# MEASURING THE COSTS AND BENEFITS OF NATIONWIDE GEOTHERMAL HEAT PUMP DEPLOYMENT – A PROGRESS REPORT

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## ABSTRACT

The use of geothermal heat pump systems (GHPs) in the United States is marginal, despite their high efficiency and minimal greenhouse gas emissions. To evaluate the consequences of broader deployment of GHPs we are conducting a national cost-benefit analysis for 30 metropolitan regions. The three-year effort is known as the GHPsRUS Project ("Geothermal Heat Pumps are U.S."). In previous papers, we reported on the project's basic approach and progress in acquiring geological data needed to quantitatively model GHP design specifications and cost. In this paper, we report on the progress of the GHPsRUS Project.

## INTRODUCTION

Geothermal heat pumps (GHPs) deliver reliable, cost effective, and energy efficient heating and cooling. Among the most efficient heating and cooling technologies available, GHPs use the relatively constant temperature of the earth to heat and cool buildings. GHPs may also provide domestic hot water (DHW). GHPs are an important energy conservation technology; they use significantly less energy than conventional heating or cooling systems; about 70% of the total energy used in a GHP system is renewable from the ground (GeoExchange, Undated).

According to the U.S. Environmental Protection Agency (EPA), GHPs can reduce energy consumption—and corresponding greenhouse gas (GHG) emissions—by up to 44% compared to air-source heat pumps and by up to 72% compared to electric resistance heating with standard air-conditioning equipment (USDOE, Undated).

A 2008 Oak Ridge National Laboratory (ORNL) study (Hughes, 2008) which examined the barriers to increased GHP use in the United States found that, although the U.S. was once the world leader in GHP technology and market development, Europe now installs two to three times more GHPs than the U.S., and the GHP market is growing faster in Europe, China, South Korea, and Canada than in the United States. While the U.S. has the greatest number of GHP units installed on a per capita basis, it has fallen behind many European countries.

The total market for GHPs in the United States in 2008, including equipment and installation cost (not reduced by government or other incentives) is estimated at $3.7 billion. The GHP market is expected to triple in value by 2013 (Priority Metrics Group, 2009). In 2009, shipments of GHPs dropped nearly 5% to 115,442 units—the first decrease in GHP shipments since 2003 (USEIA, 2009). Shipments increased, however, in 2010.

Figures 1 and 2 show GHP shipments by number of units and rated capacity in tons (one ton = 12,000 Btu/hr) from 1994, when the Energy Information Administration (EIA) first began surveying the industry, through 2010. No survey was conducted in 2001. Funding for EIA's annual data collection and report on GHPs was terminated in the Fiscal Year 2011 budget. Data for 2010 came from the *GHPsRUS Project Manufacturer & OEM Survey.*

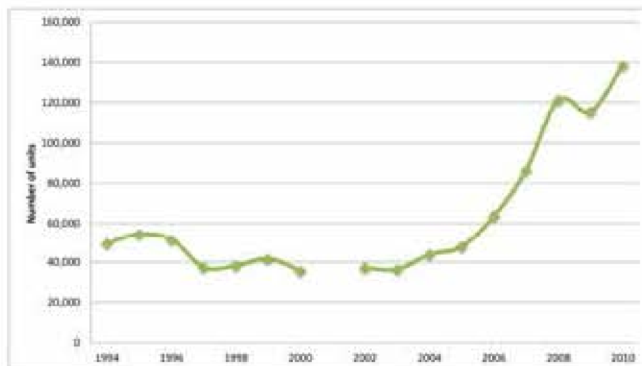



*Figure 1. Geothermal heat pump shipments (number of units), 1994-2010.*

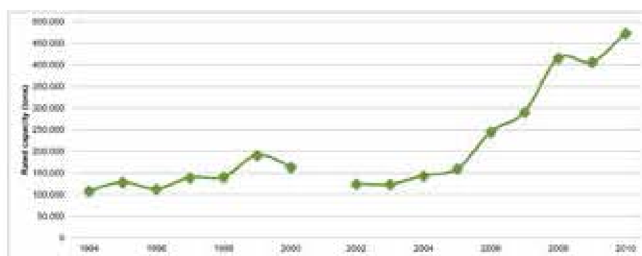


*Figure 2. Geothermal heat pump shipments (rated capacity in tons), 1994-2010.*

Figure 3 shows the value of shipments of GHPs in relation to all heating, ventilating, and air conditioning (HVAC) equipment from 2005 through 2010 (US Census Bureau, 2011). Figure 4 shows GHPs as a percentage of all air-conditioning and warm air heating equipment shipments from 2005 through 2010. The U.S. Census Bureau withheld the value of GHP shipments in 2009 and 2010 "to avoid disclosing data of individual companies." GHP data for 2009 came from the EIA; 2010 data came from the *GHPsRUS Project Manufacturer & OEM Survey.*

While the technology has been in use since the late 1940s, GHPs currently account for about 2% of the total U.S. heating and cooling market. In 2010, in terms of value of equipment shipments, GHPs made up $372 million or 2.3% of the $16-billion U.S. HVAC market. In comparison, $2.1 billion of air-source heat pumps, or 13.5% of all HVAC equipment, was shipped in 2010.

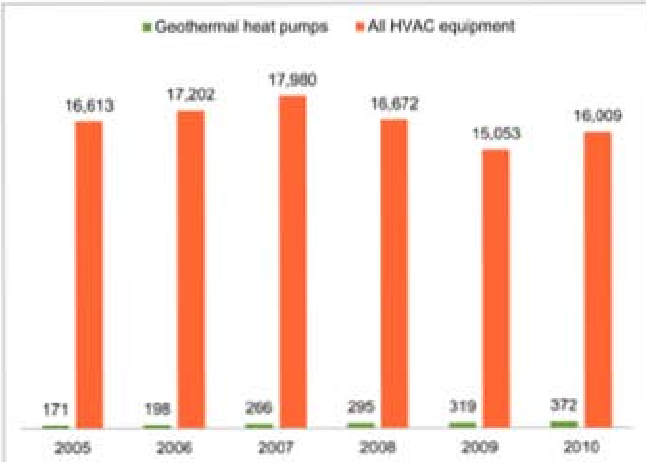



*Figure 3. Value of shipments of air-conditioning and warm air heating equipment, 2005-2010 (millions of dollars).*

But, what if the numbers were higher? How would a nationwide deployment of GHPs benefit the country economically, environmentally, and socially?

With support from the U.S. Department of Energy through the American Recovery and Reinvestment Act of 2009, Bob Lawrence & Associates, Inc. (BL&A) and the California Geothermal Energy Collaborative (CGEC) are in the final year of a three-year study to help determine the answers to these questions. The three-year effort is known as the GHPsRUS Project ("Geothermal Heat Pumps are U.S.") (http://ghpsrus.com). The GHPsRUS Project is composed of two main components: (1) Market Analysis and (2) Regional Modeling Analysis.

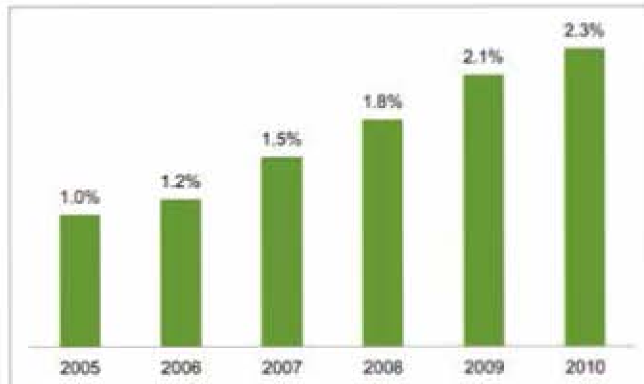



*Figure 4. Geothermal heat pumps as a percentage of all air-conditioning and warm air heating equipment shipments, 2005-2010.*

In previous papers, we reported on the project's basic approach (Battocletti and Glassley, 2010) and progress in acquiring geological data necessary to quantitatively model GHP design specifications and cost (Glassley and Battocletti, 2011). In this paper, we report on the progress of the GHPsRUS Project. This paper presents results collected and analyzed through April 2012.

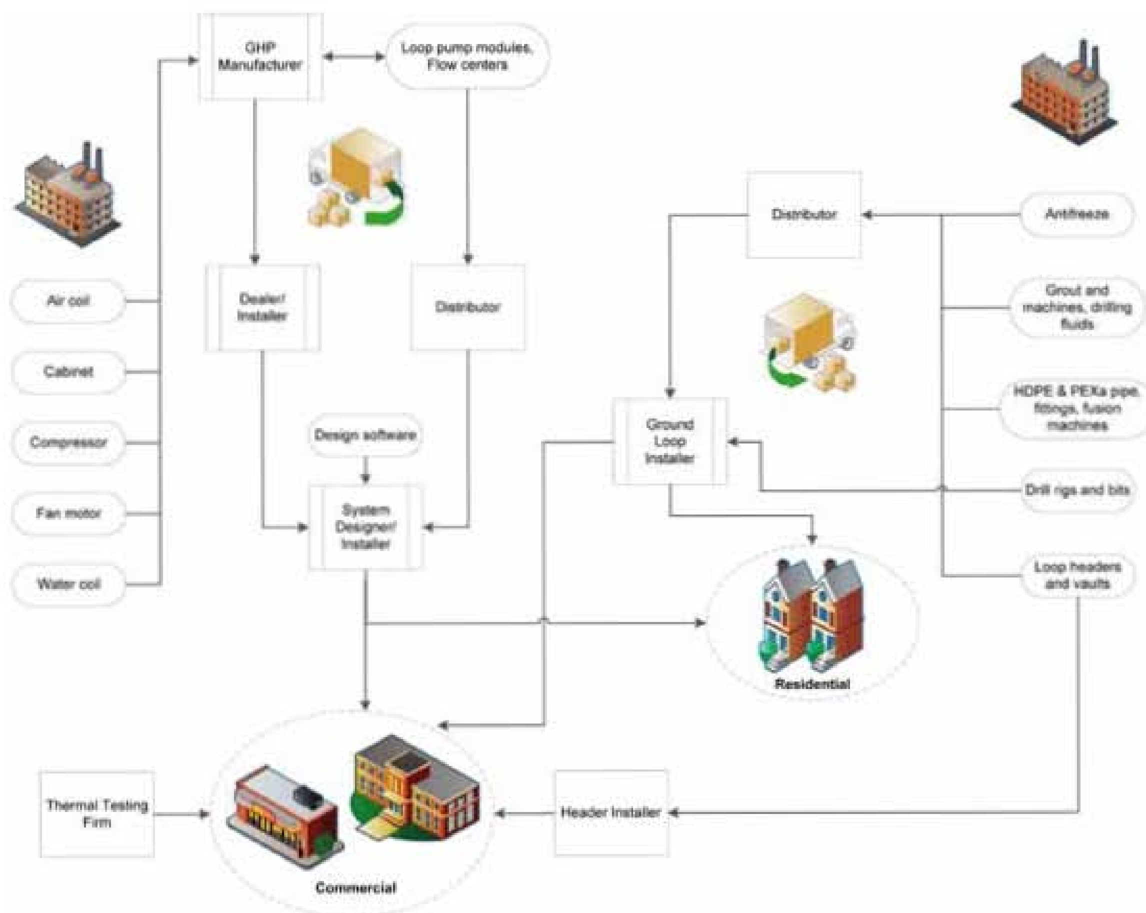



*Figure 5. Major components of the U.S. geothermal heat pump industry*

## MARKET ANALYSIS

The purpose of the market analysis is to measure the current state of the GHP industry in order to establish a baseline for forecasting the benefits which would result from varying degrees of market penetration. Previous market analyses have generally focused on GHP manufacturers only. This analysis attempts to quantify the entire GHP industry—from manufacturing to design to installation (Figure 5).

We divided the GHP industry into four segments:

1. Manufacturers, Original Equipment Manufacturers (OEMs), and suppliers;
2. Geothermal loop installers;
3. Mechanical equipment installers; and
4. Other

The GHPsRUS Project created and widely disseminated four surveys to collect economic data from the four segments of the U.S. GHP industry. To maximize industry buy-in, increase credibility, and ensure that the data collected was as relevant as possible, each survey was carefully designed in close collaboration with GHP industry members. To encourage participation, respondents were assured that all information provided would be kept completely confidential and used only in the aggregate.

Survey Monkey (https://www.surveymonkey.com) was selected to create and publish the surveys and collect and analyze data. Survey Monkey was chosen for its ability to create and disseminate online and PDF surveys which are easy to complete, as well as for its data collection and analysis tools.

As of April 2012, 232 companies accounting for 6,458 direct full-time and 744 part-time jobs responded to one of the four economic surveys (Table 1). Indirect jobs are not included here but will be in the final analysis.

**Table 1. Direct Jobs provided by Respondents to the GHPsRUS Project Economic Surveys (April 2012).**

| Company Type | Number of Companies | Full-Time Jobs | Part-Time Jobs |
|---|---|---|---|
| Builder/Developer | 2 | 3 | 0 |
| Dealer | 1 | 15 | 0 |
| Distributor | 22 | 1,959 | 234 |
| Driller | 94 | 736 | 168 |
| Engineer | 7 | 82 | 30 |
| Geothermal system designer | 4 | 12 | 4 |
| GHP manufacturer/OEM | 24 | 2,594 | 127 |
| Government official (local, state, federal) | 3 | 37 | 0 |
| HVAC company | 2 | 503 | 0 |
| Manufacturer, other | 2 | 10 | 2 |
| Mechanical equipment installer | 52 | 274 | 50 |
| Other | 7 | 5 | 16 |
| Professional, other | 1 | 2 | 2 |
| Supplier | 4 | 165 | 12 |
| Supplier, pump | 1 | 50 | 50 |
| Trade association | 1 | 0 | 2 |
| Utility | 5 | 11 | 47 |
| **Totals** | **232** | **6,458** | **744** |

Responses were received from Canada and 40 states: Alabama, Arkansas, California, Colorado, Connecticut, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New York, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Vermont, Washington State, and Wisconsin (Figure 6).

*Figure 6. Locations of companies that responded to a GHPsRUS Project economic survey (in orange).*

Geothermal heat pump industry jobs by state are shown in Table 2. The five states with the most GHP-related jobs are Indiana, Oklahoma, Georgia, Minnesota, and Florida. WaterFurnace International is based in Fort Wayne, Indiana; ClimateMaster, Inc. in Oklahoma City, Oklahoma; and FHP – Bosch Group in Fort Lauderdale, Florida.

**Table 2. Geothermal Heat Pump Industry Jobs by State.**

| State | Full-time jobs | Part-time jobs | State | Full-time jobs | Part-time jobs |
|---|---|---|---|---|---|
| AL | 2 | 8 | MO | 166 | 2 |
| AR | 37 | 1 | MT | 14 | 7 |
| CA | 11 | 6 | NE | 36 | 20 |
| CO | 123 | 13 | NV | 8 | 8 |
| CT | 35 | 3 | NJ | 22 | 14 |
| DE | 8 | 0 | NY | 300 | 39 |
| CN | 16 | 8 | NC | 29 | 4 |
| FL | 360 | 63 | OH | 102 | 72 |
| GA | 676 | 2 | OK | 822 | 9 |
| ID | 26 | 18 | OR | 2 | 3 |
| IL | 375 | 8 | PA | 106 | 39 |
| IN | 1,833 | 6 | SC | 12 | 100 |
| IA | 14 | 32 | SD | 23 | 0 |
| KS | 62 | 52 | TN | 8 | 29 |
| KY | 6 | 0 | TX | 50 | 22 |
| ME | 4 | 3 | UT | 4 | 3 |
| MD | 111 | 6 | VT | 10 | 19 |
| MA | 9 | 2 | VA | 242 | 5 |
| MI | 125 | 21 | WA | 43 | 4 |
| MN | 549 | 52 | WI | 74 | 41 |
| MS | 3 | 0 | | | |

All segments of the U.S. GHP industry are bullish about the future and expect that their GHP business will increase in the next few years (Figure 7).

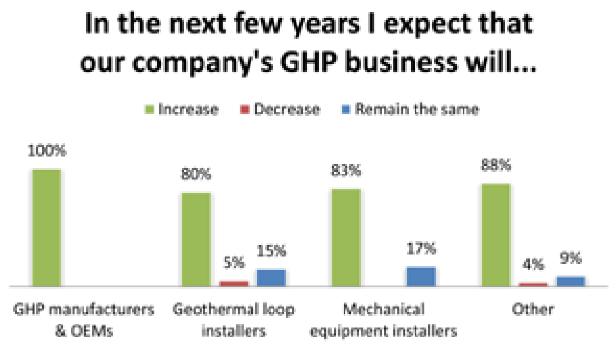



*Figure 7. Outlook of U.S. geothermal heat pump industry segments.*

Preliminary results of the four surveys as of April 2012 are described below.

## Manufacturers, OEMS, and Suppliers

The *Manufacturer & OEM Survey* was launched on 23 June 2011. Its purpose is to collect economic data from manufacturers and Original Equipment Manufacturers (OEMs) including location of manufacturing facilities, number and location of full- and part-time jobs, plans for expansion, and data on up- and down-stream channels.

"Manufacturer" is defined as a company that manufactures geothermal heat pumps. "Original Equipment Manufacturer (OEM)" is defined as a company that buys geothermal heat pumps from a Manufacturer for sale under their own brand name(s). "Supplier" is defined as a company that manufactures the five most costly components of a GHP unit in terms of their cost as a percentage of the final unit (air coil, cabinet, compressor, fan motor, and water coil), and sells them to the Manufacturer.

As of April 2012, 24 responses were received to the *Manufacturer & OEM Survey*; 17 companies (70.8%) fully completed the survey. The 24 companies provided 2,594 direct full-time and 127 part-time jobs. They reported combined sales in 2010 of 118,347 units with a rated capacity of 373,731 tons (Table 3). Responses came from companies in 17 states: Arkansas, Connecticut, Florida, Georgia, Illinois, Indiana, Maryland, Michigan, Minnesota, New York, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Texas, and Washington State.

**Table 3. Results of Manufacturer and OEM Survey (April 2012)**

| | |
|---|---|
| Began survey | 24 |
| Completed survey | 17 |
| Companies | 24 |
| States | 17 |
| Full-time jobs | 2,594 |
| Part-time jobs | 127 |
| Sales in 2010 | Number of units: 118,347<br>Rated capacity (tons): 373,731 |
| Dealers | 19,803 |
| Distributors | 493 |
| Commercial representatives | 418 |
| Other sales outlets | 42 |

Half of the manufacturers produce water-to-air geothermal heat pumps (50%), followed by water-to-water (37%). Direct Geoexchange heat pumps _ account for 10% of GHP units produced (Figure 8).

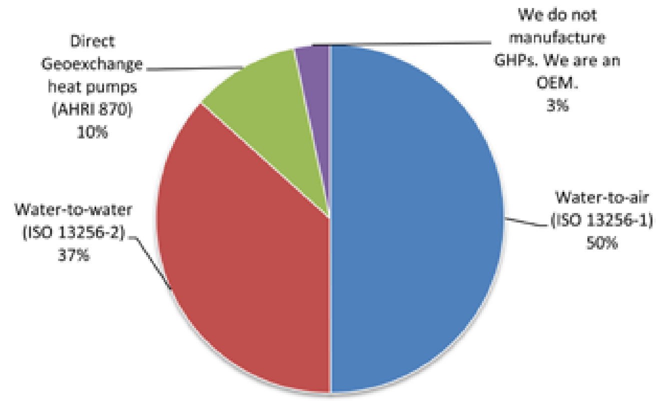



*Figure 8. Types of geothermal heat pumps manufactured.*

Fifteen (15) companies manufacture for the residential market, 13 for the commercial market, and 7 for the industrial market. The largest numbers of manufacturing facilities are located in New York and Oklahoma followed by Florida, Indiana, Maryland, New Mexico, Ohio, Oregon, Pennsylvania, South Dakota, and Texas. Two companies reported having manufacturing facilities in all 50 states.

### *Upstream Supply Chain*

Since the GHPsRUS Project is trying to measure how the entire geothermal heat pump industry benefits the country, companies were asked about their upstream supply chain. Manufacturers and OEMs were requested to rank the most costly components of a GHP unit in terms of their cost as a percentage of the final unit. The five most costly components are the compressor, air coil, water coil, cabinet, and fan motor.

Companies were asked from what vendors they purchase the most costly components. The most commonly named suppliers were Bristol Compressors International, Inc., Emerson Climate Technologies (Copeland), Luvata (Heatcraft), Packless Industries, Regal Beloit (Genteq, Century), Tecumseh Products Company, and Turbotec (Table 4).

**Table 4. Suppliers of Major Geothermal Heat Pump Components.**

| Supplier name | U.S. location | Component |
|---|---|---|
| Bristol Compressors, International, Inc. | Bristol, VA | Compressor |
| Emerson Climate Technologies (Copeland) | St. Louis, MI | Compressor |
| Luvata (Heatcraft) | Grenada, MS | Water coil |
| Packless Industries | Waco, TX | Water coil |
| Regal Beloit (Genteq, Century) | Fort Wayne, IN<br>Tipp City, OH | Fan motor |
| Tecumseh Products Company | Arbor, MI | Compressor |
| Turbotec | Windsor, CT<br>Hickory, NC | Air coil |

## *Downstream Supply Chain*

The 24 GHP manufacturers and OEMs sell GHPs through a nationwide distribution network of 19,803 dealers, 493 distributors, 418 commercial representatives, and 42 other sales outlets. The most common distribution channels are distributors (55.6%), commercial representatives (50%), dealer-direct (33.3%), and OEM to other brands (33.3%) (Figure 9).

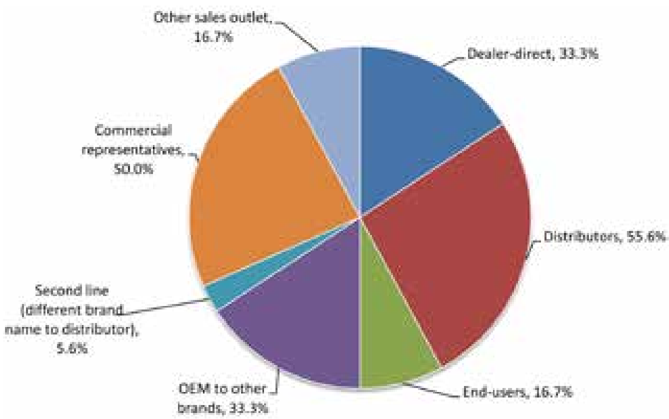



*Figure 9. Distribution channels for geothermal heat pump manufacturers and OEMs*

## *Loop Installers*

The *Ground Loop Survey* was launched on 23 March 2011. It is directed towards geothermal loop installers to collect economic and geological data and determine drilling price per linear foot by zip code. "Geothermal loop installer" is defined as a company that installs the geothermal loop heat exchanger for a geothermal heating and cooling system.

As of April 2012, 105 responses were received to the *Ground Loop Survey* of which 71 people (67%) fully completed the survey. Ninety-four (94) companies in 32 states provided 736 full-time and 168 part-time jobs. The respondents installed a total of 6,722 geothermal loops in 2010. Respondents had an average of 12.75 years of experience installing geothermal loops; most companies entered the GHP industry 10 to 20 years ago (Table 5).

**Table 5. Results of Ground Loop Survey (April 2012).**

| | |
|---|---|
| Began survey | 105 |
| Completed survey | 71 |
| Companies | 94 |
| States | 32 |
| Full-time jobs | 736 |
| Part-time jobs | 168 |
| Installations in 2010 | 6,722 |
| Year in which company started installing GHPs | 1979 (earliest)<br>2011 (latest)<br>1999 (average) |
| Average number of years installing GHPs | 12.75 |

Responses were received from companies in 32 states: Alabama, California, Colorado, Connecticut, Delaware, Florida, Idaho, Illinois, Iowa, Indiana, Kansas, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, New Jersey, North Carolina, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, Texas, Utah, Vermont, Virginia, Washington State, and Wisconsin. The greatest numbers of responses were received from companies in Michigan, Wisconsin, Ohio, Pennsylvania, and Virginia (Table 6).

**Table 6. Location and Number of Responses to the Ground Loop Survey by State.**

| State | Number of responses | State | Number of responses |
|---|---|---|---|
| Alabama | 1 | North Carolina | 5 |
| California | 3 | Nebraska | 2 |
| Colorado | 4 | Nevada | 1 |
| Connecticut | 2 | New Jersey | 2 |
| Delaware | 1 | Ohio | 7 |
| Florida | 3 | Oklahoma | 2 |
| Iowa | 2 | Oregon | 1 |
| Idaho | 3 | Pennsylvania | 7 |
| Illinois | 2 | South Carolina | 1 |
| Indiana | 3 | Texas | 3 |
| Kansas | 2 | Utah | 1 |
| Maryland | 3 | Virginia | 6 |
| Massachusetts | 1 | Vermont | 2 |
| Michigan | 12 | Washington | 4 |
| Minnesota | 3 | Wisconsin | 8 |
| Montana | 2 | | |

Mud drilling was the most common drilling method reported followed by air drilling (Figure 10). Vertical boreholes accounted for 74% of all installations, horizontal trenches for 17%, horizontal (directional) drilling for 7%, and Direct Exchange for 1%. No pond or lake loops were reported (Figure 11).

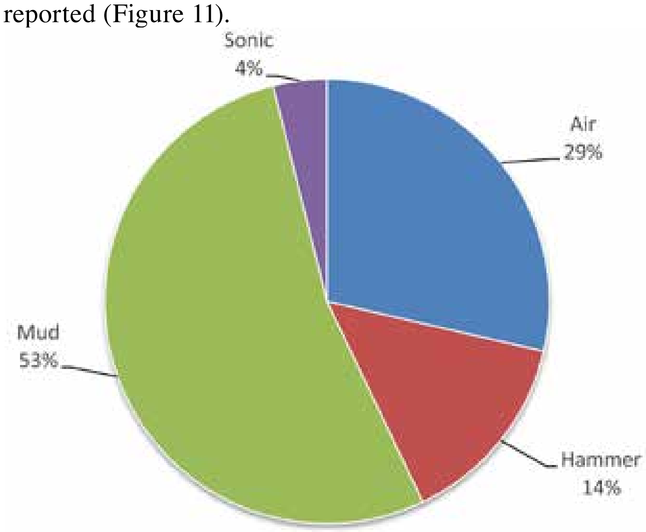



*Figure 10. Drilling methods reported in Ground Loop Survey.*

Respondents were given a choice of supplying geological and price data for either an average or an actual ground loop installation. Geology encountered with the approximate thickness of each (feet) was requested for vertical boreholes. Data on borehole depth was reported for a total of 62 vertical ground loops—49 average loops and 13 actual loops. The value (price) of all 62 vertical boreholes combined was $259,597 (Table 7).

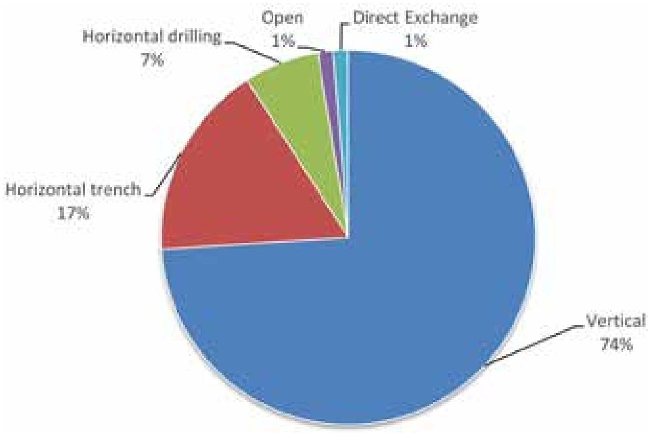



*Figure 11. Loop types reported in Ground Loop Survey*

**Table 7. Average and Actual Vertical Boreholes.**

| Installation type | Number of vertical boreholes reported | Average borehole depth (feet) | Average price per foot | Average price per borehole | Total price |
|---|---|---|---|---|---|
| Average | 49 | 272 | $13.63 | $3,707 | $181,661 |
| Actual | 13 | 351 | $17.08 | $5,995 | $77,936 |
| | | | | **Total** | **$259,597** |

## *Mechanical Equipment Installers*

The *Mechanical Equipment Installation Survey* was launched on 11 November 2011. Targeted towards companies that install the GHP equipment inside the building, the survey was created to collect basic economic data and equipment installation price by zip code. "Mechanical equipment installer" is defined as a company that installs the mechanical GHP equipment inside the building for a geothermal heating and cooling system.

As of April 2012, 54 responses were received to the *Mechanical Equipment Installation Survey* of which 44 people (81.5%) fully completed the survey (Table 8). The 52 companies provided 274 full-time and 50 part-time jobs, and have worked in the GHP industry an average of 13 years. The respondents installed a total of 1,773 GHP systems in 2010. The majority of companies had 1 to 5 or 10 to 20 years of experience installing GHP systems.

**Table 8. Results of Mechanical Equipment Installation Survey (April 2012).**

| | |
|---|---|
| Began survey | 54 |
| Completed survey | 44 |
| Companies | 52 |
| States | 29 |
| Full-time jobs | 274 |
| Part-time jobs | 50 |
| Installations in 2010 | 1,773 |
| Year in which company started installing GHPs | 1978 (earliest)<br>2011 (latest)<br>1999 (average) |
| Average number of years installing GHPs | 13 |

Responses were received from companies in 29 states: Alabama, Connecticut, Delaware, Florida, Georgia, Idaho, Indiana, Kansas, Kentucky, Maine, Maryland, Michigan, Minnesota, Mississippi, Missouri, Montana, Nebraska, Nevada, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Texas, Virginia, Vermont, Washington State, and Wisconsin.

Respondents were asked to provide information for up to five equipment installation jobs their company recently completed. Equipment installations were reported for residential (93.6%), educational (4.3%), and commercial (2.1%) buildings. Retrofit installations (57%) outnumbered new construction (43%).

Table 9 summarizes the data collected on mechanical equipment installations through April 2012. Companies provided information on installations into 86 buildings totaling 766,398 square feet of conditioned space. Installed tons were 1,851 using 414 geothermal heat pumps. The total installation price for all installations was $7.2 million.

## *Other*

The *Geothermal Heat Pump Industry Survey* was posted on 21 November 2011. Its purpose is to collect economic data including location, jobs, plans for expansion, etc. from members of the U.S. GHP industry not addressed by one of the other three surveys.

**Table 9. Mechanical Equipment Installations (April 2012).**

| Building type | Number of buildings | New/ Retrofit | Total conditioned space (ft2) | Installed tons | Number of GHPs | GHP type | Price |
|---|---|---|---|---|---|---|---|
| Commercial | 1 | New | 25,000 | 60 | 10 | Water-to-air | $225,000 |
| Commercial | 1 | Retrofit | 5,000 | 5 | 1 | Direct Geoexchange | $15,000 |
| Commercial | 1 | Retrofit | 4,000 | 10 | 2 | Water-to-air | $30,000 |
| Educational | 1 | New | 450,000 | 1,250 | 250 | Water-to-air Water-to-water | $3,500,000 |
| Medical | 1 | New | 7,000 | 22 | 12 | Water-to-air | $360,000 |
| Residential | 7 | New | 28,960 | 56 | 14 | Water-to-air Water-to-water | $312,440 |
| Residential | 3 | New | 7,000 | 12 | 3 | Water-to-water | $92,000 |
| Residential | 24 | New | 96,150 | 148 | 40 | Water-to-air | $1,041,235 |
| Residential | 4 | Retrofit | 21,900 | 61 | 17 | Water-to-air Water-to-water | $408,000 |
| Residential | 1 | Retrofit | 2,500 | 4 | 1 | Other (i.e. hybrid, etc.) | $50,000 |
| Residential | 2 | Retrofit | 7,105 | 11 | 2 | Water-to-water | $69,490 |
| Residential | 39 | Retrofit | 108,183 | 208 | 61 | Water-to-air | $1,070,740 |
| Residential | 1 | Retrofit | 3,600 | 4 | 1 | Water-to-air | $22,000 |
| Totals | 86 | | 766,398 | 1,851 | 414 | | $7,195,905 |

"Other" is defined as all other companies involved in the U.S. GHP industry including distributors; pipe and fittings manufacturers; drill rig, bit, and fluid manufacturers; grout manufacturers; design software companies; header installers; antifreeze manufacturers; etc.

As of April 2012, 58 responses were received to the *Geothermal Heat Pump Industry Survey* of which 54 people (93.1%) fully completed the survey. The 57 companies provided 2,812 full-time and 391 part-time jobs, and have worked in the GHP industry an average of 15.3 years. About one-third of the companies are relative newcomers to the GHP industry: 32% entered the industry within the last five years. Almost half of the companies entered the GHP industry within the past 10 years (Table 10).

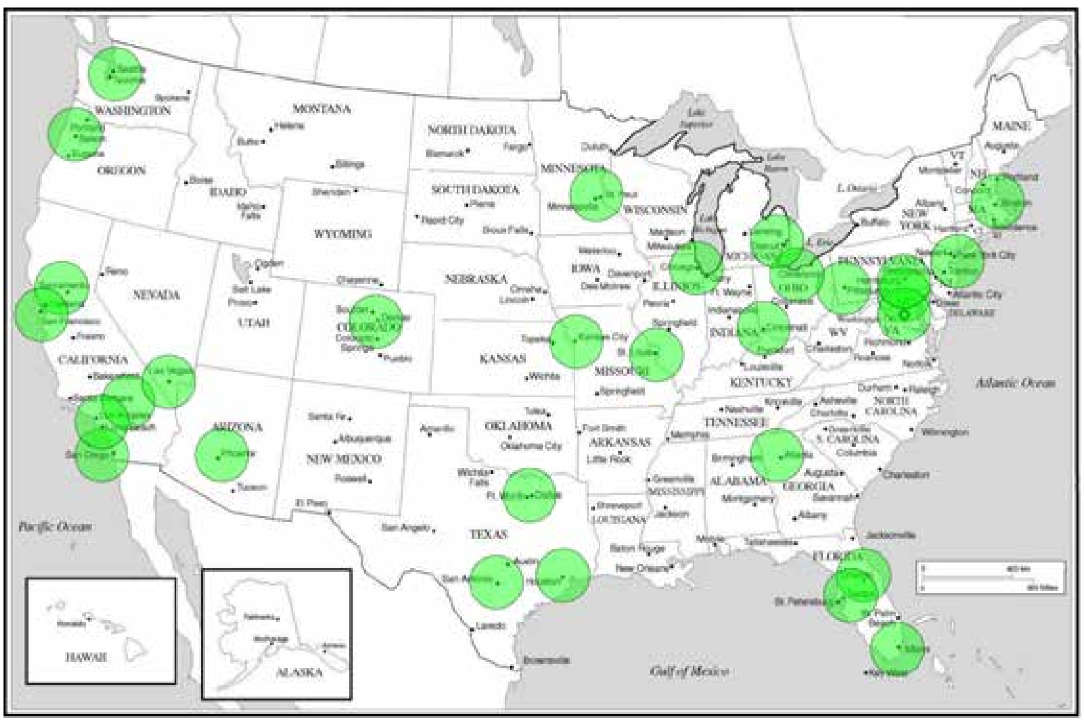
Responses were received from companies in Canada and 27 states: Colorado, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan,Minnesota, Missouri, Montana, Nebraska, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington State, and Wisconsin.

**Table 10. Results of Geothermal Heat Pump Industry Survey (April 2012)**

| | |
|---|---|
| Began survey | 58 |
| Completed survey | 54 |
| Companies | 57 |
| States | 27 |
| Full-time jobs | 2,812 |
| Part-time jobs | 391 |
| Year in which company started in the GHP business | 1935 (earliest)<br>2011 (latest)<br>1997 (average) |
| Average number of years in the GHP business | 15.3 |

## REGIONAL MODELING ANALYSIS

To accomplish an analysis of the regional and national benefits of GHP deployment, it is important to evaluate the effects on energy consumption and atmospheric pollutants, including greenhouse gases, if GHP systems displace conventional HVAC systems. To do this, we have




New York-Northern New Jersey-Long Island, NY-NJ-PA
Los Angeles-Long Beach-Santa Ana, CA
Chicago-Naperville-Joliet, IL-IN-WI
Dallas-Fort Worth-Arlington, TX
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD
Houston-Sugar Land-Baytown, TX
Miami-Fort Lauderdale-Pompano Beach, FL
Atlanta-Sandy Springs-Marietta, GA
Washington-Arlington-Alexandria, DC-VA-MD-WV
Boston-Cambridge-Quincy, MA-NH
Detroit-Warren-Livonia, MI
Phoenix-Mesa-Scottsdale, AZ
San Francisco-Oakland-Fremont, CA
Riverside-San Bernardino-Ontario, CA
Seattle-Tacoma-Bellevue, WA
Minneapolis-St. Paul-Bloomington, MN-WI
San Diego-Carlsbad-San Marcos, CA
St. Louis, MO-IL
Tampa-St. Petersburg-Clearwater, FL
Baltimore-Towson, MD
Denver-Aurora, CO
Pittsburgh, PA
Portland-Vancouver-Beaverton, OR-WA
Cincinnati-Middletown, OH-KY-IN
Sacramento--Arden-Arcade--Roseville, CA
Cleveland-Elyria-Mentor, OH
Orlando-Kissimmee, FL
San Antonio, TX
Kansas City, MO-KS
Las Vegas-Paradise, NV

*Figure 12. Thirty (30) largest metropolitan areas in the United States (from largest to smallest)*

undertaken a systematic modeling effort in which loop designs for standard residential and commercial buildings were developed using commercially available software. Load characteristics for the buildings were modeled for the 30 largest metropolitan areas in the United States (Figure 12), and used as input for the loop design software (Glassley and Battocletti, 2011).

As previously noted, GHP systems utilize the constant thermal properties of the subsurface as a reliable reservoir for storing and/or extracting heat. Performance of these systems depends, as a result, on a variety of properties important for heat transfer in geological materials, including soil thermal conductivity and diffusivity, degree of saturation, and temperature. We have assembled and made databases for these properties web-accessible (http://cgec.geology.ucdavis.edu/ghpstudy.php).

Although we have used this information in conducting the loop design calculations, the common absence of reliable thermal conductivity data made it necessary to calculate loop length over a range of thermal conductivity values for each metropolitan area. This allows us to characterize, over a range of conditions, likely loop properties. Although the data we collected showed that, contrary to common assumptions (Glassley and Battocletti, 2011), subsurface temperature varies considerably in many metropolitan areas, insufficient data coverage required that we utilize a standard table of assumed temperatures (McQuay International, 2002) in order to conduct the calculations. These constraints raise several caveats about the model results that must be borne in mind when discussing the outcomes. First, loop lengths as a function of thermal conductivity are approximate and strongly dependent on the assumptions noted above. Second, even using a range of thermal conductivities, in order to address uncertainties in soil properties, the use of a single subsurface temperature for a given metropolitan area will introduce some error in the calculated loop length for a given installation, since subsurface temperatures are variable, even within a single metropolitan area. These points are intended to emphasize that these model results should not be used as a substitute for rigorous design efforts for specific building applications. Rather, these results are intended to establish a means for comparative analysis across many regional sites, and should not be used as a construction guide.

In Figure 13 we present a comparison of the annual energy use (in kWh/yr) for residential heating and cooling using conventional HVAC equipment and GHP systems. Energy use by energy source (electricity, natural gas, coal, etc.) was accounted for based on EIA and Federal Energy Regulatory Commission (FERC) data. It was assumed that the thermal conductivity of the soil fell in the range of 0.8 to 1.2 (BTU/hr-ft-F). Because of this range, error bars of +/-10% are also drawn for each point

As Figure 13 shows, the greatest energy savings are obtained in regions where the building air conditioning is dominated by a heating load. This is consistent with the fact that current GHP designs run most efficiently in a heating mode. The overall national average energy savings would be close to 50%, if GHP deployment was evenly distributed throughout these cities and conventional HVAC systems replaced. Similar results are obtained for commercial deployment.

Because of the correlation between energy production and use, reductions in greenhouse gas emissions and atmospheric pollutants (e.g., CO, SO, and NOx) follow closely the same patterns shown for energy use in Figure 13.

## CONCLUSION

The U.S. GHP industry has a well-distributed national presence. Although currently small, if encouraged to grow, the consequence would be national jobs and economic growth – this is not just a Midwest or rust belt industry. The impact would be broad, since the industry is distributed over many components of the economy – manufacturing, drilling, construction, engineering and design, distribution, etc. Energy use and greenhouse gas emissions could be reduced significantly in nearly all regions of the country. Results of the GHPsRUS Project to date are robust. Although specifics are not currently evident several months prior to the project's end, the overall impact is very heavily weighted to the positive side.

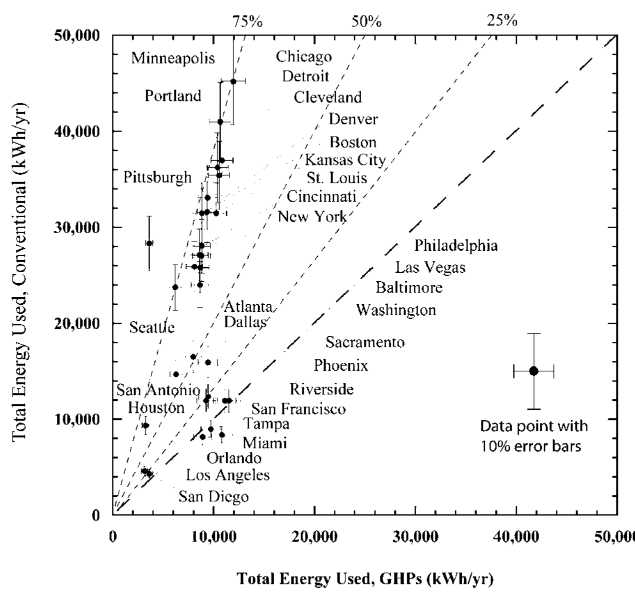



*Figure 13. Comparison of energy use for residential buildings (in kWh/yr) for each of the indicated 30 metropolitan areas. Conventional HVAC system energy use is shown on the vertical axis, GHP energy use is on the horizontal axis. The light dashed lines show the reduction in energy use (in percent) for GHP use relative to conventional HVAC use.*

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## DISCLAIMER



## REFERENCES

Battocletti, E. and Glassley, W.E., 2010. "Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment." *Geothermal Resources Council Transactions 34*, p. 901-904.

GeoExchange, undated. "Geothermal Heat Pumps," http://www.geoexchange.org/

Glassley, W.E. and Battocletti, E., 2011. "Measuring the Costs and Economic, Social, and Environmental Benefits of Nationwide Geothermal Heat Pump Deployment: A Progress Report on the Geological Impacts." *Geothermal Resources Council Transactions 35*, p. 1107-1109.

Hughes, Patrick J., 2008. "Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers," Oak Ridge National Laboratory, ORNL/TM-2008/232.

McQuay International, 2002. *Geothermal Heat Pump Design Manual, Application Guide AG 31-008*, McQuay International.

Priority Metrics Group, 2009. "Energy Beneath the Backyard - Global Geothermal Heat Pump Market 2009," Priority Metrics Group, Roebuck, South Carolina 29376.

U.S. Census Bureau, 2011. "Refrigeration, Air-Conditioning, and Warm Air Heating Equipment-2010," MA333M(10), http://www.census.gov/manufacturing/cir/historical_data/ma333m/index.html.

U.S. Department of Energy, undated. "Benefits of Geothermal Heat Pump Systems," http://www.energysavers.gov/your_home/space_heating_cooling/.

U.S. Energy Information Administration, 2009. "Geothermal Heat Pump Manufacturing Activities," http://www.eia.gov/fuelrenewable.html

## EDITOR'S NOTE

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