GEOTHERMAL HEAT PUMP CASE STUDIES

Paul J. Lienau and Tonya L. Boyd
Geo-Heat Center (GHC)
Oregon Institute of Technology

KEYWORDS

case studies, ground coupled, ground source, groundwater, heat pump, performance, utilities, national assessment

PROJECT BACKGROUND AND STATUS

Geothermal heat pump (GHP) systems are a promising new energy technology that has shown rapid increase in usage over the past ten years in the United States. These systems offer substantial benefits to consumers and electric utilities in energy (kWh) and demand (kW) savings.

The Department of Energy (DOE) and the Environmental Protection Agency (EPA) are rapidly expanding their involvement in programs to promote increased use of both renewable-energy resources and energy-efficient technology. Federal implementation of the Clean Air Act Amendments of 1990 and the Energy Policy Act of 1992, and other regulations still under development are a result of increasing worldwide environmental consciousness. Geothermal heat pump (GHP) systems can help meet the challenge by increasing our energy efficiency, with resulting benefits in better load management, to customers in lower utility bills and to society in a cleaner environment (Pratsch, 1992).

Electric utilities are the ultimate market target for GHPs, especially utilities that are already committed to demand side management (DSM). Recommendations for implementation of geothermal heat pumps must be consistent with prevailing energy policies and supported by data. The data must show that the resource and technology are available, reliable, and cost competitive with other options. Concerns of utilities considering GHP technology as a DSM option include: (1) amount of demand and energy savings; (2) first cost of ground loop and wells; (3) effect of ground loop temperature increase for summer and long-term operation, especially for commercial applications; (4) utility rebates and other incentives; and (5) infrastructure availability of heat pump dealers and loop installation contractors.

The project was started in July 1992 and was completed in October 1995.

PROJECT OBJECTIVES

The objectives of this program were to provide information on geothermal heat pump (GHP) performance and the status of electric utility companies in promoting the technology.

Technical Objectives

- Determine what existing monitored data (metered) are available on GHP installations for residential, school and commercial buildings.
- Determine seasonal energy use, savings patterns and economics of GHP systems with competing energy systems in typical residential and commercial situations.
- Develop information that will include electric utility marketing, incentive programs, barriers to market penetration, number of installations in utility service area and benefits to utilities.
- Evaluate temperature changes in loop fluid at a system near Helena, Montana through two household heating seasons.

Expected Outcomes

- Database of monitored GHP systems for residential and commercial applications.
- Efficiency improvements, energy use, demand savings and economics of GHP systems compared with competing energy systems in typical residential and commercial situations.
- Information on electric utility and rural electric cooperative programs to implement GHP into demand-side management programs.

APPROACH

The Geo-Heat Center's approach was to compare as many types of like case studies taken from as many sources as possible. Information was collected for 256 case studies, mainly from utilities throughout the United States. The information extracted from the case studies were compiled into a database. The database was organized into general information, system information, ground system information, system performance, and additional information.

Information was developed on the status of demand-side management of geothermal heat pump programs for about 60 electric utility and rural electric cooperatives on marketing, incentive programs, barriers to market penetration, number of units installed in service area and benefits.

Under agreement with the Montana Power company, separate meters were installed at a Helena, Montana, residence to monitor energy consumption of the heat pump, the electric hot-water heater, and the auxiliary strip heater. The utility meters recorded kilowatt-hours of consumption at 15-minute intervals, accessed by data loggers. The loop was monitored continuously to obtain the minimum daily loop temperatures.

RESEARCH RESULTS

In recent years, there has been a substantial increase in the efficiency of geothermal heat pump equipment. Based on the performance of a typical machine reported in the American Refrigeration Institute (ARI) directory for 1987 and 1994, the average increase in energy efficiency ratio (EER) ranged from 26 to 56 percent, and in coefficient of performance (COP) from 35 to 50 percent. (Figure 1)

In order to verify the performance of geothermal heat pumps, information from 256 case studies has been collected on residential, commercial, and school systems from primarily utilities throughout the United States. These were compiled into a database. The systems were monitored for various parameters, ranging from only energy (kWh) input to the heat pump to eight other parameters. Unfortunately, there were very few case studies with a comprehensive set of monitored data available. Many testing techniques were used; but ultimately the goal was to determine annual energy usage and peak demand savings compared with competing energy systems. There were 184 residential, 26 school, and 46 commercial systems in the 256 case studies (Lienau, 1995).

Case Studies

Of the 184 residential systems, only 128 GHP and 46 conventional systems were monitored. These conventional systems were compared to GHP systems for energy saving patterns, power reduction for eclectic resistance (heating only), operating costs, etc. The average annual energy savings of GHP systems ranged from 31% to 71% and dollar savings ranged from 18% to 54%. For a breakdown of each conventional system see Table 1. The residential GHP system peak demand reduction compared to single-zone electric resistance heating for 13 case studies ranged from 5.3 kW to 10.4 kW with a mean of 7.2 kW. (Figure 2)

The potential for savings of GHP systems in schools are documented in 26 case studies, with 23 of the 26 monitored. The benefits reported using GHP systems in schools are the addition of mechanical cooling, improved control, and simplicity of maintenance and repair. In southern climates, the benefits include: elimination of cooling towers, outdoor equipment, mechanical rooms and ductwork.

Commercial systems were monitored in 84% of the 46 case studies, with only 20% compared to conventional systems. They ranged in capacity from 30 to 4700 tons. These systems employed ground-coupled well fields of up to 370 boreholes for a 850-ton system, to 3 wells for a 4700-ton groundwater system. The average annual energy savings of geothermal heat pump systems ranged from 40% to 72% and dollar savings ranged from 31% to 56%.

The savings attributable to the use of GHP systems in commercial buildings vary over a wide range (Figure 3). This is due mainly to such parameters as climate, GHP system type, soil conditions, equipment efficiency, sizing and other issues which influence GHP applications. Unique to commercial buildings are building use, internal heat gains, and more complex rate structures. Clearly given all the potential influences upon commercial building energy use, prediction of savings to be achieved with a GHP system becomes a very site-specific endeavor.

The economics of GHP systems are represented by the simple payback reported in the case studies. There were 27 residential, 5 school, and 17 commercial systems that reported simple paybacks. A favorable payback is considered to be 5 years. The range for residential simple paybacks was 1.4 to 24.1 with a mean of 6.8 years. Simple paybacks for schools were reported in only 5 out of 26 case studies. Therefore, this is not a good statistical representation of economics for using GHPs in schools. Commercial building case studies reported simple paybacks for 17 out of 46 GHP systems. The range was 1.3 to 4.7 with a mean of 2.8. All but four of the simple paybacks represent buildings located in northern climates.

Utility Programs

The geothermal heat pump is one of the many technologies electric utilities are considering or implementing for demand-side management (DSM), especially aimed at improving the efficiency with which customers use electricity. The results of DSM programs aimed at energy efficiency provide two benefits: they save energy and reduce peak demands.

Information was developed on the status of DSM programs for about 60 utilities and rural electric cooperatives including: marketing programs, barriers to market penetration, incentive programs, number of GHP units installed in service area, and the benefits to the utility. The most common marketing programs were newspaper and radio/television advertisement, test and demonstration of GHP system performance, education programs, and home shows.

The primary barrier to marketing GHP systems according to a majority of the utilities is the incremental cost of installing the ground loop. Other deterrents to the implementation of GHPs cited by the utilities are: natural gas is inexpensive; lack of manufacturers, suppliers, dealers and loop installers; and customers resistance to heat pump technology.

Utilities have designed several incentive packages to encourage the installation of GHPs. In most cases, these incentives include cash rebates (average $60/kW), low cost financing, discount energy rates, lease/purchase programs and in a few cases ground loop installations.

Montana House

The monitored home in Helena, from beginning operation on April 12, 1991 until March 23, 1995, has drawn 44,670 kWh of electrical energy. Of these, 887 kWh were used by a resistance strip heater to augment the heat pump output and the remaining 43,783 kWh served the heat pump providing household heat and supplemental heat for the hot water heater. The strip heater use was mostly frivolous, done in experimentation with various thermostat settings. Over the 3.95 years of operation, energy consumption averaged 11,310 kWh per year, about 20% greater than that predicted by the installers' computer design program. Likewise, the predicted annual heating and cooling cost of $598 was exceeded by 16% in the actual average of $692. The cause for the discrepancy is unknown, and may be unique to this particular installation or may require a different application of general design criteria (Van Voast, 1995).

FUTURE PLANS

The geothermal heat pump industry is currently in a state of transition from primarily residential applications to a broader based residential-commercial form. The success of this transition to larger projects hinges on information availability: design information for engineers, performance information for utilities, and economic information for owners.

An effective means of address this information need would be a digital database containing design, energy and cost information on a wide variety of existing GHP systems. The database which could be accessed via the Internet would permit users to quickly compare their applications to existing systems. This would afford the opportunity to quickly and efficiently evaluate feasibility, compare costs, refine mechanical design, and identify key contact individuals associated with similar systems.

Based on the results of "Geothermal Heat Pump Case Studies", the Geothermal Heat Pump Consortium, Inc., has requested the GHC propose to maintain the database, and update or enhance its availability for the public.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

The following are industries and institutions that have expressed an interest in the results of this project:

Organization(s)	Type and Extent of Interest
Electric Utilities Rural Electric Cooperatives	Performance and economic information.
Engineering Firms Contractors	Design information, economics and contacts.
Geothermal Heat Pump Consortium, Inc.	Maintenance and update of the database and Internet access.

REFERENCES

Lienau, P., Boyd, T. and R. Rogers, 1995. "Ground-Source Heat Pump Case Studies and Utility Programs", Technical Report to USDOE, Geothermal Division, Oregon Institute of Technology, Geo-Heat Center, Klamath Falls, OR.

Pratsch, L. W., 1992. "Geothermal Heat Pumps Benefit the Consumer Utility and Nation", Geo-Heat Quarterly Bulletin, Vol. 14, No. 1, pp. 1-6.

Rafferty, K., 1994. "Groundwater and Ground-Coupled Heat Pump Systems", Geo-Heat Quarterly Bulletin, Vol. 15, No. 3, pp. 9-12.

Van Voast, W., 1995. "Ground-Source Heat Pump System Near Helena, Montana - Loop Temperature Analysis", Montana Bureau of Mines and Geology. Montana Tech of the University of Montana, Technical Report to the Oregon Institute of Technology, Geo-Heat Center, 22 p.

CONTACTS

DOE Program Manager:

Marshall Reed
U. S. Department of Energy
Geothermal Division, EE-122
1000 Independence Ave., SW
Washington, D. C. 20585
Tel: (202) 586-8076
Fax: (202) 586-8185

Principal Investigator:

Paul J. Lienau
Geo-Heat Center
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Tel: (541) 885-1750
Fax: (541) 885-1754

Operations Office Program Manager:

Joel Renner
Idaho National Engineering Laboratory
P.O. Box 1625-3830
Idaho Falls, Idaho 83401-1563
Tel: (208) 526-9824
Fax: (208) 526-0969

Table 1. Residential Dollar and Energy Savings

Conventional System	Mean Annual Savings (%)			
	Number[a]	Energy	Number[a]	Dollars
Electric Resistance Heat/AC	21	57%	18	54%
Air-Source Heat Pump	33	31%	21	31%
Natural Gas Furnace/AC	17	67%	21	18%
Oil Furnace AC	6	71%	9	33%
Other (propane, unspecified)	7	46%	7	39%

a. Case studies

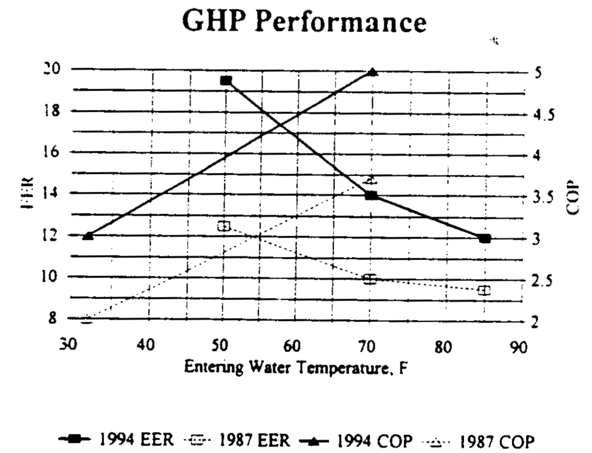

Figure 1. EER and COP efficiency improvements from 1987 to 1994.

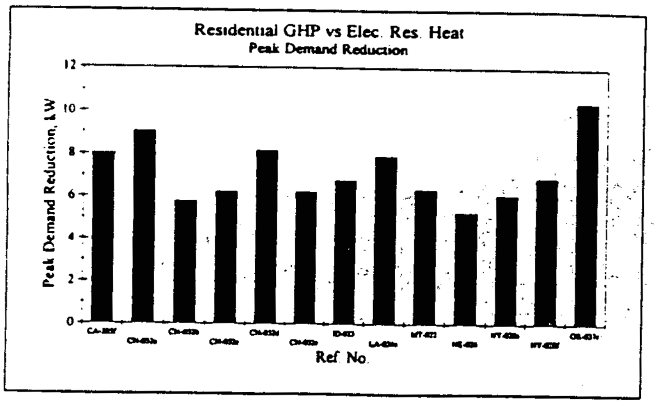

Figure 2. Peak reduction for residential.

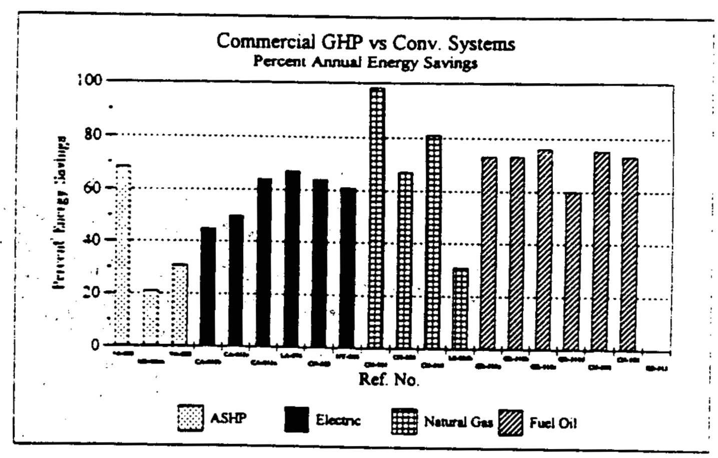

Figure 3. Commercial annual energy savings.