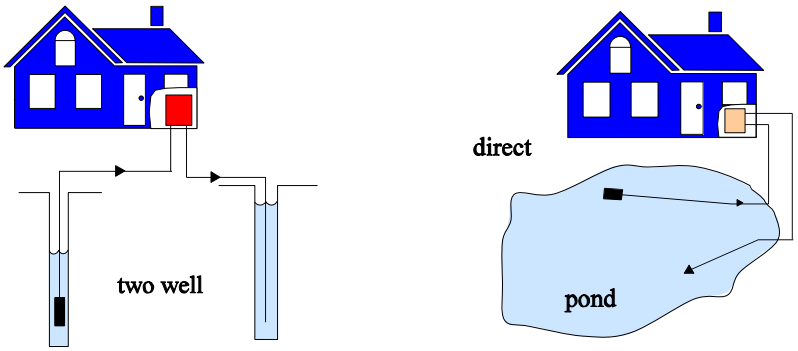

Figure 2. Groundwater (open-loop) types.