Introductory Overview of Ground Source Heat Pump Technologies

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Introduction to Ground Source Heat Pumps
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Outline

- Background
  - Energy demand
  - Geothermal systems
- State of the GSHP industry
- Types of GSHP systems
  - Closed loop systems
  - Open loop systems
Learning Objectives

- Gain background on ground source heat pump (GSHP) systems
- Identify the basic principles of GSHP systems
- Identify different GSHP systems (closed loop vs. open loop, vertical vs. horizontal loop systems)
- Discuss advantages and disadvantages of GSHP systems
- Discuss cost related information on GSHP systems
- Learn about different applications of GSHP systems
Significant energy consumption in buildings mainly for heating and cooling

Lawrence Livermore National Lab (2009)

U.S. Energy Flow Chart

VirginiaTech
U.S. Geothermal Resources & Projects
Temperatures above 212°F
Temperatures below 212°F
Suitable for geothermal heat exchange (entire U.S.)
What is a Ground Source Heat Pump (GSHP)?

- GSHP is an electrically powered system that utilizes the relatively constant ground or groundwater temperatures to provide heating, cooling, and hot water.
- Instead of burning fossil fuels to create heat like conventional systems, GSHPs move heat that already exists.
- In heating mode, a GSHP moves heat from the ground or groundwater into the building.
- In cooling mode, a GSHP moves heat from the building and deposits it into the ground or groundwater.
Ground Source Heat Pump Systems

1. Ground or groundwater heat exchanger
2. Heat pump
3. Interior heating/cooling distribution system
4. Domestic hot water heating (optional)
Ground Temperature Profile

Mean ground temperature

Temperature (°F)

Richmond, VA

T_{mean} = 59°F
Ground Temperature Profile

Ground temperature fluctuations

Ground Temperature (°C)
30
40
50
60
70
80
Day of the Year
0 30 60 90 120 150 180 210 240 270 300 330 360
Ground Surface
5 ft
10 ft
50 ft

Ground Temperature (°F)
35
40
45
50
55
60
65
70
75
80
85
Depth (ft)
0
10
20
30
40
50
60
70
80

Richmond, VA
T_{mean} = 59°F

Ground temperature fluctuations
Mean ground temperature
Ground Temperature Profile

Mean ground temperature

Baltimore, MD  $T_{mean} = 57^\circ F$
Ground Temperature Profile

Mean ground temperature
Ground Temperature Profile

Mean ground temperature

\[ T_{\text{mean}} = 72^\circ \text{F} \]

Houston, TX
Terminology

- Ground source heat pumps (GSHP)
- Geothermal heat pumps (GHP)
- Ground coupled heat pumps (GCHP)
- GeoExchange systems
- Earth energy systems
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.
Geothermal heat exchange systems provide ground-source energy for heating and cooling.

The use of ground-source systems for heating and cooling has increased exponentially especially in Europe.

Basic idea been around for long time – make use of the heat energy stored in the ground; access this energy using heat exchangers buried in the ground (fluid-filled HDPE loops).

In ideal conditions these systems can provide majority of required heating/cooling energy and significantly reduce costs and carbon footprint.
Common Comments on GSHPs

**Advantages**
- High efficiency results in lower energy consumption cost
- Lower maintenance cost
- Lower life cycle cost
- No outdoor equipment
- Greater occupant comfort
- All electric - can be powered by renewable energy

**Disadvantages**
- First cost can be significantly higher than conventional systems
- Not all system types feasible in all locations
- Limited pool of qualified designers and installers in many locations
GSHP Domestic Shipments, 2002-2006

GSHP Domestic Shipments, 2002-2006

GSHP: Closed Loop Systems

- Borehole Wells
- Horizontal Loops
- Helical Coils
- Energy Piles
Open Loop Systems

Groundwater Heat Pumps (GWHP)
a.k.a. open loop heat pumps

- Two well
- Single well

Surface Water Heat Pumps (SWHP)
a.k.a. lake or pond loop heat pumps

- Indirect
- Direct

Source: eere.energy.gov
Barriers to wider GSHP Implementation

- Tend to have significantly higher first costs compared with conventional systems
- Generally longer paybacks when replacing natural gas heating systems
- Lack of awareness
- Lack of uniform standards – design and installation accreditation has yet to receive nationally standardized accreditation
- Shortage of qualified designers and installers.
GSHP : Closed Loop Systems

- Borehole Wells
- Horizontal Loops
- Helical Coils
- Energy Piles
Borehole Wells

- 200 ft - 500 ft deep
- Small residential to large commercial

Major cost is drilling and materials
Borehole Wells
Borehole Wells – Design Considerations

- Spacing
- Grout Type
- Single U-bend or Double U-bend
- Ground properties:
  - Temperature
  - Thermal conductivity
  - Thermal diffusivity

Ground water

Long-term effects
Helical Coils
Energy Piles
# Vertical Ground Source Heat Pump Systems

Piping is inserted to deep vertical boreholes. Boreholes are grouted to improve heat transfer and protect groundwater.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires less land than other closed loop systems</td>
<td>Higher initial cost due to the drilling of boreholes</td>
</tr>
<tr>
<td>Requires smaller amounts of pipe and pumping energy</td>
<td>Problems in some geological formations (an issue in parts of MA)</td>
</tr>
<tr>
<td>Likely to yield the most efficient performance of closed loop systems</td>
<td>Limited availability of experienced drillers and installers</td>
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GSHP: Closed Loop Systems

- Borehole Wells
- Horizontal Loops
- Helical Coils
- Energy Piles
Horizontal Loops

6-10 ft
Horizontal Loops

- Soil properties:
  - Temperature (seasonal variation)
  - Thermal conductivity
  - Thermal diffusivity

- Pipe configuration:
  - Straight
  - Horizontal Slinky
  - Vertical Slinky

- Spacing

- Shallow ground water
Horizontal Loops

Recently built house in Blacksburg VA with a trench loop system
Horizontal Loops

Horizontal loop systems within/beneath slabs
Horizontal Loops

Energy slab (Messe U2 metro station, Vienna)
Horizontal Loops – Deicing
Horizontal Ground Source Heat Pump Systems

Placement of straight or “slinky” piping in shallow (6-8ft) horizontal trenches.

Advantages
- Likely less expensive to install vertical closed loop
- Requires less specialized skill and equipment to install, so contractors are more widely available

Disadvantages
- Need more space
- Ground temperature and thermal properties fluctuate with season, rainfall, and burial depth
- Lower efficiency
Open Loop Systems

Groundwater Heat Pumps (GWHP)
a.k.a. open loop heat pumps

- Two well
- Single well

Surface Water Heat Pumps (SWHP)
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Disposal to lake, pond, river, creek, etc.
Open Well Systems

- Heat exchange rate is enhanced by the pumping action
- Often utilized where little land is available or the bedrock is close to the surface
- During peak heating and cooling, the system can use a bleed cycle to control the column temperature

Water is pumped from bottom of well and re-injected at the top

Groundwater Heat Pump Systems

Uses groundwater as heat sink and source. Water is pumped through the system, then discharged.

**Advantages**
- Have the lowest installed cost, especially in larger applications
- Uses less space
- Well water contractors are widely available
- Long track record in large commercial applications

**Disadvantages**
- Local water and environmental regulations may restrict use
- Limited water availability
- May need fouling precautions
- High pumping energy required if system poorly designed or water pulled from deep aquifer

Source: 2003 ASHRAE Applications Handbook
The piping is anchored to the bottom of a nearby body of water

**Advantages**
- Low cost due to reduced excavation costs
- Low maintenance
- Low operating costs

**Disadvantages**
- Possible damage to piping in public lakes
- Significant temperature variation if lake is small/shallow
Hybrid Systems

- Use several different geothermal resources, or a combination of a geothermal resource with outdoor air (most often, a cooling tower)
- Particularly effective where cooling needs are significantly larger than heating needs.
- Cooling tower used to reject excess heat
- Main benefits:
  - Reduces loop field size, and thus costs, by allowing for the ground loop to be undersized for the cool load, but sized for the smaller heating load
  - Avoid increase in ground temperature due to seasonal load imbalances

Thank You !