GROUND-SOURCE HEAT PUMP CASE STUDIES AND UTILITY PROGRAMS

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ABSTRACT

Ground-source heat pump systems are one of the promising new energy technologies that has shown rapid increase in usage over the past ten years in the United States. These systems offer substantial benefits to consumers and utilities in energy (kWh) and demand (kW) savings. The purpose of this study was to determine what existing monitored data was available mainly from electric utilities on heat pump performance, energy savings and demand reduction for residential, school and commercial building applications. In order to verify the performance, information was collected for 253 case studies from mainly utilities throughout the United States. 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 ground-source heat pump programs for about 60 electric utility and rural electric cooperatives on marketing, incentive programs, barriers to market penetration, number units installed in service area, and benefits.

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GROUND-SOURCE HEAT PUMP CASE STUDIES AND UTILITY PROGRAMS

EXECUTIVE SUMMARY

Background

The purpose of this summary is to present an overview of the findings from 256 case studies of ground-source heat pumps (GSHP), also known as geothermal heat pump installations for residential, school, and commercial buildings. The case studies were compiled into a database that is easily accessible and maintained on personal computers. The database contains information on what data was monitored (metered) or simulated (modeled) and used to establish patterns of energy savings, peak demand reduction and economics for residential and commercial situations. Information was also summarized on the status of demand-side management of GSHP programs for about 60 electric utilities and rural electric cooperatives on marketing, incentives, barriers to market penetration, number of units installed in service areas, and benefits.

The savings attributable to the use of GSHP systems in residential, school and commercial buildings vary over a wide range. This variation is the result of a large number of factors that can affect a system's performance. A total of 31 variables have been identified including such parameters as climate, GSHP system type, soil conditions, equipment efficiency, sizing and other issues which influence all GSHP applications. For example in recent years, there has been a substantial increase in the efficiency of GSHP 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. The range is a function of the entering water temperature. Due to these complex variations, the goal was to compare as many case studies of similar data to establish a pattern rather than attempt to remove the variables for an exact comparison. All the case studies evaluated were prepared by other researchers, utilities and manufacturers, and their validity was not investigated.

Residential Ground-Source Heat Pumps

Residential GSHP systems were documented for 184 case studies which include 24% vertical ground-coupled, 24% horizontal ground-coupled, 21% groundwater, 3% spiral (slinky) and 28% other types. Of these systems, 127 GSHPs were monitored (metered) and compared to 111 conventional energy systems of which only 46 were monitored.

The average annual energy savings of GSHP systems ranged from 31% to 71% and dollar savings ranged from 18% to 54%.

Residential GSHP Annual Savings

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

a. AC means with electric air conditioning.

b. Natural gas or oil furnaces with electric air conditioning had annual operating costs less than GSHP systems for 23% of the case studies.

The mean annual dollar savings of GSHPs shown above may appear attractive; however, due to the relatively low-annual operating costs of conventional energy systems, it is difficult in many cases to recover the additional incremental cost (ground loop) of GSHP systems.

Residential GSHP 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.

School Ground-Source Heat Pumps

The potential for savings of GSHP systems in schools are documented in 26 case studies which include 54% vertical ground-coupled, 19% groundwater, 12% horizontal ground-coupled, and 15% other types of systems.

School GSHP Annual Savings

Conventional System	Mean Annual Savings (%)			
	Number	Energy	Number	Dollars
Electric Resistance Heat	2	51%	3	45%
Natural Gas	3	61%	1	13%
Fuel Oil	1	76%	1	58%

Benefits reported for using GSHP systems in schools are: 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 Ground-Source Heat Pumps

Case studies (46) documented for commercial GSHP systems ranged in capacity from 30 to 4,700 tons. These systems employed vertical ground-coupled (43%), groundwater (35%), horizontal ground-coupled (11%) and other (11%) types of ground systems. Commercial GSHP systems were monitored in 84% of the case studies, and conventional energy systems is only 20% of the comparisons.

The average annual energy savings of GSHP systems ranged from 40% to 72%, and dollar savings ranged from 31% to 56%.

Commercial GSHP Annual Savings

Conventional	Mean Annual Savings (%)			
System	Number	Energy	Number	Dollars
Electric Resistance Heat/AC	6	59%	5	56%
Air-Source Heat Pump	3	40%	3	37%
Natural Gas	4	69%	4	49%
Fuel Oil	6	72%	7	31%

The savings attributable to the use of GSHP systems in commercial buildings vary over a wide range. In addition to parameters common to all GSHP applications, unique to commercial buildings are building use, internal heat gains and more complex rate structures.

Predictions of savings to be achieved with a GSHP system are a very site-specific endeavor for commercial buildings.

Economics

The economics of residential GSHP were reported as simple paybacks in only 15% of the 184 case studies. A favorable simple payback is considered to be less than 5 years.

Residential GSHP system simple paybacks ranged from 1.4 to 24.1 years, and the mean was 7.0 years.

Residential GSHP Economics

Conventional System	Number	Simple Payback (yrs) Range	Mean
Electric Resistance Heat/AC	4	2.7 to 6.8	4.4
Air-Source Heat Pump	3	2.0 to 9.5	5.9
Natural Gas/AC	9	4.2 to 24.1	11.6
Fuel Oil/AC	6	1.4 to 7.1	4.4
Other	5	2.0 to 6.8	4.3

The biggest barrier to faster paybacks of GSHP systems is the incremental cost of the ground loop.

Since residential GSHP systems are usually included in the mortgage, a break-even value of electric rates is a more meaningful value than simple payback.

In January 1995, data became available on the cost of purchasing and installing residential GSHP systems. Based on this data, an earlier analysis of a new well insulated home and a 30-year fixed rate mortgage at 8%, the electrical break-even rates were calculated for two different climate zones. In the colder zone, the break-even rates were $0.061/kWh for vertical and $0.058/kWh for horizontal ground-coupled systems. In the warmer zones, they were $0.097 and $0.084 respectively. Electric rates in excess of these break-even values would result in the GSHP system having a positive cash flow to the homeowner. Details on this analysis are presented in the economic section of this report.

Simple paybacks for school systems were reported in only 5 out of 23 case studies. These simple paybacks ranged from 5 to 14 years for electric resistance heating, 3.5 years for natural gas system, and 5 to 7 years for others.

Case studies for commercial buildings reported simple paybacks for 17 out of 46 GSHP systems. The range of simple paybacks was 1.3 to 4.7 years with a mean of 2.8 years.

For commercial buildings, all but 4 of the simple paybacks represent buildings located in northern climates.

Caution should be used in arriving at economic conclusions for any of the three groups presented in this summary. This is due to variables of climate, ground characteristics, GSHP system type, equipment efficiency, sizing, complex utility rate structures, and a variety of economic analysis methods used in the case studies.

Commercial GSHP Economics

Conventional System	Number	Range Years	Mean Years
Electric Resistance Heat	5	1.3 - 3.0	2.3
Natural Gas	3	1.9 - 4.7	3.4
Fuel Oil	7	2.2 - 4.5	3.0
Other	2	2.5 - 2.7	2.6

When considering a GSHP system for either new or retrofit situations, it is imperative that a deliberate economic analysis be performed.

Utility Programs

Ground-source heat pumps (GSHP) are one of many technologies utilities are considering or implementing for demand-side management (DSM), especially aimed at improving the efficiency with which customers use electricity. Information was developed on the status of DSM programs for GSHPs including: utility/contacts, marketing, barriers to market entry, incentives, number of units installed in service areas and benefits. A total of 57 utilities and rural electric cooperatives out of 178 investigated were reported to have DSM programs involving GSHPs.

Marketing techniques employed by utilities included utility publications and seminars (36%), newspaper and radio/TV advertising (16%), test/demonstrations (10%), education (6%), home shows (6%) and other (26%).

The primary market penetration barrier cited by utilities was the first cost of installation of GSHP systems, especially the incremental cost (median cost of $700 to $900/ton of the ground loop). Other barriers include low-annual cost of natural gas, lack of manufacturers, dealers and loop installers, customer resistance to heat pump technology, and regulatory problems.

Utilities have designed a number of incentive packages to encourage the installation of GSHPs. The most common are cash rebates to customers (mean values of $208/ton and $382/unit) and trade ally ($200/ton). In many cases, the utility specifies a minimum Seasonal Energy Efficiency Ratio (SEER), usually 10 or greater, energy audits or minimum insulation standards. Other types of incentives include special financing, discounted energy rates, and free ground loop installation.

More than 18,800 GSHP systems (3-ton equivalent) were reported by 35 utilities out of the 57 contacted. The types of systems installed include: horizontal ground-coupled (46%), undefined systems (40%), groundwater systems (7%) and vertical ground-coupled (7%).

A total of 25 utilities reported some type of benefit from the installation of GSHPs. Most of the utilities (76%) reported that peak demand reduction (peak shaving) was the primary benefit. Other benefits include: annual load reduction, higher load factor, higher winter efficiency, environmental benefits, competitive with other fuels, maintenance free and customer satisfaction.

Conclusions and Recommendations

Residential ground-source heat pumps are an effective approach to reduce both consumer energy consumption and electric utility peak loads. Demand reduction occurred primarily on the heating side. The savings attributable to these systems varied over a wide range (energy at 31% to 71% and dollar at 18% to 54%), due to the many factors that affect their performance and economics.

The GSHP industry has been primarily involved in the residential sector and has been most successful in areas characterized by winter peaking utilities, moderate electric rates and moderate to severe winter heating requirements.

Although annual dollar savings appear attractive, especially for residential GSHP systems, the large incremental cost of these systems makes it essential that an economic analysis be performed. Marginal or negative economics occurred in areas of low electric rates or widely available natural gas. Software is available from manufacturers and independent sources to predict residential system performance and economics for specific conditions, given input on ground characteristics and climate.

Case studies of school and commercial building GSHP performance and economic results were less conclusive than those for the residential sector. Given all the potential influences upon school and commercial building energy use, predictions of savings to be achieved with a GSHP system becomes a very site-specific endeavor. There is a need to further document information on operating experience of school and commercial GSHP systems and report on success and/or failure at various locations in the United States.

INTRODUCTION

Background

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 an increasing worldwide environmental consciousness. Further, the environmental and efficiency aspects of energy production and use are expected to remain top priority items in President Clinton's Administration. Geothermal heat pump (GHP) systems can help meet the challenge by increasing our energy efficiency, with resulting benefits to utilities in better load management, to customers in lower utility bills and to society in a cleaner environment (Pratsch, 1992).

The purpose of this study was to: 1) determine what existing monitored data (metered) are available on ground-source heat pumps (GSHP) installations, also known as geothermal heat pumps, for residential, school and commercial buildings, 2) determine seasonal energy use, savings patterns and economics of ground-source heat pump systems, with competing energy systems in typical residential and commercial situations, and 3) 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.

Electric utilities are the ultimate market target for GSHPs, especially utilities which are already committed to demand-side management (DSM). A utility in its resource planning process, the Planning Director's recommendations to management 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 GSHP technology as a DSM option include:

- Demonstrated efficiency and energy/demand savings;
- High first cost of ground loop and wells;
- Effect of ground loop temperature increase for summer and long-term operation, especially for commercial applications;
- Utility rebates and other incentives;
- Infrastructure availability of heat pump dealers and loop installation contractors;
- Regulatory and public acceptance; and
- End-user satisfaction.

Data on GSHP systems were organized into case studies and compiled into a database. All the case studies evaluated in this report were prepared by other researchers, utilities and manufacturers and their validity is not investigated.

Variables

The comparisons made by the case studies must be qualified by the variables that affect their operating performance. For example, heat pump efficiencies for all energy systems vary significantly according to type of equipment and operating conditions. The energy requirements of the location vary according to the outside air conditions and the envelope of the structure.

Due to the complex variations that affect a system's performance, it is very difficult to exactly compare two different applications. It is the goal of this report to compare as many case studies of similar data to establish a pattern rather than attempt to remove the variables for an exact comparison.

The following is a list of variables that are considered significant in evaluating GSHP systems.

- Variables in Performance of GSHP Systems

  Climate conditions
  Ground conditions - soil conductivity, moisture content, soil diffusivity
  Length of loop
  Type of loop - vertical, horizontal, or spiral
  Type of equipment - COP, EER
  Capacity of the heat pump (sizing)
  Type of system - groundwater, ground-coupled, lake loop, etc.

- Variables in Monitored Data

  Monitoring equipment
  Locations monitored
  Time data were collected
  Monitored data classified into two types:
  - Basic parameters:
    - Heat pump power (kW) and energy (kWh)
    - Supply and return ground-loop temperatures
    - Flow in ground-loop, a one-time measurement
  - Comprehensive parameters:
    - Ground-loop pump power (kW) and energy (kWh)
    - Fan power (kW) and energy (kWh)
    - Air flow
    - Ground temperatures of various distances from the ground-loop
    - Air supply and return temperatures
    - Space and outside temperatures
    - Run-time

Comparative modeling techniques
Reliability of data
Collection procedures
Data analysis techniques
Continuity of data (gaps)

- Variables in Monitored Systems (buildings)

  Building usage - people/schedule
  Operation
  Orientation
  Climate conditions
  Equipment performance
  Type of installation
  Installers expertise
  Control system - set points/dead bend

- Variables in Theoretical Studies

  Weather modeling
  Equipment modeling - EER, COP, gas furnace efficiency (AFEU), etc.
  Financial assumptions - interest
  Internal gain assumptions
  Envelope assumptions - air change role

Performance

The energy performance of a GSHP system can be influenced by three primary factors: the heat pump machine, the circulating pump or well pump, and the ground-coupling or groundwater characteristics.

The heat pump is the largest single energy consumer in the system. Its performance is a function of the two things: the rated efficiency of the machine and the water temperature produced by the ground-coupling (either in the heating or cooling mode). The most important strategy in assembling an efficient system is to start with an efficient heat pump. It is difficult and expensive to enlarge a ground-coupling to improve the performance of an inefficient heat pump.

Water-source heat pumps are currently rated under one of three standards by the American Refrigeration Institute (ARI). These standards are ARI-320, ARI-325, and ARI-330. The standard intended for ground-coupled systems is ARI-330 entitled "Ground Source Closed Loop Heat Pump Equipment." Under the standard, ratings for cooling EER and heating COP are published. It's important to consider that these are single-point ratings rather than seasonal values as in the

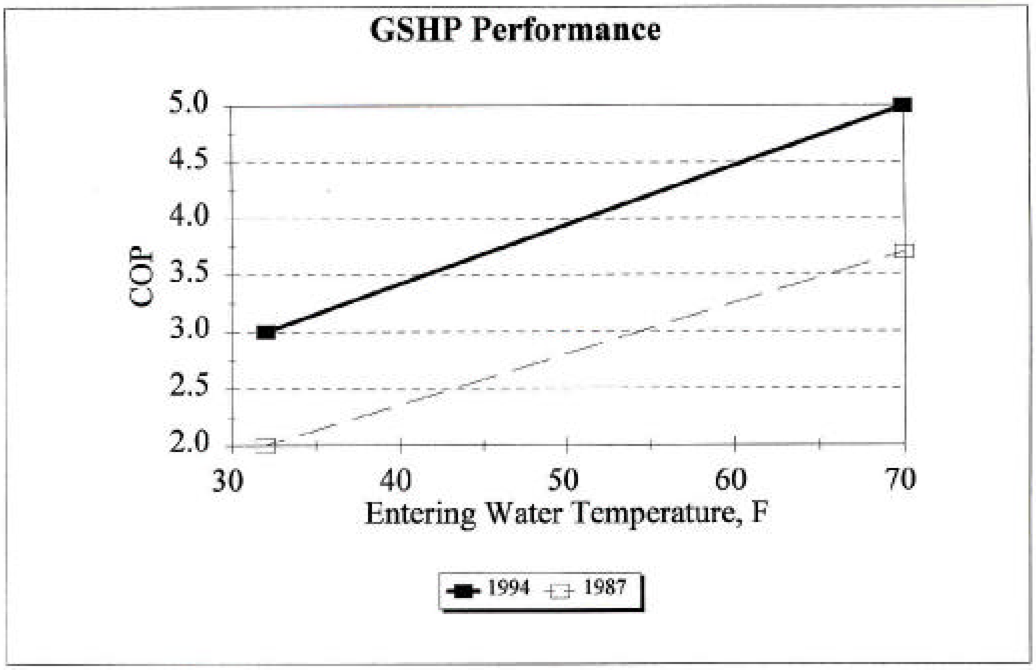


Figure 1. GSHP performance improvement from 1987 to 1994 for heating mode.

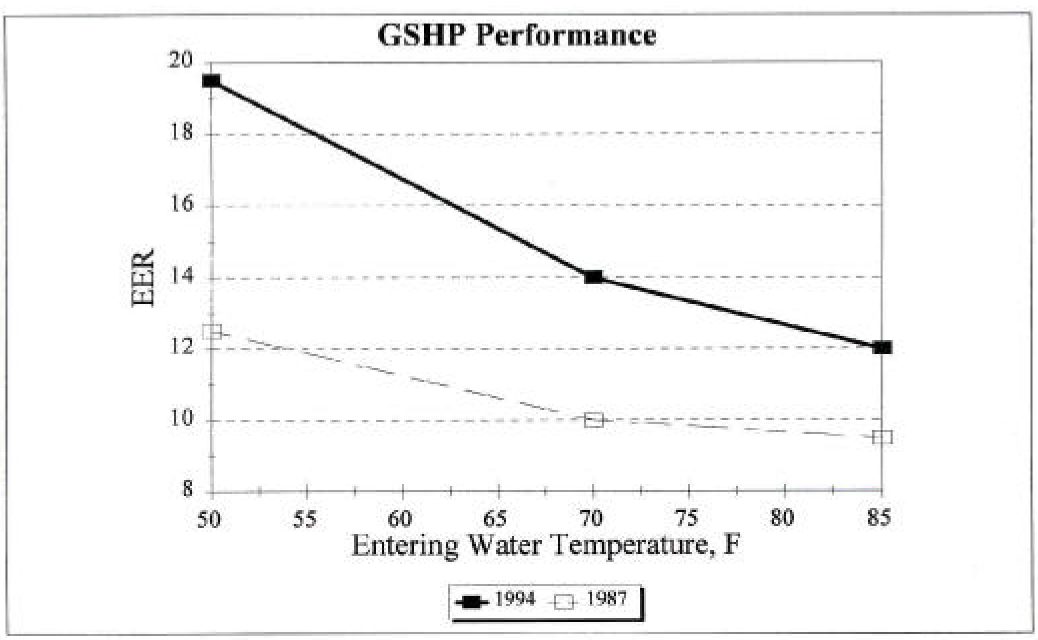


Figure 2. GSHP performance improvement from 1987 to 1994 for cooling mode.

case of air-source equipment. Cooling EER values are based on an inlet water temperature of 77°F. Heating COP values are based on a heating inlet water temperature of 32°F. These values are characterizations of a northern climate.

The current ARI directory contains equipment with EER ratings of less than 10 to a high of 18.6. COP values range from 2.8 to 3.6. It is evident that there is a wide range of equipment performance at the standard rating conditions. Based on these values, it is evident that the performance of the equipment can vary by as much as 100% according to the quality of heat pump purchased.

In recent years, there has been a substantial increase in the efficiency of GSHP equipment. Based on performance reported in the ARI directory for 1987 and 1994, the increase in EER ranges from 26 to 56 percent, and in COP from 35 to 50 percent depending on the entering water temperature. Figures 1 and 2 show this increase in performance for a typical machine based on average values of EER and COP as a function of entering water temperature.

Based on improvements in performance of GSHPs from 1987 to 1994, the date of a GSHP installation should be noted. In this report, values for energy savings, demand reduction, etc., are those reported in the case studies, some of which were from the early 1980s.

The actual performance of the equipment is a function of the water temperature produced by the ground-coupling. The values discussed above are based on standard rating conditions (77°F cooling and 32°F heating). The actual temperatures are a function of the local ground temperatures and the design of the ground-coupling. For example, in a region where the local ground temperature is 60°F and the ground loop is designed for the customary 20° to 25°F aboveground temperature, a heat pump rated at an EER of 16.8 would actually operate at an EER of 14.2 under peak load conditions. A poorly designed loop, which forced the unit to operate at 30°F aboveground temperature, would reduce the value to less than 13.0. These examples are for cooling operation which is the dominant load in commercial applications. The same relationship holds for heating operations, however.

Figures 3 and 4 show EER and COP as a function of inlet temperatures for a 3-ton machine designed for ground-coupled applications from a manufacturer's specifications.

The system energy performance is also influenced by the pumping energy required to circulate the fluid through the heat pump and the ground loop. One author (Kavanaugh, 1994) in the design of ground-coupled systems suggests the following guidelines for pumping power for commercial ground-coupled systems:

- Efficient systems: <50 watts/ton
- Acceptable systems: 50 - 100 watts/ton
- Inefficient: >100 watts/ton

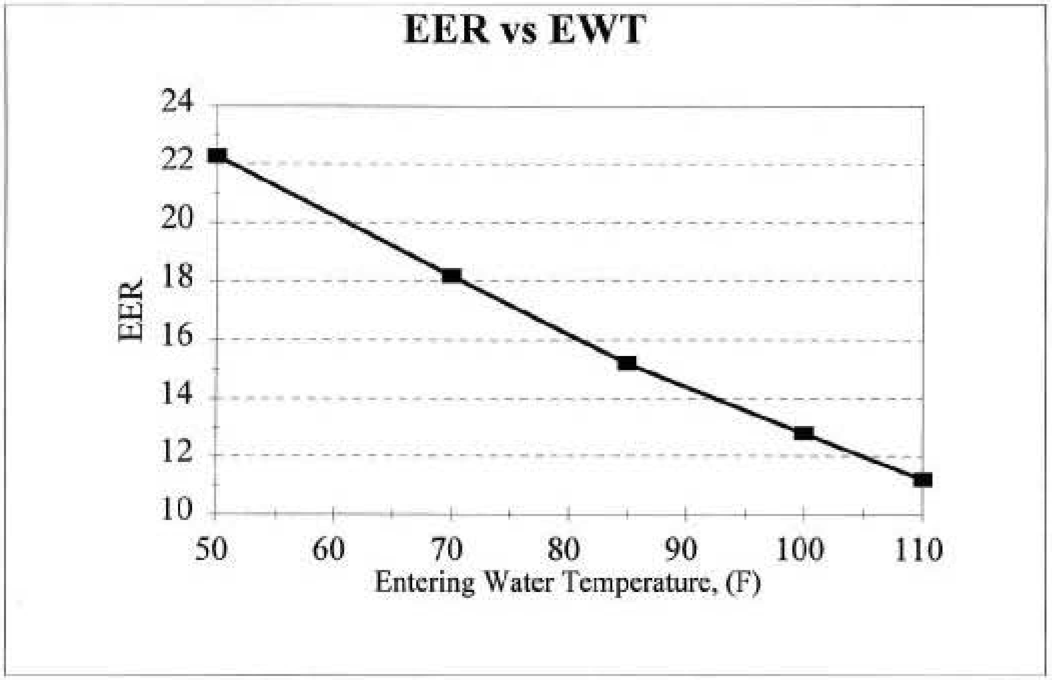


Figure 3. EER for a 3-ton GSHP

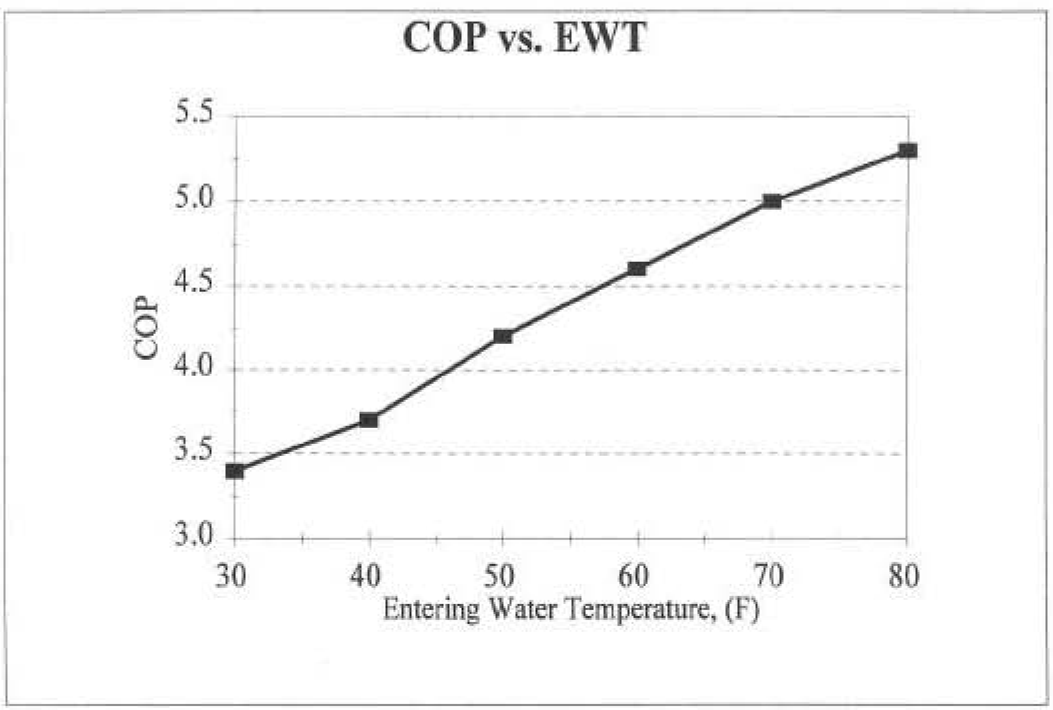


Figure 4. COP for a 3-ton GSHP

To put these values into perspective, consider an office building with a 50-ton cooling load and heat pump units selected to operate at an EER of 14 under peak conditions.

With an efficient circulating pump design (35 watts/ton), the energy demand of the circulating pump would amount to (50 tons)C(35 watts/ton) = 1750 watts. Combining the pump demand with the heat pump unit demand results in a system EER of 13.5.

The same building and equipment coupled to a poorly designed pumping system consuming 120 watts (6000 watts pumping power) per ton would yield a system EER of only 12.2; thus, compromising the premium paid for the higher efficiency equipment. As indicated above, coupling this system to an inadequate ground-coupling could easily reduce the system EER to between 10 and 11.

In summary, it is necessary when evaluating a ground-coupled system to consider the efficiency of the machine, the adequacy of the ground-coupling and the nature of the pumping design to fully understand the efficiency of the system.

DATA FORMAT

The case studies that appear on the enclosed 3-1//2 inch diskette were compiled into a database. The ground-source heat pump (GSHP) database was designed to be readily accessible and maintained on personal computers. The source data were entered into Paradox version 5.0 database containing 65 data fields. The field names, general descriptions of their contents and explanation of codes are listed in Table 1 and shown on the form "Case Study." The form can be accessed by software Paradox 5.0 or WordPerfect 6.0. The source data (on Paradox 5.0) can be accessed using the following software:

WordPerfect 6.0
Quattro Pro 5.0 and 6.0
Microsoft Excel 4.0 and 5.0
Micrsoft Word 6.0 and 2.0

Instructions on how to access, view and update the source data on either a form or table are given in Appendix A. Appendix B contains the Paradox file structure for the fields in the main file *CASESUM2.db*.

Table 1. GSHP Case Study Database Format

Field Name	Description
Ref. No.	Identification number assigned to each case study, state (__) - reference number (___). A reference number followed a lower case alpha denotes a system where more than one was analyzed. CN, GR and a SW denote Canada, Germany, and Sweden.
Reference	Source of data.
General Information	
Type of Installation	Identified as a residential, school or commercial building.
Date Installed	Date of GSHP installation.
Building Size	Area in square feet.
Location	Location of where heat pump is installed.

System Information

System Description	Description of building and its characteristics.
Type Construction	Identified as a new or retrofit.
Design Temperature	Outdoor dry-bulb design temperature.
HDD	Heating degree days.
CDD	Cooling degree days.
Capacity	Heating or cooling capacity of heat pump in tons.
Heat Pump Manufacturer	Equipment manufacturer.
Monitored Data	Identifies system components that were instrumented and monitored (i.e., compressor, circulating pump, fans, loop temperature, flow in ground loop, ground temperatures, air temperatures, space and outside temperature, and run-time).

Ground System Information

Ground Heat Exchanger Configuration	Description of ground loop or groundwater system.
Ground Temperature	Temperature of ground or groundwater in degrees Fahrenheit.
Pipe Material	Type of pipe material used for closed loop.
Pipe Size	Diameter of loop pipe in inches.

Vertical

Number of Boreholes	Number of boreholes drilled.
Borehole Depth	Well depth in feet.

Horizontal

Trench Length	Length of trench excavated for horizontal loop in feet.
Trench Depth	Depth in feet.
No. of Pipes	Number of pipes in trench.

Groundwater

Number of Wells	Number of production and injection wells.
Depth of Well	Depth in feet.
Casing Diameter	Diameter in inches.
Flow Rate	Total flow rate from all wells in gpm.

System Performance
Ground-Source Heat Pump System

Type Data	Monitored (metered) or simulated (modeled).
Run-Time Heating	Number of hours per year heat pump operated in the heating mode.
Run-Time Cooling	Number of hours per year heat pump operated in the cooling mode.
Annual Energy Usage	Annual energy required to operate the heat pump in kWh.
Percent Energy Savings	Annual energy savings of GSHP compared to specified conventional energy in percent.
COP	Coefficient of performance.
EER	Energy efficiency ratio.
Total Installed Cost	Cost of installed GSHP system including ground loop or wells.
Annual Operating Cost	Annual cost to operate the GSHP system.
Percent Dollar Savings	Annual dollar savings of GSHP system compared to conventional system in percent.

Payback Period	Time to payback GSHP system from savings over conventional energy system in years.

Conventional Energy System

Type Data	Monitored (metered) or simulated (modeled).
Air-Source Heat Pump	Annual energy required to operate air-source heat pump system in kWh.
Electric Heat	Annual energy required to operate an electric resistance heating system in kWh.
Natural Gas	Annual energy required to operate a gas furnace in Therms (10^5 Btu or 1 ccf).
Fuel-Oil	Annual energy required to operate an oil-fired system in gallons.
Annual Energy Usage Conventional	Annual energy of any of the above four systems converted to kWh.
Annual Conventional Cost	Annual cost to operate a conventional system in dollars.

Additional Information

Contact Person	Person who furnished data or contact for additional information.
Location	Address of contact person.
Phone Number	Phone number of contact person.

CASE STUDY

GROUND SOURCE HEAT PUMPS
OIT Geo-Heat Center
3201 Campus Drive
Klamath Falls, Or. 97601
(503) 885-1750

Ref No. FIELD(Ref No.1)
Reference FIELD(Reference)

GENERAL INFORMATION

Type of installation: FIELD(Type of installation)   Date Installed: FIELD(DATE INSTALLED)
Building size (square ft): FIELD(Building size (sq.ft.))
City: FIELD(City)   State: FIELD(State)   Country: FIELD(Country)   Zip: FIELD(ZIP)

SYSTEM INFORMATION

System description: FIELD(System description)
Type Construction: New: FIELD(New) Retrofit: FIELD(Retrofit)   Design temp.: FIELD(Design temperature) °F
HDD: FIELD(Heating deg days)   CDD: FIELD(Cooling deg days)   Circ. Fluid: FIELD(Circ. Fluid)
Capacity: FIELD(Capacity) tons   Heat pump manufacturer: FIELD(Heat pump manufacturer)
Monitored data: FIELD(Monitored data)

GROUND SYSTEM INFORMATION

Ground heat exch. config: FIELD(Ground heat exch. config.)
Ground temp.: FIELD(Ground temperature) °F   Pipe material: FIELD(Pipe material)
Pipe size: FIELD(Pipe size) in.

VERTICAL GROUND COUPLED:
Number of boreholes:FIELD(Number of boreholes)   Borehole depth: FIELD(Borehole depth) ft.

HORIZONTAL GROUND COUPLED:
Trench length: FIELD(Trench length) ft   Trench depth: FIELD(Trench depth) ft
No. of pipes: FIELD(No. of pipes)

GROUNDWATER:
Number of wells: FIELD(Number of wells)   Depth of well: FIELD(Depth of well) ft
Casing diam.: FIELD(Casing diam.) in   Flow rate: FIELD(Flow rate) gpm

SYSTEM PERFORMANCE

GROUND-SOURCE HEAT PUMP SYSTEM:
Type of Data: Monitored: FIELD(Monitored GSHP)   Simulated: FIELD(Simulated GSHP)
Runtime heating: FIELD(Runtime heating) hrs , Runtime cooling: FIELD(Runtime cooling) hrs
COP: FIELD(COP)   EER: FIELD(EER)
Annual energy usage: FIELD(Annual energy usage) kWh
Percent energy savings: FIELD(Percent energy savings)
Total installation cost: $ FIELD(Total installation cost)
Annual operating cost: $ FIELD(Annual GSHP cost)
Percent dollar savings: FIELD(Percent dollar savings)
Payback period: FIELD(Payback period) years

CONVENTIONAL ENERGY SYSTEM:
Type of data: Monitored:FIELD(Monitored conventional) Simulated: FIELD(Simulated conventional)
Air-source heat pump: FIELD(Air-source heat pump) kWh
Electric heat: FIELD(Electric heat) kWh
Natural gas: FIELD(Natural gas) Therms
Fuel-oil: FIELD(Fuel-oil) gallons
Annual energy usage conventional: FIELD(Annual energy usage conv.) kWh
Annual conventioanal cost: $ FIELD(Annual Conv. cost)

ADDITIONAL INFORMATION

Contact person: FIELD(Contact person)
Address: FIELD(Address)
City: FIELD(City')   State: FIELD(State')   Country: FIELD(Country')   Zip: FIELD(Zip')
Phone number: FIELD(Phone number)   FIELD(Page)

RESIDENTIAL GROUND-SOURCE HEAT PUMPS

Households use about one-fifth of the primary energy consumed in the United States (including the energy required to produce electricity and deliver it to final users). Space heating accounts for the largest single share of primary energy use in the residential sector for the nation as a whole at about 36%, followed by water heating at 15%, refrigerators at 12%, space cooling at 10%, etc. (NES, 1992).

Residential electric space heating can potentially help both summer or winter peaking utilities achieve several load shape modification objectives. A utility may make strategic conservation and peak reduction investments by promoting efficient heat pumps to replace resistance heaters (or less efficient heat pumps).

To determine the potential of ground-source heat pump (GSHP) systems to satisfy these objectives, existing monitored data and other information was collected from electric utilities, rural electric cooperatives, manufacturers, engineers, universities and other sources.

A total of 184 residential GSHP case studies are summarized on the enclosed 3-1/2 inch diskette. These systems represent GSHP installations that are groundwater, ground-coupled (vertical, horizontal and spiral) or others. Others comprise unspecified ground systems or lake loops (2). Figure 5 shows the types of GSHP systems in the database.

The type of data entered could be either monitored (metered) or simulated (modeled) for residential GSHP and conventional energy systems. GSHP systems were monitored for 128 out of the 184 case studies. Conventional systems were monitored for only 46 out of 111 systems. Conventional systems could include electric resistance heating, air-source heat pumps, natural gas furnace with electric air conditioner (AC), oil furnace with electric AC, and others. These conventional systems were compared to GSHP systems for energy savings patterns, power reduction for electric resistance (heating only), operating costs, etc. Figure 6 shows the number of combinations of monitored and simulated systems in the database.

A number of factors influence the performance of GSHP systems. These are identified in the introduction of this report. Important factors associated with residential GSHP systems are those that affect the performance in one locality apart from another, climate and ground characteristics. In addition, the efficiency of the equipment has improved considerably in recent years; therefore, the date of installation may reflect these improvements. The sizing of the ground loop to the machine relative to the load are important factors influencing performance that is affected by run-hours. The type of ground system employed is also an important consideration.

The following graphs showing energy savings patterns and peak demand reduction do not attempt to separate all of the variables, except for the locality identified as a reference number for the state where the system is located.

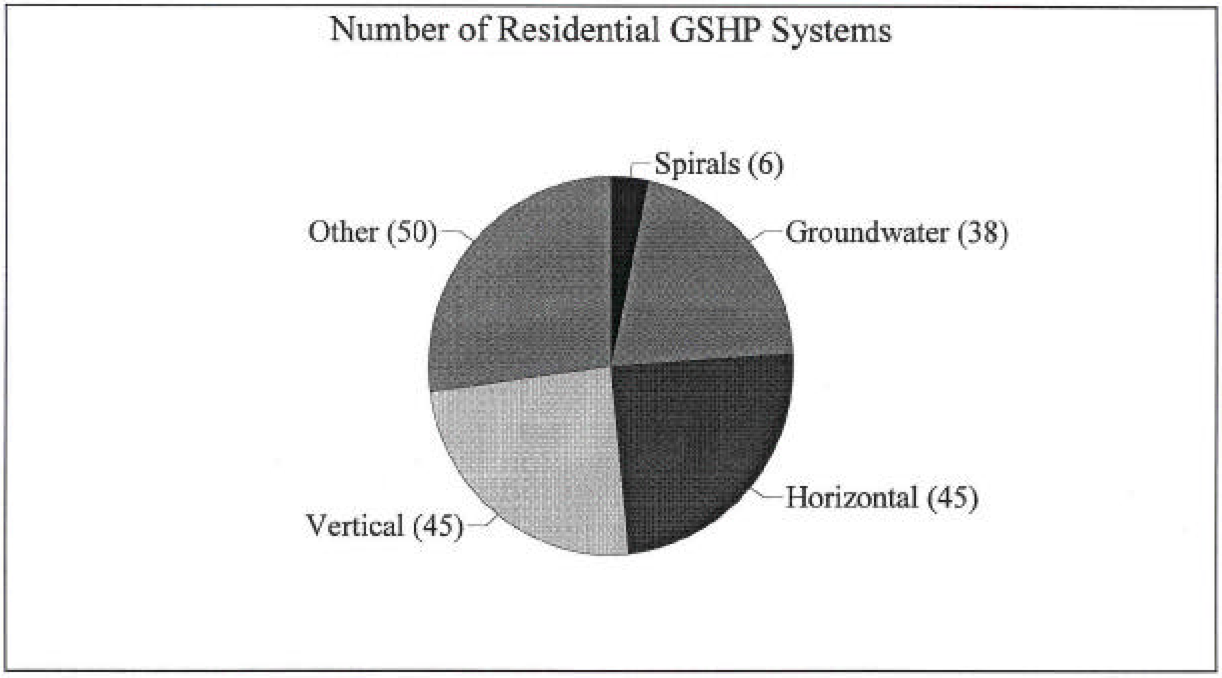


Figure 5. Types of residential GSHP systems.

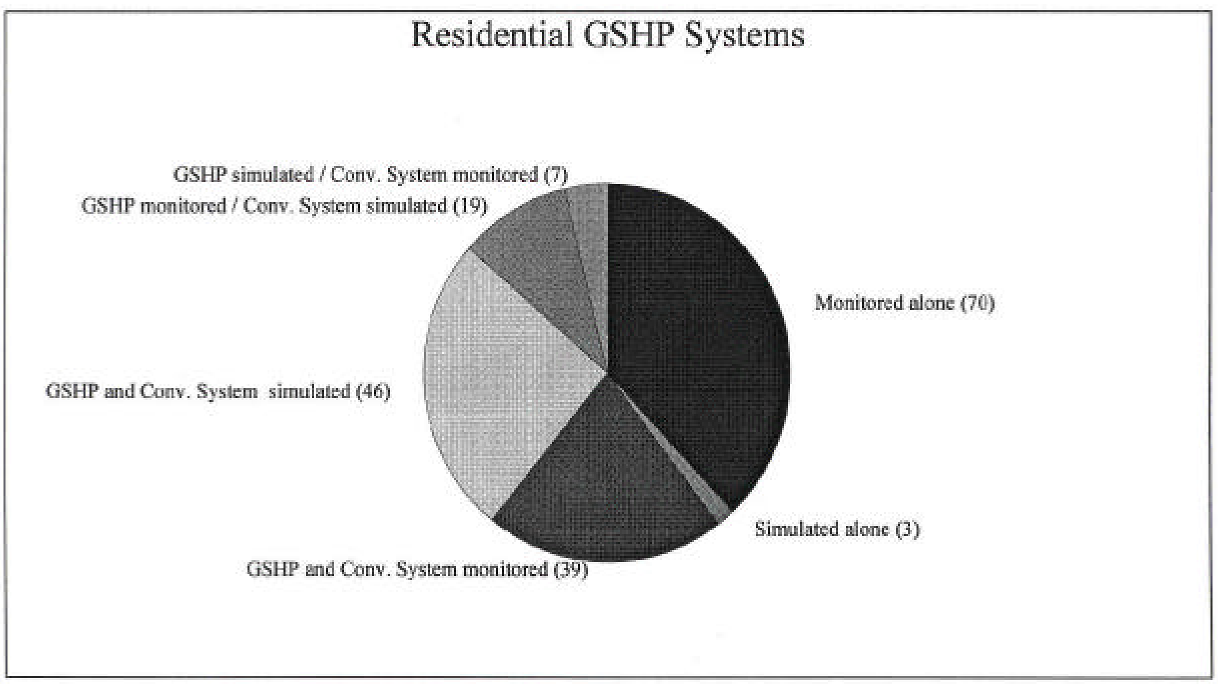


Figure 6. Residential GSHP system combinations of monitored and simulated data.

A more detailed assessment of the performance on specific systems can be obtained by referring to specific case studies summarized on the diskette or the reference from which the data was obtained.

Figures 7 through 10 show patterns of annual energy and dollar savings of residential GSHP systems compared to electric resistance heating, air-source heat pumps, natural gas furnace with electric air conditioning (AC), and oil fired furnace with electric AC.

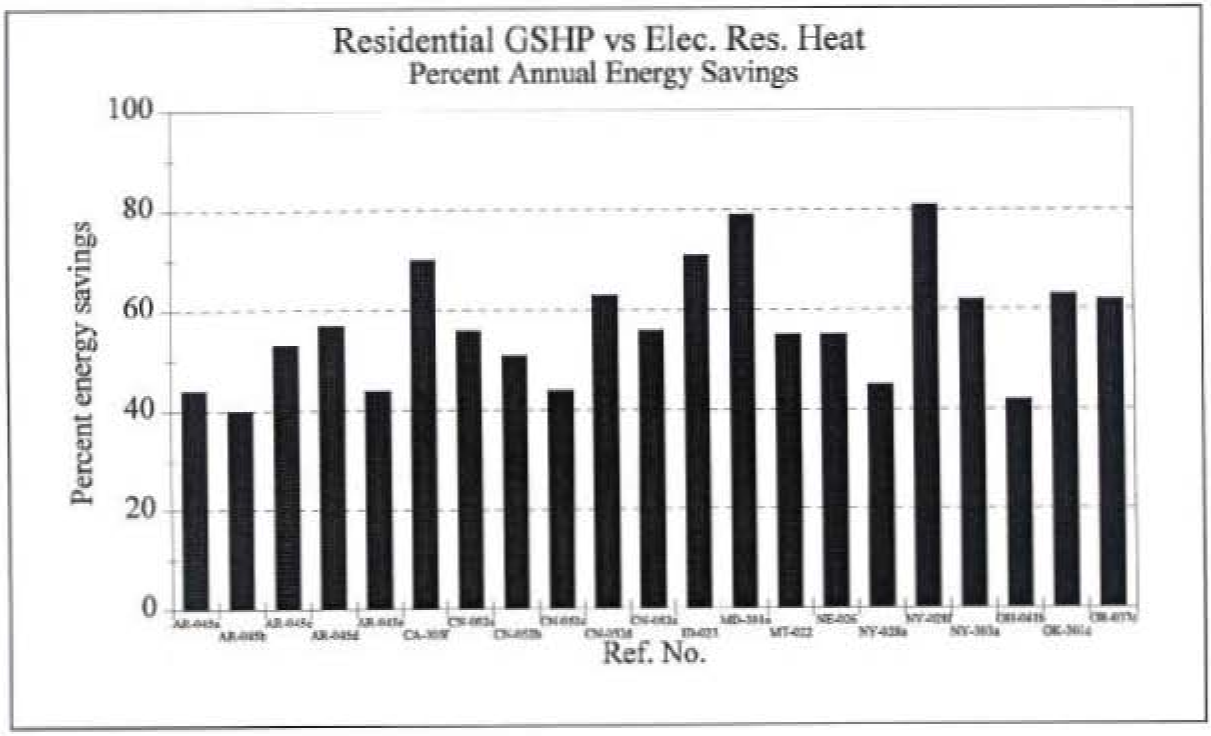
The mean annual dollar savings of GSHPs compared to electric resistance heating is 54% and for air-source heat pumps it is 31%. Due to the high first cost of GSHP systems, mainly because of the additional incremental costs of the ground loop, economics is an important issue. Even though the percent dollar savings may appear attractive, because of relatively low annual operating costs of conventional systems, it is difficult to recover the additional incremental cost of the GSHP systems. The economics section of this report addresses this problem.

In the cases of comparing natural gas and oil furnaces with electric air conditioning, there were five case studies where the conventional systems had annual operating costs less than GSHP systems.

When considering a residential GSHP system for either new or retrofit situations, it is imperative that a deliberate economic analysis be performed.

Peaking performance improvements of GSHP systems can be evaluated as a coincident peak that occurs at the time of the utility peak. A non-coincident peak occurs at the time of the greatest difference between the GSHP system load and the competing systems load.

Figure 11 shows winter non-coincident peak demand reduction of GSHP systems compared to single-zone electric resistance heating systems. For these 13 systems, the range was from 5.3 to 10.4 kW with a mean of 7.2 kW.



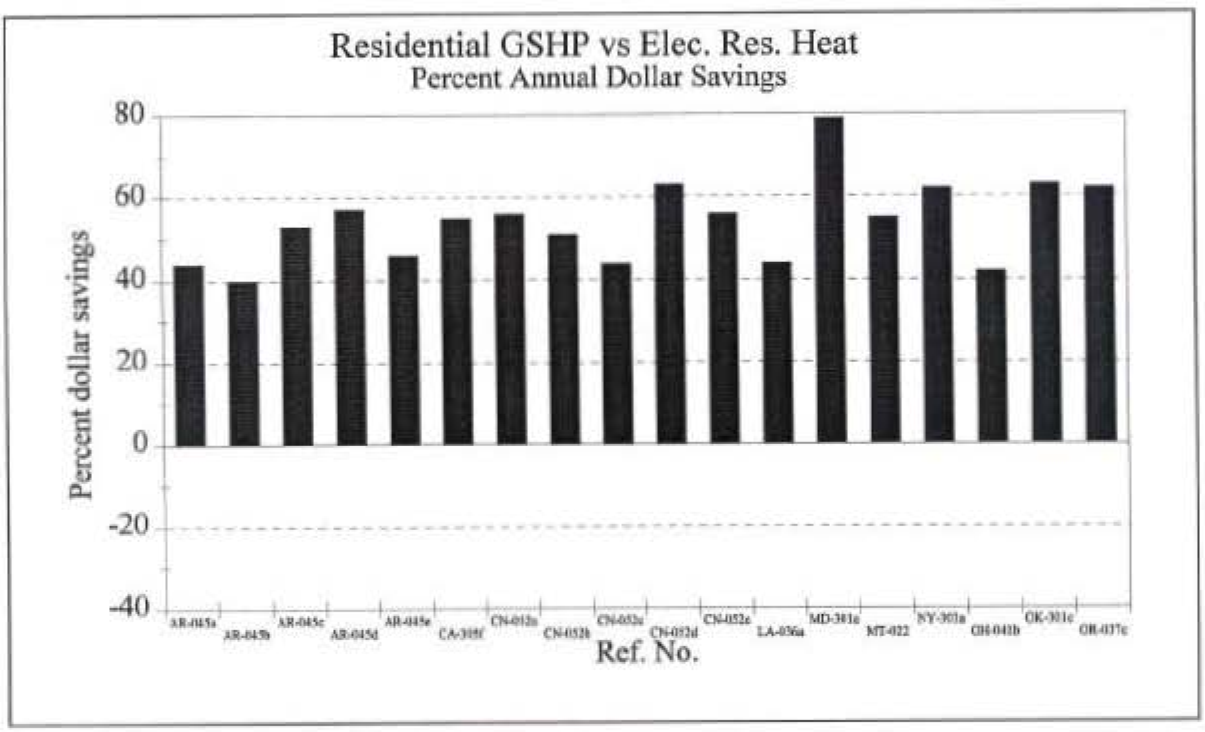
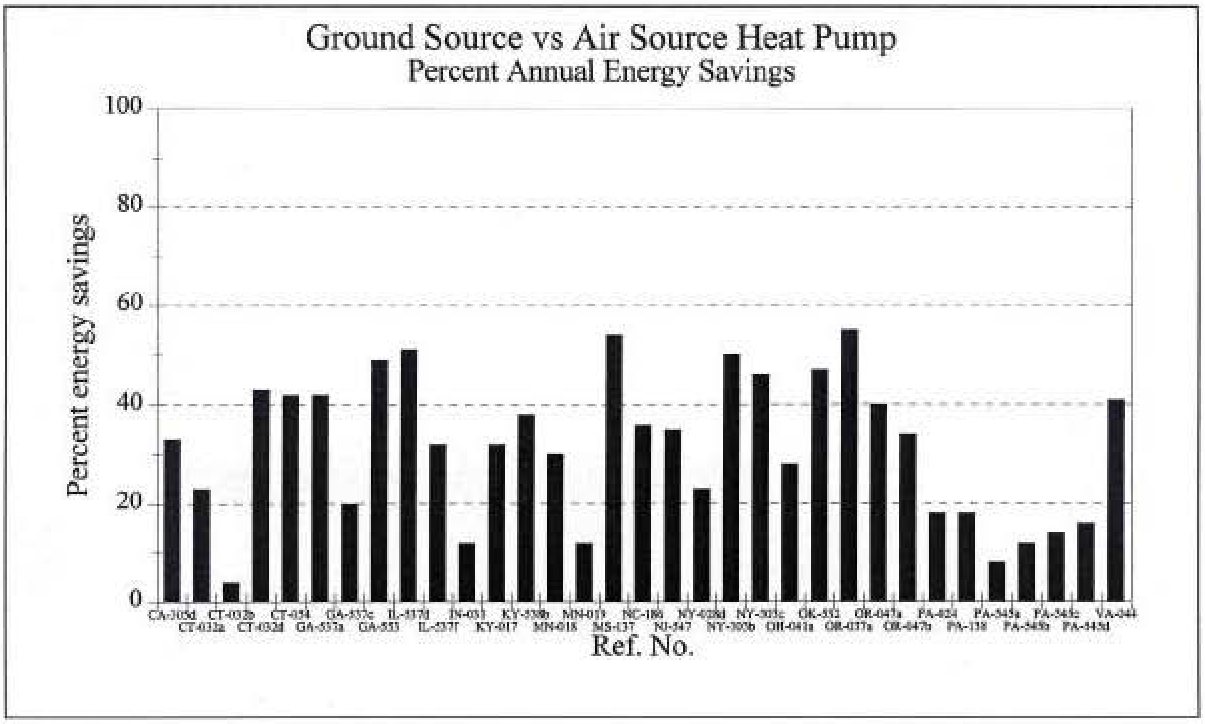


Figure 7. Residential GSHP annual energy and dollar savings compared to single zone electric resistance heating with AC in percent.



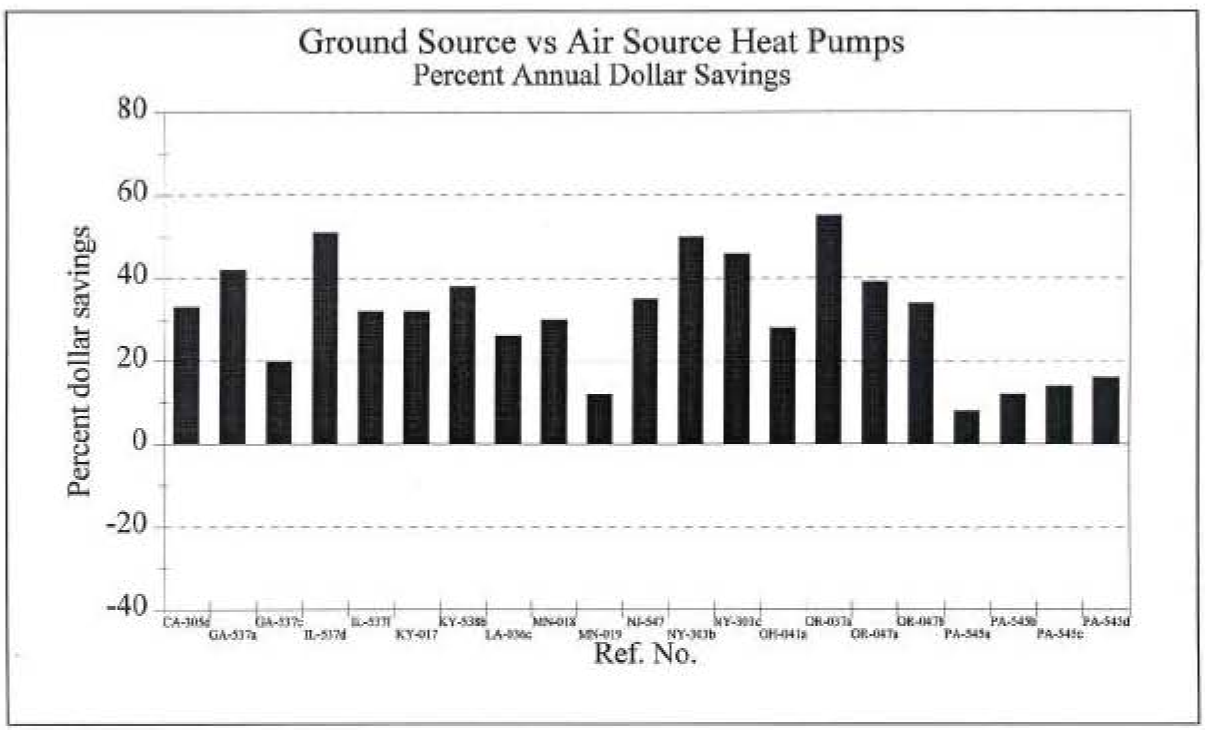
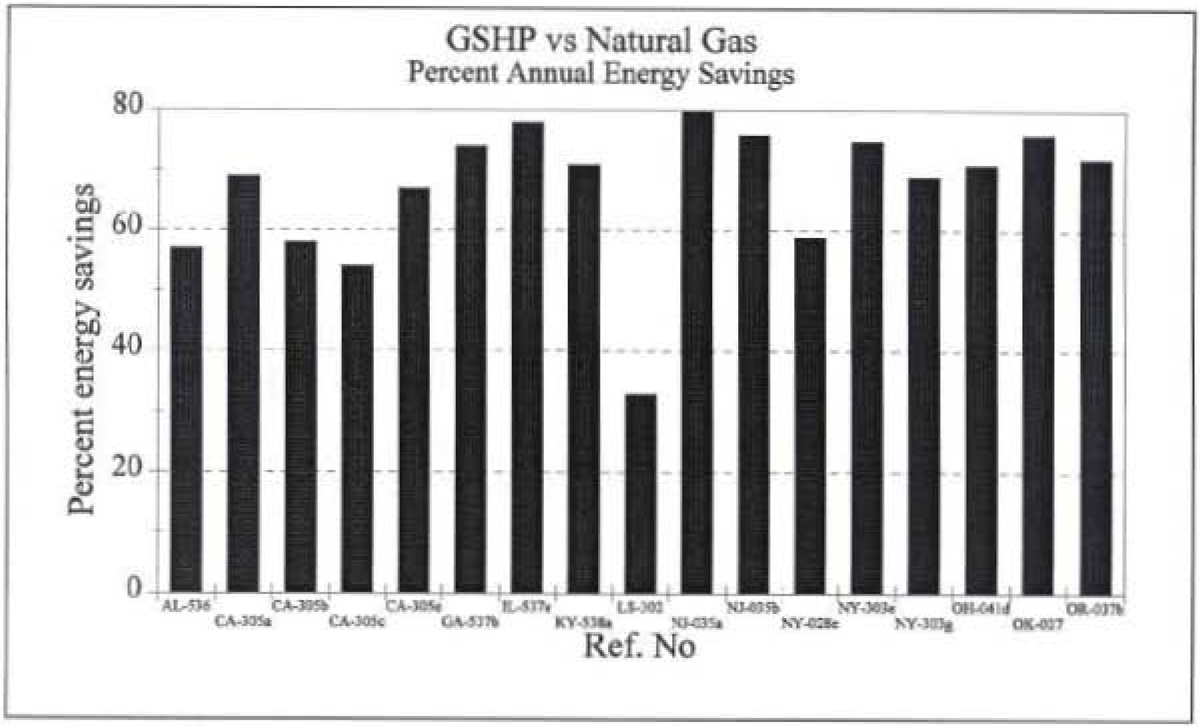


Figure 8. Residential GSHP annual energy and dollar savings compared to air source heat pumps in percent.



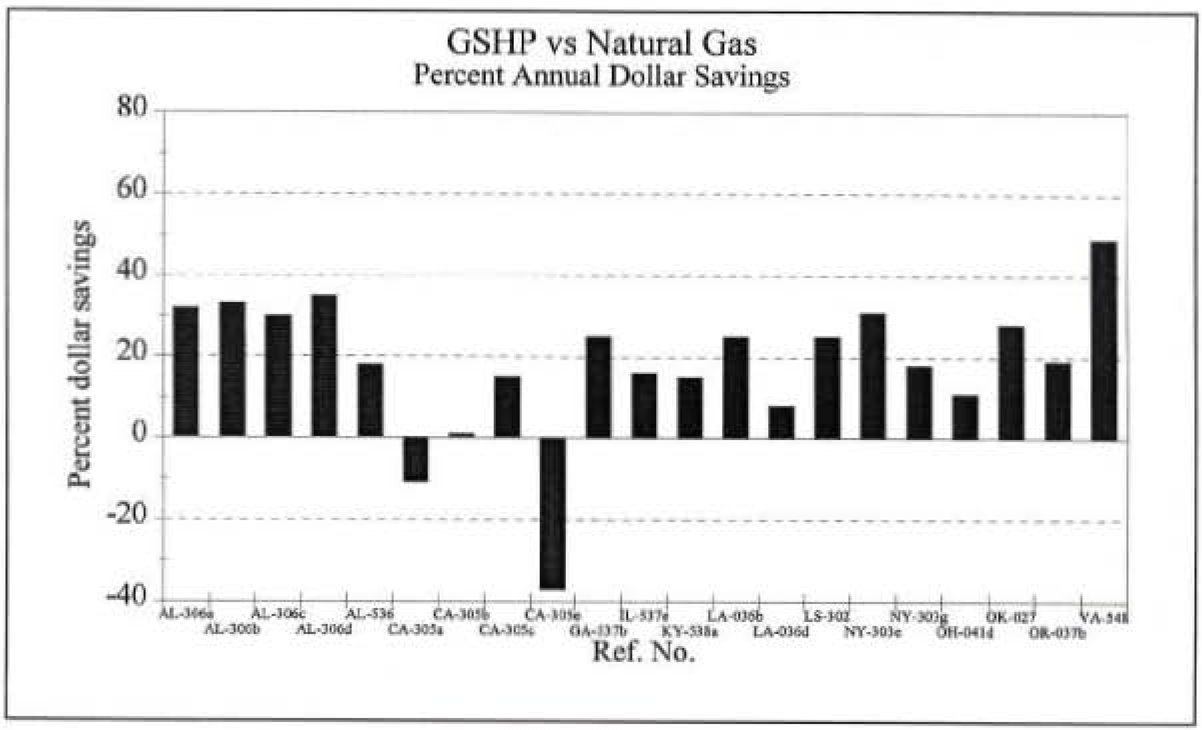
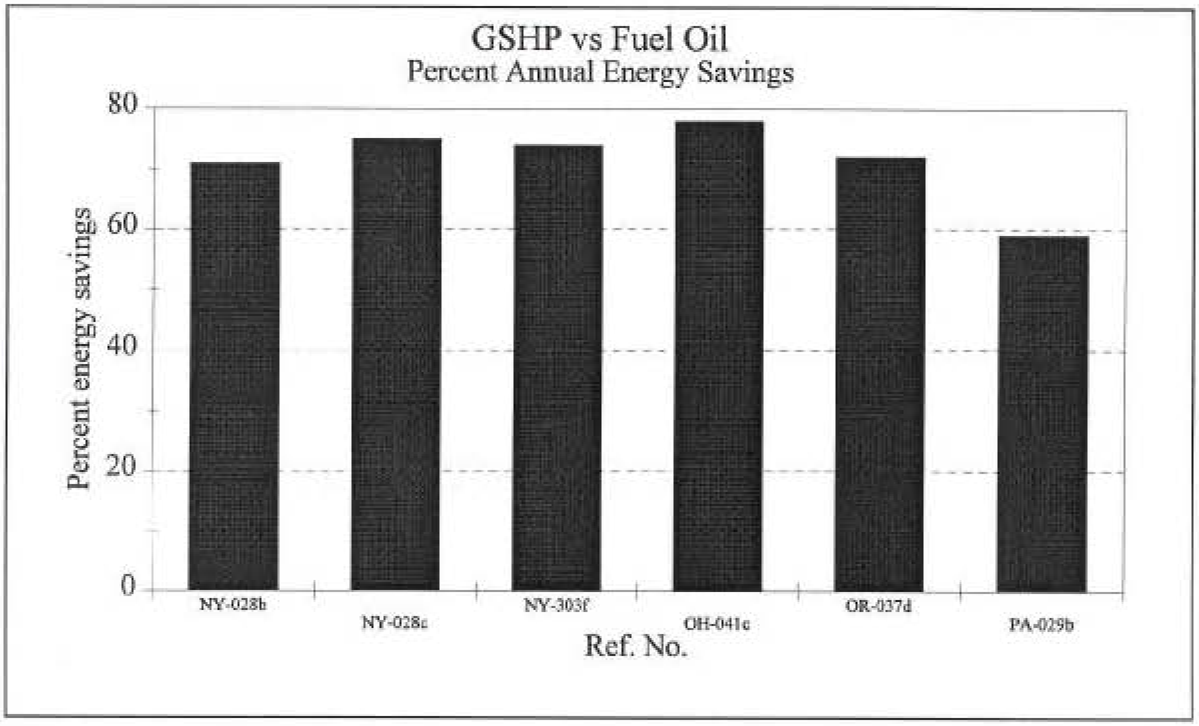


Figure 9. Residential GSHP annual energy and dollar savings compared to natural gas furnace with electric AC in percent.



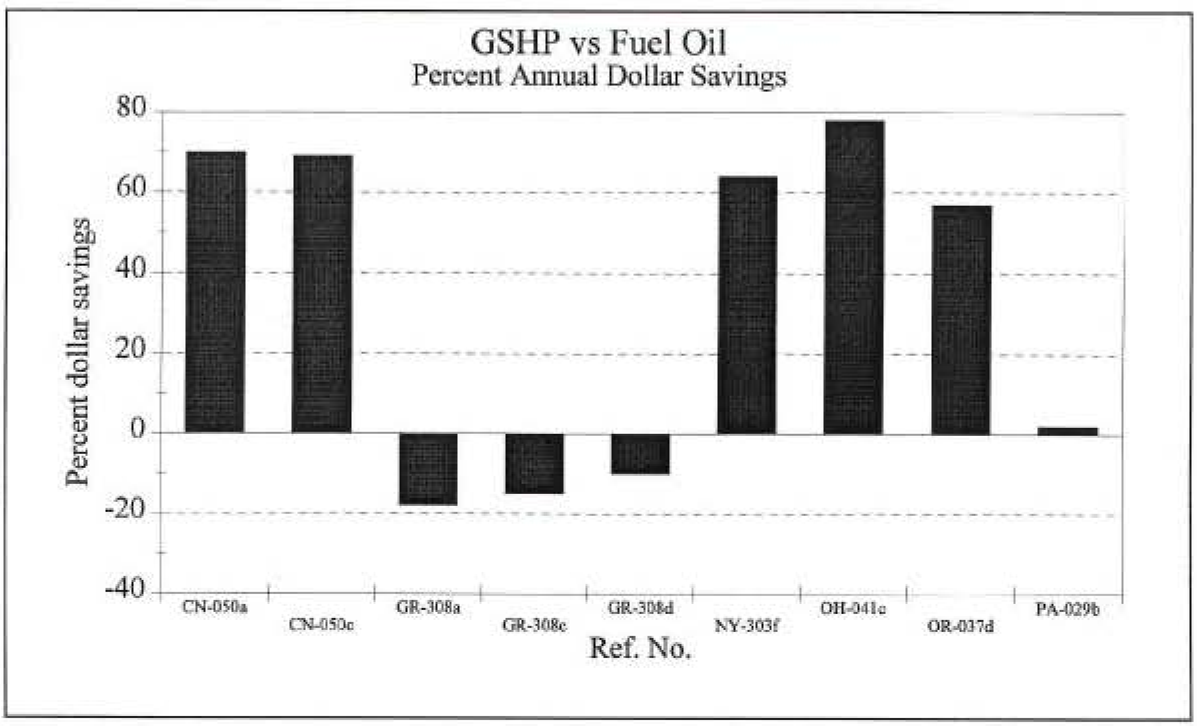


Figure 10. Residential GSHP annual energy and dollar savings compared to fuel oil furnace with electric AC in percent.

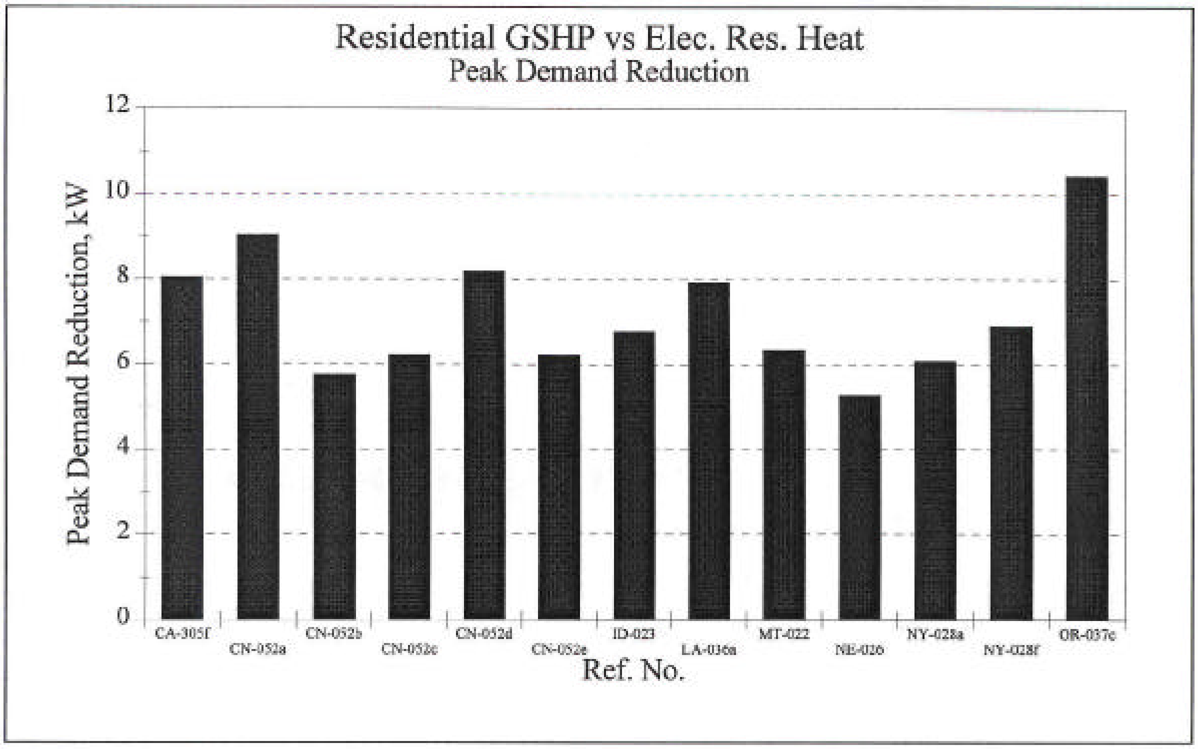


Figure 11. **Residential GHP peak demand reduction compared to single-zone electric resistance heating systems.**

SCHOOL GROUND-SOURCE HEAT PUMPS

The potential for energy savings in schools using GSHP systems is demonstrated in the 26 case studies on the enclosed diskette. Figure 12 shows the number of types of school systems documented.

School GSHP systems were monitored for 23 of the 26 systems reported; three systems were simulations. Annual energy savings were reported for only 6 schools, shown in Figure 13.

Five case studies reported percent annual dollar savings (Figure 13) and the remainder (17) were monitored alone without comparisons to conventional systems.

The largest school GSHP project is the 1,480-ton Richard Stockton College of New Jersey system in Pomona (NJ-074). This is a vertical ground-coupled system consisting of 400 boreholes, each drilled to 400 ft and located under a parking lot on 15 ft grids. The system was monitored for baseline data prior to the installation of the GSHP system and continues to be monitored since the GSHP system started operating in January 1994.

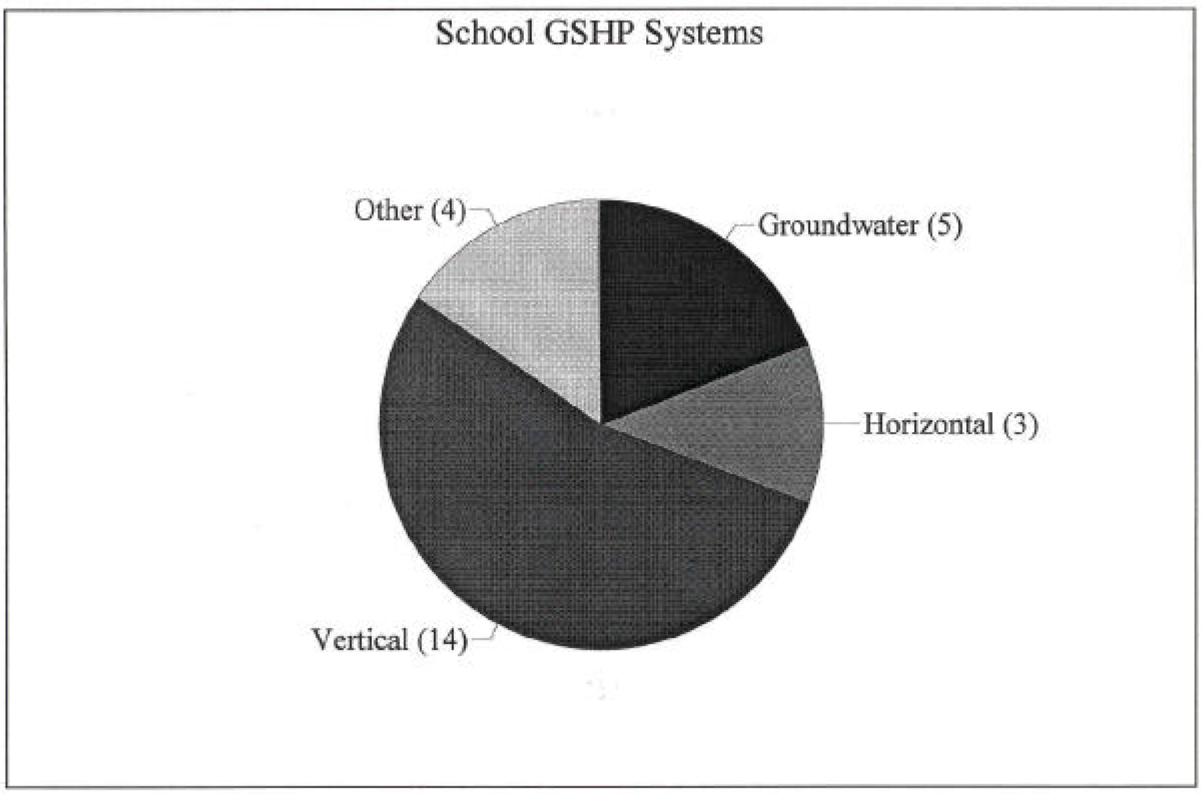
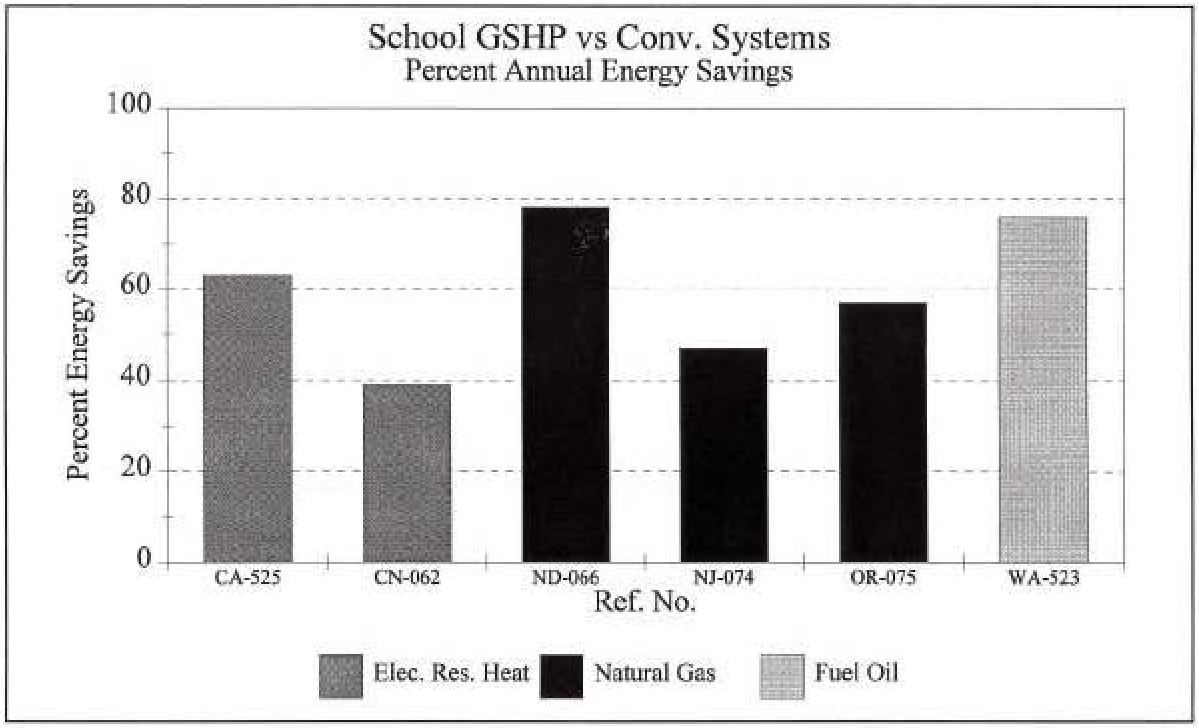


Figure 12. Type of GSHP system for school applications.



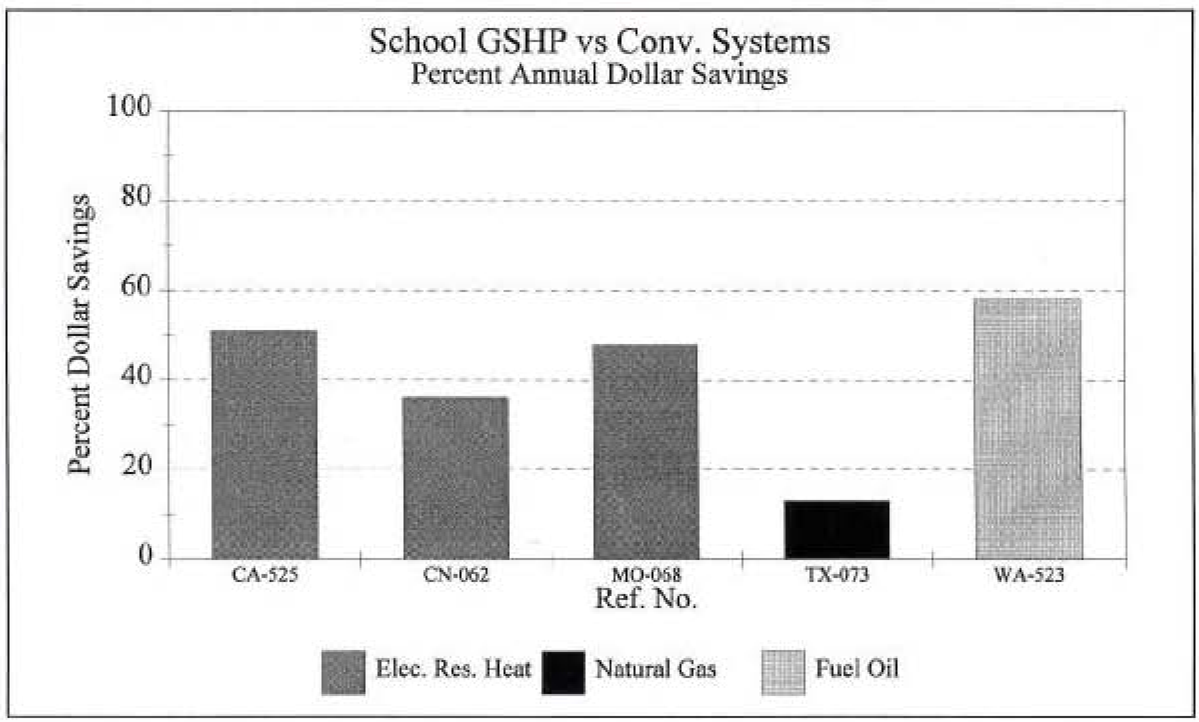


Figure 13. School GSHP annual energy and dollar savings.

In Austin, Texas, 48 elementary schools, 4 middle schools and 3 community colleges have been equipped with GSHP systems with a total installed capacity of 6,600 tons (TX-072). A total of 6,373 vertical loops were installed from 1985-1992 with 1,266 miles of pipe at an average depth of 270 ft/ton.

Table 2 shows a comparison for two different types of school GSHP systems. The first is a middle school in Wahpeton, North Dakota (ND-066), employing a vertical ground-coupled system and the second is a high school located at Junction City, Oregon (OR-075), employing a groundwater system.

Table 2. School Ground-Coupled and Groundwater GSHP Systems.

School:	Wahpeton, ND	Junction City, OR
Installed Date:	1988	1988
System:	286 boreholes (150 ft)	Production/injection wells
Application:	Middle school - 57,400 ft^2	High school - 55,300 ft^2
Design Condition:	8564 HDD[a], -25°F	4793 HDD, 17°F
Capacity:	220-tons	101-tons
Energy:	678,000 kWh/yr	193,133 kWh/yr
Installed Cost:	$418,000	$265,000
Savings/Yr:	106,800 therms of gas[b]	35,506 therms of gas

a. Heating degree day
b. Calculated

In the case of the North Dakota school, there is three times the energy savings over the Oregon school due primarily to the fact of being located in a much colder climate.

Benefits reported for using GSHPs in schools include: addition of mechanical cooling, improved control--being able to condition a very small area without having to condition the entire school, and simplicity of maintenance and repair. In southern climates, the elimination of cooling towers, outdoor equipment, mechanical rooms and ductwork were added benefits. In most cases, there were reduced maintenance costs, energy savings and peak power reduction.

COMMERCIAL GROUND-SOURCE HEAT PUMPS

Case studies (46) documented for commercial GSHP systems on the enclosed diskette ranged in capacity from 30 to 4,700 tons. These systems employed ground-coupled well fields of up to 370 boreholes for an 850-ton system (OK-078) to 3 wells for a 4,700-ton groundwater system (KY-077). Figure 14 shows the number of types of commercial GSHP systems documented.

Figure 15 shows the number of commercial GSHP and conventional systems that were monitored and simulated.

Annual energy savings for commercial GSHP systems were compared to 19 conventional energy systems and dollar savings for 19 systems, as shown in Figure 16.

In the past, some have attempted to extrapolate the savings of GSHP systems from residential to commercial applications. This is not a valid approach. Even comparing savings among commercial buildings themselves is a difficult task.

It is apparent from Figure 16 that savings attributable to the use of GSHP systems in commercial buildings vary over a wide range. This variation is the result of a host of factors some of which have been discussed above. In addition to such parameters as climate, GSHP system type, soil conditions, equipment efficiency, sizing and other issues which influence all GSHP applications, unique to commercial buildings are building use, internal heat gains and more complex utility rate structures.

Commercial building HVAC loads are heavily influenced by the nature of businesses occupying them. Retail establishments tend to have high lighting loads, offices have moderate lighting with high equipment and occupant loads. These internal heat gains tend to raise air conditioning loads and reduce heating loads. This effect is magnified as the size of the building increases. As a result, space heating requirements, in large retail and office buildings are low in terms of Btu/ft^{2}yr relative to residences and other types of commercial buildings.

Hotel and motel buildings, due to their 24-hour occupancy and domestic hot water loads, tend to have higher heating requirements than retail and office buildings. Retirement, nursing and similar medical-residential facilities also are characterized by high heating requirements. For applications in which only space conditioning is done, higher heating requirements tend to generate higher savings for GSHP systems.

A few ground source systems have been installed in small convenience store retail facilities. Although heating requirements may be small in such facilities, savings generated through connection of the display refrigeration equipment to the ground loop can generate substantial savings due to the 24-hour operation of this equipment.

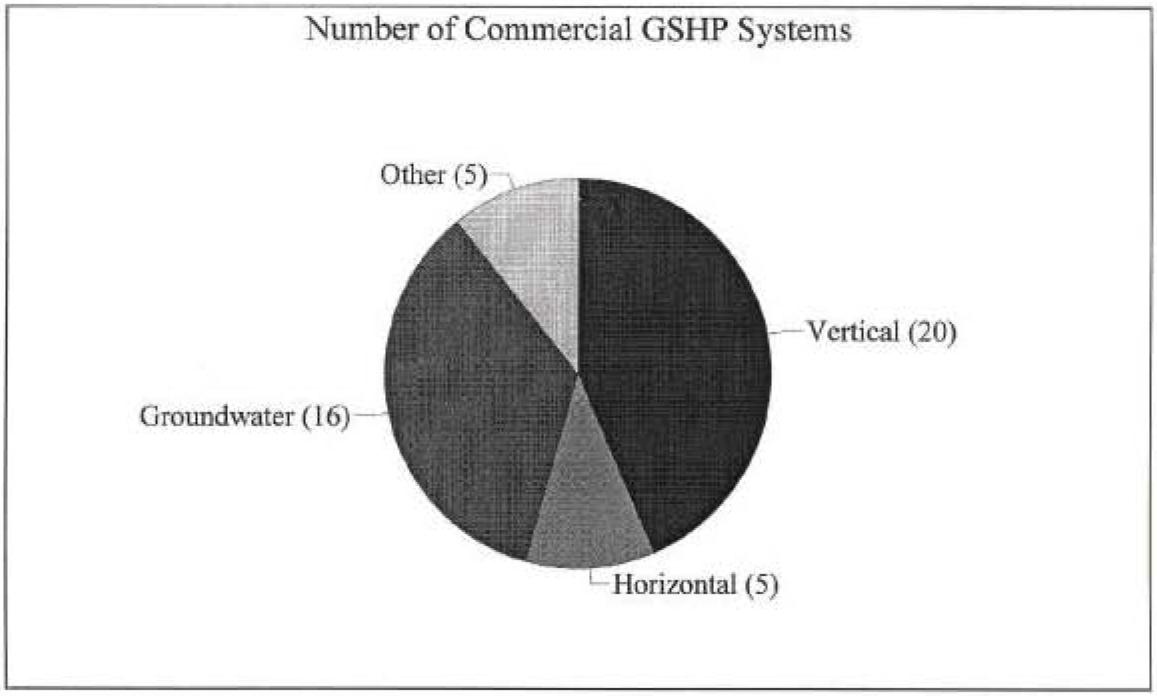


Figure 14. Type of GSHP system for commercial buildings.

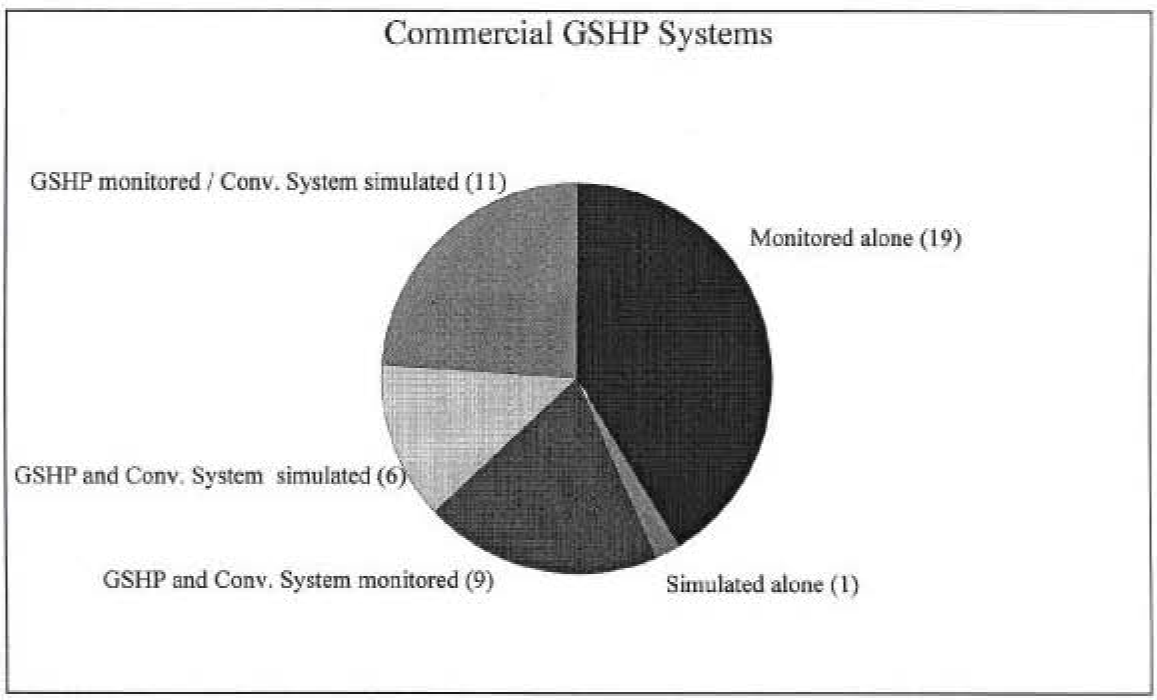
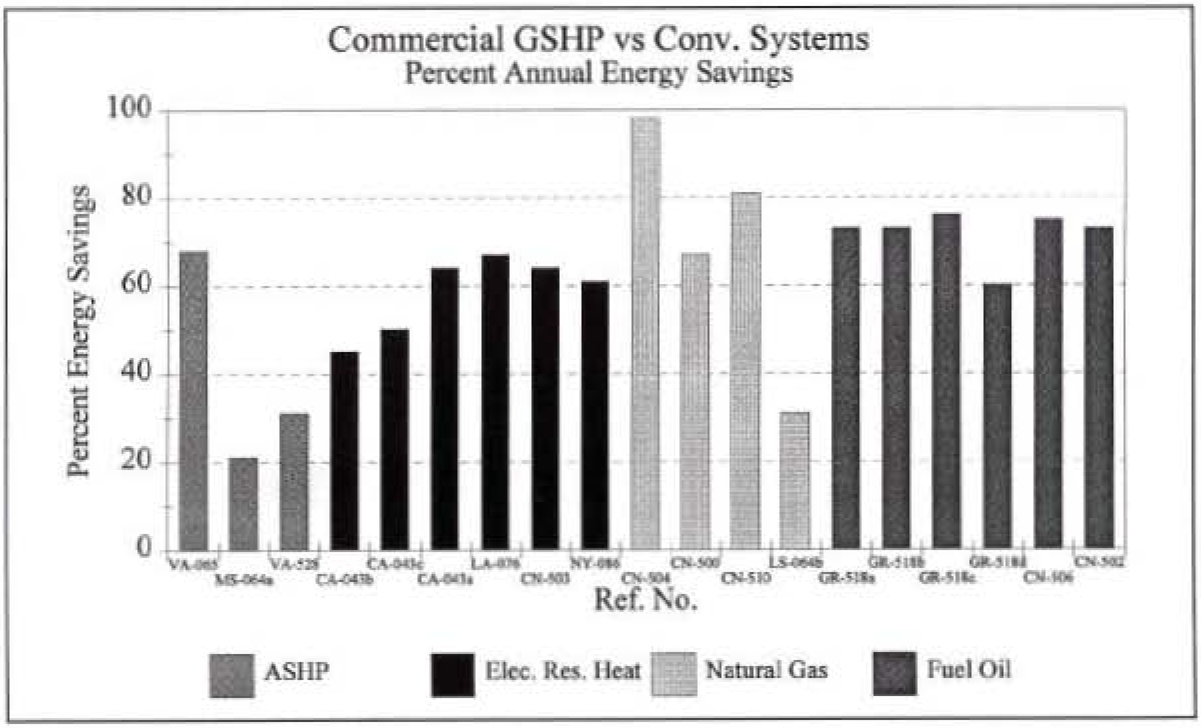


Figure 15. Combinations of monitored and simulated GSHP systems for commercial buildings.



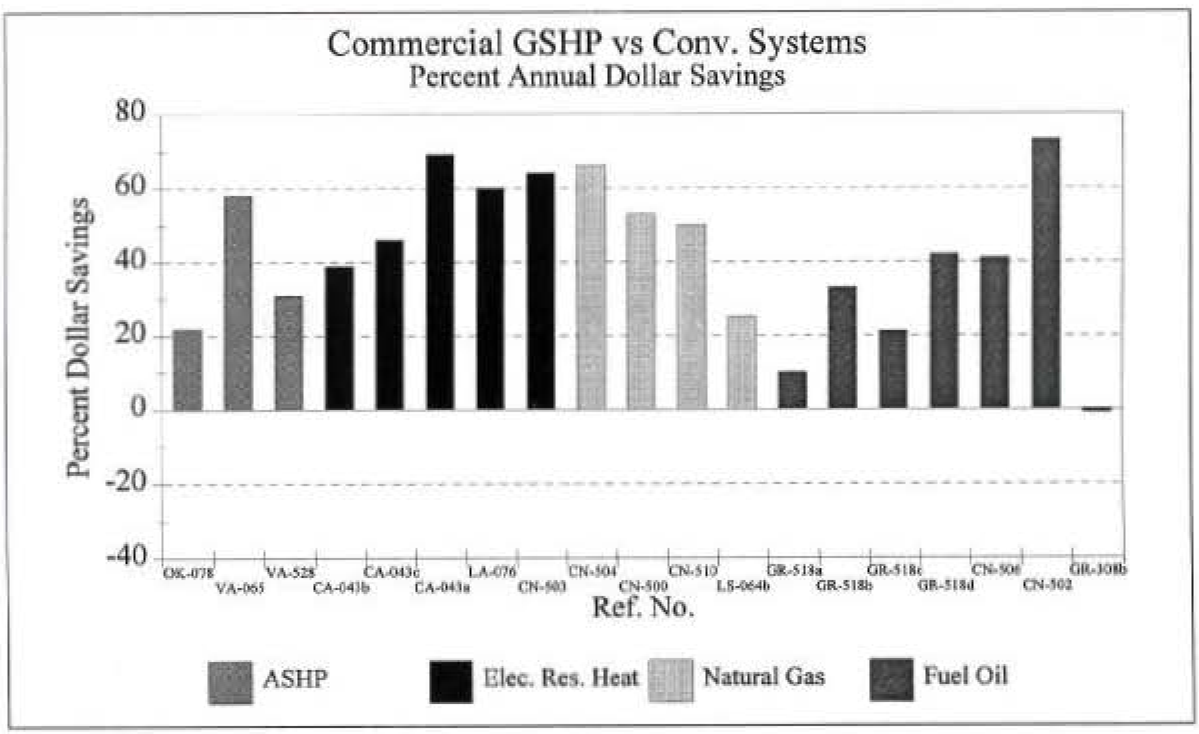


Figure 16. Annual energy and dollar savings for commercial GSHP systems.

In addition to the internal, occupancy and process loads, commercial building energy use can also be influenced by the shape and orientation of the structure, quantity of ventilation air, presence or absence of heat recovery and a host of other parameters. By influencing loads, these factors also affect savings to be achieved by more efficient HVAC system.

Beyond the loads imposed on the system, there is consideration of more complex utility rates generally used for commercial buildings. In residences, customers are billed only for the energy (kWh) used. In commercial buildings, the customer is billed for the energy used in terms of kWh, but also for the peak rate (kW) at which he uses that energy. This is called a demand charge. The time period over which the demand is calculated and the portion over which it is applied influences the cost of operation. Some utilities are moving towards time-of-day rates which alter the kWh charge according to period of the day in which the electricity is consumed. Because the electricity rates and the way they are applied vary from utility to utility, they can have a profound effect upon savings.

It is clear that given all the potential influences upon commercial building energy use, prediction of savings to be achieved with a GSHP system becomes a very site-specific endeavor.

ECONOMICS

The economics of ground-source heat pump (GSHP) systems are represented by the simple payback reported in the case studies. The survey groups are compared first as residential systems, and then as school and commercial systems.

Residential

Residential GSHP system simple paybacks are compared with various conventional energy systems in Figure 17. A favorable simple payback is considered to be 5 years.

Unfortunately, there were only 27 case studies (15%) out of the 184 residential that reported simple paybacks. It is recommended that individual case studies be reviewed when making conclusions on GSHP economics.

In the cases where simple paybacks were greater than 10 years (i.e., NY-028e, NY-028g, NJ-035a and VA-548), GSHP replaced natural gas furnaces.

According to the New York report (Hughes, 1985), "under no circumstances were earth-coupled heat pump systems found to be competitive with natural gas." Since 1985, when the New York systems were installed, there have been improvements in the efficiencies of ground source machines; however in most cases, the economics is still marginal or not competitive with natural gas.

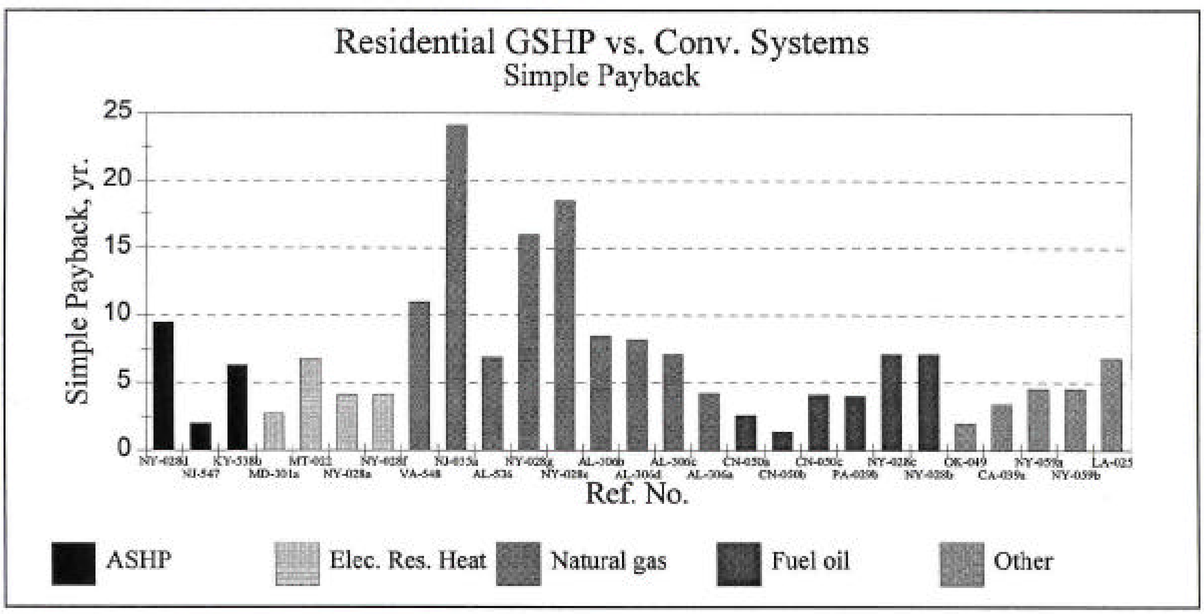


Figure 17. Residential GSHP simple paybacks compared with conventional energy systems.

The biggest barrier to faster paybacks of GSHP systems is the cost of the ground loop. In 1994, the National Rural Electric Cooperative Association (NRECA) Market Research and the University of Alabama conducted a GSHP survey in an effort to develop a national norm for the cost of purchasing and installing GSHPs (NRECA, 1995). The sample analyzed in this mailed survey consists of 285 surveys returned from 540 surveys mailed for an overall response rate of 57%.

Table 3 gives the average cost of the heat pump equipment without and with ductwork installed (no ground loop).

Table 3. Heat Pump Unit Cost (NRECA, 1995)

	Unit Costs (no ground loop)			
Size	Unit		Unit with Ductwork	
in Tons	Mean	Median	Mean	Median
Under 2 (N=31)	$1,654	$1,700	$4,795	$ 5,000
2.5 (N=49)	$2,143	$2,100	$5,504	$ 5,500
3 (N=54)	$2,453	$2,500	$5,913	$ 6,000
4 (N=58)	$5,038	$3,000	$6,993	$ 7,000
5 (N=54)	$3,602	$3,500	$8,104	$ 8,000
Over 5 (N=22)	$4,759	$4,500	$10,759	$10,100

Desuperheaters (heat recovery units) were included in the costs for 64% of the respondents. Rebates on GSHPs were available to customers or installers over 80% of the time.

The average installed cost (with ductwork) of conventional central heating and cooling systems for gas furnaces with 3-ton electric air conditioners and 3-ton air-source heat pumps are given in Table 4.

Table 4. Conventional System Installed Cost (NRECA, 1995)

System with Ductwork	System Cost Median
Gas Furnaces (78% of AFUE) 3-ton, 10 SEER AC	$4,300
Air-Source Heat Pump 3-ton, 10 SEER	$4,200

Conventional systems on the average cost $1,500 less than 3-ton GSHPs not including the added cost to install the ground loop.

Table 5 gives the average cost per ton to install the ground loops. This is based on 80 respondents who said that they installed ground-source heat pumps, 56% installed vertical loop systems, 39% horizontal slinky systems and 38% straight horizontal systems.

Table 5. Average Cost Per Ton to Install Ground Loops (NRECA, 1995)

	Cost/Ton	
Type	Mean	Median
Straight Horizontal (N=36)	$ 741	$700
Horizontal Slinky (N=37)	$ 904	$700
Vertical (N=52)	$1,028	$900

Based on median first costs reported in Tables 3 and 5, the additional cost of $3,800 to $4,400 over conventional energy systems is a substantial barrier for 3-ton ground-source heat pump systems.

Based on the results of the NRECA/University of Alabama survey, it is possible to characterize, in general, the economics of a typical 2-1/2 ton GSHP system. Because many GSHP systems are installed in new homes and the increased capital cost is financed through the mortgage, it is possible to determine where the break-even point occurs for the homeowner for a given set of conditions.

Using the survey data it is apparent that the average national cost for a 2-1/2 ton GSHP system with a vertical loop would be $5500 for the heat pump and ductwork plus $2250 ($900/ton) for the loop. This compares to $4000 for a 2-1/2 ton 10 SEER air-source heat pump system installed. As a result, the incremental capital cost of the ground source system is $7,750 - $4,000 = $3,750.

Using data from a previous evaluation (Kavanaugh, 1992) of GSHP, it is possible to evaluate the economics of GSHPs verses ASHPs. A newly constructed well insulated (R-19 walls, R-44 ceiling, and .5 air change/hr) 1740 ft^2 home was modeled to determine the electrical energy requirements of two different systems: a 10 SEER/7.15 HSPF air-source heat pump and a 13.3 EER/2.8 COP ground-source heat pump with 180 ft/ton vertical bore. Electric resistance domestic hot water heating was used for both systems and a desuperheater was included on the GSHP system.

Two different climates were modeled: 6500 HDD and 4700 HDD. The results are summarized in Table 6.

Table 6. GSHP vs. ASHP Electrical Use (kWh) (Kavanaugh, 1992)

	Heating	Cooling	DHW	TOTAL
6500 HDD				
GSHP	5,486	451	3,150	9,087
ASHP	10,143	773	4,120	15,036
4700 HDD				
GSHP	3,537	301	3,468	7,306
ASHP	6,198	513	4,120	11,065

Based on these values and the 30-year fixed rate mortgage at 8% interest, an electrical rate of $0.067/kWh in the 6500 HDD climate is required for the homeowner to break even on the added cost of the vertical GSHP system. In the 4700 HDD climate, the required electrical rate for break even is $0.109/kWh. For the slightly less expensive horizontal system, the figures are reduced as indicated in Table 7. In addition, the effects of rebates are also shown.

Table 7. Break-Even Electrical Rates ($/kWh) for 2-1/2 Ton GSHP vs. 2-1/2 Ton ASHP

Rebate:	w/o Rebate	w/$200/ton	w/$300/ton
6500 HDD			
VGSHP[a]	$0.061	$0.053	$0.049
HGSHP[b]	$0.058	$0.045	$0.041
4700 HDD			
VGSHP	$0.097	$0.084	$0.078
HGSHP	$0.084	$0.071	$0.065

a. VGSHP - vertical ground-source heat pump
b. HGSHP - horizontal ground-source heat pump

Referring to Table 7, electric rates in excess of the break-even value for the GSHP system would result in a positive cash flow for the homeowner. Electric rates below the break-even value would cost the homeowner money.

Schools

Simple paybacks for schools were reported in only 5 out of the 23 case studies. Therefore, this is not a good statistical representation of economics for using GSHPs in schools. Favorable economics, less than 5 years simple payback, were reported for three out of the five school systems as shown in Figure 18.

Commercial

Commercial building case studies reported simple paybacks for 17 out of 46 ground-source heat pump systems (Figure 19). All of these systems had simple paybacks of less than five years. Of those 17, 10 represent systems installed in Canada, one in Germany and one in Sweden, all typical of northern climates.

Summary

Caution should be used in arriving at economic conclusions for any of the three groups of graphs presented in this report. In part this is due to the many variables associated with GSHP systems and a variety of economic analysis methods used in the case studies.

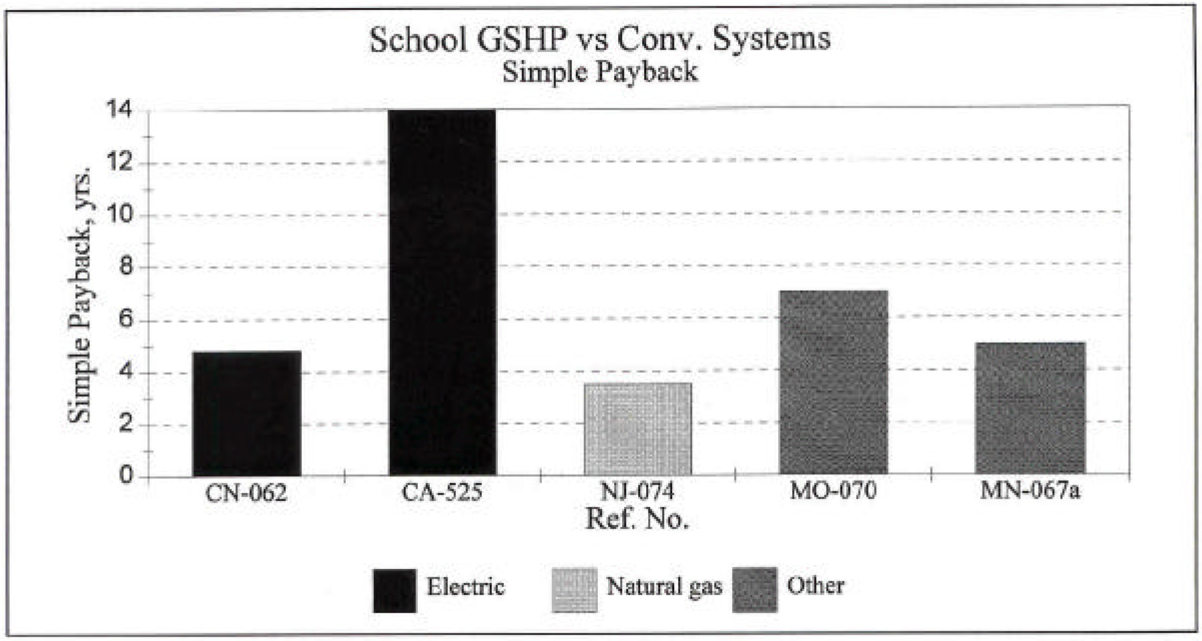


Figure 18. **School GSHP system simple paybacks compared with conventional energy systems.**

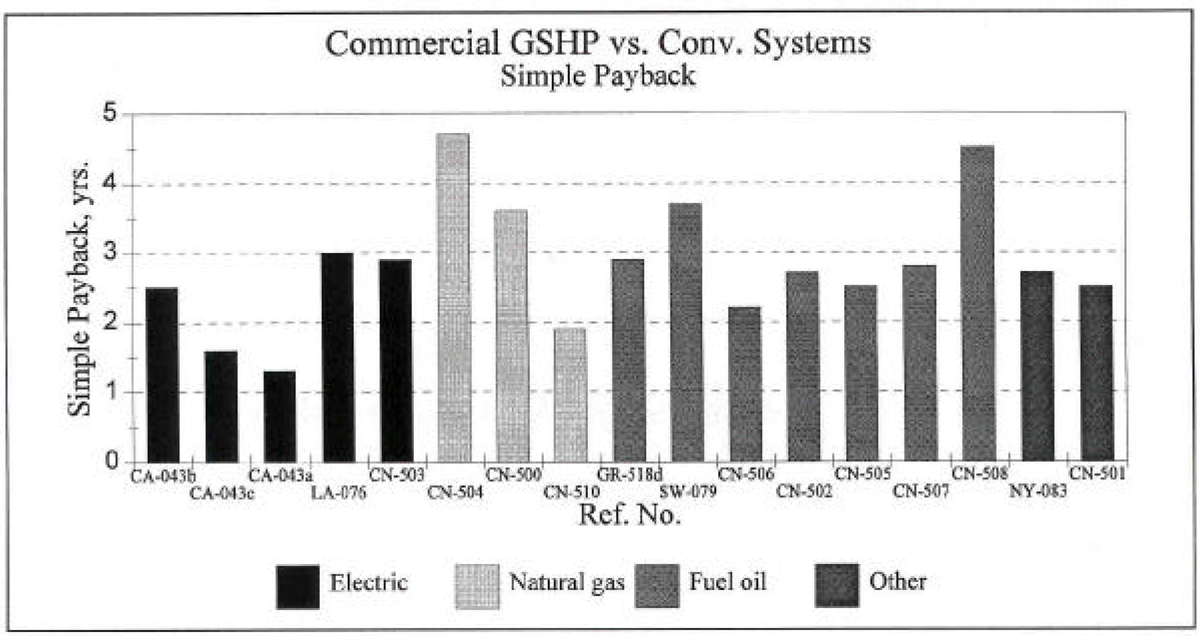


Figure 19. **Commercial GSHP system simple paybacks compared with conventional energy systems.**

In the case of residential systems, homeowners usually include the first cost of the HVAC system in the mortgage. An economic evaluation of life-cycle costs is more meaningful than simple paybacks. This could result in a break-even value for the electric rates in the area where the GSHP installation occurs.

When comparing two electrical systems (i.e., GSHP vs. air-source heat pump), the higher the electrical rate the greater the GSHP savings. In comparing GSHP to natural gas, a higher gas rate and lower electrical rate will make the GSHP dollar savings more attractive.

In the cases of school and commercial buildings, a more complex utility rate structure may be imposed on the system. The customers are billed for energy used in terms of kWh and also for the peak rate (kW) or demand charge at which he uses that energy.

Electric rates and the way they are applied vary from utility to utility and can have a profound effect on savings.

Recognizing all the potential influences upon school and commercial building energy use, predictions of savings to be achieved with a GSHP systems becomes a very site-specific endeavor.

UTILITY PROGRAMS

Demand-side planning is increasingly becoming an accepted part of the planning process of U.S. electric utilities. Stimulated by the rising costs of constructing new power plants, increasing environmental concerns over emissions from fossil fuel plants, and resulting regulatory pressure, electric utilities are looking more to the demand-side as a source of resources for meeting energy and load requirements.

Ground-source heat pumps (GSHP) are one of many technologies that utilities are considering or implementing for demand-side management (DSM), especially aimed at improving the efficiency with which customers use electricity. Types of residential DSM programs include: audit/thermal performance improvement; heating, ventilating and air conditioning (HVAC); lighting; efficient appliances; thermal storage and dual-fuel heating; load control; education; and multiple technologies. The result 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 of electric utilities and rural electric cooperatives for ground-source heat pumps, which is under the HVAC category. Information collected includes: utility/contacts, marketing programs, barriers to market entry, incentive programs, number of GSHP units installed in service area, and the benefits to the utility of GSHP installations.

The data collection process involved primarily contacting utilities that were identified to have GSHP DSM programs in an Electric Power Research Institute report (Blevins, 1989) and from member utilities in the International Ground Source Heat Pump Association. A total of 57 utilities and rural electric cooperatives, out of 178 electric utilities, were reported to have DSM programs involving GSHPs (Appendix C).

Marketing

Marketing programs employed by utilities used various implementation techniques to inform customers of GSHP programs and attract their interest. Table 8 summarizes the frequency with which utilities reported using various approaches.

Table 8. Implementation Techniques for GSHP Programs (base of 57 programs)

Technique	Frequency of Reporting (%)
Utility Publications and Seminars[a]	36
Newspaper & Radio/TV Advertising	16
Test/Demonstrations	10
Education Programs	6
Home Shows	6
Dealers	4
Builders	2
Bill Inserts	2
No Program	18

a. Includes seminars, brochures, word-of-mouth, utility newsletters and magazines, exhibits and displays.

Barriers to Market Penetration

The primary barrier to the market penetration of mainly residential GSHP systems, according to a majority of the utilities, is the incremental cost of installing the ground loop. This median cost ranged from \$700 to \$900/ton. The barriers or deterrents (not in ranked order) to the implementation of GSHPs cited by utilities included:

- First cost of installation - ground loop
- Natural gas is inexpensive
- Lack of manufacturers, suppliers, dealers and loop installers
- Reputation of a "bad" installation
- Economic downturn
- Customer resistance to heat pump technology
- Horizontal loop resulted in dryout of soil
- Lack of educational programs for installers
- High efficiency ASHPs
- New technology - more planning necessary for GSHP systems than for conventional HVAC
- Southern climates - loop temperatures heating up
- Areas limited for installation of ground loop in urban market
- Regulatory problems - drinking water standards
- Public knowledge of system benefits
- A&E firms resistance to change
- No qualified people available to install and maintain

Incentive

Utilities have designed a number of incentive packages to encourage the installation of GSHPs. In most cases, these incentives include cash rebates, special financing, discounted energy rates, in a few cases free ground loop installations, or combination of the above. Of the options, rebates are by far the most common choice, being associated with over 47% of all utilities offering incentives.

Rebate amounts differ significantly across reporting utilities; but, also vary within a given utility as a function of size, efficiency level, or rebate recipient. In many cases, the utility specifies a minimum Seasonal Energy Efficiency Ratio (SEER), usually 10 or greater. Rebates given for GSHPs were often reported in terms of dollars per ton of capacity or in terms of dollars per unit (i.e., dollars per 3-ton unit or system) and sometimes require an energy audit or minimum insulation standards. Although most rebates are paid directly to the customers, a number of utilities also pay rebates to the trade ally (selling dealer, installing contractor, or home builder). In several cases, rebates were paid for fossil fuel or electric resistance heating system retrofits. Table 9 summarizes the types of program rebates paid for GSHPs.

Table 9. Reported Ground-Source Heat Pump Program Rebates

Rebate Type	Rebate Recipient	Number Reporting Programs	Range of Reported Rebates ($)	Mean Rebate ($)
Residential $/unit	Customer	19	150 - 1000	382
Residential $/ton	Customer	6	75 - 333	208
Trade Ally $/unit	Trade Ally	3	100 - 350	200
Commercial $/ton	Customer	2	100 - 165	133
Fossil Fuel Retrofit	Customer	3	400 - 1250	733
Electric Resistance Retrofit	Customer	1	750	750

Although rebates are most common, other types of incentives are also provided by utilities for GSHP programs. These services included special financing (low-cost loans), service agreements and annual maintenance, trenching costs or entire loop installation, discounted and controlled rates (about $0.01/kWh), additional rebates for meeting insulation standards, and add-on rebates for desuperheater or full-integrated unit (on demand).

Installations

A total of 35 utilities reported installed ground-source heat pump systems out of 57 contacted. More than 18,800 GSHP systems (a system is a 3-ton equivalent) have resulted from these 35 programs. The types of systems are classified as ground-coupled vertical or horizontal, or open system which employ a producing water well, as summarized in Table 10.

Table 10. Ground-Source Heat Pump Installations by Type

Installation Type	Number
Ground-Coupled - Vertical	1,344
Ground-Coupled - Horizontal	8,572
Open System	1,406
Undefined System*	7,473
	18,795

* Undefined system could be closed-loop or open system.

Four utilities, PSI Energy, Buckeye Power, Inc., East Kentucky Power Corp., and Associated Electric Cooperative represent 81% of the installed ground-source heat pump systems for those utilities contacted. The 18,800 ground-source heat pump systems probably represent about 13% of the total GSHP equivalent 3-ton systems installed across the United States.

Utility Benefits

An electric utility can benefit from promoting GSHPs in several ways. The extent of these benefits depends on the utility's strategy for long-term demand-side management. These strategies may involve demand reduction, reduction of air pollutants, load shifting, load growth, and conservation. The electric heat pump has provided the utility an opportunity to capture the heating as well as air conditioning load among its residential and commercial customers. GSHP systems with on-demand water heating systems (triple function) can increase the competitiveness of electricity in the heating, cooling and water heating market. The added value and advantage for the utility and its customers is that GSHPs can usually be added to an electrical system without much, if any, added power (kW) of supplemental resistance heat. GSHPs will help reduce sharp heating peaks, smooth summer peaks, improve the overall load factor, and increase revenues capturing more of the change-out market.

A total of 25 utilities reported some type of benefit from the installation of GSHPs. Most of the utilities (76%) stated that demand reduction (peak shaving) was the primary benefit. Other benefits cited by utilities that could be in addition to demand reduction are:

- Load leveling and conservation
- Annual load reduction
- Controllable load
- Higher load factor
- Higher winter efficiency
- Selling more kWh
- Super efficient and environmental benefits
- 4.5 to 5 kW/customer demand reduction
- Save 60% over electric resistance heating
- Competitive with other fuels (i.e., natural gas, propane, and fuel oil)
- Customer satisfaction and comfort of dual mode heating and cooling
- Maintenance free
- Cost less to operate by customer
- Lower overall cost of service by spreading out fixed capacity costs

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APPENDIX A

Data Access

Data Access

The source data can be access within other software besides Paradox 5.0. The following shows how you may access the information and maneuver within the program using:

WordPerfect 6.0
Quattro Pro 5.0 and 6.0
Microsoft Excel 4.0 and 5.0
Microsoft Word 2.0 and 6.0

The files on the diskette are:

Casesum2.db (Paradox table)
Csform6.fsl (Paradox form)
Case1.wpt (WordPerfect template)
Casesum2.txt (ANSI Delimited Text file exported from Paradox)

For WordPerfect 6.0 (To view database in a form)

Pulldown menu:

File / open

[Open File Box]

change Drive: to a:\
change Filename: to case1.wpt
click OK

Template will show up

click on Merge button

[Merge Box]

click Merge

[Perform Merge Box]

change Output file: to c:\case1.wpd (file size will be about 900KB)
click OK (Takes from 2 minutes to 10 minutes depending on the system.)

Pulldown menu:

File / open

[Open File Box]

change Drive: to c:\
change Directories: to c:\
change Filename: to case1.wpd
click OK

For Quattro Pro 5.0 and 6.0 Users (To update or view the database)

Pulldown menu:

File open

[Open File Box]

change Drive: to a:\
change List Files of Type: to Paradox (*.db)(for 5.0 users, change File Type to Paradox (*.db)
change Filename: to casesum2.db
click OK

If the table is updated, make sure you save it as a Paradox file--if you wish to view the form in WordPerfect 6.0. The WordPerfect file case1.wpt must be merged again if the table is updated.

To save database as a Paradox file:

Pulldown menu:

File / save as

[Save File Box]

change Drive: to a:\
change Save File as Type: to Paradox (*.db)
change Filename: to casesum2.db

[Quattro Pro Box]

click Replace

[Paradox File Structure Box]

click on Write

To maneuver in the database within Quattro Pro. 5.0

To lock the headings for each field.

Pulldown menu:

Windows / locked titles

[Locked Title Box]

change Options: to Horizontal
click OK

Most of the columns are small enough to be resized to read the contents of each cell.

To resize the columns, click on the Fit button.

To read the contents in a cell under the Headings System Description, Monitored data, and Ground System Config:

move the edit box to the cell you wish to read
using the mouse, move the pointer until it is within the contents box and the pointer changes to an I-beam
click the left mouse bottom
to return to the spreadsheet
use the mouse to return the pointer to the spreadsheet
click the left mouse bottom.

To maneuver in the database within Quattro Pro 6.0:

To lock the headings for each field.

Pulldown menu

View / locked titles
[Locked Title Box]
change Options: to Horizontal
click OK

Most of the columns are small enough to be resized to read the contents of each cell.

To resize the columns:

Start with the pointer in cell A1
click the left mouse bottom and hold down
highlight entire table
click right mouse bottom

[Properties Box}

click on Block Properties

[Active Block Box]

click on Alignment
change Horizontal Alignment: to General
change Vertical Alignment: to Top
click on Word Wrap
click OK

<u>For Excel 4.0 Users</u>

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: Text Files (*.txt, *.csv)
change Filename: to casesum2.txt
click on text button

[Text File Options Box]

change Column Delimiters: to comma
change File Origin: to Windows (ANSI)
click OK

To save casesum2.txt to an Excel file.

Pulldown menu:

File / save as

[Save As Box]

change Drive: to a:\
change Save File as Type: to Normal
change Filename: to casesum2.xls
click OK

To maneuver in the database within Excel 4.0

To lock the column headings

make sure the edit box is at cell A2

Pulldown menu:

Windows / freeze panes

Most of the columns are small enough to be resized to read the contents of each cell..

To resize the columns:

move the edit box to the cell you wish to resize

Pulldown menu:

format / column width

[Column Width Box]

click on Best Fit button

To read the contents in a cell under the Headings: System Description, Monitored data, and Ground Heat Exch. Config:

move the edit box to the cell you wish to read and the text is word wrapped within the contents box

<u>For Excel 5.0 Users</u>

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: Text Files (*.pm, *.txt, *.csv)
change Filename: to casesum2.txt
click OK

[Text Import Wizard - Step 1 of 3 Box]

change Choose the Fle Type that Best Describes Your Data: to Delimited
click Next

[Text Import Wizard - Step 2 of 3 Box]

change Delimiters: to comma
change Text Qualifier: to " (quote)
click Next

[Text Import Wizard - Step 3 of 3 Box]

change Column Data Format: to General
click Finish

To insert column heading:

insert a row at the top of the sheet
follow the Case Study form for the order of the column headings.

To save casesum2.txt to an Excel file.

Pulldown menu:

File / save as

[Save As Box]

change Drive: to a:\
change Save File as Type: to Microsoft Excel Worksheet
change Filename: to casesum2.xls
click OK

[Summary Info Box]

can disregard this box
click OK

To maneuver in the database within Excel 5.0.

To lock the headings for each field:

make sure edit box is at cell A2

Pulldown menu:

Windows / freeze panes

Most of the columns are small enough to be resized to read the contents of each cell.

To resize the columns:

move the edit box to the cell you wish to resize

Pulldown menu:

format / column / auto fit selection

To read the contents in a cell under the Headings: System Description, Monitored Data, and Ground Heat Exch. Config:

move the edit box to the cell you wish to read and the text is word wrapped within the contents box

<u>For Microsoft Word 2.0 Users</u>

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: to Text Files (*.txt)
change Filename: to casesum2.txt

[Convert File Box]

change convert file from: to Text only
click OK (The data will be separated by commas and each comma represents the end of a field.)

If you converted casesum2.txt to an Excel file casesum2.xls.

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: all files (*.*)
change Filename: to casesum2.xls
click OK

[Convert File Box]

change convert file from: to Excel Worksheet
click OK (The data is separated by tabs and each tab represents the beginning of a new field.)

<u>For Microsoft Word 6.0 Users</u>

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: to Text files (*.txt)
change Filename: to casesum2.txt (The data will be separated by commas and each comma represents the end of field.)

If you converted casesum2.txt to an Excel file casesum2.xls.

Pulldown menu:

File / open

[Open Box]

change Drive: to a:\
change List Files of Type: to Excel (*.xls)
change Filename: to casesum2.xls
click OK (The data is separated by tabs and each tab represents the beginning of a new field.)

APPENDIX B

Paradox File Structure

PARADOX FILE STRUCTURE
for Casesum2.db

Fields	Length	Type
Ref. no. 1	7	A
Reference	50	A
Type of installation	15	A
Date installed	15	A
Building size (sq. ft)		N
City	20	A
State	2	A
Country	7	A
Zip	5	A
System description	225	A
New	1	A
Retrofit	1	A
Design temperature (ºF)		N
Heating degree days		S
Cooling degree days		S
Circ. fluid	20	A
Capacity (tons)		N
Heat pump manufacturer	15	A
Monitored data	225	A
Ground heat exch. config.	225	A
Ground temperature (ºF)		N
Pipe material	15	A
Pipe size (in.)		N
Vertical	1	A
Number of boreholes		S
Borehole depth (ft)		S
Horizontal	1	A
Trench length (ft)		N
Trench depth (ft)		N
Groundwater	1	A
Number of wells		S
Depth of well (ft)		S
Casing diam. (in.)		N
Flow rate (gpm)		N
Monitored GSHP	2	A
Simulated GSHP	2	A
Runtime heating (hr)		N
Runtime cooling (hr)		N
COP		N
EER		N

Annual energy usage (kWh)		N
Percent energy savings		S
Total installed cost		$
Annual GSHP cost		$
Percent dollar savings		S
Payback period (yr)		N
Monitored conv.	1	A
Simulated conv.	1	A
Air-source heat pump (kWh)		N
Electric heat (kWh)		N
Natural gas (therms)		N
Fuel-oil (gallons)		N
Air cond. (kWh)		N
Other	1	A
Annual energy usage conv. (kWh)		N
Annual conv. cost		$
Contact person	30	A
Address	35	A
City	15	A
State	2	A
Country	8	A
Zip	5	A
Phone number	13	A
Page	5	A

APPENDIX C

Utility GSHP Programs

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Alabama Power Co. John Hollingsworth Birmingham AL 205-250-4398	No program, however they have nothing against GSHP's.	Initial cost of installation - 2 times ASHP units.	Rebate program has been discontinued. Utility ensured proper installation.	Two pilot vertical systems. Contact: Greg Reardon (205-250-4448).	Demand reduction - was not attractive for summer peak. At extreme conditions GSHP showed some advantage over ASHP's.
Allegheny Electric Coop, Inc. Gilbert Freedman Harrisburg PA 717-233-5704	Demo. site which is shown to consumer, 8 yrs. operating.		None	Demo site - 2 horiz. and 2 vert. in central Penn. (Design temp: -5 deg). Short loop dried soil out.	74% savings over oil. Horizontal loop COP of 1.68 (2.33 with 1/3 hp pumping allowance).
Arkansas P&L Co. Robin Arnold Little Rock AR 501-377-5407	Promotion of residential heat pumps with emphasis on fuel conversions.		For contractor, $100/unit converted from fossil fuel. For customer, financing with repayment through electric bill.		
Associated Elec. Coop., Inc. Max Cates Springfield MO 417-881-1204	Advertising - 29% (newspaper, radio, TV, magazines and brochure/direct mail), dealer - 38%, builder - 5%, Coop. member sevices - 18%, and friend/relative - 9%.		Rebate - $250/ton, avg. amt. $925/3.7-ton unit.	3,112 units with net added demand of 4,883 kW and 20,663,594 kWh as of 1991.	Add demand during selected times, lower overall cost of service by spreading out fixed capacity costs and excess capacity ends 1998

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Atlantic City Electric Co. Dave Crouch Pleasantville NJ 609-645-4846	Promotion of high efficiency heat pumps.		Rebate to be given of \$1.1 million to Stockton Sate College.	About 200 homes in the Scranton-Harrisburg-Allentown area. About 800 homes in the south Jersey area. Stockton State College large tonnage (1480 tons) - 400 vertical bores of 400 ft depth each.	Demand reduction and reduction of. air pollutants.
Baltimore Gas & Elec. Co. Richard Hobson, Sr. Baltimore MD 410-298-1826			Merchandise gift certificates at completion of contract.	Two ground-water and one ground-coupled heat pump with magnetic tape metering.	
Basin Electric Dale Niezwaag Bismark ND 701-223-0441	Promotion with utilities, PR firm to do promotion. Target special events (i.e. home shows, ect.). Education mainly for contractors.		Service agreement (\$100 deductible) and annual maintenance (filter replacement, refrigerant check, motor lubrication and adjustment) for \$60/year.	Documenting case studies.	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Black Hills Power & Light Co. Harry Swander Rapid City SD 605-342-3200	Mainly by word of mouth, need better customer program. Joint with 3 REC'S in area. Heat pump maintenance service for residential customers.	Initial cost and old "bad" reputation of an installed GSHP. Nat. gas is cheap ($0. 42/therm). Ground loop costs $3000.	Rebate program - $202 for 3-ton unit, based on Btu/SEER. Demand energy rate - $10/kW, rebate on water heater. GSHP - $500 grant in addition.	Mostly vertical loops, 20 total installed, 12 on-line in 1992.	Sell load (controlled load), 3-4% growth /yr. 7435 deg. day - high winter and summer peaks.
Buckeye Power, Inc. Gary Dean Columbus OH 614-846-5757	Promo. campaigns through residential Bulletin, advertising (newspapers, TV and radio), monthly newsletter. Typical person interested in GSHP contacts a local REC office. G&T Co. services 27 RECs of which 24 participate in GSHP program.	Initial cost. Land area required for loop (+1 acre). Infrastructure of dealers and contractors was a problem 5 yrs ago, getting better - more manufacturers and better job working with dealers.	Cost share a $600/system rebate (50%) with 24 out of 27 REC in service area (300 rebates processed/yr). Off-peak rates ($0.01 to $0.015/kWh) for consumers. In addition dealers receive a $100 gift certificate.	Estimate 6,000 GSHP systems in service area of 285,000 customers - 70% horiz., 20% open, 5% vert. and 5% pond.	Demand reduction - control back-up resistance with radio switch. Least cost way for consumer heating, cooling and water heating.
Butler Rural Electric Coop. Lisa Staggs Hamilton OH 513-867-4400	Promo. campaigns of GSHP's - i.e. Country Living Magazine.	Generated interest but not enough dealers - only 3	Coop. picks up trencing cost. In Jan. 91 began free loop instal. prog. (pipe not included). Discount on rate of $0.01/kWh of GSHP usage, all other $0.065/kWh. $400 rebate and 5% loan.	100 GSHP systems installed for 8000 customers - all closed-loop horiz. Loop Master is contractor.	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Cajun Electric Andy Vaughn Baton Rouge LA 504-291-3060	Promotion of GSHP from 1989 to 1992.	Many problems - lack of suppliers and manufactureres, cost not a problem. Manufacteres left state due to down turn in economy. GSHP declining due to reduction in new construction and fewer qualified dealers & installers.	Rebate: $125/ton + $500/ton (GSHP and super eff. air-HP), desuperheater - $100 for HW recovery	1991 - retrofit 31 units (105.5 tons), new construction 286 units (937.5 tons). 1992 (6 mos.) - retrofit 56 units (128.5 tons), new constr. 10 units (33.5 tons). Mostly vertical, 50% open.	
Cass County Electric Coop. Tom Thorson Fargo ND 701-428-3292	None	Low growth in area. Lack of contractors and installers. Loop field cost is a deterent.	Discounted and controlled rates.	25 including bank, school office buildings. 14,000 customers.	Customer satisfaction and comfort of dual mode heating and cooling. Competitive with other fuels.
Cedar Falls Utilities Bob Cavin Cedar Falls IA 319-266-1761	Promotion of residential GSHP - any customer out of city limits beyond gas lines.	Initial cost. Dry out of clay/sandy soil caused horiz. loop to not work properly, installed systems are vertical closed loop (125 ft/ton) using Ditch Witch machine.	$300/unit rebates to residential customers. Utility reserves the right to monitor energy consumption and use the information for marketing purposes.	5 GSHP systems installed - 2 conversions from ASHP, 2 new builts and 1 commercial (City Recreation Center). Total customers are 14, 000 (2,000 rural).	Lower demand and satisfied customers.

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Central Illinois Light Co. Sue Hagel Peoria IL 309-672-5271	Promotion of residential heat pumps.	Low participation attributable to customer resistance to heat pump technology.	$200 rebate for customer, cooperative advertising for dealer whereby utility incurs 30% of costs.		
Clark Rural Electric Coop. Paul Ambs Winchester KY 606-744-4251	R-loads program (heat loss/gain). Work with developer, a subdivision as an example		Rebate program - $500 for installing GSHP (must meet install. standards) + $500 for meeting insul. stand. Jan 1, 1993 changes to rebate on tonnage - $333/ton for residential or $165/ton w/o insul. standards. Commercial - $165/ton rebate.	60 GSHP installed in 3 years + 20 homes under constr.	Demand reduction of 28.7 MW by 2000 at a cost of $2500/kW.
Consumers Power Co. G.J. Kloock Kalamazoo MI 616-337-2262	Test of a residential GCHP. Comparison information available from previously installed ASHP.		None.	2.5-ton heat pump with eight 60-foot heat exchanger pipes.	
Cornhusker Public Power Dist. Norm Hoge Columbus NE 402-564-2821	Nebraska Public Power provides program - Cliff Anderson (402-563-5539), provide 2/3 of NE power. Also provide rebates to local utilities and inspections of installed systems.	Not many installers, many of which don't have education.	For new homes, $200 for a GSHP and $150 for an ASHP. For retrofit, $550 for converting from fossil fuel.	Not many, most air-to-air, GSHP are ground water type.	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Cotton Electric Coop. Kim Hooper Walter OK 405-875-3351	Promotion of GSHP in conjunction with local dealers. Utlity inspects installations.	Only one dealer in area that installs. $2000 additional cost for GSHP ground loop.	Rebate prog. - $300/unit for any type with a minimum of 10 SEER rating.	100-150 GSHP installed. More likely to go to ASHP with high SEER.	..
Dakota Electric Assn. Don Boyd Farmington MN 612-463-6235	Good management program. Northland Heat Pump Assn. provides promo. and certification. Test home open for public viewing during home show.	Residential installations suffering from non-qualified installers. Contractor needs to be comfortable with the technology.	Rebate program - $400 for installation of any type heat pump. Low interest loan (5%) up to $3000 max. Propose to increase rebate and $6000 on loan.	10 GSHP installed, one will use slinky design.	
Detroit Edison Co. Jim Lagowski Detroit MI 313-237-9231	Promotion of GSHPs to residential customers		Rebates for customers whose homes meet integrity standards. Payments to dealers. Advertising incentives for dealers and distributors.	Estimate 300 units.	
E. Mississippi Elec. Power Harold Johnson Meridian MS 601-483-7361	Promotion of heat pumps for new and existing homes. Part of the Energy Conservation and Load Factor Improvement Program.	Mainly cost - 2 times cost of air-source	Rebate $125 to $450/ton; air-to-air rebates are $50/ton. $100 bonus for replacing fossil fired or elect. furnace.	17 systems installed - mostly vertical	Curb peak demand.

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
East Kentucky Power Coop. Dan Fleming Winchester KY 606-744-4812	Promotional campaigns - geothermal program specific and increased insulation.		Rebate program - \$500 for GSHP + \$500 for insulation. Savings in rate.	1,700 units installed in KY, 600/yr and expect 800-1,000/yr by 2000. 265,000 residential customers.	Demand reduction of 4.5-5 kW/customer. Estimate 30 MW savings (winter) by 2000.
Farmers Elec. Coop. Corp. Larry Bride Newport AR 501-523-3691	Promotion of heat pumps. To receive rebate, participants must sign contract agreeing to potential load control.		\$150 rebate per heat pump.	One GSHP unit installed.	
Greenville Utilities Co. Robert Tugwell Greenville NC 919-752-7166	Did analysis on operating costs for customers, 1989 - 90 were peak years for GSHP - no interest today!	People going to air-to-air - high efficiency	No incentives, hesitant to do these - none in State of North Carolina	5 to 10% of 300 installed in 1989-90 were GSHP - mostly horizontal systems	Contact for Coops in NC - Jim Autry, Marketing Director 800-768-7697
Guadalupe Valley Elec. Coop. Mike Absher Gonzales TX 512-672-2871	Promotion of residential heat pumps.	Difficult to market; loop temp. heating up.	\$525 max. rebate per heat pump	Mainly for cooling	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Gulf Power Co. Vernon Flower Pensaclola FL 904-444-6379	Promotion of heat pumps for new homeowners and to existing homeowners with fossil-fired systems. Utility representatives inspect installations and educate the customer to ensure proper installation.		Low interest (7.5%) loan for energy efficient homes - no rebate.	Ground coupled heat pumps - mostly vertical	
Harrison County RECC Larry Jones Cynthiana KY 606-234-3131	Advertisement inserts in newsletter and radio spots. East Kentucky Power does most of the marketing.		$166/ton rebate for installed residential and commercial and $333/ton for new homes meeting min. insulating standards.	120 GCHP systems (75-80% are vertical). Surface rock prohibits trenching, several drillers charge about $650/ton.	Mainly replacement of propane and heating load reduction.
Hoosier Energy Dave Stolz Bloomington IN 812-876-2021	Help member utilities with advertising.	1. Initial cost - $2000 for ground loop. 2. Who makes the decision to install HVAC equip. - contractor, developer, home owner, etc.? 3. New technology - more planning necessary for GSHP than for convential HVAC systems.	$1250 rebate for installation of residential GSHP to replace fossil-fired, $750/unit rebate to replace elect. resistance. Commercial rebate is negotiated to offset cost of equipment.	In 1992, 396 units installed - mostly horizontal (1 or 2 vertical). Total customers about 170,000. Loop Master installs ground loops. Direct expansion has COP of 4-6, copper lasting and envir. concern	Demand reduction and higher load factor. Customer service - meeting all the needs for heating and cooling.

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Indianapolis P&L Co. Dave Getz Indianapolis IN 317-261-8494	None for GSHP. RIM tests - rate impact management.	Dense urban market, i.e. areas limited for installation of ground loop.	Two programs - retention and conversion for minimum SEER of 10.	2 units/yr.	
Kansas Gas & Elec. Co. Richard Moscher Wichita KS 316-261-6418	Test of residential GSHP.			Two test units: 2-ton GCHP with 3 vert. loops.	In winter, SPF of about 3.1. In summer SEER of 14.0.
Lakeland Dept. Elec. & Water Allan Lukhaub Lakeland FL 813-499-6523	None. Tested direct expansion (vertical) unit and compared to a high-efficiency ASHP. Improvement of the GSHP over ASHP in the summer was 23. 49% and winter was 49.76%. On an annual basis, the weighted average improvement of GSHP over ASHP was 31.58%	Initial cost and specialized equipment required.	None.	5 to 6 units installed - 85,000 customers.	Demand reduction, winter efficiency improved. Cooling did not show improvement over ASHP except at extreme conditions.
Midwest Energy, Inc. Pat Parke Hayes KS 913-625-3437	Promotion of heat pumps. Presenting seminars on heat pumps for interested customers.		$200 rebate and 2% loan.		

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Mississippi Power Co. Leonard Lowe Gulfport MS 601-865-5925	None	First cost of ground-loop. $600 to $1000/ton for vertical loops and a "little less for horizontal". Horiz. is labor intensive.	None	200 - 300 units installed in a service area of 172,000 residential customers.	Reduced load factor for both summer and winter demand. Electric furnace change out.
Nebraska Public Power Clifford Anderson Columbus NE 402-563-5539	Newest program - media advertizing (radio, newspaper) for all heat pumps.	(1) Regulatory problems - drinking water standards, in NE Dept of Health a GCHP classified as water well, cannot be installed within 1000 ft of drinking water well - trying to change regs., (2) initial cost of $2000 to $3000 for vertical.	Residential - (1) convert resistance heat - $200, (2) convert air-source - $400, (3) convert to GSHP - $600; Efficiency rating $12/ton/SEER above 10. Mult. Family/Commercial - resist. $15/kW, air-source $30/kW, GSHP $45/kW + $12/ton/SEER>10.		Short and long term benefits - shaving peaks
Nevada Power Co. Jim Galva Las Vegas NV 702-367-5112	Have a program for air source.	Installation cost too high.	None	One GSHP installed in area and one home uses pool for the loop.	
Northland Heat Pump Group Joseph Holland Minneapolis MN 612-927-9220	Promotion and certification of contractors, educators, well drillers and manuf. /distributors for four years. Includes states of ND, SD, WI, IW, AND MN.	Largest problem - education of contractors. Ed. chm. is Dale Niezwaag, Basin Elec., Bismark, ND (701-223-0441).	Rebate program - $400 to 500/ unit, low interest loans are more common. Developed ad campaign ($70,000).		

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Northwestern REC Assn. Carl W. Spaid Cambridge Springs PA 814-398-4651	None. Three contractors available in area.	Initial cost a problem - 7 year payback too long, minimum of 5 years. No education program. Cooling a larger demand.	None.	In the range of 100, commercial systems use water well as source. Total customers 18,000.	Customer satisfaction of double duty - heating and cooling. Demand reduction - better for winter peaking. Load factor >70%, 8.44/kWh for ETS - 4.35/kWh.
Ohio Edison William Holley Akron OH 216-384-5201	GSHP market program in place 7 - 8 yrs. Studied PSI of Indiana program - bought into logo and purchased rights to material.	Installed cost - $2000 more for ground loop.		17% of heat pump sales are GSHPs (90% are GCHPs). 900, 000 customers in service area.	Save up to 60% over elect. resistance. Customer - efficiency, cleanliness, and quietness.
Oklahoma Gas & Elec. Co. Karey Barnes Oklahoma City OK 405-272-3587					
Otter Tail Power Co. Charles Hewlett Fergus Falls MN 218-739-8361	None.	Loop field cost is a deterent. Lack of contractors and installers (well drillers). Public knowledge of system benefits and architect/engineers resistance to change.	$75/ton rebates to customers. Contractor rebates of 150 points/unit - convert to $ or gift certificates. Interruptible and controlled rates - residential up to 80 kW and commercial > 80 kW.	640 units in service area of 120,000. 44 new GSHP units in 1992, including a number of commercial and institutional buildings.	Customer satisfaction and comfort with dual mode heating and cooling system. Competitive with other fuels. Selling more kWh. Controlable load and demand reduction. Maintenance free.

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
PSI Energy Jim Roath Plainfield IN 317-838-1325	1986 - customer objections to ASHP being "cold" resulted in corporate commitment - newspapers, TV advertisement, home shows, etc. 1993 - Smart Saver Home Program is now driving force, includes Geothermal Heating, Cooling & Water Heating systems.	First cost of ground loop - 80 - 85% are horiz., 15% vertical. Infrastructure of dealers and loop contractors is good.	1986 - signed contracts with developers of subdivision for loop installation on each lot ($1,700 to $2, 000). 1993 - Cash incentive and DSM measures - builder $350/system + $225 for other DSM meas. Customer - 28% discounted rate during heating season	5 to 10% market penetration for all new homes constructed annually over last 5 yrs. Estimate 4400 installed 3-ton equiv. units for service to 617, 000 customers.	1. Demand reduction, 2. GSHP product competitive with natural gas. 3. Customer satisfaction - quiet operation, clean, and environmentally compatible.
PUD #1 of Benton Co. Nancy Phillips Kennewick WA 509-582-2175	Have heat pump program - considering for own office building.				
Pennsylvania Power & Light Co. Joann Kramer Allentown PA 215-774-5270	Advertising - residential GSHP systems adv. on TV and print add. Promote GSHP through bill insert - energy tip of the month, May 1993.	Installed up front costs. Reduced by educational programs with dealers.	Grant - $1,000 /residential unit, add $100 for DHW, add $300 for full integrated unit (on demand), and HP water heater $200.		DSM - peak load reduction, super efficient and environmental benefits.
Portland General Electric Dale ? Portland OR 503-624-1002	Subsidies are being evaluated.		Provide financing.	Approx. a dozen in area. Two commercial - groundwater source (open-loop)	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Potomac Edison Co. Irv Cather Hagerstown MD 301-790-3400	Train heat pump dealers. Sponsor presentations of info. to dealers. Work in MD, W.VA and VA in a collaborative process. R&D group developing goals.	Education with dealers and customers. Proper installation.	Rebates to customer or dealer, min. insulation required. Inspections by private contactors.	33 total units.	More efficient and load reduction. Cost less to operate by customer.
Public Service of Oklahoma Ron Huntley Tulsa OK 918-599-2727					
San Luis Valley REC, Inc. Karen Webb Monte Vista CO 719-852-3538	No program	Groundwater too cold - didn't work properly!			
Shelby REC Corp. Dudley Bottom, Jr. Shelbyville KY 502-633-4420	Promotion of GSHP and electric water heaters.		$500 cash incentive for GCHP. Water heaters sold at $50 below utility cost.	25 GSHP units	
Snohomish PUD Eldon Samp Everett WA 206-258-8650			Had incentive program - discontinued in 1992.		
Tri State G&T Assn. Mary Ballard Denver CO 303-452-6111	Wholesaler - some advertizing in state-wide magazine (REA). Cover Nebraska, Wyoming and Colorado.	1. Main - cost of installation, 2. service territory has low population, 3. no qualified people to install or maintain	Rebate program- $350 for GSHP, some members provide additonal rebates. Energy audit required to receive rebate.	Command Air of Waco, TX had coop programs sith REA's in CO - trying to get cost down	

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Umatilla Elec. Coop. Assn. Bill Brown Hermiston OR 503-567-6414	No real problem?	Lot of activity in area due to high summer temperatures. Cost is somewhat of a barrier.	Financing up to $5, 000 at 5%, may institute new program.	Mostly horiz. loops, cost $12-$15,000/unit.	Load leveling and conservation, buy BPA power.
United Illuminating Co. Bob Blake New Haven CT 203-787-7585					
United Power Ed Maycumber Brighton CO 303-659-0551	Not pushing as hard as 4 years ago - in competion with Denver	Cost of loop - at least $3000	Rebate - $850; dual fuel heat pump more popular with NG or porpane backup	Vertical loops mostly installed - 8 to 10 units installed, none in the last 2 years	
United Power Assoc. Gary Connett Elk River MN 612-241-2253					
Verdigris Valley Elect. Coop. Verdigris ValleyOK			Rebate - $300 granted on each GCHP system in 1988	70 units installed - 40 replaced nat. gas or propane, 14 replaced electric resistance, 5 replaced ASHPs, and 11 new homes.	70 units will use 630,000 kWh/yr producing $35, 000/yr ($0.06/kWh in summer & $0. 055/kWh in winter). Coop. saves 106 kW in peak load demand, saving $10,513/yr (base on avg. 3-ton unit at $9/kW).

UTILITY GSHP PROGRAMS

Utility/Contacts	Marketing Programs	Barriers to Market Entry	Incentive Programs	Installations	Benefits to Utility
Western Area Power Admin. Doug Mollet Billings MT 406-657-6530	Deals with public utilities in 15 state area. Developing GSHP booklet, available spring of 1993. In data gathering stage for GSHP's.				
YW Electric Assoc., Inc. Bruce Johnson Akron CO 303-345-2291		Installation cost, knowledgeable installers & contractors, market saturated for environmetal reasons.	Sent two contractors to IGSHPA school; none by Utility itself, however Tri-State (see Tri-State entry) has $350/heat pump rebate.	39 tot. units- 5 new homes, 4 nat gas conversions, 12 propane conversions, 1 fuel oil, and 17 electric conversions	Annual load reduction of 30, 000 kWh