# Public Service of Oklahoma

## Ground Source Heat Pump Research Project

### Profile #59

# Executive Summary

Jim Ezell of Public Service of Oklahoma notes that, "Ground source heat pumps are really a product of Oklahoma. While the technology can be applied across the United States and perhaps around the world, it has its genesis in Oklahoma." Thus it is fitting that this profile focuses on the PSO program and incorporates the national perspective by using detailed analytical work done by U.S. Environmental Protection Agency.

Ground source heat pumps, like water and air coupled heat pumps, have distinct advantages over conventional HVAC systems but have been criticized by some environmentalists as electrification technologies whose primary purpose is to increase energy sales. Nevertheless, utilities and energy policymakers simply cannot ignore the fundamental efficiencies of these systems and must carefully analyze their potential applications compared to standard HVAC systems, taking into account geographic location, fuel availability, and regional power sources.

While ground source heat pumps have been installed in a variety of applications for more than 30 years, recent advances in the technology have opened up the market for increased installations. Ground source heat pumps work on the same principle as air source heat pumps. Instead of exchanging heat with the air, a loop of water and antifreeze is circulated through the ground. Through the loop, heat is extracted from the ground during the winter, and deposited into the ground in the summer.

Public Service of Oklahoma (PSO) promotes installation of ground source heat pumps through its Good Cents Commercial and Good Cents Apartments programs. These programs offer financial incentives for installing energy-efficient heat pumps. Incentives are the same regardless of whether the heat pump is ground source, air source, or water source. Additionally, customers may receive a lower winter heating season electric rate if they meet several program criteria, including installation of an energy-efficient electric heat pump. Customers who meet all Good Cents criteria also receive higher incentives than those who install heat pumps unaccompanied by other energy-efficiency measures.

Although there are many benefits to ground source heat pump systems, there are also some obstacles that may make their installation less desirable or impractical to a building owner. First, he or she must be willing to take a long-term view regarding system benefits. The systems have high first costs, which, even when offset by PSO's incentive, are typically not paid back through low operating costs and energy savings for five to seven years. Second, the building site must be of appropriate size and geology. Horizontal loop systems require a sizeable footprint and both horizontal and vertical systems require geological characteristics that are amenable to trenching or drilling.

### Ground Source Heat Pump Research Project

| | |
|---|---|
| Utility: | Public Service of Oklahoma |
| Sector: | Commercial and Apartments |
| Measures: | Ground source heat pumps |
| Mechanism: | Incentives for installation of heat pumps of qualifying efficiencies |
| History: | Ground source heat pump systems first installed through the program in 1987. Eight systems have been installed or are under construction, ranging from 7 tons to 625 tons. |

### Ground Source Heat Pump Data

(for conversion from standard electric system to 3 ton residential ground source heat pump system)

| | |
|---|---|
| Annual energy savings: | 8.8 - 20.8 MWh |
| Winter capacity savings: | 5.6 - 9.7 kW |
| Summer capacity savings: | 4.6 - 5.4 kW |
| System costs: | $5,699 - $8,615 |

### Conventions

For the entire 1993 profile series all dollar values have been adjusted to 1990 U.S. dollar levels unless otherwise specified. Inflation and exchange rates were derived from the U.S. Department of Labor's Consumer Price Index and the Federal Reserve's foreign exchange rates.

*The Results Center* uses three conventions for presenting program savings. **Annual savings** refer to the annualized value of increments of energy and capacity installed in a given year, or what might be best described as the first full-year effect of the measures installed in a given year. **Cumulative savings** represent the savings in a given year for all measures installed to date. **Lifecycle savings** are calculated by multiplying the annual savings by the assumed average measure lifetime. **Caution:** cumulative and lifecycle savings are theoretical values that usually represent only the technical measure lifetimes and are not adjusted for attrition unless specifically stated.

Public Service of Oklahoma (PSO) is an investor-owned utility serving 462,557 customers throughout about one-third of Oklahoma in a highly discontiguous service territory. PSO is one of two investor-owned electric utilities in Oklahoma; Oklahoma Gas and Electric serves other parts of the state. Many municipal systems and rural electric cooperatives provide electric service to segments of the population not included in the investor-owned utilities' service territories.

The largest community served by PSO is the City of Tulsa and its surrounding area. Tulsa, with a population of about 445,000, was originally a Creek Indian village. The discovery of oil in the vicinity led to development of refineries and other facilities vital to the oil manufacturing industry, and the subsequent development of Tulsa into a cultural, financial, and industrial center. PSO also serves much of the eastern portion of the state and several smaller municipalities in southwest Oklahoma. The City of Lawton (population 85,000) in southwest Oklahoma is the home of the Fort Sill army reservation.

The climate is variable in different parts of PSO's service territory. In general, the southern and eastern parts of Oklahoma are humid while the north is colder and the west is drier than the rest of the state. The average annual temperature for the state is 60°F. Warm and cold air masses often merge in Oklahoma, thus the state has a well-deserved reputation for heavy thunderstorms, blizzards, and tornadoes.

PSO is a summer peaking utility. In 1992, summer peak demand was 3,010 MW. The utility's generating capacity of 3,644 MW provides a 21% reserve margin. Virtually all of PSO's generating capacity is provided by coal, gas and oil-fired steam turbines, and diesel generators.

Of PSO's 462,557 customers, 404,170 (87%) are residential customers, 52,215 (11%) are commercial customers, 5,163 (1%) are industrial accounts, and 1,009 (<1%) are other types of customers. Annual energy sales of 13,401 GWh are fairly evenly split among the main customer classes, with residential customers purchasing 4,139 GWh (31%), commercial customers purchasing 4,092 GWh (31%), and industrial customers consuming 4,420 GWh (33%). The remaining 750 GWh (5%) were purchased by other types of customers.[R#1]

### PSO 1992 STATISTICS

| | | |
|---|---|---|
| Number of Customers | 462,557 | |
| Energy Sales | 13,401 | GWh |
| Energy Sales Revenues | $578 | million |
| Summer Peak Demand | 3,010 | MW |
| Generating Capacity | 3,644 | MW |
| Reserve Margin | 21 | % |
| **Average Electric Rates** | | |
| Residential | 5.80 | ¢/kWh |
| Commercial | 4.61 | ¢/kWh |
| Industrial | 2.57 | ¢/kWh |

Energy sales and revenues in 1992 were down slightly from the previous year. Sales suffered from the struggling economy which caused many of PSO's industrial customers to reduce their operations. An unusually cool summer was also responsible for the decrease in sales, especially for residential customers. Average annual electricity consumption for residential customers dropped 10% from 11,432 kWh in 1991 to 10,297 kWh in 1992.[R#1]

### DSM OVERVIEW

Since 1983 under the Good Cents umbrella, PSO has implemented DSM programs to certify energy-efficient homes, apartments and commercial buildings. The programs provide incentives for installation of energy-efficient heat pumps. Low-interest financing is also available to support residential and commercial energy-efficiency improvements. ■

# Program Overview

Public Service of Oklahoma has been promoting ground source heat pumps through its Good Cents Commercial and Good Cents Apartments programs since 1987. Through these programs, energy-efficient heat pumps are eligible for rebates in new and renovated buildings. These programs do not distinguish between ground source, water source, and air source heat pumps. However, PSO makes a concerted effort to promote ground source systems whenever appropriate.

While ground source heat pumps have been installed in a variety of applications for more than 30 years, recent advances in the technology have opened up the market for increased installations.

Heat pumps have become better recognized as an exciting form of heating and cooling equipment as they tap essentially renewable energy resources. The energy required for heat pumps is used to compress the latent energy in the earth, water, or air. While this latent energy is at a lower temperature than is useful, by compressing these heat sources using a standard refrigeration cycle it is possible to bump up the heat value to useful levels. Note the fundamental difference between heat pumps and conventional furnaces and resistance heating systems is that the latter depend upon continual fuel inputs to provide heat. Heat pumps, on the other hand, only require energy to power compressors which is a fraction of the energy required by conventional systems.

Another distinct and fundamental advantage of heat pumps is that they can be operated in reverse, thus providing air conditioning in the summer and heating in the winter. As such, a single heat pump system can take the place of conventional HVAC systems that often have independent heating and cooling components.

Ground source heat pump systems may save up to 50% of the energy used by conventional systems. Energy savings with ground source heat pump systems may be up to 65% over oil fired heating systems, 50% over gas or electric resistance heating, and 50% over air coupled heat pumps. Peak capacity savings are significant for ground source heat pump systems. Due to the low fluctuation of temperatures in the ground, there is no need for electrical resistance heat backup during the coldest days of the year. Ground source heat pumps can operate at consistent levels, creating a relatively flat load shape. Thus, winter peak loads may be reduced by as much as 66% over conventional systems.[R#9]

Ground source heat pumps work on the same principle as air source heat pumps. Instead of exchanging heat with the air, a loop of water and antifreeze is circulated through the ground. Through the loop, heat is extracted from the ground during the winter, and deposited to the ground in the summer.

Three basic configurations for ground source loops are commonly used. Each system requires that a length of pipe be buried in the ground through which the water and antifreeze mix is circulated. For each ton capacity of the ground source heat pump system, approximately 175 to 200 feet of pipe is typically necessary in Oklahoma. The required length of pipe differs depending upon local soil conditions and thermal characteristics.

The **horizontal loop** configuration requires the largest amount of land area, but installation costs are the least expensive with this type of loop. The required length of pipe is placed in a trench three to six feet deep that loops through the land area. Typical trench lengths are 400 to 600 feet per ton. Multiple pipes may be placed in each

**CHARACTERISTICS OF TYPICAL RESIDENTIAL GROUND SOURCE HEAT PUMP SYSTEM**

| *Loop Configuration* | *Typical Land Space Requirement (sq. ft./ton)* | *Type of Excavation* | *Depth of Excavation (feet)* | *Width / Diameter of Excavation (inches)* | *Loop Length (feet/ton)* | *Typical Loop Cost ($/ton)* |
|---|---|---|---|---|---|---|
| Horizontal | 1,600 | Trench | 3 - 6 | 4 - 34 | 400 - 600 | $350 - $500 |
| Vertical | 160 | Bore hole | 60 - 200 | 3 - 6 | 250 - 450 | $700 - $1000 |

[R#2]

trench, with backfill in between each pipe. By using multiple pipes in each trench, the necessary land area may be reduced by as much as 40%, however this method usually requires about 20% more pipe.

A new type of horizontal loop called the **"Slinky"** has been developed. This configuration requires less land area and shorter trench lengths than a traditional horizontal loop installation. The Slinky system requires a trench about 6 inches wide into which a coiled pipe of the required length is placed and backfilled. About twice the length of pipe is required than for a traditional horizontal loop installation. However, trench lengths of 80 to 125 feet per ton are used, significantly less than a traditional horizontal loop system.

The **vertical loop** is usually more expensive to install than a horizontal loop as this method requires drilling several bore holes about 5 to 6 inches in diameter, into which the ground source pipes are inserted. The typical depth of the bore holes differs depending on the local geology. In most of Oklahoma, depths of 200 to 250 feet may be used. Pipe installation becomes difficult at depths greater than 250 feet. This configuration is attractive as it requires a significantly smaller land area than the horizontal loop installations.

The **alternating ground loop** configuration may be used with either horizontal or vertical loop installations, and with loops of varying sizes. Developed by Geotech of Troy, New York, this system uses multiple independent loops which can be used alone or in combination with each other. As heat is exchanged, the soil temperature surrounding a ground loop may change. When soil temperature changes this configuration allows switching to a new loop where the soil temperature is stable and allowing the heat around the first loop to dissipate or replenish. In this way operation of the ground source heat pump system is stabilized, increasing efficiency and allowing for shorter pipe length requirements.[R#2,7] ■

## MARKETING AND DELIVERY

Installation of ground source heat pumps is marketed through PSO's Good Cents Commercial and Good Cents Apartments programs. These programs offer commercial customers and apartment building owners financial incentives for installing energy-efficient heat pumps. Incentives are the same regardless of whether the heat pump is ground source, air source, or water source. Additionally, customers may receive a lower winter heating season electric rate if they meet several program criteria, including installation of an energy-efficient electric heat pump. Customers who meet all Good Cents criteria also receive higher incentives than those who install heat pumps unaccompanied by other energy-efficiency measures.

The Good Cents Commercial and Good Cents Apartments programs are marketed primarily through direct mail and personal contact. Both trade allies and customers are targeted in the marketing strategy. PSO also conducts seminars and distributes its quarterly newsletter "Power Connections" to professionals in the commercial marketplace throughout the state. Additionally, PSO has put together several "Power Profiles" of successful Good Cents projects, describing the Good Cents elements of each project, along with the names of the engineers, architects, and other contractors involved with the project. Two of the "Power Profiles" discuss projects that have used ground source heat pumps. Finally, advertising in magazines and newspapers is conducted throughout the year.

PSO's 12 commercial sales representatives work directly with interested customers to determine their needs and recommend measures that will qualify the project for the Good Cents Incentive and the Good Cents Price. The sales representatives try to recognize appropriate potential ground source heat pump applications. In this way, customers who have been motivated to install a heat pump are encouraged to consider ground source heat pumps as an alternative to air source or water source heat pumps. In its 1993 Marketing Summary, PSO stated that it hoped to continue emphasizing ground source heat pumps in an effort to increase awareness of their advantages.

**CRITERIA FOR PSO GOOD CENTS NEW COMMERCIAL CERTIFICATION**

**Option 1**

1. Primary heating from electricity
2. Electric heat pump min. 8.2 EER or 9.0 SEER
   or
   Electric A/C min 8.8 EER or 9.0 SEER
3. No simultaneous heating and cooling of the same air in the same space
4. R-19 ceiling insulation
5. Three of the following:
   - R-30 ceiling insulation
   - R-11 wall insulation
   - metal insulated or insulating glass outside doors
   - insulating glass or storm windows
   - tinted or shaded glass
   - glass area not to exceed 10% of total floor area
   - any mechanical ventilation must be controllable
   - interior lighting load must be ballasted or not exceed 2 w/sq. ft.
   - energy management system
   - programmable thermostats on all systems

**Option 2**

1. Same as Option 1
2. Same as Option 1
3. Same as Option 1
4. interior lighting load must be ballasted or not exceed 2 w/sq. ft.
5. any mechanical ventilation must be controllable
6. solar and transmission design heat gain criteria:

| Building Size | Maximum Heat Gain |
|---|---|
| up to 5,000 sq. ft. | 10 BTUH/Sq. ft. |
| 5,001 to 25,000 sq. ft. | 7 BTUH/Sq. ft. |
| larger than 25,000 sq. ft. | 5 BTUH/Sq. ft. |

Although there are many benefits to a ground source heat pump system, there are also some obstacles that may make their installation less desirable or impractical to the

**GOOD CENTS COMMERCIAL HEAT PUMP INCENTIVES**

| *Heat Pump Efficiency Rating* | | *Payment* | |
|---|---|---|---|
| EER | SEER | Certified Good Cents Buildings | All Other Commercial Buildings |
| 8.20 - 8.5 | 9.00 - 9.5 | $75/ton | $50/ton |
| 8.51 - 9.0 | 9.51 - 10.0 | $90/ton | $60/ton |
| 9.01 - 9.5 | 10.01 - 10.5 | $105/ton | $70/ton |
| Above 9.5 | Above 10.5 | $120/ton | $80/ton |

owner. First, the customer must be willing to take a long-term view of the system benefits. Ground source heat pump systems have a high first cost, which, even when offset by PSO's incentive, is typically paid back through low operating costs and energy savings in five to seven years. Second, the building site must be of appropriate size and geology. Horizontal loop systems require a sizeable footprint, (that is, the area of land under which the system is installed), and both horizontal and vertical systems require geological characteristics that are amenable to trenching or drilling.

Once the decision has been made to install a ground source heat pump, the PSO sales representative works closely with the customer to identify contractors and equipment suppliers capable of designing and installing the system. A significant amount of preliminary work must be completed to ensure that the system is properly sized, designed, and installed. Incentives for commercial applications are based on whether the project also includes several other energy-efficiency criteria. If the building is certified as a Good Cents facility, the heat pump incentive is higher and the building qualifies for a discounted winter electric rate. Criteria for Good Cents certification of new commercial buildings are listed in the accompanying table. Existing commercial buildings may receive Good Cents certification if they meet similar criteria. The glazing area percentage maximum under Option 1 is 15% for existing buildings, and the heat gain criteria under Option 2 is 16 BTUH/square foot for buildings up to 5,000 square feet, 12 BTUH/square foot for buildings between 5,001 and 25,000 square feet, and 6 BTUH/square foot for buildings greater than 25,000 square feet.

## MEASURES INSTALLED

Ground source heat pumps of qualifying efficiency are eligible for incentives through PSO's Good Cents Commercial and Good Cents Apartments programs. Incentives are shown in the Heat Pump Incentives tables.

**GOOD CENTS APARTMENTS HEAT PUMP INCENTIVES**

| *Heat Pump Efficiency Rating (SEER)* | *Payment* |
|---|---|
| 10.01 - 11.00 | $110/ton |
| 11.01 - 12.00 | $130/ton |
| Above 12.00 | $150/ton |

## STAFFING REQUIREMENTS

Jim Ezell, Commercial Marketing Manager, is primarily responsible for promoting ground source heat pumps through PSO's Commercial Good Cents and Good Cents for Apartments programs. The commercial incentives program is implemented by 12 commercial sales representatives - six in the Tulsa office and six in PSO's regional offices. ■

# Monitoring and Evaluation

PSO makes use of the extensive monitoring and evaluation efforts conducted at Oklahoma State University in relation to ground source heat pumps. Several studies have been completed and are ongoing at the University, the results of which have been instrumental to PSO in the design, implementation, and evaluation of the impacts of its Ground Source Heat Pump program.

One important project ongoing at Oklahoma State University is a study of the thermal properties of soils that is being conducted in conjunction with the Electric Power Research Institute. The project involves installation of sensors at several sites to collect data on soil temperature, moisture, and thermal resistivity. Researchers are particularly interested in the effects of rainfall on soil moisture and soil profile characteristics. The information that will be generated by this study is vital to the proper sizing and installation of ground coils for ground source heat pumps. The project is a long term study; to develop valid conclusions on average conditions, measurements must be taken over the course of several years. Thus, the project will not be completed for another five to ten years.[R#10]

Other ongoing research involves investigation into multiple pipe trenches. By placing several pipes in one trench, separated by layers of soil, the ground loop may take less space while still retaining the same heat transfer characteristics. The "Slinky" loop is essentially a variation on the multiple pipe concept.

Researchers are also studying the applicability and savings associated with advanced heat pumps. These heat pumps typically have a single speed scroll compressor, a variable speed blower, and a water desuperheater. The desuperheater exchanges heat from a refrigerant gas with water in a hot water tank. While supplying hot water needs, the desuperheater also increases the cooling season efficiency of the system, as less heat must be transferred to the ground. Two studies of advanced heat pumps are currently ongoing in Indiana and Pennsylvania.[R#2]

Oklahoma State University is also conducting an independent study of a new antifreeze solution developed by Chevron. This substance appears to be non-toxic, non-corrosive, bio-degradable, and has good mechanical properties. The Oklahoma State University study focuses on the corrosive characteristics of the material. The metal parts of the heat pumps used in the ground source heat pump systems are particularly vulnerable to corrosion; there is less concern about corrosive action on the ground loop pipes.[R#11] If all of the properties of this material are found to be irrefutable, then its introduction could expand the applicability of ground source heat pumps to areas where there are concerns about environmental safety posed by circulating a foreign substance through the ground.

Another ongoing study is being conducted in severely cold climates in Minnesota where temperatures drop to -40°F. Ground temperatures may be as much as 15°F colder in such areas than they are in Oklahoma. Researchers are trying to determine the efficiency and savings of ground source heat pump systems in such applications.[R#11]

Finally, the Environmental Protection Agency (EPA) recently completed a report that included a location-by-location comparison of space conditioning equipment in residential applications. The study compares costs, savings, and environmental benefits of various space conditioning options in six representative cities in the United States. The study presents the results of several scenarios whereby ground source heat pump systems, advanced air source heat pump systems, and efficient gas and oil fired systems replace electric resistance heat, standard air source heat pumps, standard gas furnaces, and standard oil furnaces. Emerging ground source heat pump systems, with two-speed scroll compressors and fully integrated demand water heat, were consistently better than any other option for source heating efficiency, and source cooling efficiency. Ground source heat pumps had the lowest annual operating costs. For source water heating efficiency, ground source heat pumps were less efficient than advanced gas fired heat pump systems and, in some cases, less efficient than advanced air source heat pumps. The results of this study are discussed further in the Program Savings, Cost of the Program, and Environmental Benefits sections.[R#2] ■

## CASE STUDY: DAILY FAMILY YMCA

In 1987, a 92-ton GSHP system was installed in the new 34,000 square foot Daily Family YMCA in Bixby, Oklahoma. The new system uses a horizontal loop of 32,000 feet of polyethylene pipe located under the parking lot where soil temperatures range between 60°F and 62°F.

The system allows independent control of fourteen separate zones throughout the building. Sixteen small indoor heat exchange units are unobtrusively located within the building. Fifteen of the units have Energy Efficiency Ratios (EERs) in the range of 11.0 to 11.2; the unit in the pool area has a lower EER of 9.0. As with most GSHP systems, the system is more aesthetically pleasing and is expected to be cleaner and longer lasting than a system with equipment located outdoors.

The Daily Family YMCA project qualified for a $10,000 incentive payment. The building is expected to save up to $100,000 in energy costs over a ten-year period. In the first ten months of operation, the Daily Family YMCA monthly electric bills were approximately $2,000 less than the average monthly electric bills for other similarly-sized YMCAs in the U.S. After 11 months of operation, Dale Isgrigg, Daily Family director stated, “We’re exceptionally pleased with this system.”[R#8,10]

### CASE STUDY: GREEN COUNTRY FEDERAL SAVINGS & LOAN

When the Green Country Federal Savings & Loan decided to build a new, larger building in 1987, the architect/engineer and contractor considered two types of systems for the new building's HVAC system. Based on lower operating costs and the incentive provided by PSO, bank Vice President Bob Wallace chose the ground source heat pump system even though the upfront costs would be much higher than the conventional alternative.

The new 4,000 square foot building required 11 tons of cooling capacity. The ground source heat pump system installed was a closed loop vertical shaft system with four indoor heat pumps. The SEER of the indoor units ranges from 9.1 to 11.

The ground source heat pump system, combined with the other energy efficiency measures installed in the new building, resulted in energy-cost savings of 60% over the bank's costs at its older building. Wallace was very pleased with the new system, especially the fact that no outside compressors and no boiler room was necessary. "We've been very satisfied. We'd recommend it to anybody," said Wallace of the new system.[R#8]

Savings for ground source heat pump systems vary depending on the equipment used, the climate in which the system is operating, and the type of equipment that the system is replacing. The 1993 EPA report on advanced space conditioning technologies includes a summary of energy and capacity savings that are likely to be realized by typical residential systems in six representative U.S. cities. These savings are shown in the two tables on page 11. The study assumed an average home that would require a 3 ton system in a temperate climate. Thus, the analysis assumed a 3 ton system in Chicago and New York, a 3.5 ton system in Burlington (Vermont), and a 2.5 ton system in Phoenix, Portland, and Atlanta.[R#2]

For emerging ground source heat pump systems (with high efficiency, two-scroll compressors, and fully integrated demand water heat) replacing standard electric resistance heating/AC systems, energy savings range from 8,856 kWh per system to 20,827 kWh per system, winter demand savings range from 5.6 kW to 9.7 kW per system, and summer demand savings range from 4.6 kW to 5.4 kW per system. Energy savings are smaller for systems replacing standard air source heat pump systems, and negative energy and winter demand savings result from conversions from gas and oil furnace/AC systems. Demand savings for systems replacing standard air source heat pump systems are 4.9 kW to 9.5 kW per system in the winter and 4.6 kW to 5.8 kW per system in the summer. Summer demand savings of 0.1 kW to 1.3 kW per system may be realized when converting from standard gas furnace/AC systems, and 4.6 kW to 5.4 kW summer demand savings may result when converting from standard oil furnace/AC systems.[R#2]

## PARTICIPATION RATES

Since PSO began offering incentives for ground source heat pumps in 1987, eight systems have been installed or are under construction in the utility's service territory. The systems installed have ranged in size, from 7 tons of capacity for a medical clinic, to 625 tons for a 415 unit apartment building.

Of the eight systems, six have been vertical shaft systems, and two have been horizontal loop systems. Of the horizontal loop systems, one 126 ton Slinky system is being installed at a new school.

## FREE RIDERSHIP

Free ridership is not yet an issue for the ground source heat pumps component of PSO's Good Cents programs. Because ground source heat pumps are an emerging technology, PSO is focusing on introducing the technology and its appropriate applications to customers. Due to the high initial cost and the unfamiliarity of the equipment, customers might want to choose a ground source heat pump system, but do not due to the barriers to the technology's installation. The incentives from PSO serve to overcome the barrier of high first cost that often precludes installation of a ground source heat pump system.

## MEASURE LIFETIME

Ground source heat pump systems typically have a longer life and require less maintenance than conventional HVAC systems. The loop installation technology has evolved to the point where, if properly installed, the ground loops require virtually no maintenance. Unlike conventional systems, the heat pump and system components can usually be located in a single cabinet indoors, thus protecting the equipment from outside temperature fluctuations, and extending its life. Typical lifetimes for a ground source heat pump system may be 30 years. ■

### ENERGY SAVINGS (kWh) FOR TYPICAL EMERGING GSHP SYSTEM (RESIDENTIAL INSTALLATION) IN DIFFERENT CITIES

| *City* | *Conversion from:* | | | |
|---|---|---|---|---|
| | *Standard electric resistance heating/AC* | *Standard air source heat pump* | *Standard gas furnace/AC* | *Standard oil furnace/AC* |
| Burlington | 20,827 | 11,973 | (6,175) | (2,975) |
| Chicago | 16,651 | 8,607 | (4,945) | N/A |
| New York | 16,157 | 8,050 | (4,722) | (1,270) |
| Portland | 11,941 | 5,620 | (3,278) | N/A |
| Atlanta | 9,991 | 5,362 | (1,184) | N/A |
| Phoenix | 8,856 | 6,551 | 1,870 | N/A |

[R#2]

### CAPACITY SAVINGS (kW) FOR TYPICAL EMERGING GSHP SYSTEM (RESIDENTIAL INSTALLATION) IN DIFFERENT CITIES

| *City* | *Conversion from:* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *Standard electric resistance heating/AC* | | *Standard air source heat pump* | | *Standard gas furnace/AC* | | *Standard oil furnace/AC* | |
| | *Winter* | *Summer* | *Winter* | *Summer* | *Winter* | *Summer* | *Winter* | *Summer* |
| Burlington | 6.0 | 4.6 | 6.0 | 4.6 | (11.4) | 0.1 | (6.9) | 4.6 |
| Chicago | 5.6 | 4.8 | 5.6 | 5.0 | (9.7) | 0.3 | N/A | N/A |
| New York | 5.7 | 5.4 | 5.7 | 5.3 | (9.7) | 0.9 | (5.2) | 5.4 |
| Portland | 8.8 | 5.1 | 7.7 | 5.1 | (1.9) | 0.6 | N/A | N/A |
| Atlanta | 9.7 | 5.1 | 9.5 | 5.4 | (1.6) | 0.6 | N/A | N/A |
| Phoenix | 7.5 | 5.1 | 4.9 | 5.8 | (1.7) | 1.3 | N/A | N/A |

[R#2]

### PSO GROUND SOURCE HEAT PUMP PROJECTS

| *Facility Type* | *System Type* | *Size* | *Year Completed* |
|---|---|---|---|
| Financial Facility (new) | Vertical Shaft Heat Sink | 11 tons | 1987 |
| Bixby Y (new) | Horizontal Heat Sink | 92 tons | 1987 |
| Medical Clinic (new) | Vertical Shaft Heat Sink | 7 tons | 1991 |
| Dentist Office (new) | Vertical Shaft Heat Sink | 10 tons | 1992 |
| Creek Nation Tribal (new) | Vertical Shaft Heat Sink | 28 tons | 1993 |
| Ketchum School (new) | SLINKY Heat Sink | 126 tons | under construction |
| Union School (new) | Vertical Shaft Heat Sink | 425 tons | under construction |
| 415 Unit Apartment Building (remodel) | Vertical Shaft | 625 tons | under construction |

# Cost of the Program

**RESIDENTIAL GROUND SOURCE HEAT PUMP SYSTEM TYPICAL COSTS**

| *System Type* | *Capacity* | *Cooling EER at 70°F* | *COP at 50°F* | *1993 Cost Range for System* |
|---|---|---|---|---|
| Standard Ground Source Heat Pump | 3 ton | 10.9 | 3.1 | $5,699 - $8,200 |
| Advanced Ground Source Heat Pump ARI 325 | 3 ton | 13.7 | 3.7 | $6,370 - $8,615 |

[R#2]

The cost to install a ground source heat pump system may vary depending upon the climate, geology, and availability of materials and experienced contractors. Loop installation costs represent a large portion of the total system costs.

Installation of horizontal loops typically cost $350 to $500 per ton of heat pump capacity. The lower cost is for Slinky installations, which require smaller trenches than typical horizontal loop systems. Trench excavation is a significant component of the loop installation cost, so even though Slinky loops require longer lengths of pipe than a conventional horizontal loop, the overall loop installation cost is lower.

Vertical loops are typically more expensive to install than horizontal loops. The equipment necessary to drill bore holes is more expensive to purchase and operate than that needed to excavate trenches. Typical loop costs for vertical systems are in the range of $700 to $1,000 per ton. Costs vary depending upon local geology, driller experience, and economies of scale.

Total system installation costs differ depending upon the type of ground source heat pump system. Standard 3-ton systems may cost between $5,699 and $8,200 in 1993. Advanced 3-ton systems, with improved efficiency over the standard system, may cost between $6,370 and $8,615.[R#2]

## COST EFFECTIVENESS

The 1993 EPA report included an extensive analysis of the benefits and costs of ground source heat pump systems in residential applications. The Total Resource Cost (TRC) test was performed for different ground source heat pump systems replacing several different standard space conditioning options. In performing the test, it was as-

| **Total Resource Cost Test Results for Different Cities** | *Replace electric resistant heating/AC system with:* | | | *Replace standard air source heat pump with:* | | |
|---|---|---|---|---|---|---|
| | *Emerging Ground Source Heat Pump (Slinky)* | *Emerging Ground Source Heat Pump (Vertical)* | *Advanced Ground Source Heat Pump* | *Emerging Ground Source Heat Pump (Slinky)* | *Emerging Ground Source Heat Pump (Vertical)* | *Advanced Ground Source Heat Pump* |
| Burlington | 3.17 | 2.48 | 2.34 | 3.80 | 2.58 | 2.37 |
| Chicago | 3.30 | 2.66 | 2.51 | 4.55 | 3.08 | 2.88 |
| New York | 2.59 | 2.13 | 2.02 | 3.41 | 2.43 | 2.27 |
| Portland | 3.22 | 2.54 | 2.40 | 3.57 | 2.53 | 2.34 |
| Atlanta | 2.20 | 1.70 | 1.62 | 2.94 | 2.02 | 1.91 |
| Phoenix | 2.99 | 2.17 | 2.03 | 4.21 | 2.67 | 2.49 |

[R#2]

sumed that utilities would pay the full incremental cost of the ground source heat pump system as an incentive, and that administrative costs were $150 per system. In the study, emerging (with high efficiency, two-scroll compressors, and fully integrated demand water heat) ground source heat pumps with Slinky loops were found to have the highest TRC benefit-cost ratio in several instances. When converting from electric resistance heating/AC or standard air source heat pump systems, Slinky ground source heat pump systems had the highest B/C ratio in Burlington, Chicago, New York, and Portland. (Advanced air source heat pumps at costs lower than present cost scored higher ratios in Atlanta and Phoenix.)[R#2]

The results of the TRC test for conversions from electric resistance heating/AC and standard air source heat pump systems are shown for six different cities in the accompanying table. Conversions to emerging ground source heat pump systems (both Slinky and vertical) and to advanced ground source heat pump systems result in benefit-cost ratios over 2.0 in all but three scenarios. In all cases shown, the Slinky loop with an emerging ground source heat pump system scored the best on the TRC test.[R#2] ■

**AMOUNT OF REDUCED EMISSIONS (IN KILOGRAMS/YEAR) FOR A TYPICAL RESIDENTIAL SYSTEM**

| *Region (emissions reductions are based on typical regional fuel mixes)* | *Slinky or Vertical GSHP* | *Advanced GSHP* | *Advanced ASHP* | *Adv. Gas Furnace + High Eff. AC* | *Gas-Fired Air-to-Air Heat Pump* |
|---|---|---|---|---|---|
| **Conversion from electric resistance heating/AC** | | | | | |
| | | | CO2 reductions | | |
| New England | 6,614 | 6,056 | 4,620 | 2,731 | 3,183 |
| Mid-West | 13,245 | 11,976 | 10,397 | 13,431 | 13,211 |
| Northwest | 1,341 | 1,172 | 1,163 | (1,739) | (1,092) |
| | | | NOx reductions | | |
| New England | 16.70 | 15.29 | 11.67 | 16.74 | 7.01 |
| Mid-West | 41.01 | 37.08 | 32.20 | 48.90 | 42.66 |
| Northwest | 6.51 | 5.69 | 5.65 | 5.36 | 0.84 |
| | | | SO2 reductions | | |
| New England | 66.81 | 61.17 | 46.66 | 87.58 | 88.32 |
| Mid-West | 61.52 | 55.63 | 48.29 | 79.36 | 82.27 |
| Northwest | 0 | 0 | 0 | (0.07) | (0.06) |
| **Conversion from standard air source heat pump** | | | | | |
| | | | CO2 reductions | | |
| New England | 3,802 | 3,244 | 1,807 | (82) | 370 |
| Mid-West | 6,944 | 5,675 | 4,097 | 6,131 | 6,910 |
| Northwest | 631 | 462 | 453 | (2,449) | (1,802) |
| | | | NOx reductions | | |
| New England | 9.60 | 8.19 | 4.56 | 9.64 | (0.09) |
| Mid-West | 21.50 | 17.57 | 12.69 | 29.39 | 23.15 |
| Northwest | 3.06 | 2.24 | 2.20 | 1.91 | (2.61) |
| | | | SO2 reductions | | |
| New England | 38.41 | 32.77 | 18.26 | 59.17 | 59.91 |
| Mid-West | 32.25 | 26.36 | 19.03 | 50.10 | 53.01 |
| Northwest | 0 | 0 | 0 | (0.07) | (0.06) |
| **Conversion from standard gas furnace/AC** | | | | | |
| | | | CO2 reductions | | |
| New England | 5,558 | 5,000 | 3,564 | 1,674 | 2,126 |
| Mid-West | 2,202 | 933 | (645) | 1,388 | 2,168 |
| Northwest | 3,948 | 3,779 | 3,770 | 868 | 1,515 |
| | | | NOx reductions | | |
| New England | 1.60 | 0.19 | (3.44) | 1.63 | (8.10) |
| Mid-West | (6.10) | (10.03) | (14.92) | 1.78 | (4.46) |
| Northwest | 1.97 | 1.15 | 1.11 | 0.82 | (3.70) |
| | | | SO2 reductions | | |
| New England | (19.67) | (25.31) | (39.82) | 1.10 | 1.84 |
| Mid-West | (16.63) | (22.52) | (29.85) | 1.22 | 4.13 |
| Northwest | 0.08 | 0.08 | 0.08 | 0.02 | 0.03 |

[R#2]

The 1993 EPA study of space conditioning options investigated the environmental impacts of ground source heat pump systems and other advanced and standard space conditioning options. (The study has already been referred to quite extensively in the Monitoring and Evaluation, Program Savings, and Cost of the Program sections of this profile.) The study looked at reductions in carbon dioxide, nitrogen oxide, and sulfur dioxide emissions when equipment was replacing electric resistance heating/ AC systems, standard air source heat pump systems, standard gas furnace/AC systems, and standard oil furnaces. The results of the comparison for electric resistance, standard air source heat pumps, and standard gas furnace/AC systems for three of the regions are summarized in the accompanying table.

(Comparisons using standard oil furnace/AC systems as the baseline were only done in two regions. Conversions from oil to electric or gas technologies result in increases in carbon dioxide and nitrogen oxide emissions, with ground source heat pumps typically having the lowest increase in these emissions. Conversions to gas technologies from standard oil furnace/AC systems result in reductions in sulfur dioxide emissions, while conversions to electric technologies, including ground source and air source heat pumps, result in increased sulfur dioxide emissions.)

In determining emissions reductions for each of the six regions, different regional fuel mixes were assumed. Thus in the Northwest which is dominated by hydropower and where sulfur dioxide emitting fuels are not typically used, there is essentially no reduction in sulfur dioxide emissions. Small reductions in carbon dioxide and nitrogen oxide emissions are also evident in the hydropower-dominated Northwest. Conversely, the carbon dioxide and nitrogen oxide emissions reductions in the Midwest were found to be quite high, as this region is typified by a high use of coal. Of course, emissions are not solely dependent on fuel type and will vary depending upon the type of power plant, emissions controls, and other factors.

When comparing advanced electric space heating technologies, ground source heat pump systems consistently result in emissions reductions that exceed reductions by advanced air source heat pump systems. Furthermore, the emerging ground source heat pump systems result in greater emissions reductions than advanced ground source heat pump systems.

In some cases when the base system is not electric, conversion to an advanced gas space conditioning system may result in better emissions reductions than conversions to a ground source heat pump system. Nonetheless, conversion from any standard electric system to a ground source heat pump system is likely to result in significant improvements in emissions.[R#2] ■

## LESSONS LEARNED

The Ground Source Heat Pump component of PSO's Good Cents Commercial and Good Cents Apartments programs has resulted in a steadily increasing interest in the technology throughout PSO's service territory. The number of projects completed or underway during 1993 will double the number of ground source heat pump installations attributed to the program since 1987. As more installations are completed and more contractors become available to install the equipment, costs have gone down and ground source heat pumps have become more prevalent. By promoting the technology through the Good Cents programs, PSO has successfully supported the acceptance of ground source heat pumps as a viable option for heating and cooling.

In 1993, PSO expects to complete a baseline study of the Good Cents program in an effort to ensure that PSO's DSM program is encouraging energy efficiency that exceeds industry standards. PSO has made a commitment to offer incentives that effectively encourage installation of state-of-the-art energy efficient equipment. In its 1993 filing with the Oklahoma Corporation Commission, PSO will seek to increase the amount of the incentives it offers for ground source heat pumps. This change, if approved, is expected to increase the number of ground source heat pump installations within PSO's service territory.

Many lessons have been learned about ground source heat pump systems in the past several years. The development of new installation techniques, such as the Slinky, have expanded the applicability of ground source heat pump systems. Now, buildings with smaller lot sizes can install a ground source heat pump system without having to drill deep shafts. The Slinky technology also significantly reduces the installation expense, as the pipe is installed in a trench, which is much less expensive than a vertical system. While the Slinky was originally designed to apply to residential systems, PSO is exploring the opportunities to apply the technology in commercial applications. In fact, the one Slinky installation supported by PSO in 1993 was a rather large, 126-ton system at a school.

Another alternative to trenching has been developed that will allow installation of ground loops under existing structures. The technology uses a boring rig that feeds sections of boring bits into the earth at an angle. The first bit has a radio transmitter which allows control of angle, depth, and direction of the bore hole. The ground loop pipe is attached to the bit after it emerges from the ground, and as the bit is withdrawn through the bore hole, the pipe is installed in the hole.[R#2]

Recent improvements in the ground loop antifreezes have also enhanced the safety and performance of ground source heat pump systems. Chevron Chemical Corporation has developed a compound which it claims to be less toxic than table salt, non-flammable, biodegradable and efficient.[R#2] Most ground loop installations are done with a 50-year warranty, and there are few concerns about the integrity of the ground loop pipes. Nonetheless, the development of this new antifreeze provides reassurance that if a problem did occur, damage to the environment would be limited.

## TRANSFERABILITY

The State of Oklahoma has been a focal point for research and promotion of ground source heat pump technology. Much of the ongoing research is conducted at Oklahoma State University, and many of the largest manufacturers of ground source heat pump systems — including loops and other equipment — are located in Oklahoma.

Nonetheless, ground source heat pump technology is applicable in most regions. However, the specifics of design and installation will differ depending on local climate and geology. Many other utilities include incentives for ground source heat pumps in their commercial, industrial, and residential financial incentives programs. Some utilities have pilot or system-wide programs aimed specifically at installation of ground source heat pumps. TU Electric, for example, is building in ground source heat pumps for an entire new subdivision in its service territory, an experiment that will likely result in dramatically reduced unit costs for loop trenching or drilling. ■

Traditional utility ratemaking, where each and every kilowatt-hour sold provides profit, is a major barrier to utilities' implementation of energy efficiency programs. Several state regulatory commissions and their investor-owned utilities have been pioneers in reforming ratemaking to: a) remove the disincentives in utility investment in DSM programs, and b) to provide direct and pronounced incentives so that every marginal dollar spent on DSM provides a more attractive return than the same dollar spent on supply-side resources.

The purpose of this section is to briefly present exciting and innovative incentive ratemaking mechanisms where they're applied. This we trust, will not only provide some understanding to the reader of the context within which the DSM program profiled herein is implemented, but the series of these sections will provide useful snapshots of incentive mechanisms being used and tested across the United States.

To date the Oklahoma Corporation Commission (OCC) has not taken action to remove the regulatory barriers to DSM nor has it put in place financial incentives for DSM. There is also no formal IRP process in place in Oklahoma and utility ten-year capital plans are not required to explicitly consider either DSM or least-cost options.[R#5,6]

In September of 1992, however, the Public Utility Division of the OCC requested Commission authorization to establish an IRP process in the state. The PUD is requesting voluntary financial contributions from the state's utilities to cover the cost of retaining a consultant so it can proceed with the state's least cost integrated resource planning docket, but no action has occurred. In short, integrated resource planning in Oklahoma is at a standstill.[R#5,6]

DSM costs are not expensed annually nor ratebased in Oklahoma. Instead, with one exception, DSM program expenditures are recovered at the time of the general rate case, with rate cases taking place every five years. To date, this has not been much of an issue as DSM expenditures have been very low in the state. Some audit programs which were fairly inexpensive were put in the ratebase in the past and in 1988 the Commission granted PSO permission to capitalize and amortize over a ten-year period the costs of its Good Cents efficiency programs for new construction. This was the first significant DSM expenditure that was allowed into a utility's ratebase in the state.

One of the interesting debates occurring at the Oklahoma Corporation Commission currently is whether the costs of the heat pump program ought to be allowed to be recovered. While heat pumps qualify for rebates under the Good Cents program and have inherently high efficiencies when compared to even natural gas heating and cooling systems, they are load building nevertheless. While they are load building in character, they represent a tremendous opportunity for the efficient use of primary energy units, or BTUs. The Commission may elect to rule on this and establish a policy for recovery for heat pump program costs in early 1994.[R#6]

In November 1992, Public Service Company of Oklahoma filed a rate increase request in which it proposed that DSM program costs be deferred and recovered in the next appropriate proceeding. This filing calls for a rate increase that covers DSM expenditures including heat pump program costs. PSO wants to be assured of complete recovery as it plans to spend $5 million on DSM over the next five years, a significant increase over past expenditures and the largest investment in DSM of any utility in the state. The Commission's staff has rejected this proposal, suggesting that all DSM costs should be explicit and paid up-front. A ruling is expected to be passed in early 1994 when the Commission addresses the PSO general rate case filing.

Currently, PSO and the state's other utilities are not eligible to recover lost revenues associated with DSM programs nor shareholder incentives of any kind. ■

# References


1. Public Service Company of Oklahoma, "1992 Annual Report."

2. Environmental Protection Agency, "Space Conditioning: The Next Frontier," EPA 430-R-93-004, April 1993.

3. Public Service Company of Oklahoma, "Marketing Summary 1993."

4. Public Service Company of Oklahoma, "Good Cents Commercial Programs," promotional brochure.

5. National Association of Regulatory Utility Commissioners, "Incentives for Demand-Side Management," Committee on Energy Conservation, 2nd edition prepared by Barakat & Chamberlin, Inc., March 1993.

6. Ken Zimmerman, Economic Policy Analyst, Oklahoma Corporation Commission, personal communication, June 1993.

7. Jim Ezell, Commercial Marketing Manager, personal communication, May-July 1993.

8. Public Service Company of Oklahoma, "Good Cents Power Profiles," Number 1 & Number 9.

9. Earth Energy Association, "Geothermal Heat Pumps – A Viable Alternative!" October 16, 1991.

10. Electric Power Research Institute, "Heat Pump News Exchange," Vol. 2 No. 4, Winter 1990 -91 and Vol. 3 No. 3, Fall 1991.

11. Dr. Jim Bose, Professor of Engineering Technology, Oklahoma State University, personal communication, June 1993.



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