Geothermal Heat Pump Economics: How the Numbers Really Work

Demystifying the Costs & Benefits of Geothermal Heating & Cooling Systems

PRESENTER:
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Northern GroundSource Inc.
www.NorthernGroundSource.com
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1. The Geothermal Heat Pump Concept

The Simple Logic of a “Ground Source” Approach & Its Ultimate Benefit
Heating Remains #1 U.S. Home Energy Need!

A common air conditioner is a simple Air-to-Air Heat Pump—exchanges 74°F indoor air with outdoor temperatures that fluctuate broadly and can often swing to over 100°F.
An air source heat pump adds Air-to-Air heating capability—it exchanges 70°F indoor air with outdoor temperatures that can swing well below 20°F (common ASHP operating range limit).
Where might we find temperatures nearby that are **moderate** and **stable** all year round?
Heat pump technology logically goes...underground! (Video)
Heat pump technology logically goes...underground!
All GHP System Mechanical Equipment is Located Inside.
High Grade Geothermal Energy

Old Faithful Geyser

“Hot Rocks” Power
Low Grade Geothermal Energy
Lower heat from the ground is “concentrated” …into higher heat for distribution inside structure

...only a slight energy "penalty" to run the electric motors of a compressor, a couple small pumps and a blower.
Introducing: The Compressor

The Compressor is the GHP’s primary working unit where gas is compressed, heated, and “pumped” to its heat exchange delivery point.

A refrigerant gas (with much better heat concentrating properties than air) is used.
Zeroth Law of Thermodynamics

When two systems...are brought in diathermic contact with each other they exchange heat to establish a thermal equilibrium between each other.

Heat moves to Cold...Always!
Typical Forced Air GHP System

- Air Loop
- Refrigerant Loop
- Domestic Hot Water Loop
- Ground Loop
ULTIMATE BENEFIT: OVER 70% OF HEAT ENERGY IS FROM GROUND!
### ANNUAL ENERGY COSTS FOR TYPICAL 4 TON HOME IN DULUTH

<table>
<thead>
<tr>
<th>System Type</th>
<th>Heating</th>
<th>Cooling</th>
<th>Hot Water</th>
<th>Total</th>
<th>vs. GSHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Source Heat Pump (GSHP)</td>
<td>$1,270.51</td>
<td>$86.00</td>
<td>$382.87</td>
<td>$1,739.38</td>
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<tr>
<td>RH</td>
<td>$3,817.20</td>
<td>$108.48</td>
<td>$536.30</td>
<td>$4,461.98</td>
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<tr>
<td>Nat Gas</td>
<td>$1,310.40</td>
<td>$108.48</td>
<td>$536.30</td>
<td>$1,955.18</td>
<td>$215.80</td>
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<tr>
<td>Propane</td>
<td>$3,221.37</td>
<td>$108.48</td>
<td>$536.30</td>
<td>$3,866.15</td>
<td>$2,126.77</td>
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<tr>
<td>Fuel Oil</td>
<td>$3,712.94</td>
<td>$108.48</td>
<td>$536.30</td>
<td>$4,357.72</td>
<td>$2,618.34</td>
</tr>
</tbody>
</table>

- GSHP: $1,739.38
- RH: $4,461.98
- Nat Gas: $1,955.18
- Propane: $3,866.15
- Fuel Oil: $4,357.72

Costs are for heating, cooling, and hot water.
2. What Does a Geothermal System Cost?

Examining the main factors that determine GHP system cost.
2. What Does a Geothermal System Cost?

Examining the main factors that determine GHP system cost.
**GHP System Cost Factors**

- GHP System Sizing
- Site Geology & Conditions
- Delivery System Preferences
- GHP Configuration
- Electric Power Requirements
- Incentive Programs
- Quality of Equipment
- Quality of Installation
GHP System Sizing

- The first most critical step in establishing GHP system cost is accurate system sizing.

- Proper sizing is achieved by first establishing the peak heating load of the structure (peak cooling load is used in South).

- As peak load increases, so does GHP system sizing requirement...and therefore cost.
Accepted Load Calculation Standard: 

Use “Manual J” Referenced Software

IN GENERAL: As heat requirement increases—GHP system sizing increases proportionately...along with the total system design and installation cost!
Alternate Load Method (Retrofits): Based on Fuel/Electric Usage History

<table>
<thead>
<tr>
<th>Heating Estimate Design Data</th>
<th>w/o Desuper</th>
<th>w/Desuper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated BTU/Hr Heat Loss</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Heat Pump BTU/Hr Output</td>
<td>45,500</td>
<td>41,405</td>
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<tr>
<td>Number of Kw of Aux Ht Suggested</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Heat Pump C.O.P.</td>
<td>3.60</td>
<td>3.60</td>
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<tr>
<td>Overall H.P. Heating System C.O.P.</td>
<td>3.57</td>
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<td>Heating Degree Days</td>
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<td>Temperature Difference</td>
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<td>KWH Rate for Heat Pump</td>
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<tr>
<td>KWH Rate For Aux. Electric Heat</td>
<td>$0.115</td>
<td>$0.115</td>
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<tr>
<td>KWH Rate for Furnace Fan</td>
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<table>
<thead>
<tr>
<th>Conventional Source Table</th>
<th>Units</th>
<th>Efficiency</th>
<th>Cost</th>
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<tbody>
<tr>
<td>1 Electric (Radiant)</td>
<td>KWH</td>
<td>100%</td>
<td>$0.130</td>
</tr>
<tr>
<td>2 Electric (Forced Air)</td>
<td>KWH</td>
<td>100%</td>
<td>$0.130</td>
</tr>
<tr>
<td>3 Fuel Oil</td>
<td>Gallon</td>
<td>80%</td>
<td>$3.750</td>
</tr>
<tr>
<td>4 L.P. Gas</td>
<td>Gallon</td>
<td>90%</td>
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<tr>
<td>5 Natural Gas</td>
<td>Therm</td>
<td>90%</td>
<td>$0.999</td>
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<table>
<thead>
<tr>
<th>Conventional Source Selection</th>
<th>Heating</th>
<th>DHW</th>
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<tr>
<td>Number of Other Energy Source</td>
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<td>1</td>
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<tr>
<td>Other Source Efficiency</td>
<td>80%</td>
<td>100%</td>
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<tr>
<td>Other Source Cost or Rate</td>
<td>$3.750</td>
<td>$0.130</td>
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### Alternate Load Method (Retrofits):
**Based on Fuel/Electric Usage History**

#### Estimated Energy Consumption

<table>
<thead>
<tr>
<th>Source</th>
<th>Heating w/o Desuper</th>
<th>Heating w/Desuper</th>
<th>Cooling w/o Desuper</th>
<th>Cooling w/Desuper</th>
<th>DHW w/o Desuper</th>
<th>DHW w/Desuper</th>
<th>Total w/o Desuper</th>
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<tr>
<td>ECONAR GeoSource Heat Pump</td>
<td>7,583</td>
<td>7,520</td>
<td>377</td>
<td>650</td>
<td>7,959</td>
<td>8,547</td>
<td>7,959</td>
<td>8,547</td>
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<td>Auxiliary Ht and Electric Water Htr</td>
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<td></td>
<td></td>
<td>237</td>
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<td>237</td>
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<tr>
<td>Other Fuel Source</td>
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<td></td>
<td>851</td>
<td>4,549</td>
<td>4,549</td>
<td>691</td>
<td>4,549</td>
<td>691</td>
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<td>1. Electric (Radiant)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Electric (Forced Air)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3. Fuel Oil</td>
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<td>4. LP Gas</td>
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<tr>
<td>5. Natural Gas</td>
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#### Estimated Operating Costs

<table>
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<tr>
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<th>Cooling w/Desuper</th>
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<th>DHW w/Desuper</th>
<th>Total w/o Desuper</th>
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<td>$27.23</td>
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<tr>
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<tr>
<td>2. Electric (Forced Air)</td>
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<tr>
<td>3. Fuel Oil</td>
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<tr>
<td>4. LP Gas</td>
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<tr>
<td>5. Natural Gas</td>
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</table>

#### Estimated Cost Savings

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<th>Source</th>
<th>Heating w/o Desuper</th>
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<th>Cooling w/o Desuper</th>
<th>Cooling w/Desuper</th>
<th>DHW w/o Desuper</th>
<th>DHW w/Desuper</th>
<th>Total w/o Desuper</th>
<th>Total w/Desuper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Heating, Cooling and DHW</td>
<td>$3,322.23</td>
<td>$3,322.23</td>
<td>$86.36</td>
<td>$86.36</td>
<td>$591.32</td>
<td>$591.32</td>
<td>$3,999.91</td>
<td>$3,999.91</td>
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<tr>
<td>ECONAR GeoSource Heat Pump</td>
<td>$599.27</td>
<td>$918.06</td>
<td>$47.11</td>
<td>$300.77</td>
<td>$1,537.70</td>
<td>$1,265.94</td>
<td>$1,597.70</td>
<td>$1,265.94</td>
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<tr>
<td>Savings Using ECONAR Heat Pump</td>
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<td>$2,404.16</td>
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<td>$0.00</td>
<td>$2462.21</td>
<td>$2,733.98</td>
<td></td>
<td></td>
</tr>
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</table>
Consider that GHP installation costs and benefits are scalable!
Foxboro, WI = 60,000 BTUH   Babbitt, MN = 70,000 BTUH

A 6T home built in Foxboro, WI might be a 7T home in Babbitt, MN
1 Ton (British) = 12,000 BTUH

BUT...

A cold climate GHP system might have a design output of only 10,000 BTUH/Ton

A “Ton” is a long-established British thermal unit we still use
EXAMPLE 1:

5 Ton GHP (SM060)

60,300 BTUH Output @ 50°F EWT
48,000 BTUH Output @ 32°F EWT

The colder the fluid temperature from the loop...the lower the output of the GHP

GHP output depends on the fluid temperature entering from the loop
EXAMPLE 2:

Horizontally-trenched loop circuits for cold climate GHP systems:

1 Loop $\approx 8,000$ to $10,000$ BTUH\textsuperscript{PEAK TON}

Approx. 1 loop circuit of sufficient length for every 10,000 BTUH of the peak heating load

Loop Sizing Follows Peak Heating Load...Not Just GHP Capacity!
Peak heating Load = 49,537 BTUH
(Future Insulation = 41,761 BTUH)
4.0<5T GHP (TVC048) @ 30°F EWT = 45,500 BTUH
Site Geology & Conditions

- One of the most limiting factors in determining GHP system cost is site geology and conditions
- A primary objective is to achieve maximum GHX performance benefit at minimal cost and impact to site
- Different kinds of loops come at different cost... and mostly achieve the same result
Common GHX Options by Increasing Cost:

- Open Loop / Pump & Dump
- Existing Pond & Lake Loops
- Horizontally Trenched or Excavated
- Excavated Pond Loop
- Horizontally Drilled
- Vertically Bored in Deep Soil/Overburden
- Vertically Bored in Rock

Common GHX/Loop Options
Instead of a buried closed loop GHX, domestic water from house is simply pumped through the GHP coil then discharged somewhere outside. (Pictured is a simple shallow drain tile in sand.)
Main Cost Factors:
- Well must have sufficient recovery rate
- Size of well pump might slightly increase
- Cycle-stop or variable speed pump often specified (driller advises)
- Flow control assembly required at GHP
- Discharge pipe trench & site drainage
- State water use limits may eliminate option (MN: 10K gal/day—1M gal/year)

Open Loop / Pump & Dump Systems
Existing Pond & Lake Loops
Main Cost Factors:

- Lake permits difficult to obtain, usually ruled out as option if other options exist
- Pond expansion sometimes required
- Less loop pipe but more labor and other materials for weighting and containment
- Ground loop excavation eliminated, but still requires a S/R pipe trench
Closer Spacing = longer pipe requirement, smaller consolidated excavation footprint (500 ft²/T)

Wider Spacing = shorter pipe requirement, expanded excavation footprint (1,000 ft²/T)

Horizontally Excavated
Main Cost Factors:

- Excavation cost...per site conditions!
- Unknown or unforeseen encumbrances
- Loop size and configuration (at roughly 1 loop circuit per 10K BTUH of peak load)
- Largest footprint, greater impact to site
- Finished landscaping and vegetation (excavation is commonly rough-in only)

Horizontally Excavated
Pond Heat Exchangers combine exceptional GSHP system performance...

With an aesthetic component you just can’t get from a conventional earth loop.

Excavated Pond
Main Cost Factors:

- Possible wetland concerns
- Loop footprint roughly same as an excavated GHX
- Must deal with displaced soil material
- Additional containment materials or 1’-2’ sand/gravel backfill required

Excavated Pond
Horizontally Drilled HDD Machine Drilling 150 Ton GHEX for a Minnesota School
Main Cost Factors:

- HDD loops minimize site impact but usually cost more per design Ton than excavated loops (machine time & grout).
- Unknown or unforeseen encumbrances.
- Loop size and configuration by qualified designer using design software.
- Some excavation still required if manifold is buried (interior manifold also adds cost).

Horizontally Drilled
Vertically Bored in Deep Soil
Main Cost Factors:

- Vertically bored ground loops may require less pipe than HDD but usually cost more for machine, crew and grout
- Depth of unconsolidated overburden
- Loop size and configuration by qualified designer using design software
- Excavation required to connect loops, impact determined by bore field footprint
Vertically Bored in Rock
Main Cost Factors:

- Drilling through dense rock requires heavier equipment than "mud" drilling, typically at higher cost (including grout)
- Depth of overburden for extracting casing
- Loop size and configuration by qualified designer using design software
- If header excavation is over shallow rock, a costly insulation detail may be required

Vertically Bored in Rock
➢ Delivery System Preferences

• Geothermal heating is inherently a low-temperature technology

• Heat delivery systems must conform to GHP temperatures not the other way around

• Combining hydronic radiant heating with forced air heating and/or cooling generally adds cost to the GHP system itself

• GHP system configuration follows delivery system preferences if they are compatible
The “geothermal system” is generally assigned to the “supply” side of heating/cooling functions.

<table>
<thead>
<tr>
<th>Supply Side (GSHP)</th>
<th>Delivery Side (HVAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Ground Heat Exchanger (GHX)</td>
<td>• Duct System (incl. Air Exchanger)</td>
</tr>
<tr>
<td>• Ground Source Heat Pump (GSHP or GHP)</td>
<td>• Radiant Floor Tubing, Manifolds, Zone Pumps and Controls</td>
</tr>
<tr>
<td>• Loop Pump or Flow Center</td>
<td>• Radiant Baseboards, Panels, Radiators</td>
</tr>
<tr>
<td>• Some Peripheral and Auxiliary Components (incl. Controls)</td>
<td>• Plumbing/Piping Delivery Systems</td>
</tr>
</tbody>
</table>
High Temp @ 50,000 BTUH!

130°F - 180°F

Low Temp @ 50,000 BTUH!

85°F - 115°F

High Temp versus Low Temp?
GENERAL PREMISE: The Lower the Temperature—the Higher the Efficiency!
GHP Configuration

GHP SYSTEM COST OPTIONS—33,645 BTUH HOME:
(Not including any HVAC 'delivery' side costs)

3.0<4T Forced Air Heating & Cooling
Requires full house duct system only.

$18K GHP/GHX + Approx. $3.5K Excavation = $21.5K

3.0<4T Hydronic Heating Only
Requires radiant floor tubing only but some minimal ductwork for ventilation system.

$20K GHP/GHX + Approx. $3.5K Excavation = $23.5K

3.0<4T Hydronic Heating & Cooling (Split System)
Requires radiant floor tubing plus medium sized duct system.

$25K GHP/GHX + Approx. $3.5K Excavation = $28.5K
GHP Configuration

GHP SYSTEM COST OPTIONS W/GARAGE ADDED
(Not including any HVAC 'delivery' side costs)

5.0T Hydronic Heating Only
Requires radiant floor tubing only but some minimal ductwork for ventilation system.
$22K GHP/GHX + Approx. $4K Excavation = $28K

5.0T Hydronic Heating & Cooling (Split System)
Requires radiant floor tubing plus medium sized duct system for house.
$27K GHP/GHX + Approx. $4K Excavation = $31K
GHP Configuration

GHP SYSTEM COST OPTIONS W/ GARAGE ADDED
(Not including any HVAC 'delivery' side costs)

5.0T Hydronic Heating Only
Requires radiant floor tubing only but some minimal ductwork for ventilation system.

$22K GHP/GHX + Approx. $4K Excavation = $28K

5.0T Hydronic Heating & Cooling (Split System)
Requires radiant floor tubing plus medium sized duct system for house.

$27K GHP/GHX + Approx. $4K Excavation = $31K

COST SCALES: $21.5K > $23.5K > $28K > $28.5K > $31K
State-of-the-Art 2-Stage Forced Air GHP System Installation

Older Generation Stand-Alone Combined F/A & HYD GHP System

Stand-Alone Forced Air GHPs
Main Cost Factors:

- The higher the GHP Ton, the higher the fan velocity @ 400 CFM/Ton heating load!
- Ductwork sizing and expense increases proportionately by Forced Air GHP Ton

<table>
<thead>
<tr>
<th>GHP Ton</th>
<th>CFM/Ton @ 400 CFM/Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1,200 CFM</td>
</tr>
<tr>
<td>4</td>
<td>1,600 CFM</td>
</tr>
<tr>
<td>5</td>
<td>1,200 CFM</td>
</tr>
<tr>
<td>6</td>
<td>2,000 CFM</td>
</tr>
</tbody>
</table>

Stand-Alone Forced Air GHPs
HYD Heat Only GHP System
Main Cost Factors:

- No ductwork, low-temp radiant heat only
- Cannot use baseboard, radiators, or staple-up tubing—must use slab, gypsum or some other top-of-floor assembly
- Added hydronic thermal storage (buffer) tank, GHP primary pump(s) and controls
- If Interruptible Dual Fuel (IDF) system, integrated sidearm gas boiler preferred

HYD Heat Only GHP System
Split GHP System (DX)
Main Cost Factors:

- GHP includes DX A-coil for installing inside plenum of gas furnace or other air handler, which are bought separately.
- Ductwork can often remain sized to furnace blower, typically only 1,200 CFM.
- Eliminates need for outdoor AC/ASHP unit.
- Works well for Dual Fuel, but GHP shuts off with any 2nd stage call for gas heat.

Split GHP System (DX)
HYD Split GHP System
HYD Split GHP System
HYD Split GHP System
Main Cost Factors:

- Among the most advanced and versatile GHP configurations, but also more costly
- Hydronic air handler/fan coil and controls
- Stainless steel/foam pump packs and pipe insulation for chilled water cooling
- Works exceptionally well for Dual Fuel and 2\textsuperscript{nd} stage with integrated sidearm boiler

HYD Split GHP System
GHP Power Requirements

- The GHP compressor is basically a “small motor” and uses the most energy on the system—demand increases with GHP size.
- Fluid pumps and blowers are secondary consumers on the GHP system.
- Electrical infrastructure must meet the entire demand of the system including LRA!
- You can run a residential GHP on a small generator, but you can’t start it.
### GHP Power Requirements

<table>
<thead>
<tr>
<th>Model</th>
<th>Voltage Code</th>
<th>60 Hz Power</th>
<th>Compressor</th>
<th>ECM Fan Motor FLA</th>
<th>HWG Pump FLA</th>
<th>Ext Pump FLA*</th>
<th>Total Unit FLA</th>
<th>Min Circuit AMPS</th>
<th>Max Fuse HACR</th>
<th>Min AWG</th>
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<tbody>
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<td>3 TON</td>
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<td>0</td>
<td>208/230</td>
<td>1</td>
<td>104</td>
<td>21.2</td>
<td>6.8</td>
<td>N/A</td>
<td>N/A</td>
<td>28.0</td>
<td>33.3</td>
<td>80</td>
</tr>
<tr>
<td>4 TON</td>
<td>1</td>
<td>208/230</td>
<td>1</td>
<td>152.9</td>
<td>27.1</td>
<td>6.8</td>
<td>0.3</td>
<td>5.5</td>
<td>39.7</td>
<td>46.5</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>208/230</td>
<td>1</td>
<td>152.9</td>
<td>27.1</td>
<td>6.8</td>
<td>N/A</td>
<td>N/A</td>
<td>34.2</td>
<td>41.0</td>
<td>60</td>
</tr>
<tr>
<td>5 TON</td>
<td>1</td>
<td>208/230</td>
<td>1</td>
<td>179.2</td>
<td>29.7</td>
<td>9.1</td>
<td>0.3</td>
<td>5.5</td>
<td>44.6</td>
<td>52.0</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>208/230</td>
<td>1</td>
<td>179.2</td>
<td>29.7</td>
<td>9.1</td>
<td>N/A</td>
<td>N/A</td>
<td>39.1</td>
<td>46.5</td>
<td>70</td>
</tr>
</tbody>
</table>

- Electric data for a specific GHP model or series is provided in the engineering manual of most manufacturers.
- Data typically includes amperage for compressor, blower, external pump(s) and the desuperheater pump.
GHP Incentive Programs

- Utility Rebate Programs
- 30% Federal Tax Credit (through 2016)
- GHP Installation Financing Programs

Also consider that geothermal heating and cooling may **still** offer a good Return on Investment (ROI) even **without** these!
2016 Geothermal Rebate Programs

**Minnesota Power**
$200/T Closed Loop ($100/T Open Loop) + $200 ECM
[Bonuses Frequently Offered: $50/T GSHP + $50 ECM or $100/T & ECM for Triple-E Home]

**Great River Energy Affiliates:**
$400/T Closed or Open Loop ($200/T from East Central Energy) + $100 ECM

*Cooperative Light & Power*
http://www.clpower.com/pdfs/2013GSHP.pdf

*Lake Country Power*

*East Central Energy*

*Arrowhead Electrical Cooperative*

**Wisconsin Focus On Energy Program:**
$650 Flat Geothermal Rebate from Participating Utilities for Retrofits
http://www.focusonenergy.com/residential/renewable/geothermal-heat-pumps
**Geothermal Heat Pump Residential Tax Incentives**

**Federal Income Tax Credit:**
- 30% of total geothermal system cost
- Credit capped at $2,000 for 2008
- Credit unlimited for 2009 through 2016
- Can be used to offset AMT tax
- Can be combined with other tax credits
- Can be used in more than one year

**Eligibility:**
- Home must be located in U.S.
- Includes houses, cooperatives, condos, mobile homes
- Does not have to be your main house
- GSHP must meet Energy Star requirements
- Must be placed in service between 1/1/2008-12/31/2016
Geothermal Heat Pump Business Tax Incentives

**Federal Income Tax Credit:**
- 10% of total geothermal system cost
- Credit is not limited
- Can be used to offset AMT tax
- Can be used in combination with subsidized financing
- Can be used in more than one year

**Accelerated Depreciation:**
- 5 year MACR depreciation of entire system
- Eligible for bonus depreciation in 2009 (50% write-off in first year)

**Eligibility:**
- Building must be located in U.S.
- Original use begins with taxpayer
- Must be placed in service between 10/3/2008-12/31/2016
- Can be used by regulated utilities
- Must be claimed by owner of property (effects non-taxable)
Loan Terms:
- Loan amounts up to $20,000
- 4.99% fixed interest rate (5.385% Annual Percentage Rate*)
- No maximum income limit
- Terms up to 10 years
- This loan is secured by a mortgage on the property. Closing costs apply

Property Eligibility:
- Single family, owner-occupied, primary residence
- Properties under construction or held in Trust are not eligible

Types of Improvements:
- Eligible improvements include: ground source heat pumps that meet or exceed Energy Star 1 efficiency requirements; heat pump water heaters and air source heat pumps that are Energy Star qualified

*APR is based on $20,000 for 10 years.
2016 Geothermal Financing Programs
CEE Loans Sponsored by Utility Partners

http://www.mnbrighterideas.com/financing/cee.cfm

Loan Terms:
- Loan amounts up to $7,500 and up to $25,000 at...
- 0% - 2.9% financing respectively!
- No family income limits
- Terms up to 10 years
- Loans must be secured via a mortgage against the property not to exceed $25,000 or up to 100 percent of the property value

Property Eligibility:
- Dwelling must be a residential, one-unit, owner-occupied property
- Member must be in good standing with the utility

Types of Improvements:
- Eligible improvements include: ground source heat pumps that meet or exceed Energy Star 1 efficiency requirements; heat pump water heaters and air source heat pumps that are Energy Star qualified; electric thermal storage (ETS) space and water heating systems with some restrictions.
Quality of Equipment
Quality of Installation
3. What Determines GHP System Benefit?

Examining the main factors that determine GHP economic benefit.
GHP Benefits Determined By:

- Climate (Moderate vs Extreme)
- Current Energy Rates & Inflation
- GHP Capacity to Peak Load
- Adequacy of HVAC Distribution
- System Life Cycle
- Warranty & Service Distance
- Alternative Equipment Cost
- Loan Interest
- GHP System Cost Recovery
Climate Moderate vs Extreme

Annual State Temperature Averages


<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ALASKA</td>
<td>30.1° F</td>
<td>49</td>
</tr>
<tr>
<td>MINNESOTA</td>
<td>38.6° F</td>
<td>48</td>
</tr>
<tr>
<td>NORTH DAKOTA</td>
<td>39.0° F</td>
<td>47</td>
</tr>
<tr>
<td>WISCONSIN</td>
<td>40.2° F</td>
<td>46</td>
</tr>
</tbody>
</table>
Climate Moderate vs Extreme

DULUTH INTL AP, ST. LOUIS COUNTY, MINNESOTA USA
Located at about 46.83°N 92.18°W. Height about 435m / 1427 feet above sea level.

**Heating Degree Days**  9,817

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>998</td>
<td>820</td>
<td>699</td>
<td>440</td>
<td>247</td>
<td>94</td>
<td>33</td>
<td>62</td>
<td>182</td>
<td>366</td>
<td>610</td>
<td>898</td>
<td>5454</td>
</tr>
<tr>
<td>°F</td>
<td>1796</td>
<td>1476</td>
<td>1258</td>
<td>792</td>
<td>445</td>
<td>169</td>
<td>59</td>
<td>112</td>
<td>328</td>
<td>659</td>
<td>1098</td>
<td>1616</td>
<td>9817</td>
</tr>
</tbody>
</table>

**Cooling Degree Days**  180

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>52</td>
<td>40</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>°F</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>71</td>
<td>94</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>180</td>
</tr>
</tbody>
</table>
### Current Energy Rates...

#### Energy Prices (Heating Months)

<table>
<thead>
<tr>
<th>Type</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Electric</td>
<td>0.050 $/kWh</td>
</tr>
<tr>
<td>ASHP Electric</td>
<td>0.000 $/kWh</td>
</tr>
<tr>
<td>GSHP Electric</td>
<td>0.060 $/kWh</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.000 $/ccf</td>
</tr>
<tr>
<td>Propane</td>
<td>2.899 $/gal</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>3.899 $/gal</td>
</tr>
</tbody>
</table>

#### Energy Prices (Cooling Months)

<table>
<thead>
<tr>
<th>Type</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Electric</td>
<td>0.130 $/kWh</td>
</tr>
<tr>
<td>ASHP Electric</td>
<td>0.000 $/kWh</td>
</tr>
<tr>
<td>GSHP Electric</td>
<td>0.130 $/kWh</td>
</tr>
</tbody>
</table>
...and Inflation

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Range in Years</th>
<th>Average Yearly Increase (EIA)</th>
<th>Average Yearly Increase (BLS)</th>
<th>Range in Years</th>
<th>Average Yearly Increase (BLS)</th>
<th>Starting Price (EIA)</th>
<th>Ending Price (EIA)</th>
<th>Price per</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>1967-2010</td>
<td>5.54%</td>
<td>N/A</td>
<td>1979-2011*</td>
<td>4.08%</td>
<td>$1.04 (1967)</td>
<td>$11.20 (2010)</td>
<td>1,000 cu ft</td>
</tr>
<tr>
<td>Electricity</td>
<td>1990-2009</td>
<td>2.05%</td>
<td>2.30%</td>
<td>1979-2010*</td>
<td>3.13%</td>
<td>$0.078 (1990)</td>
<td>$0.115 (2009)</td>
<td>KWH</td>
</tr>
<tr>
<td>Propane</td>
<td>1991-2010</td>
<td>5.60%</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>$0.92 (1991)</td>
<td>$2.59 (2010)</td>
<td>gallon</td>
</tr>
<tr>
<td>#2 Heating Oil</td>
<td>1991-2010</td>
<td>5.54%</td>
<td>5.71%</td>
<td>1979-2010*</td>
<td>4.59%</td>
<td>$1.07 (1991)</td>
<td>$3.00 (2010)</td>
<td>gallon</td>
</tr>
<tr>
<td>CPI**</td>
<td>1990-2011*</td>
<td>N/A</td>
<td>2.64%</td>
<td>1913-2011*</td>
<td>3.24%</td>
<td>$1.30 (1990)</td>
<td>$2.78 (2010)</td>
<td>gallon</td>
</tr>
</tbody>
</table>

Range in years determined by available data
Values for US residential average nation wide
Sources: EIA (U.S. Energy Information Administration), BLS (Bureau of Labor and Statistics)
* 2011 data up to current available
** CPI (Consumer price index)
^ #2 Fuel Oil
GHP Capacity to Peak Load
GHP Capacity to Peak Load

**Heating** *(Peak Load = 73,182 BTUH @ -20°F OAT / 70°F)*

- Heating Capacity: 74,200 Btu/hr
- % Sizing: 101.4%
- % Energy From Geo: 96.3%
- Installed COP: 3.25
- Balance Point Temp.: -19.9 °F
GHP Capacity to Peak Load

Heating (Peak Load = 73,182 BTUH @ -20°F OAT / 70°F)

- Heat Pump Energy Use: 15,003 kWh
- Pumping Energy Use: 529 kWh
- Supplemental Energy Use: 0 kWh
- Dual Fuel Energy Use: 79 gal
## GHP Capacity to Peak Load

### Heating

( IDF @ 0.06 $/kWh w/ LP Backup @ $2.899/gal )

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Cost</td>
<td>$900.23</td>
</tr>
<tr>
<td>Supplemental Cost</td>
<td>$0.00</td>
</tr>
<tr>
<td>Dual Fuel Cost</td>
<td>$232.29</td>
</tr>
<tr>
<td>Pumping Cost</td>
<td>$31.74</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>$1,164.26</strong></td>
</tr>
</tbody>
</table>
• **Cooling-Dominant Derived Rule:** *Do not size GHP heating capacity more than 25% above the cooling load* (impractical?)

• **Manufacturer-Derived Rule:** *Do not size GHP to less than 85% of the peak heating load* (roughly 1 Ton undersizing)

• **Cold Climate Sizing Trend:** *Size to perform 96-100% of all the heating* (but consider sizing scale-back for honest “hardships”)

**GSHP Sizing Rules of Thumb**
4.0<7T Vertically Bored GHP System @ 62.2% GHP Sizing
GHP Capacity to Peak Load

Heating  (Peak Load = 73,167 BTUH @ -20°F OAT / 70°F)

Heating Capacity  45,509 Btu/hr

% Sizing  62.2%

Installed COP  3.71

Balance Point Temp.  10.4 °F
GHP Capacity to Peak Load

Heating  (Peak Load = 73,167 BTUH @ -20°F OAT / 70°F)

- Heat Pump Energy Use: 12,504 kWh
- Pumping Energy Use: 847 kWh
- Supplemental Energy Use: 3,272 kWh
- Dual Fuel Energy Use: 0 gal
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GHP Capacity to Peak Load</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Heating</strong></td>
<td>(Full Residential Electric Rate @ 0.120 $/kWh)</td>
</tr>
<tr>
<td>HP Cost</td>
<td>$1,500.57</td>
</tr>
<tr>
<td>Supplemental Cost</td>
<td>$392.66</td>
</tr>
<tr>
<td>Dual Fuel Cost</td>
<td>$0.00</td>
</tr>
<tr>
<td>Pumping Cost</td>
<td>$101.70</td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td>$1,994.93</td>
</tr>
</tbody>
</table>
Adequacy of Distribution
Adequacy of Distribution

- Low-temp GHP (refrigeration) technology likes to maintain system balance without being called on to perform extreme tasks
- Sufficient and adequately distributed air flow is vital for comfort, as well as proper air coil performance and heat exchange
- Continuous low speed ECM fan is extremely beneficial for air quality, efficiency and comfort!
System Life Cycle

• With the newer GHP technologies, most manufacturers now project a design life 25 to 30 years... if the GHP system is properly designed, installed and maintained

• EPA life cycle rating for geothermal HDPE pipe is 200 years

• Life cycle varies for secondary components, such as circulating pumps, blowers and some electrical parts
Warranty & Service Distance

• To meet Energy Star Tier 3 standards, the EPA now requires GHP manufacturers to warranty all parts and labor for 5 years.

• Many manufacturers also offer an additional 5 years for refrigeration parts only (without labor) and/or “lifetime” compressor.

• Because GHP technology is specialized, non-warranty service work can cost more, and a qualified technician may not be close by.
Alternative Equipment Cost

- Alternative equipment is the heating and cooling equipment that would otherwise be installed at lesser cost (furnace, boiler, AC)

- Conventional HVAC equipment costs vary widely, but there is ultimately some net difference in cost to upgrade to geo'

- GHP system cost recovery calculations must consider alternative equipment costs for a true assessment of GHP economic benefit!
Alternative Equipment Cost

How much more is a GHP system compared to the alternative?
## Alternative Equipment Cost

Cost difference between RH Thermal Storage & 7T GHP system

<table>
<thead>
<tr>
<th>Resistance Heat w/ Central A/C</th>
<th>GSHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Cost $17,421.00</td>
<td>Installation Cost $39,987.00</td>
</tr>
<tr>
<td>Incentives $0.00</td>
<td>Incentives $14,306.00</td>
</tr>
<tr>
<td>Actual Cost $17,421.00</td>
<td>Actual Cost $25,681.00</td>
</tr>
</tbody>
</table>
## Interest

<table>
<thead>
<tr>
<th>Resistance Heat w/ Central A/C</th>
<th>GSHP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Installation Cost</strong></td>
<td>$39,987.00</td>
</tr>
<tr>
<td><strong>Incentives</strong></td>
<td>$14,306.00</td>
</tr>
<tr>
<td><strong>Actual Cost</strong></td>
<td>$25,681.00</td>
</tr>
<tr>
<td><strong>Loan Amount</strong></td>
<td>$25,681.00</td>
</tr>
<tr>
<td><strong>Loan Interest Rate</strong></td>
<td>3.900%</td>
</tr>
<tr>
<td><strong>Loan Term</strong></td>
<td>20 years</td>
</tr>
<tr>
<td><strong>Down Payment</strong></td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>Monthly Payment (P&amp;I only)</strong></td>
<td>$104.65</td>
</tr>
<tr>
<td></td>
<td>$154.27</td>
</tr>
</tbody>
</table>

Cost difference between RH Thermal Storage & 7T GHP system
GHP System Cost Recovery

- **SIMPLE PAYBACK**—how long it takes for the net upgrade cost of the GHP system to be fully recovered using current energy rates

- **SHORT TERM SAVINGS**—snapshot of annual and monthly savings with incremental loan interest taken into account

- **30 YEAR SAVINGS**—difference in cost of ownership between a conventional HVAC system and GHP system over 30 years
### SIMPLE PAYBACK

<table>
<thead>
<tr>
<th>System Type</th>
<th>Heating</th>
<th>Cooling</th>
<th>Hot Water</th>
<th>Total</th>
<th>vs. GSHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Source Heat Pump (GSHP)</td>
<td>$1,164.26</td>
<td>$160.42</td>
<td>$168.17</td>
<td>$1,492.84</td>
<td></td>
</tr>
<tr>
<td>RH</td>
<td>$2,567.85</td>
<td>$150.83</td>
<td>$226.52</td>
<td>$2,945.20</td>
<td>$1,452.36</td>
</tr>
<tr>
<td>Propane</td>
<td>$6,185.92</td>
<td>$150.83</td>
<td>$226.52</td>
<td>$6,563.27</td>
<td>$5,070.43</td>
</tr>
<tr>
<td>Fuel Oil</td>
<td>$6,237.71</td>
<td>$150.83</td>
<td>$226.52</td>
<td>$6,615.06</td>
<td>$5,122.22</td>
</tr>
</tbody>
</table>

- **GHP (IDF)**: $1,492.84
- **RH (Off Peak)**: $2,945.20
- **Propane**: $2.899/gal
- **Fuel Oil**: $3.699/gal
SIMPLE PAYBACK

Simple Payback

<table>
<thead>
<tr>
<th>GSHP Install Cost</th>
<th>$25,681.00</th>
<th>Conventional Install Cost</th>
<th>$17,421.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Operating Cost</td>
<td>$2,945.20</td>
<td>GSHP Operating Cost</td>
<td>$1,492.84</td>
</tr>
</tbody>
</table>

⇒ $8,260.00
⇒ $1,452.36
⇒ Simple Payback Period 5.7 years
<table>
<thead>
<tr>
<th>Short Term Savings</th>
<th>Difference in Monthly Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monthly Operating Savings</strong></td>
<td><strong>Difference in Monthly Payment</strong></td>
</tr>
<tr>
<td>Conventional Op. Cost $245.43</td>
<td>Payment w/ GSHP $154.27</td>
</tr>
<tr>
<td>GSHP Op. Cost $124.40</td>
<td>Payment w/ Conv. $104.65</td>
</tr>
<tr>
<td>Monthly Op. Savings $121.03</td>
<td>Incremental Payment $49.62</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monthly Operating Savings $121.03</th>
<th>Incremental Payment $49.62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Savings w/ GSHP $71.41</td>
<td>12 Annual Savings w/ GSHP $856.92</td>
</tr>
<tr>
<td>Monthly Savings w/ GSHP $71.41</td>
<td>12 Annual Savings w/ GSHP $856.92</td>
</tr>
<tr>
<td></td>
<td>Resistance Heat w/ Central A/C</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Adjusted Install Price</td>
<td>$25,116.51</td>
</tr>
<tr>
<td>Ownership Cost</td>
<td>$165,235.62</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional Ownership Cost</td>
<td>$165,235.62</td>
</tr>
<tr>
<td>30 Year Savings</td>
<td>$57,187.40</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
LIFETIME SAVINGS!

Over 70% of home’s heating energy needs will be FREE forever.
DON'T FORGET...ENVIRONMENTAL "SAVINGS"
RESOURCES:

- Northern GroundSource Inc.  
  www.ColdClimateGeothermal.com
- International Ground Source Heat Pump Association  
  www.igshpa.okstate.edu
- Minnesota Geothermal Heat Pump Association  
  www.MNGHPA.org
- Wisconsin Geothermal Association  
  www.wisgeo.org
- GeoExchange  
  www.GeoExchange.org
- Association of Energy Engineers  
  www.aeeecenter.org