DOE Webinar – Residential Geothermal Heat Pump Retrofits

NREL
DOE Webinar Series

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Technology Options – Vertical vs. Horizontal

Applications on Residences

Costs

Use & Availability – Certified Designers, & Installers

Financing Options

Key Information for RFPs

Project QA/QC and Monitoring

Tools & More Information on GHP
Geothermal Energy

• Heat energy contained in the earth
• Shallow temperature fluctuate with the seasonal air temperatures
• Temperature become stable at depths of 30 ft and approach annual average air temps
• This is all true, absent a geothermal anomaly or high temperature gradient areas
Geothermal Heat Pumps (GHP)

- Highly efficient method of providing heating and cooling
- Work by using ground temperature as a renewable resource for pumping heat in winter and rejecting heat in summer
- Cost effective
- Economic and environmental benefits
What is a Heat Pump & How Does it Work?

The ground loop transfers ground energy to a refrigerant in the heat pump.

Increasing the pressure increases in the temperature.

Heat is transferred to the heating fluid or air handler.

Heat is transferred to the room by radiant floor heating or air distribution system.

Refrigerant expands causing it to cool.
**Geothermal Efficiency**

- Use the green under your feet…as close to the money tree as you can get
Why is GHP useful and efficient?

- Ground Warmer than Air
- Ground Cooler than Air
Types of Heat Pumps

• Characterized by medium used for the Heat Source & Heat Sink
  – Air to Air – Air Source Heat Pump
  – Water to Air – Water Source Heat Pump
  – Water to Water – Uses hydronic pipes through the building

• Heats, Cools, & Produced Hot Water
  – Capacity is measured in tons, like AC units
GHP System & Components

- Air Fan – circulates building air
- Air Coils – heats or cools air
- Refrigerant Loop
- Compressor
- Controls
- Ground Loop & Refrigerant Loop Connection

Innovation for Our Energy Future
Types of Ground Heat Exchangers

• Open Loop
  – Ground water from a well, river, or pond
  – Exchanges **Heat & Water** with the ground
  – Returns water to the ground

Closed Loop
  – Buried HDPE or copper (direct exchange) pipe
  – Circulates as secondary fluid (water or water/antifreeze mix or refrigerant with copper pipe)
  – Exchanges **Heat** with the ground
  – Configuration – depends on available space and installation costs
Horizontal Trench Loop

• Cost effective when land is plentiful
• Trench depth is 6 ft or more to go below frost line

Rule of thumbs
• Trench length – typically 300 ft
• Pipe length – out & back = 600 ft

Source: Klaassen, Iowa Energy Center
Horizontal Layout Options

- Single flow path
- Large land area required
- Larger pipe diameters required to reduce friction loss
- Increased antifreeze fluid volume

- Single flow path
- Shorter trench required than a single pipe system
- Larger pipe diameter than a parallel system

- Reduced trench length
- Parallel flow
- Deeper trench is generally required

Source: IGSHPA
Vertical Ground Loop - Borehole

- Used in areas with land area restrictions
- Temperatures are typically more constant than horizontal
- Depths are usually 200-300 ft
- Pipe length 400-600 ft

Rule Of Thumb:
1 ton for every 200-300 ft borehole
Vertical Configuration Options

Parallel

- Small diameter pipe than series system
- Larger capacity heat exchanger can be designed
- ¾ and 1 inch pipe loops are common
- Bore hole depths can be increased in limited land areas

Series

- Larger pipe required for series system
- Large pipe difficult to handle
- Heat exchanger limited to about 3-tons because of pipe friction

Source: IGSHPA
Applications on Residences
Process for Residential

- Determine the heating/cooling loads (Btuh)
- Select heat pump size
- Select indoor air/water distribution system
- Estimate the building’s energy requirement
- Estimate the ground heat exchanger loads
  - Annual load
  - Design month’s load
### TABLE 3.3: Energy Calculation by the Bin Method: Ground-Source Heat Pump

<table>
<thead>
<tr>
<th>Residence in Stillwater, Oklahoma</th>
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<tbody>
<tr>
<td>Bin Temp-°F</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>112</td>
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<td>107</td>
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<td>7</td>
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<td>2</td>
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<tr>
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</table>

**TOTAL COOLING COST: 376.17**
**TOTAL HEATING COST: 455.91**
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NREL Geothermal Technology Team

Building Heating and Cooling Load Profile

Design Heating Load: 50,000 Btuh
Design Cooling Load: 36,000 Btuh

Outdoor Temperature F

13 62 96

67
Free Hot Water

• Domestic Water Heating Applications
  – Desuperheater to heat domestic water
    • Cooling Season = Free Water Heating
    • Heating Season = High COP water heating
  – Water to water heat pumps preheat Domestic Water at COP of 3.0 to 5.0
Costs
First Costs

• Generally, the geothermal system cost inside the building is less than or equal to conventional systems

• The incremental cost over a conventional system is in the Geothermal Heat Exchanger (aka. ground loop)

• Manage the installed costs
  – Reduce heating/cooling loads
    • Efficient building envelopes
  – TC (thermal conductivity) test as applicable for project size
  – Organize & minimize geothermal system piping
Cost of Installation

• Installed cost – ground loops
  – Ground coupled – horizontal: $1,100/ton
  – Ground coupled – slinky: $1,300/ton
  – Ground coupled – vertical: $1,500/ton
  – Ground water (3 ton, w/o well): $950/ton

• Water-to-air heat pump units
  – 8.8 kW (2.5 tons): $2,750 ($1,100/ton)
  – 10.5 kW (3.0 tons): $3,000 ($1,000/ton)
  – 14.1 kW (4.0 tons): $3,600 ($900/ton)

• Substantial variations possible

Ref: Kavanaugh & Gilbreath (1995), and Rafferty (2008)
## Estimations on Installed Costs

<table>
<thead>
<tr>
<th></th>
<th>2008 Mature Market Est. from Graph</th>
<th>2008 Immature Market</th>
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<tbody>
<tr>
<td><strong>$ per Ton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASHP</td>
<td>$2,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>Gas w/AC</td>
<td>$1,967</td>
<td>$3,933</td>
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<tr>
<td>Ground Water</td>
<td>$3,333</td>
<td>$6,667</td>
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<tr>
<td>Horizontal</td>
<td>$3,933</td>
<td>$7,867</td>
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<tr>
<td>Slinky</td>
<td>$4,033</td>
<td>$8,067</td>
</tr>
<tr>
<td>Vertical</td>
<td>$4,300</td>
<td>$8,600</td>
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Estimates includes both inside (ductwork, heat pump unit, controls etc) and outside (ground loop, piping, excavation and/or drilling)

*Source: Kevin Rafferty, 2008 - "An Information Survival Kit For The Prospective Geothermal Heat Pump Owner"*
Savings

• Average Energy savings: 31% to 71%
• Average Cost savings ($): 18% to 54%
• Heating efficiencies 50 to 70% higher than other heating systems
• Cooling efficiencies 20 to 40% higher than available air conditioners

Savings in Energy Costs in USA Compared to GHP ($ per Btu or kWh)

• 4x for electric resistance
• 3x for propane
• 2x for ASHP
• 2x for fuel oil
• 2x for natural gas

Operational & Maintenance Costs

• Make sure circulating pumps are sized correctly
  – Oversized pumps are energy hogs

Source: Kavanaugh, K & McInerny, S, "Energy Use of Pumping Options for GSHP"
Habitat for Humanity Project – Hope Crossing, OK

<table>
<thead>
<tr>
<th></th>
<th>Standard Gas House</th>
<th>Low Energy GHP &amp; PV House</th>
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<tbody>
<tr>
<td>Energy Use</td>
<td>95 MMBtu</td>
<td>19 MMBtu</td>
</tr>
<tr>
<td>Energy Cost</td>
<td>$1,739</td>
<td>$522</td>
</tr>
<tr>
<td>CO₂ Emissions</td>
<td>25,460 lbs</td>
<td>9,825 lbs</td>
</tr>
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Source: Ellis, D. (presented by Paul Bony 2010, April 19), ClimateMaster
Use & Availability – Certified Designers & Installers
Feel Confident with the Team

- Find certified contractors, designers, & installers:
  
  - IGSHPA
  - GEO

- Call around to University's in the area who might do research on GHP and find out who are the best contractors

- Get firms that understand the critical importance of designing a GHP system that fits the building use and loads
Financing Options
Help with the Costs

• ESCOs - Energy Services Company
  – Successful with Fort Polk
  – Energy Saving Performance Contract (ESPC)

• Utility Negotiations
  – Reduce rates due to reduction of summertime peak loads with GHP

• Utility & Tax Incentives
  – DSIRE - [http://www.dsireusa.org/](http://www.dsireusa.org/)
Key Information for RFPs
Things you should have in an RFP

1. All contractors, installers, designers, & drillers must be IGSHPA certified
2. Require a minimum number of previous successful GHP projects in your area and references
3. Contact the bidders previous clients
4. Costs
   1. What are the actual performance savings of previous projects
   2. Clearly state how you want the GHP components broken down – NO LUMP SUM Contracts

Project Specifications

- GHP General Specifications – by Oak Ridge Lab
Project QA/QC and Monitoring
QA/QC

• Get GHP Smart...Fast
• Know the processes and what to look for
• If you get qualified owners rep, make sure that they are IGSHPA certified or have worked on several successful GHP projects.
Tools & More Information on GHP
## Software & Certified Installer Directories

<table>
<thead>
<tr>
<th>Software</th>
<th>Industry Directory</th>
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<tbody>
<tr>
<td>• RETScreen</td>
<td>• IGSHPA</td>
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<tr>
<td>• GeoKISS</td>
<td>• GEO</td>
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<tr>
<td>• Gaia Geothermal</td>
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<tr>
<td>– <a href="http://www.gaiageo.com/">http://www.gaiageo.com/</a></td>
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### More Information

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<td>• Geo-Heat Center</td>
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<tr>
<td>• GROUND-MED</td>
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<td>– <a href="http://www.groundmed.eu/">http://www.groundmed.eu/</a></td>
<td></td>
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<tr>
<td>• Geothermal Surviver Kit - Rafferty</td>
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