MEASURING THE COSTS AND BENEFITS OF NATIONWIDE GEOTHERMAL HEAT PUMP DEPLOYMENT

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ABSTRACT

While the technology has existed since the late 1940s, geothermal heat pumps, also known as ground-source heat pumps and GeoExchange®, currently account for less than two percent of the total North American heating and cooling market. With support from the United States Department of Energy Geothermal Technologies Program through the American Recovery and Reinvestment Act of 2009, Bob Lawrence & Associates, Inc. and the California Geothermal Energy Collaborative will gather and analyze manufacturing and installation costs and geological and geographic data to assess the costs and economic, environmental, and social benefits resulting from three varying scenarios of nationwide geothermal heat pump deployment.

INTRODUCTION

According to the U.S. Energy Information Administration (EIA), buildings annually account for almost half (48 percent) of energy consumption and greenhouse gas (GHG) emissions in the United States. Residential, commercial, and industrial building operations consume 76 percent of total U.S. electricity generation. Weather-related energy use, in the form of heating, cooling, and ventilation, accounted for more than 40 percent of all delivered energy use in residential and commercial buildings in 2006 (U.S. Energy Information Administration, 2008b). And trends show that the building sector is growing faster than any other energy-use sector. The building sector is one of the best areas in which to economically reduce energy consumption and limit GHG emissions.

GHPs currently account for about 1.54 percent of the North American heating, ventilating, and air conditioning (HVAC) market. In 2008, total shipments of geothermal heat pumps were up more than 40 percent to 121,243 units; capacity shipped rose almost 43 percent to 416,105 tons (U.S. Energy Information Administration, 2008a). Figure 1 shows geothermal heat pump shipments from 1994 (when EIA first began surveying the GHP industry) through 2008. No survey was conducted in 2001. The total market for U.S. GHPs in 2008, including equipment and installation cost (not reduced by government or other incentives), was estimated at $3.7 billion dollars. Effective 1 January 2009, for residential GHPs, the American Reinvestment and Recovery Act (ARRA) of 2009 provides a tax credit of 30 percent of the cost (including installation and labor costs) with no upper limit through 2016. The previous federal tax credit was limited to $2,000. For commercial applications, the ARRA provides a 10 percent tax credit and allows for accelerated depreciation. The GHP market is expected to triple in value by 2013 (Priority Metrics Group, 2009).

Since geothermal heat pumps (GHPs) use the constant temperature of the earth, they are among the most efficient heating and cooling technologies currently available (U.S. Environmental Protective Agency). GHPs move heat between buildings and the earth three to five times more efficiently than other HVAC systems.

According to an Oak Ridge National Laboratory (ORNL) study (Hughes, 2008) which examined the barriers to increased GHP use in the United States, although the U.S. was once the world leader in GHP technology and market development, Europe now absorbs two to three times the number of GHP units per year as the U.S. Market growth rates in Europe, China, South Korea, and Canada exceed those in the United States. While the U.S. has the greatest number of GHPs installed, on a per capita basis it falls behind many European countries.

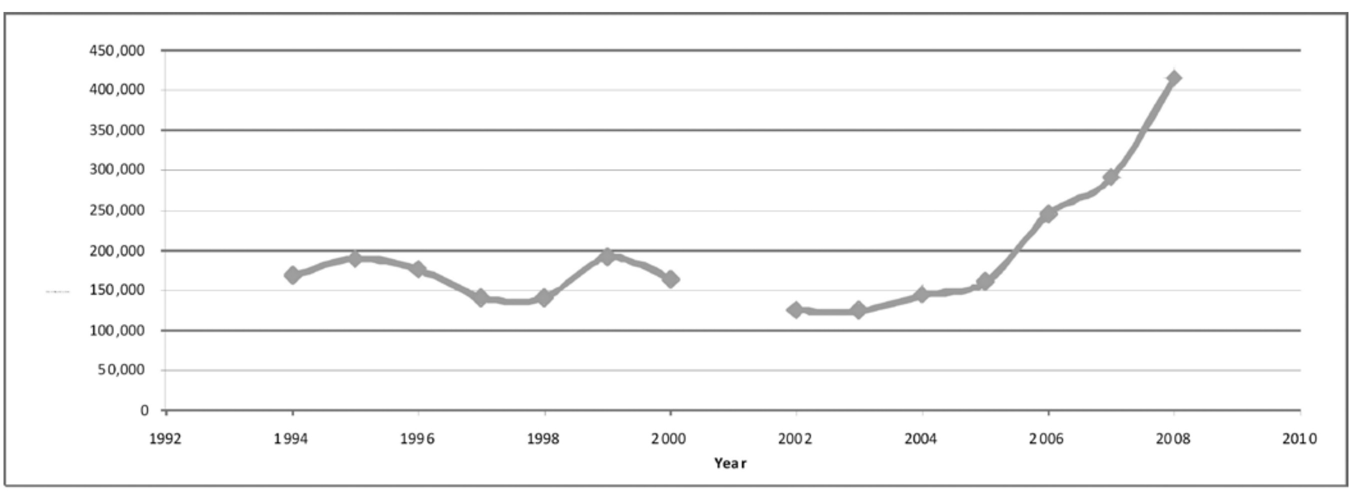

Figure 1. Geothermal heat pump shipments, 1994-2008

The ORNL study concluded that:

- "If the federal government set a goal for the U.S. buildings sector to use no more nonrenewable primary energy in 2030 than it did in 2008…it is estimated that 35 to 40 percent of this goal, or a savings of 3.4 to 3.9 quads annually, could be achieved through aggressive deployment of GHPs." (A quad is equal to 10^{15} BTU, or 1.055×10^{18} joules).
- GHPs could avoid the need to build 91 to 105 GW of electricity generation capacity, or 42 to 48 percent of the 218 GW of net new capacity additions projected to be needed nationwide by 2030.
- Aggressive deployment of GHPs could result in $33 to 38 billion annually in reduced utility bills (at 2006 rates).

ORNL determined that the two most significant actions that could be taken to increase GHP use in the U.S. were to:

1. Assemble independent, hard data on costs and benefits, and
2. Independently assess the national benefits of GHP deployment.

With support from the United States Department of Energy Geothermal Technologies Program through the American Recovery and Reinvestment Act of 2009, the three-year Geothermal Heat Pump Cost-Benefit Project will focus on independent data collection and analysis. Bob Lawrence & Associates, Inc. (BL&A) and the California Geothermal Energy Collaborative (CGEC) will collect two types of data: 1) manufacturing and installation cost data, and 2) geological and geographical data. BL&A will take the lead on the former, the CGEC on the latter. Figure 2 illustrates the project's overall data collection and analysis approach.

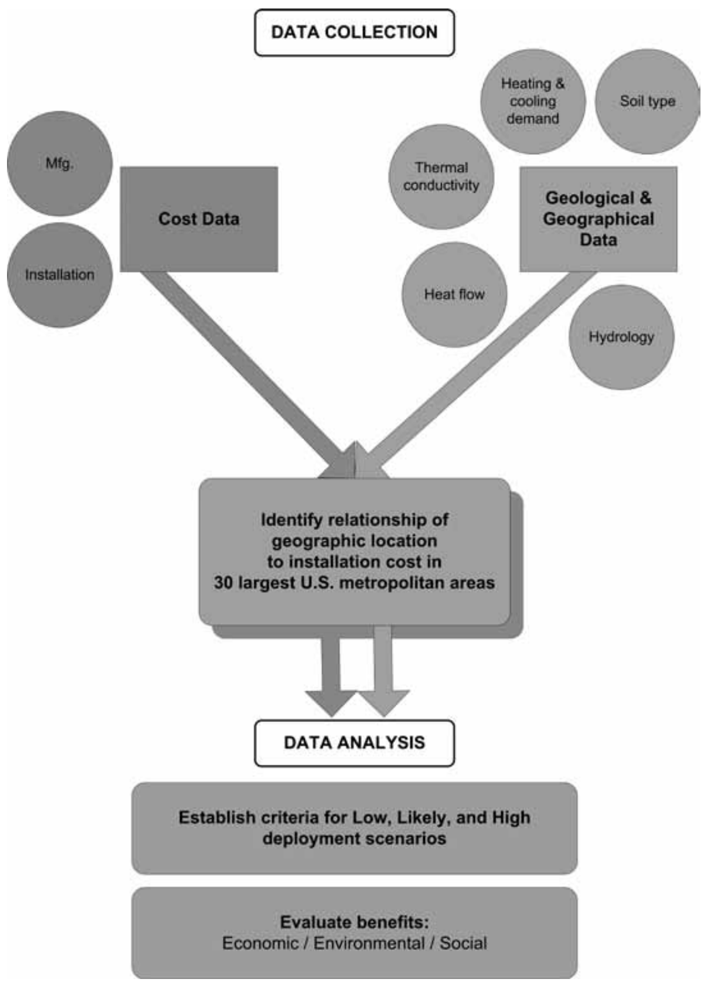

Figure 2. Geothermal Heat Pump Cost-Benefit Project data collection and analysis approach

Manufacturing and Installation Cost Data

In 2008, there were about 23 known U.S. manufacturers of geothermal heat pumps (Table 1). Four of the total 23 account for over 80 percent of annual GHP sales. An additional 10 to 15 companies account for the remainder of the U.S. market. Some serve the entire U.S.; others cater to specific markets. Some GHPs are rebranded and sold under different names. BL&A will seek economic data from the 23 GHP manufacturing companies that responded to the EIA's most recent annual survey.

Manufacturing cost data sought may include:

- Number and locations of full-time, part-time, and contractual jobs;
- Location of factories;
- Annual sales;
- Number of GHP models manufactured;
- Names and contact information for suppliers;
- Number and location of dealers; and
- Plans for future manufacturing expansion.

Table 1. Respondents to the Energy Information Administration, Form EIA-902, "Annual Geothermal Heat Pump Manufactures Survey," for 2008

Company	Location
Addison Products Company	Orlando, Florida
AquaCal AutoPilot, Inc.	Petersburg, Florida
Bard Manufacturing Company	Bryan, Ohio
Carrier Corporation	Syracuse, New York
Climate Master, Inc.	Oklahoma City, Oklahoma
Earth To Air Systems, LLC	Franklin, Tennessee
EarthLinked Technologies, Inc.	Lakeland, Florida
EarthSource Energy Solutions, Inc.	Brookline, Massachusetts
ECONAR GeoSystems, LLC	River, Minnesota
ECR Industries Incorporated (does business as Advanced Geothermal Technology)	Reading, Pennsylvania
Enertech Manufacturing, LLC	Greenville, Illinois
FHP Manufacturing Company	Ft. Lauderdale, Florida
GeoFurnace Manufacturing, Inc.	De Smet, South Dakota
GeoMaster, LLC (GeoExcel Inc,)	Fort Wayne, Indiana
Heat Controller, Inc.	Jackson, Michigan
HydroHeat, LLC	Monroeville, Pennsylvania
Hydro-Temp Corporation	Pocahontas, Arkansas
Mammoth Inc.	Chaska, Minnesota
McQuay International	Auburn, New York
Rittling - Hydro-Air Components Inc.	Buffalo, New York
Sunteq Geo Distributors	Howard, Pennsylvania
Trane Company	Clarkeville, Tennessee
Water Furnace International, Inc.	Fort Wayne, Indiana

In addition to seeking data from GHP manufacturers, the economic analysis will also consider manufacturers of GHP system and loop components, i.e., heat exchangers, high-density polyethylene (HDPE) and cross-linked polyethylene (PEXa) pipe (only high-density polyethylene (HDPE) or cross-linked polyethylene (PEXa) are acceptable for use in the underground loop), and geothermal grouts. Figure 3 illustrates the various segments of the GHP industry.

In addition, BL&A will seek installation cost data from GHP system and loop installers, contractors, designers, and drillers dating back to 2005. Installation cost data sought may include:

- Installation zip code;
- Installation date;
- Installation type, i.e., residential, commercial, industrial, school;
- Building size (square feet);
- Installer information;
- Equipment, i.e., heat pump(s), controls, hot water heater, humidifier/dehumidifier, cooling tower; and
- Ground loop, i.e., closed, open, or Direct Geoexchange (DGX); horizontal or vertical.

BL&A will coordinate with Technical Committee 6.8 - Geothermal Energy Utilization of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to determine the precise installation cost data that will be requested. The objective is to define installation costs in terms of dollars per ton or square foot. In the interest of keeping proprietary company data confidential, all manufacturing and installation cost data collected will be aggregated.

Geological and Geographical Data

The geographic analysis includes developing a quantitative analysis of the thermal properties that influence heat pump performance. The first step in this effort is to identify regions in the U.S. that share similar geological and hydrological characteristics and climate patterns. For each of those regions the CGEC will compile a database in which soil and bedrock characteristics are assembled (e.g., soil types, thermal conductivity, heat flow, depth to bedrock, depth to the water table, hydrological properties, etc.) and heat-cooling demand. These data will be made web-accessible for general use. Although much of this data is already available, assembling it in a coherent, single database has not been done.

Once assembled, the data will be used to generate optimized ground loop design parameters for each region. Of course, local variability in the geological, hydrological, and climatic parameters dictates that these optimized designs should not be taken as necessarily the best design for any specific application. Rather, they will form the basis for a standardized approach to examining cost.

The standardized designs can then be used to examine the sensitivity of the analyses to variations in specific parameters using the range of geological, hydrological, and climatic values identified for each region. This approach will allow uncertainty bounds to be established for the base case results. This approach will also allow comparisons across regions of costs, and provide a basis for establishing a national "roll-up" of the results to allow a thorough cost-benefit analysis at a higher resolution than previously achieved.

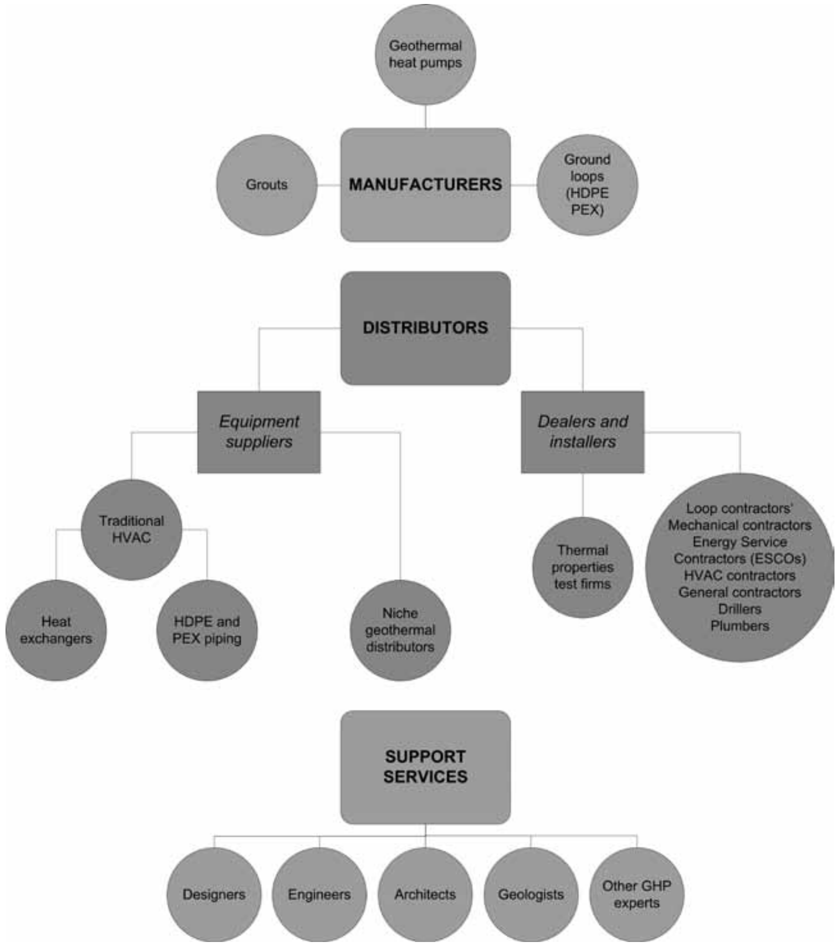

Figure 3. Geothermal heat pump industry segments

Because the greatest potential benefit will be achieved in regions of high population, the project will focus on the 30 largest metropolitan areas (see Figure 4, U.S. Census Bureau, 2009) and conduct the analyses using the representative properties in those areas that are appropriate for their respective geological, hydrological, and climatic conditions. Since these are often areas that have a strong impact on greenhouse gas emissions and electricity consumption, evaluating the impact on these elements will be an important part of the analysis.

This approach provides a way to characterize geological provinces, i.e., the metropolitan areas can be grouped by geological characteristics. For example, New York, Chicago, and Philadelphia are classic "old continental basement" geology. Los Angeles, San Diego, and San Jose are "young, convergent margin" geology. Houston, San Antonio, and Dallas are "Great Plains sedimentary basin" geology. And Phoenix is Basin and Range geology. Each city has layered on to this different degree heating and cooling days. This break out will be done for all 30 areas which will be broken down into groups of 10 each. In this way, the analysis can examine how results vary by geological province, how results vary within a geological province, and how local climate affects the results within a geological province.

Data Analysis

The project's data analysis effort contains three interrelated components:

- Identify the relationship of geographic location to installation cost in the 30 largest U.S. metropolitan areas;
- Establish criteria for Low, Likely, and High scenarios; and
- Evaluate and quantify the economic, environmental, and social benefits resulting from the Low, Likely, and High scenarios.

Installation cost and geological and geographical data will be overlaid to examine if and how the cost of installing a GHP varies across the country. Second, the data analysis will consider the installation of GHPs across the U.S. wherever they make "economic sense." "Economic sense" will be defined vis-à-vis current sources of heating, cooling, and electricity, and geographic factors. The criteria for Low, Likely, and High scenarios will thus be defined. Finally, BL&A and the CGEC will estimate the economic, environmental, and social benefits resulting from the Low, Likely, and High deployment of GHPs. Economic benefits include jobs created; taxes paid by manufacturers, designers, and installers; business expansion; and energy savings. Environmental benefits include reduced GHG and air pollutants and the decreased need for new electricity generation. Social benefits include improved quality of life.

BL&A and the CGEC will seek to engage a wide range of groups to gather the most reliable and comprehensive data. BL&A and the CGEC will seek data from state energy offices and agencies; the U.S. Geological Survey and state geological surveys; GHP manufacturers; the International Ground Source Heat Pump Association (IGSHPA) and IGSHPA-accredited installers and designers; ASHRAE; the Geothermal Exchange Organization, Inc.; and other relevant trade associations, architects, engineers, developers, drillers, and interested parties. With their help and support, the ambitious Geothermal Heat Pump Cost-Benefit Analysis will be a unique and powerful tool for evaluating the benefits and costs of installing GHPs in the United States.

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Figure 4. Thirty largest metropolitan areas in the United States (listed below in order of size, from largest to smallest)

Group One

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

Group Two

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

Group Three

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