In-Depth Exploration of Ground Source Heat Pump Technologies

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Introduction to Ground Source Heat Pumps
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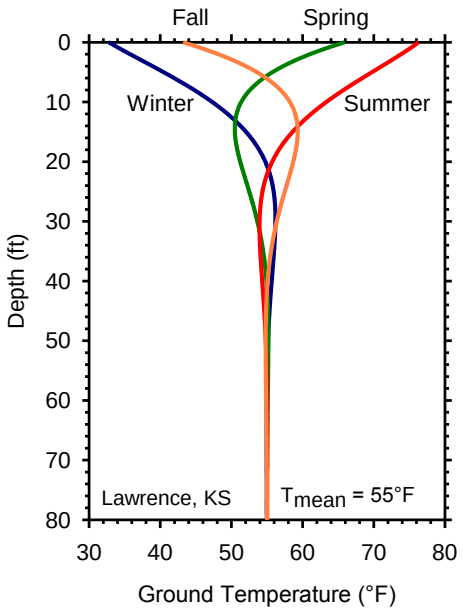
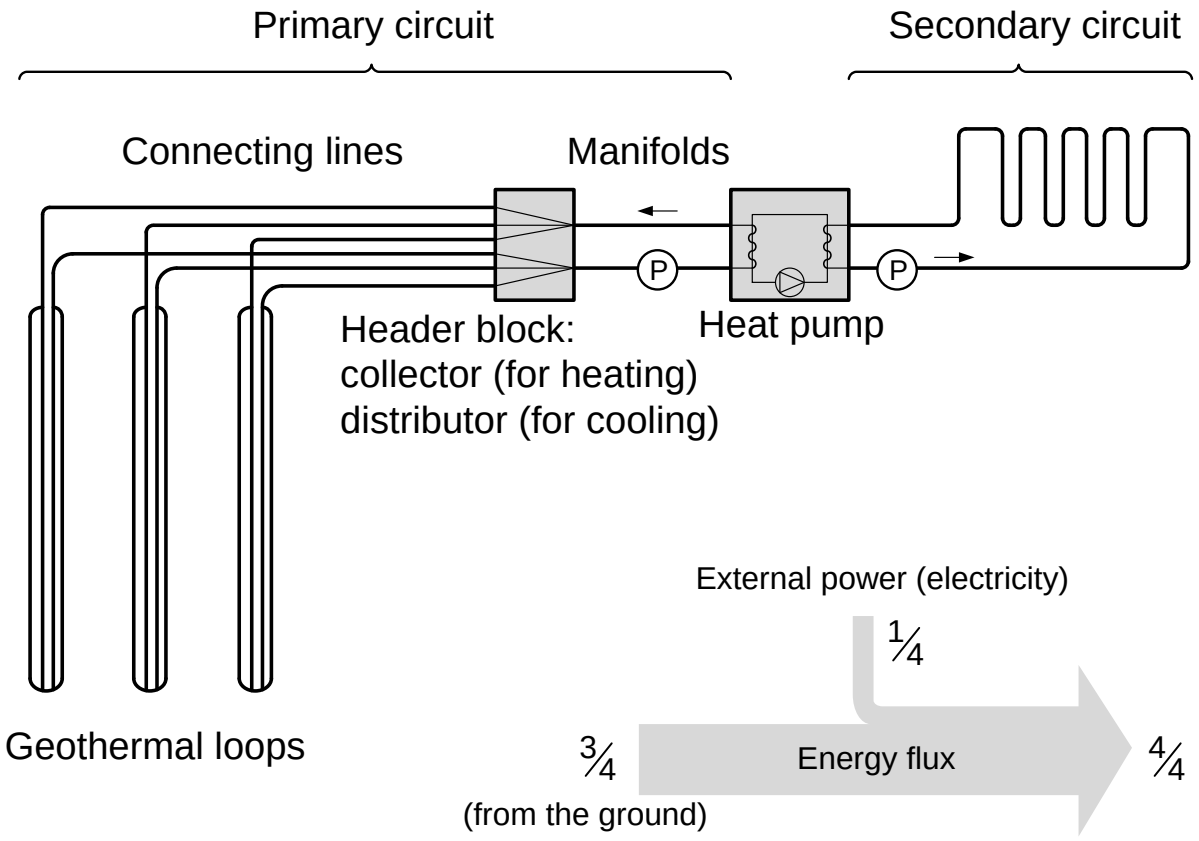
Ground Source Heat Pump Systems





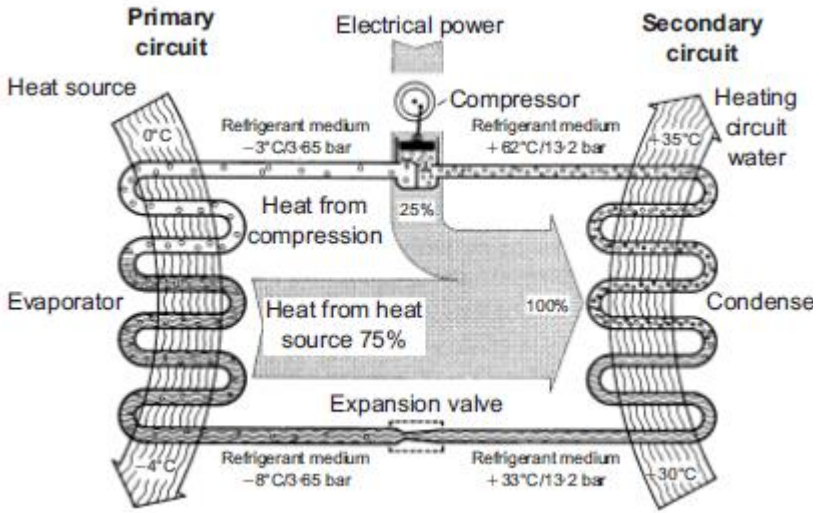
Utilize the relatively constant temperature of the ground and use it for heating in the winter and cooling in the summer

Heat Pump Performance Standards

- EER (Energy Efficiency Ratio)
  - Cooling capacity (in Btu/hour) of the unit divided by its electrical input (in watts) at standard (ARI/ISO 13256-1) conditions of 77F entering water for closed loop models and 59F entering water for open loop systems.
- COP (Coefficient of Performance)
  - Heating capacity (in Btu/hour) of the unit divided by its electrical input (also in Btu/h) at standard (ARI/ISO 13256-1) conditions of 32F entering water for closed loop models and 50F entering water for open loop equipment.

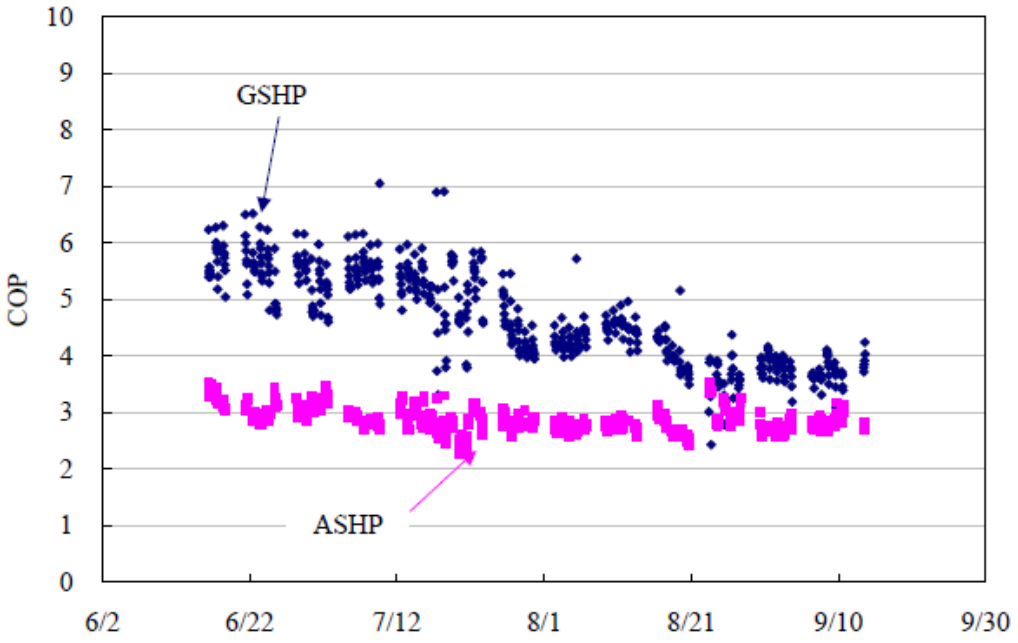
Ratings are only used as a measure to compare one GSHP to another, and do not reflect actual performance

Efficiency of GSHP Systems



(Brandl 2006)

$$\mathrm{COP} = \frac{\text{energy output after heat pump [kW]}}{\text{energy input for operation [kW]}}$$



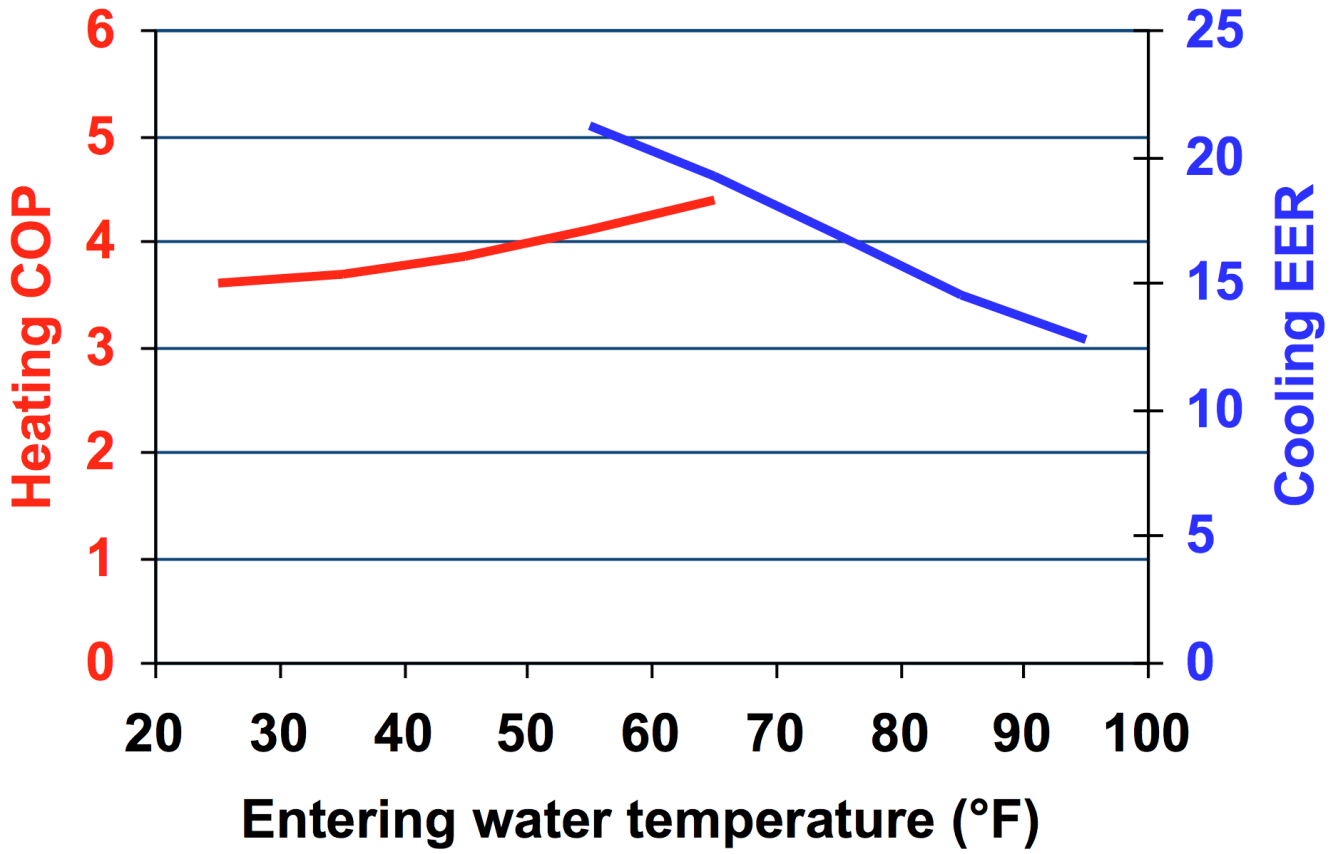
Ooka et al. (2007)

Efficiency of heat pump systems is influenced by the temperature differential between heat source and sink

Selecting the Most Energy-Efficient GSHP

- Choose models that qualify for the Energy Star label
  - Open Loop: >=3.6 COP (H); >=16.2 EER (C)
  - Closed Loop: >=3.3 COP (H); >=14.1 EER (C)
- Most efficient models have dual-speed compressor systems and increased heat exchange area, and thus cost significantly more

Heat Pump Efficiency and Entering Water Temperature



Source: Shonder, ORNL

Inside the Building

- Design similar to any conventional HVAC system
- Determine peak heating and peak cooling load for the building
- Select heat pumps to meet design loads (remember that capacity depends on entering water temperature)
- Heat pumps should be located with due consideration for serviceability
- Size ventilation system components: ductwork, fans, preheating coils, etc.

For retrofits, existing equipment (ductwork) greatly influences cost-effectiveness of GSHP

Outside the Building: Site Evaluation

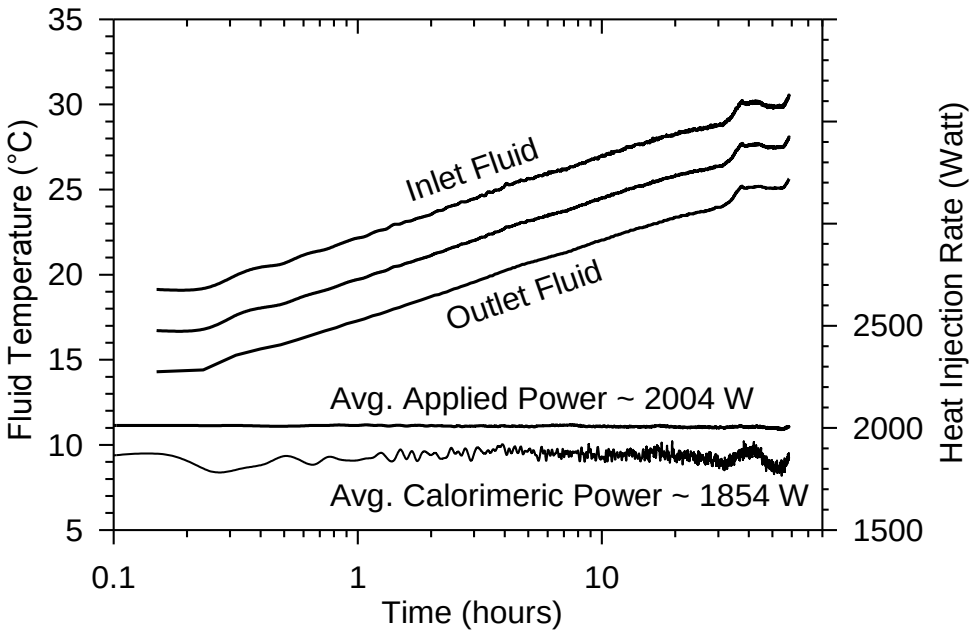
Tests are Required for Commercial-Sized Systems

- Vertical Ground Coupled: Thermal Conductivity Test
  - Measures in-situ ground temperature as well
  - Important for loop field design
- Groundwater: Well Test
  - Water flow
  - Water quality (including chemistry)

Using “rules of thumb” are not recommended

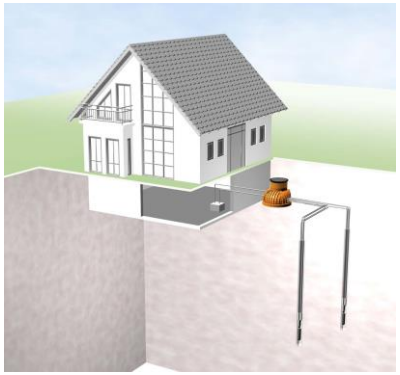
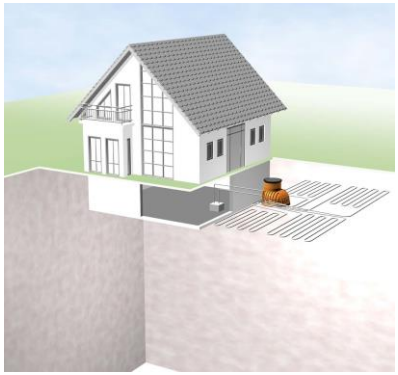
Source: Shonder, ORNL

Thermal Conductivity Testing



Inject heat into the ground at a constant rate and monitor temperature increase rate to evaluate thermal conductivity

Performance of GSHP Systems

	Vertical	Horizontal	Energy Pile
			
Poor ground quality	26 Btu/hr-ft	3.2 Btu/hr-ft²	26 Btu/hr-ft
Average ground quality	52 Btu/hr-ft	8 Btu/hr-ft²	52 Btu/hr-ft
Excellent ground quality	83 Btu/hr-ft	13 Btu/hr-ft²	83 Btu/hr-ft

1Btu/hr ~ 0.3W

Performance of GSHP Systems

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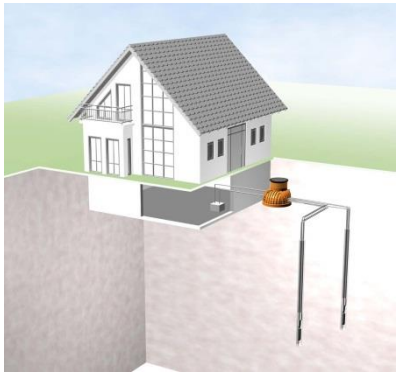
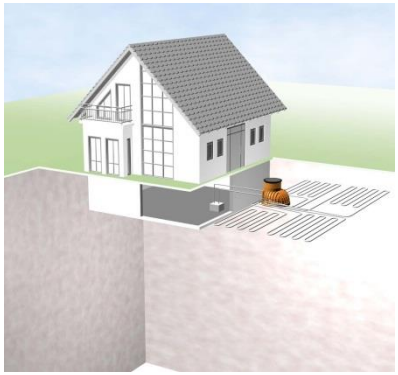
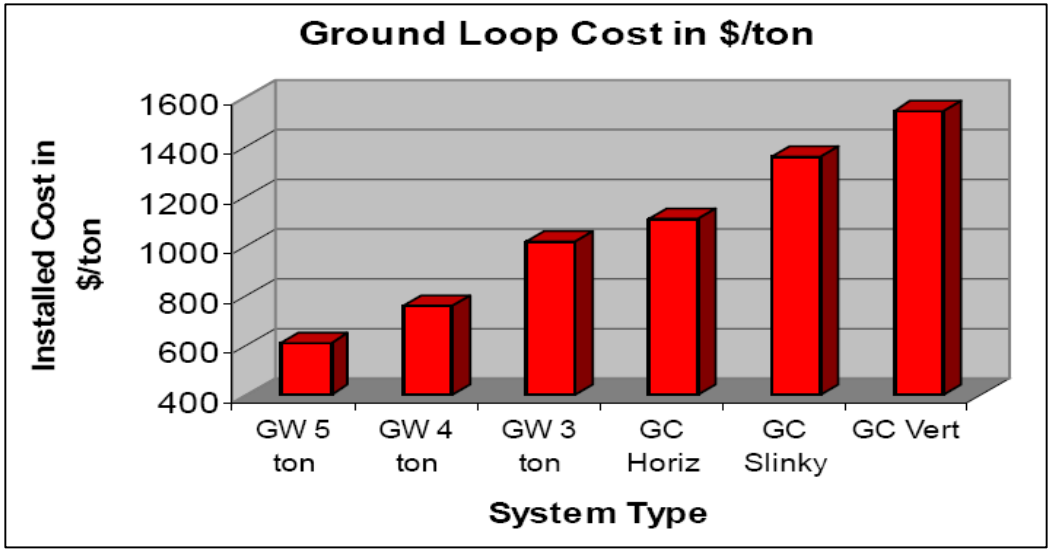
			
Poor ground quality	8 W/ft	1 W/ft²	8 W/ft
Average ground quality	15 W/ft	2.5 W/ft²	15 W/ft
Excellent ground quality	25 W/ft	4 W/ft²	25 W/ft

1W ~ 3.4Btu/hr

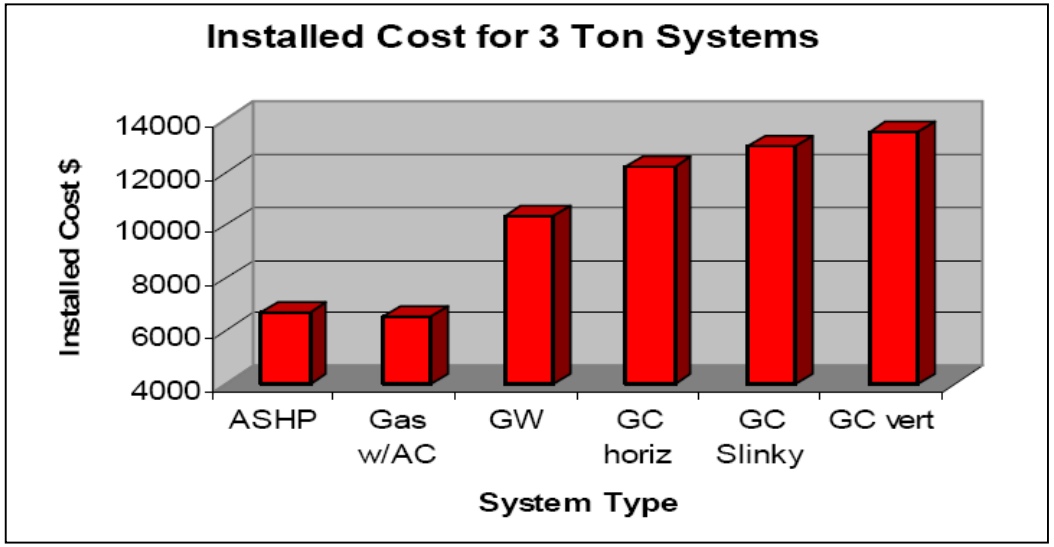
Example GSHP Design

- Performance depends on many site-specific factors, such as soil type (thermal conductivity is key!), ground water depth, initial ground temperature
- Best conditions are saturated sands and clays, especially with ground water flow
- Thermal yield from an energy pile under favorable (i.e. high thermal conductivity) ground conditions ~25W/ft
- Say heating/cooling load for this building is about 20 kW or less
- Assuming good soil conditions, and using 100-ft long geothermal boreholes
- We would need about 8 boreholes to supply heating and cooling needs for such a building

Residential Installation Costs



Source: An Information Survival Kit: For the Prospective Geothermal Heat Pump Owner, Rafferty, for Heat Spring Energy, 2008, http://www.heatspring.com/downloads/intro/GeothermalSurvivalKit.pdf



Residential Installation Cost from Indiana Study

Tons	Total Systems	Heat Pump only
2	$12,285	$8,400
2.5	$13,483	$7,922
3	$13,719	$9,465
3.5	$13,297	$9,959
4	$13,969	$9,765
5	$16,865	$11,188
Total	$14,278	$9,990

Note: Indiana has a mature GSHP industry.

Source: Indiana Residential Geothermal Heat Pump Rebate: Program Review, 2008, http://www.in.gov/oed/files/GHPProgramreport.pdf

Residential GSHP Costs

- Installation costs:
  - $20K to $30K for a 3-4 ton system
  - Viewed as the primary barrier
  - Much higher than the new generation of high efficiency air source heat pumps and gas furnaces
- Energy cost savings:
  - Most significant when replacing electric resistance or heating oil
  - Marginal to no savings when compared high efficiency air source heat pumps and gas furnaces/AC systems
  - Highly dependent on the price of electricity vs natural gas/heating oil

Residential Case Study (1997) – Hartford, CT

- New Construction (well-insulated, tightly sealed building envelope)
- Heating Load – 49,614 Btu/hr
- Cooling Load – 30,568 Btu/hr
- Closed loop vertical – 2x250ft boreholes
- 4.2 ton heat pump
- Total cost - $19,283 (includes ductwork)
- Northeast Utilities Rebate - $2,971 ($713/ton)
- Oil-fired furnace/electric AC cost estimate - $16,200

Annual Operating Cost Estimates (Simulated performance)	
GHP w/ dual fuel back-up	$1,410
Oil-fired furnace & Electric AC	$1,570
Gas-fired furnace & Electric AC	$1,441
Electric Resistance	$3,839

Source: Geothermal Heat Pump Consortium

ASHRAE Case Studies (vertical, closed-loop)

Building Type **Building Size** **System Size** **System Type**	**Borehole depth** **Borehole $** **Bedrock depth** **Bedrock type**	**GSHP Cap. $** **Conventional Cap.$** **Annual Op Savings $** **Simple payback period**
Golf Clubhouse 15,000 sq ft 25.5 tons Vertical, Closed	600ft (4), 300ft (2) $3.00/ft 20ft Limestone	$40,000 $32,900 $2,790 2.5 years
Hotel 39,900 sq ft 97 tons Vertical, Closed	300ft (30) $6.88/ft 75ft Granite	$269,380 $200,575 $9,844 7.0 years
Education Center 8,000 sq ft 24 tons Vertical, Closed	250ft (16) $7.38/ft 0ft Granite	$75,000 $34,500 $6,161 6.6 years

Source: Operating Experiences with Commercial Ground-Source Heat Pump Systems, ASHRAE, 1998

Thank You !