Geothermal 101:
Ground Sourced Heat Pumps for Beginners

NY-GEO 2019 Conference
Geothermal Systems Module 1

Attendees will learn by the end of this presentation to understand the operation, context and verbiage of geothermal HVAC systems.
Learning Objectives for Students & Design Professionals:

1. Understand the context and verbiage of the (geothermal) clean heating and cooling technology

2. Identify the importance, adaptability, and benefits of the technology as vital to infrastructure and building construction

3. Understand why the technology is important to health, human safety, and imperative industry goals

4. Internalize our collective capability and responsibility to make these changes

5. Leave with the intent to offer, specify, & apply the technology in every application going forward
A geothermal system utilizes all types of heat transfer

- Distribution System
- Heat Pump
- Ground Loop Exchanger
Applying Thermodynamics to Indoor Thermal Comfort

**Radiation**
At a campfire, face and hands are warmed by radiant heat.

**Convection**
Using forced air to transfer heat, as in a hair dryer, is called convection.

**Conduction**
Like sodas in a cooler full of ice, conduction is an efficient way to cool or heat.

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A Building can use these heat transfer mediums

- Wall radiators
- Forced air
- In floor heating
Measuring Performance Thresholds Coefficient of Performance (COP)

- Electric Resistance Heating
- Engages when temperatures outside are cold
- Efficiency (COP = 1)

1 kW of Electricity = 1 kW of Heat = COP of 1
A Water Pump is like a Heat Pump

Water is not available for our use until it’s pumped out of the Earth. Similarly, the heat in the Earth needs to be pumped out for our use. That is the purpose of a geothermal heat pump; to pump heat.
Learning about geothermal heat pumps

• Just like a water-pump is used to “pump” water up into a building...
• A geothermal system “pumps” solar heat stored in the ground “up” into their home
• It “pumps heat” in or out of the home, depending on summer or winter weather conditions
How to cool & heat spaces by “pumping heat” - exactly like a refrigerator

Heat Pump = about 3.0 to 5.0 + COP
The Basics of Geothermal Exchange

• A geothermal heat pump 4 units of solar energy out of the Earth, while using only one unit of energy for the heat pump (5.0 COP)

• For a 3 ton, the **geothermal heat pump is producing/delivering** **8.4 kWh** of net-energy (every hour)

A 3 ton GHP produces **8.4 kWh** each hour that it runs (5.0 COP)

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Understanding the refrigeration cycle in a GHP

Animated Heat Pump Cycle
https://youtu.be/cGyEUZVGpxw
Less Energy required to move BTUs in Water

- A $\frac{3}{4}”$ pipe can effectively carry the same cooling and heating energy as an 8” X 14” air duct
- Construction is simplified and space is optimized
- Energy is saved in pumping vs. fan power
- Almost 10x more energy is lost through the walls of the duct
Low Viscosity + Health and Safety = Solutions

• Water alone is the best vehicle for carrying BTU energy.

• As glycol is added, the “Prandtl Number” goes up, denoting decreased heat transfer efficiency. Safe products like Propylene Glycol [PG] (or similar safety profiles/properties) can have superior heat transfer efficiency and lower viscosity (especially at cold temps) for hydronic systems.
NYSERDA is testing products that will protect the Environment & save energy

Kilfrost GEO® and GEO® Plus
Revolutionary Low Viscosity Heat Transfer Fluids

Direct replacement for traditional systems
Includes rheology modifiers resulting in low viscosity profile
FDA GRAS (Generally Regarded as Safe) fluid chemistry
Non-toxic, Non-petroleum based and low environmental impact
Kilfrost GEO® Plus is NSF certified and is the worry-free option
Understanding efficiency; the ASHRAE Building in Atlanta

Ground-coupled HPs consume less energy than air-source HPs

Power Consumption at ASHRAE Bldg, Atlanta

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Benefits of Geothermal Heating and Cooling

- Utility Benefits
  - Highly efficient heating and cooling systems.
  - Potentially a cost-effective option to defer capital commitment for utility gas and electric infrastructure.
  - Reduces electric peak demand, improves load factor and improves the efficiency of the electric delivery system.
  - Gas peak load reductions.

Air Source Heat-Pumps tend to “peak” in the winter, as well as the summer

Combination Gas-Heat & Electric-Cooling Peaks in the Summer

Ground Source Heat-Pumps Shave Both Summer and Winter Peaks
Reforming the Energy Vision (REV)

2030 Goals

40% Reduction in GHG emissions from 1990 levels

Reducing greenhouse gas (GHG) emissions from the energy sector—power generation, industry, buildings, and transportation—is critical to protecting the health and welfare of New Yorkers and reaching the longer term goal of decreasing total carbon emissions 80% by 2050.
Emissions Comparison Between Combustion and Electric Heat Pumps

The Electric Grid is “Greening” Continuously
Assessment of National Benefits from Retrofitting Existing Single-Family Homes with Ground Source Heat Pump Systems

Table E-1. Potential Benefits of Retrofitting Existing U.S. Single-Family Homes with State-of-the-Art GHP Systems at Various Market Penetration Rates

<table>
<thead>
<tr>
<th>Estimated national benefits</th>
<th>Market penetration rate of GHP retrofit</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>20%</td>
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<tr>
<td>Primary energy savings [quad BTU]</td>
<td>0.8</td>
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<tr>
<td>Percentage savings</td>
<td>9.0%</td>
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<tr>
<td>CO2 emissions reduction [MM ton]</td>
<td>54.3</td>
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<tr>
<td>Percentage savings</td>
<td>9.1%</td>
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<tr>
<td>Summer peak electrical demand reduction [GW]</td>
<td>43.2</td>
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<tr>
<td>Percentage savings</td>
<td>11.2%</td>
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<tr>
<td>Energy expenditures savings [Billion $]</td>
<td>10.4</td>
</tr>
<tr>
<td>Percentage savings</td>
<td>9.6%</td>
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</tbody>
</table>

Notes: (MM ton, million metric ton).
With **GHP** Technology, we eliminate peaks, and add load in the Winter

A Geothermal System:
- Reduces Summer Peak Electric Load
- Adds Winter Base Electric Load

Makes good use of electrical infrastructure
Understanding heating and cooling loads
Manual and Simplified

Manual Heat Load Calculations

The first calculations to determine the amount of heating or cooling needed for a space were done manually. The equation for calculating heat transfer through a building element can be expressed as the steady state single dimensional heat transfer equation of...

\[ DQ = U \times A \times (T1 - T2), \]

...where DQ is the amount of heat needed, U is a measurement of the resistance to heat flow of each different type of building material, A represents the area of the wall, window, roof, door, or other building component, and T1 – T2, commonly referred to as the “delta T” (DT), is the temperature difference between the desired inside temperature and the historical outdoor design temperature.
The effect of ventilation, infiltration and heat transfer

Figure 8-21  Occupant comfort is a result of a good HVAC system.
Software based heat gain and loss programs

- Climate zone is identified
- Physical orientation (N,S,E,W)
- Each zone is identified
- Building materials and associated R-values
- Windows, doors, adjacent walls
- Internal gains
- Sensible and Latent loads are calculated
- Hourly calculations for commercial loads
- ANSI/CSA C448-Series-16.
Infiltration occurs when the building has leaks. Some examples—

Three external loads—transmission, ventilation and infiltration—are primarily a function of the difference between indoor and outdoor temperature.

Since the outdoor temperature will vary, these loads may be either a heat loss (requiring heating energy to compensate) or a heat gain (requiring cooling energy to compensate).

-These are opportunities to save energy!
Deeper Dive - Efficiency Ratings: EER and COP

• Energy Efficiency Rating (EER) is often used for Cooling Efficiency
• EER is the Net Cooling Capacity/Applied Energy in watts

• Coefficient of Performance (COP) is often used for Heating Efficiency
• COP is the BTUs delivered/BTUs consumed

EER = COP x 3.412

1 watt of electricity = 3.412 BTU
Efficiency Ratings: COP

A “Heat Pump” “Pumps Heat” Into the building

- 3 ton GHP = 36000 BTUH
- Consumes 7200 BTUH, or 2110 watts (7200/3.412)
- Delivers 36,000 BTU, or 10,550 watts of heat
- 36,000/7200= 5.0 COP
- 5.0 COP(×3.412)=17 EER
- This 3 ton GHP generates 10550-2110= 8440 watts of energy each hour it runs
Efficiency Rating: EER

- EER = COP x 3.412
- 1 watt of electricity = 3.412 BTU

- 3 ton GHP = 36000 BTUH
- Consumes 2110 watts
- Moves 36,000 BTU, or 10,550 Watts back into the Earth
- $36,000 \text{ BTU}/2110 \text{ w} = 17 \text{ EER}$
- $17 \text{ EER}/3.412 = 5 \text{ COP}$
Animated Heat Pump Cycle
# Understanding efficiency (COP Factors)

<table>
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<tr>
<th>Equipment</th>
<th>EER</th>
<th>IEER</th>
<th>IPLV</th>
<th>HSPF</th>
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<td>Air-cooled condensing units</td>
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<td>Constant speed</td>
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<td>Variable speed</td>
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<tr>
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<td>Constant speed</td>
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<td>26°</td>
<td>19°</td>
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<tr>
<td>Variable speed</td>
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<td>31°</td>
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<td>Geothermal heat pumps</td>
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<td>33°</td>
<td>15°</td>
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<td>32°</td>
<td>14°</td>
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<table>
<thead>
<tr>
<th>Type</th>
<th>Size of System (Cooling Power)</th>
<th>Minimum Efficiency</th>
<th>Input power, kW^d</th>
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<td>BTU/h</td>
<td>kW^b</td>
<td>Tons^c</td>
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<td>&lt;30,000</td>
<td>&lt;8.8</td>
<td>2.5</td>
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<tr>
<td>Small duct, high velocity air cooled air conditioner</td>
<td>&lt;65,000</td>
<td>&lt;19</td>
<td>&lt;5.4</td>
</tr>
<tr>
<td>Other air cooled air conditioners</td>
<td>&lt;65,000</td>
<td>&lt;19</td>
<td>&lt;5.4</td>
</tr>
<tr>
<td>Other air cooled air conditioners</td>
<td>65k ~ 135k</td>
<td>19 ~ 40</td>
<td>5.4 ~ 11.3</td>
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<td>135k ~ 240k</td>
<td>40 ~ 70</td>
<td>11.3 ~ 20</td>
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<td>240k ~ 760k</td>
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<td>&gt;760,000</td>
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<td>&gt;63</td>
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<td>Water cooled air conditioners</td>
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<td>&lt;19</td>
<td>&lt;5.4</td>
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<td>Water cooled air conditioners</td>
<td>65k ~ 135k</td>
<td>19 ~ 40</td>
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<tr>
<td>Water cooled air conditioners</td>
<td>&gt;135,000</td>
<td>&gt;40</td>
<td>&gt;11.3</td>
</tr>
</tbody>
</table>
A typical vertical installation on a small plot

Vertical Closed Loop (tight spot)
A single GHP installed for 3 floors

Ground Source Heat Pump

Flow Center

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Residence After Installation of Loop

Net Zero Energy
Equipment is All-Inside and out of the weather

• No more outdoor equipment to replace
• More hurricane and storm resilient (no HVAC equipment outside)
• HVAC system longevity (a benefit of having equipment inside)
• No combustion or electric strip heating
• Noticeably superior comfort and heating and cooling modes
• Remarkable system efficiency at standard equipment pricing
• Geothermal Wells are permanent infrastructure
Variations Earth Loop Systems

Attendees will become familiar with the primary functions of the earth loop/exchanger, and understand how it serves the HVAC equipment.
Solar Energy in the Earth

What Energy Source is Feeding Your Geothermal Heat Pump?
Earth is a collector of solar energy

The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both additive components (in and out) and

Incoming solar radiation 340.4
Reflect by clouds & atmosphere 77.0
Reflect by surface 22.9
XII: reflected solar radiation 80.9
Absorbed by atmosphere 165.9
Absorbed by surface 238.2
Emit by atmosphere 159.9
Emit by surface 29.9

The Earth's energy budget describes the various kinds and amounts of energy that enter and leave the Earth system. It includes both additive components (in and out) and

Comparison of Energy Inputs to Earth's Climate System

www.nasa.gov

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The Earth stores solar energy like a battery

Earth is a BIG Solar Battery
Above 1000’ in depth, solar is dominant

- Below the ground, there are seasonal variations for the first 50 feet, and then the temperature stabilizes and remains constant to a depth at which the temperature starts increasing incrementally.

- Real deep impact starts about 1000’.

- A little math: NASA says the earth absorbs 163.3 W/m², while the steady flow from Earth’s interior (the “hot” core) is 0.09 W/m². That’s a ratio of 1814 to 1 in favor of Solar Energy dominance as a source for geothermal heat pumps. [http://science-edu.larc.nasa.gov/energy_budget/](http://science-edu.larc.nasa.gov/energy_budget/)
We Harvest Solar Energy with a GHP
The GHP Increases and Decreases Energy Density (Carnot Cycle)

Compressor changes (increases) the temperature by design

Geothermal “Heat-Pump”

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Architecture of closed loop systems

**Figure 5-1** The three types of closed-loop systems are horizontal, vertical, and surface water. (Sarah Cheney.)
Horizontal ground loops

Figure 5-2  Several types of horizontal ground loops can be considered, each requiring a different set of engineering criteria. (Artwork: Sarah Cheney; photograph: Geofinity.)
Understanding Earth Loop Systems
Vertical ground loops

- Borehole
- HDPE and “U” Bend
- Backfilled with grout
- Grout is a plastic concrete like material that ensures sealing of the borehole to protect the aquifers below from contamination, and facilitates heat transfer from the pipe material to the surrounding Earth.

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What’s happening below the surface:

- During the winter time, your geothermal heat pump is extracting heat from the Earth all winter long. During that time, the Earth surrounding the ground Loop cools in some degree.
- By the end of the summer, the Earth around the ground Loops is warmed to some degree.
- This is seasonal thermal energy storage.
Open Loop “Pump-to-Injection” = Class V
Open Loops, SCW need less borehole; here’s why:

**Figure 3-4** Standing-column wells use conductive and advective heat transfer. In a standing-column well system, 60 to 80 ft/ton of borehole is typically required with a 10 percent periodic bleed. A bleed line is favorable. (Sarah Cheney.)

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Measuring soil thermal conductivity

Watts per meter-Kelvin or ‘K’ value
Direct Exchange also saves borehole costs

- Refrigerant Piping goes into the earth
- Utilizes less borehole per ton than water based closed loop
- NYSERDA Provides Incentives
- Federal Gov’t provides tax credit
Water Sourced Equip & Thermal load sharing

Thermal Advantage:

• In the process of extracting heat from the earth loop for the elephants, the geothermal heat pump is extracting heat, the same heat that has just been pulled out of the Polar Bear exhibit. This is essentially a dynamic, seemingly “perpetual” use and reuse of thermal loads or, “thermal load sharing”.

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Basic components of geothermal heat pumps

Focus on component quality

- Cabinet
- Sound levels
- Compressor
- Fan
- Drain pan
- Valves
- Pumps
Typical Piping

Not yet insulated to show typical construction.

Vertical Water-to-Air GHP

Horizontal Water-to-Air GHP
Domestic hot water options

Use of a buffer tank significantly improves the performance of hot water generators.
GHPs to fit every type of structure
GHPs to fit every type of structure

Replacement Roof Top GHPs

All Inside 100% Fresh Air (DOAS)

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Various Geothermal Heat Pumps

Vertical GHP (water-to-air GHP)

Pool GHP (water-to-water GHP)

Dedicated Hot Water GHP (water-to-water GHP)
Environments for ground-loop systems: beneath yards, fields, parking lots and buildings
Thank You