GEOTHERMAL

Harnessing the Power of the Earth

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Geological, Environmental, Water Supply, Geotechnical & Mapping Services

Environmental Management Assistance Program

SBDC PENNSYLVANIA

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Introduction

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- 10% annual increase of geothermal systems in past ten years
- 46% Vertical closed Loop system, 38% horizontal closed loop and 15% Open loop
- Competitive when operating costs are included in a life cycle cost analysis
- 37% to 48% lower energy consumption
- 25% greater life expectancy
- 4 to 6.8 year ROI depending on current systems

Introduction

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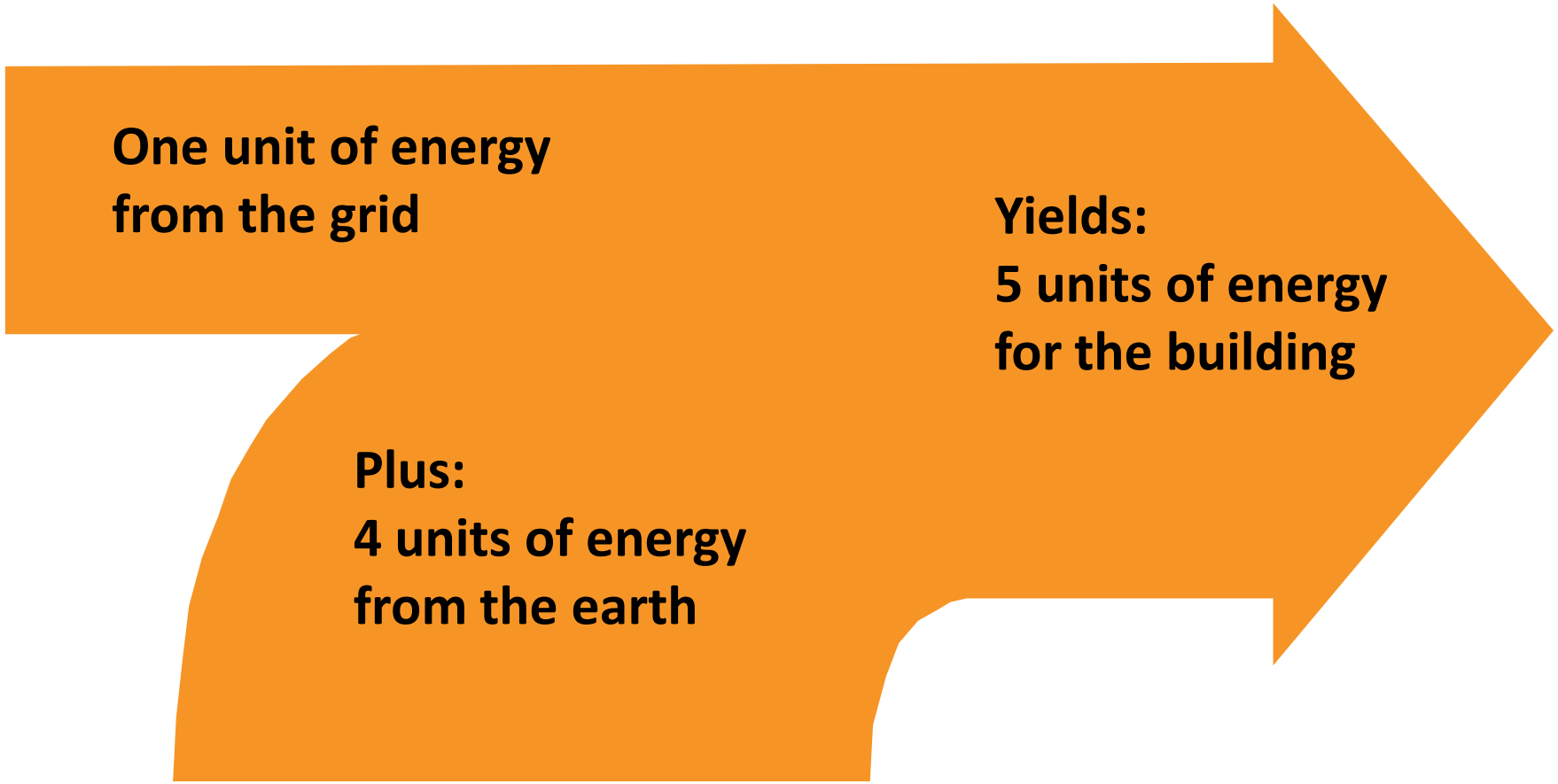

Introduction

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Advantages

- Energy efficiency
- Simplicity
- Low maintenance
- Water heating
- No auxiliary heat (in most cases)
- No outdoor equipment
- Packaged equipment
- Environmentally "green"
- Lowers peak demand
- Low life-cycle cost
- Allows more architectural freedoms
- Better zone comfort control

Introduction

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Disadvantages

- First (capital) cost
  - However, incentives, energy-savings mortgages or loop-leasing are some ways of off-setting costs
- Limited qualified designers
- Geographically limited contractors
- Supply/demand => higher vendor markups

Geothermal Basics

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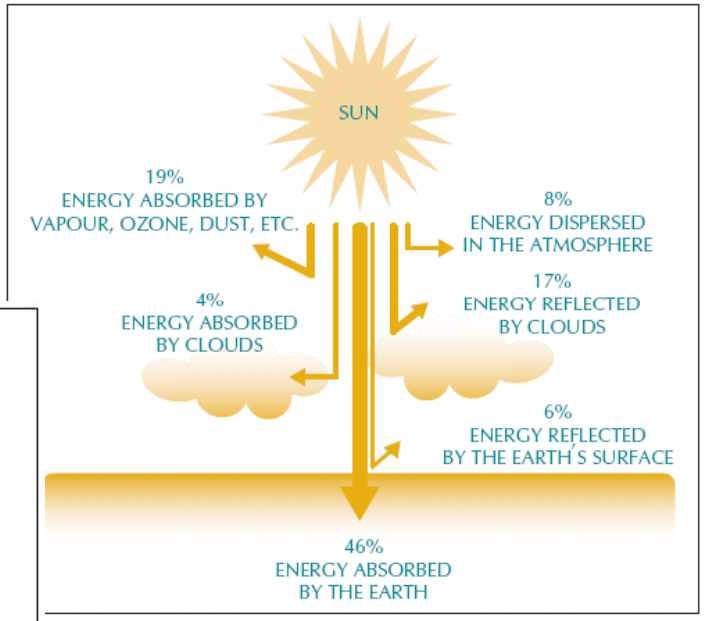
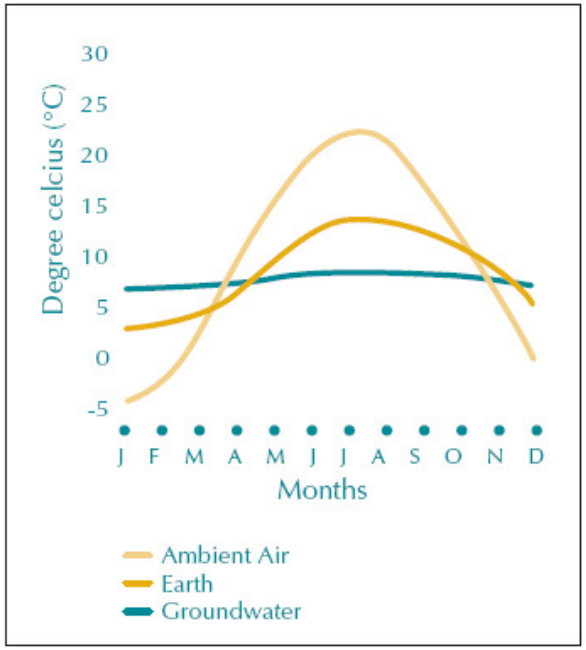
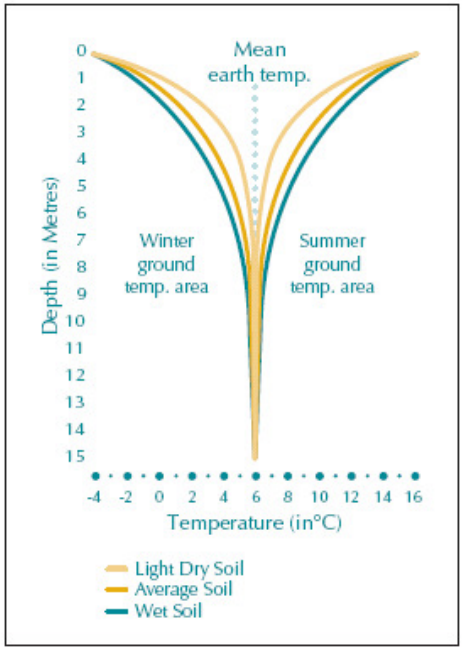
- The earth is a massive sink for solar energy
- Earth energy is available on any site
- The earth maintains a very consistent temperature







Geothermal Basics

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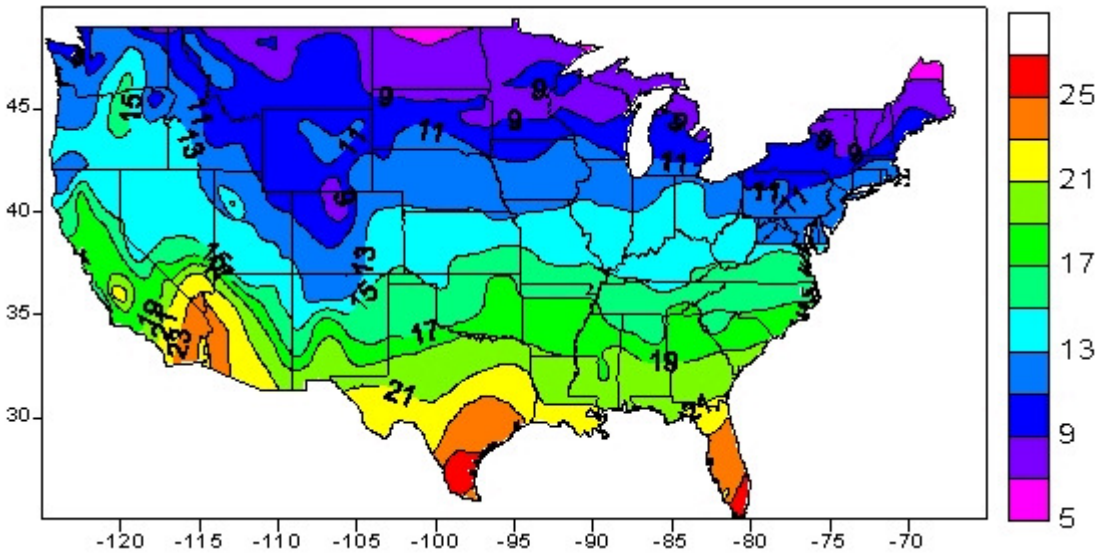
- Shallow groundwater maintains a very consistent temperature.
- Pennsylvania groundwater temp is typically 9°C to 11°C (48 °F to 52 °F)
- Urban site data often show anomalies.
- ***Deep earth temperature*** is a very important design criteria



Geothermal Basics

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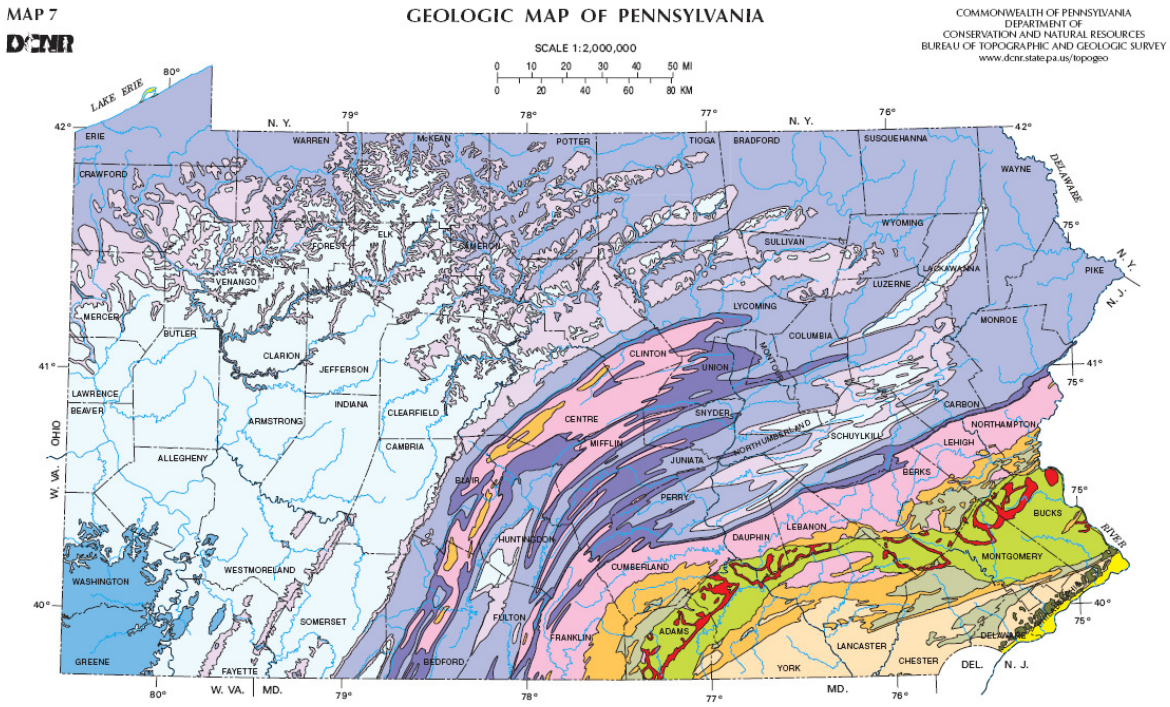
- Geology of the site is very important
- Soil, bedrock and groundwater flow influence the systems ability to transfer heat.
- Pennsylvania has very diverse geology.



Geothermal Basics

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IMPORTANT DESIGN VALUES OBTAINED FROM THE FORMATION

- ***Thermal Conductivity*** (site specific) – the ability of the formation to conduct heat. Values obtained from in-situ formation testing.
- ***Thermal Diffusivity*** (site specific) - the ratio of thermal conductivity to volumetric heat capacity. Substances with high thermal diffusivity rapidly adjust their temperature to that of their surroundings, because they conduct heat quickly in comparison to their thermal 'bulk'.
- ***Specific Heat Capacity*** (Literature)- is the measure of the heat energy required to increase the temperature of a unit quantity of a substance by a certain temperature interval.
- ***Density*** (site specific)- mass per unit volume of the geologic formation. Values can be obtained from field logging of wells and from laboratory analysis.
- ***Borehole Thermal Resistance*** (site specific)- resistance is the inverse of conductance. Therefore boreholes can act as an insulator.

Geothermal Basics

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Selected Thermal Properties of Rock

Rock Type	Thermal Conductivity* Btu/h·ft·°F (W/m·°C)	Density lb/ft^3 (g/cm^3)
Granite (25% quartz)	1.5 - 2.1 (2.60 - 3.63)	165 (2.64)
Andesite	0.9 - 1.4 (1.56 - 2.42)	160 (2.56)
Basalt	1.2 - 1.4 (2.08 - 2.42)	180 (2.88)
Limestone	1.4 - 2.2 (2.42 - 3.81)	150 - 175 (2.40 - 2.80)
Sandstone	1.2 - 2.0 (2.08 - 3.46)	160 - 170 (2.56 - 2.72)
Wet Shale (no quartz)	0.6 - 0.9 (1.04 - 1.56)	130 - 165 (2.08 - 2.64)
Dry Shale (no quartz)	0.5 - 0.8 (0.86 - 1.38)	130 - 165 (2.08 - 2.64)
Gneiss	1.3 - 2.0 (2.25 - 3.46)	160 - 175 (2.56 - 2.80)
Schist	1.4 - 2.2 (2.42 - 3.81)	170 - 200 (2.72 - 3.20)

* this represents the mid-range for samples of rock

Geoexchange Loop

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- The geoexchange loop is a heat exchanger, where fluid flowing through the loop exchanges heat with the earth
- Synonyms: Ground-loop heat exchanger, earth energy exchanger, ground (or earth) coupling, borehole field, loop field
- Design goal is to size the loop to provide fluid temperatures to the heat pump(s) within the design target range (usually 35^{o}F to 90^{o}F) to meet thermal loads of the building

Geoexchange Loop

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- Closed Loop
  - Vertical
  - Horizontal
  - Surface Water
- Open Loop
  - Single Well (discharge to standing well or surface)
  - Withdrawal and Injection Wells
  - Surface Water

Geoexchange Loop

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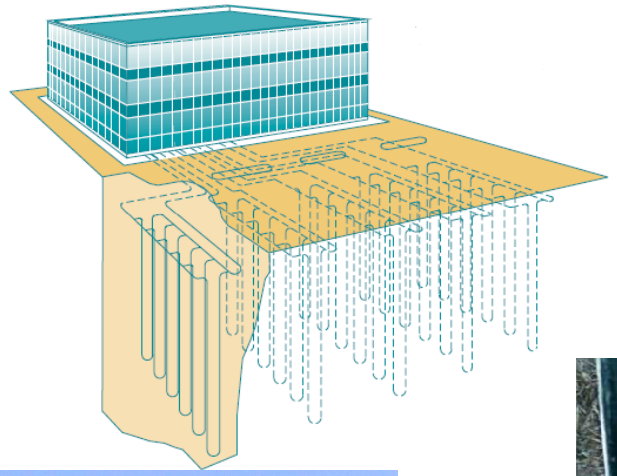
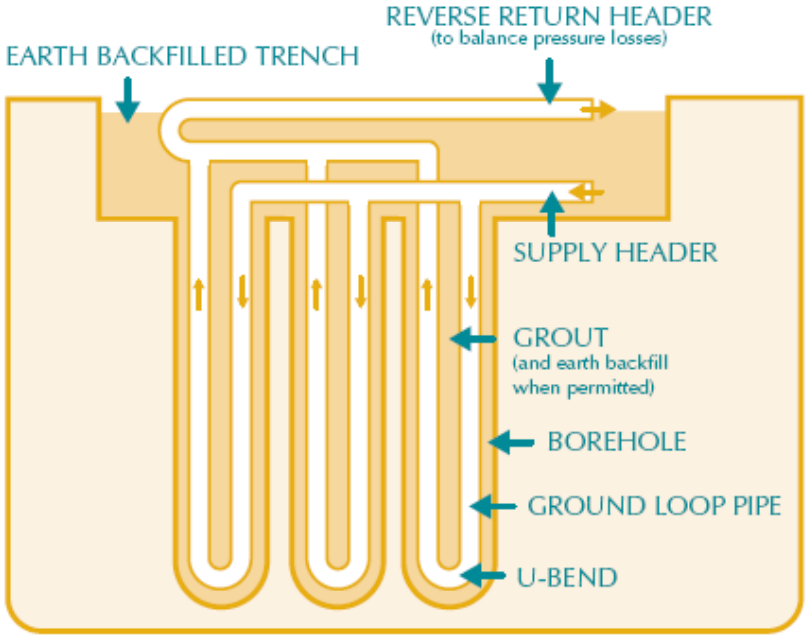
- ***Vertical Closed Loop***





Geoexchange Loop

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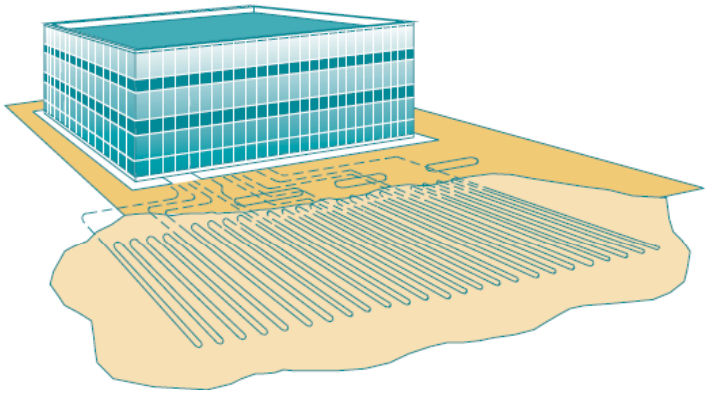
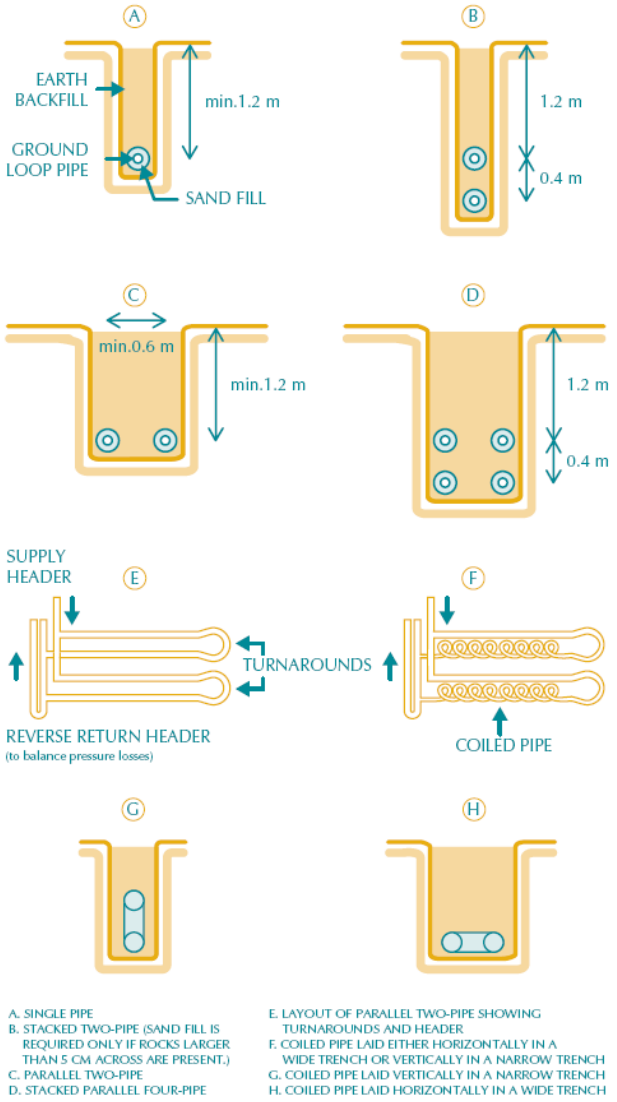
- ***Horizontal Closed Loop***





A. SINGLE PIPE
B. STACKED TWO-PIPE (SAND FILL IS REQUIRED ONLY IF ROCKS LARGER THAN 5 CM ACROSS ARE PRESENT.)
C. PARALLEL TWO-PIPE
D. STACKED PARALLEL FOUR-PIPE
E. LAYOUT OF PARALLEL TWO-PIPE SHOWING TURNAROUNDS AND HEADER
F. COILED PIPE LAID EITHER HORIZONTALLY IN A WIDE TRENCH OR VERTICALLY IN A NARROW TRENCH
G. COILED PIPE LAID VERTICALLY IN A NARROW TRENCH
H. COILED PIPE LAID HORIZONTALLY IN A WIDE TRENCH

Geoexchange Loop

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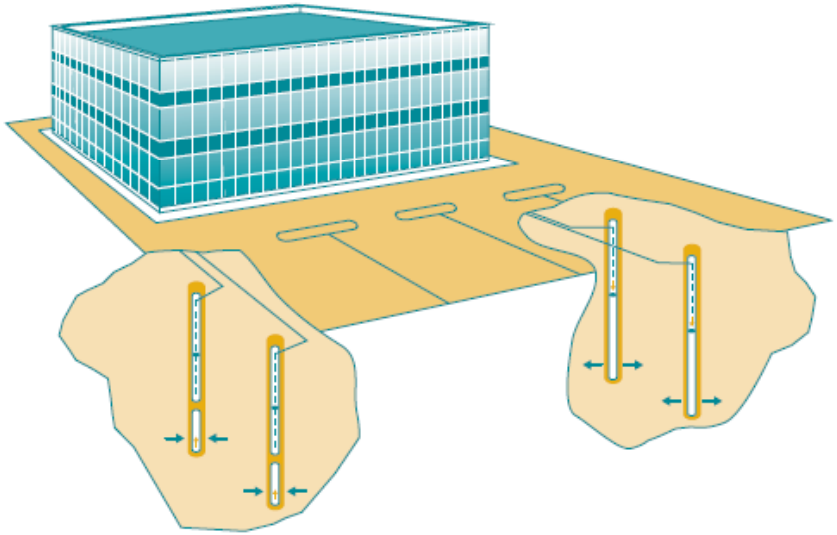
- Open Loop



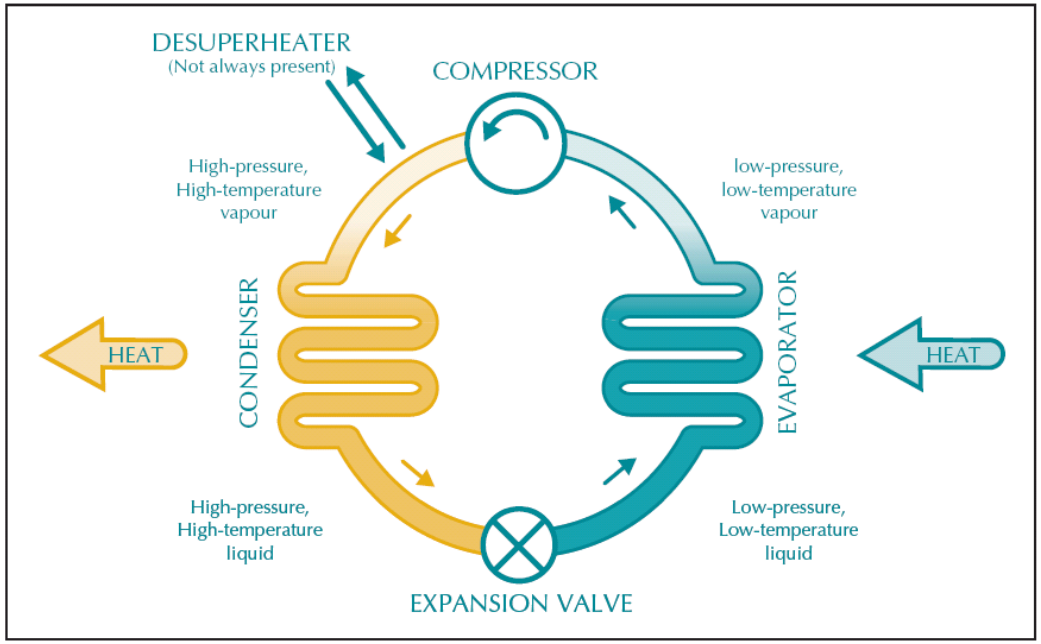
Heat Pumps

- Fourier Law of Heat Conduction

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta t}$$

Heat flows from warm to cool mediums (Second Law of Thermodynamics)

- Heat Pumps are needed to overcome nature



SYSTEM DESIGN

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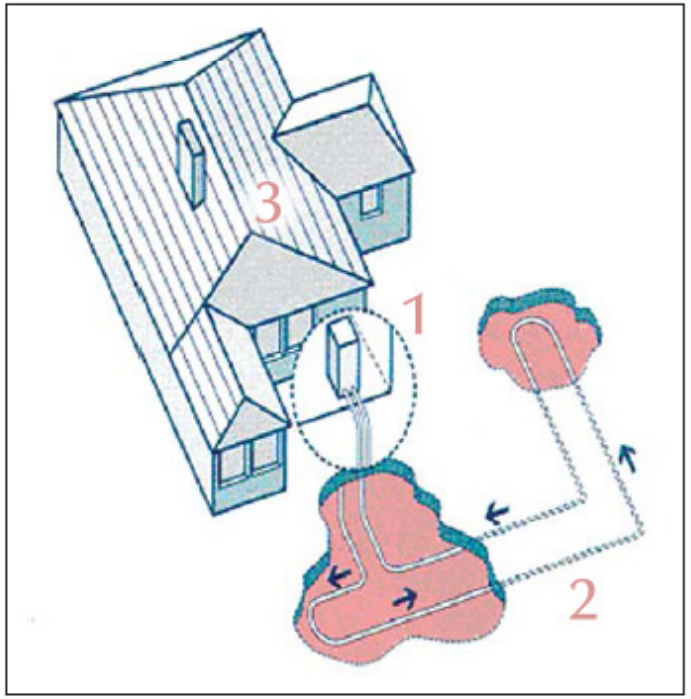
1. Heat Pump
2. Earth Connection (Geoexchange Loop)
3. Heat Distribution System



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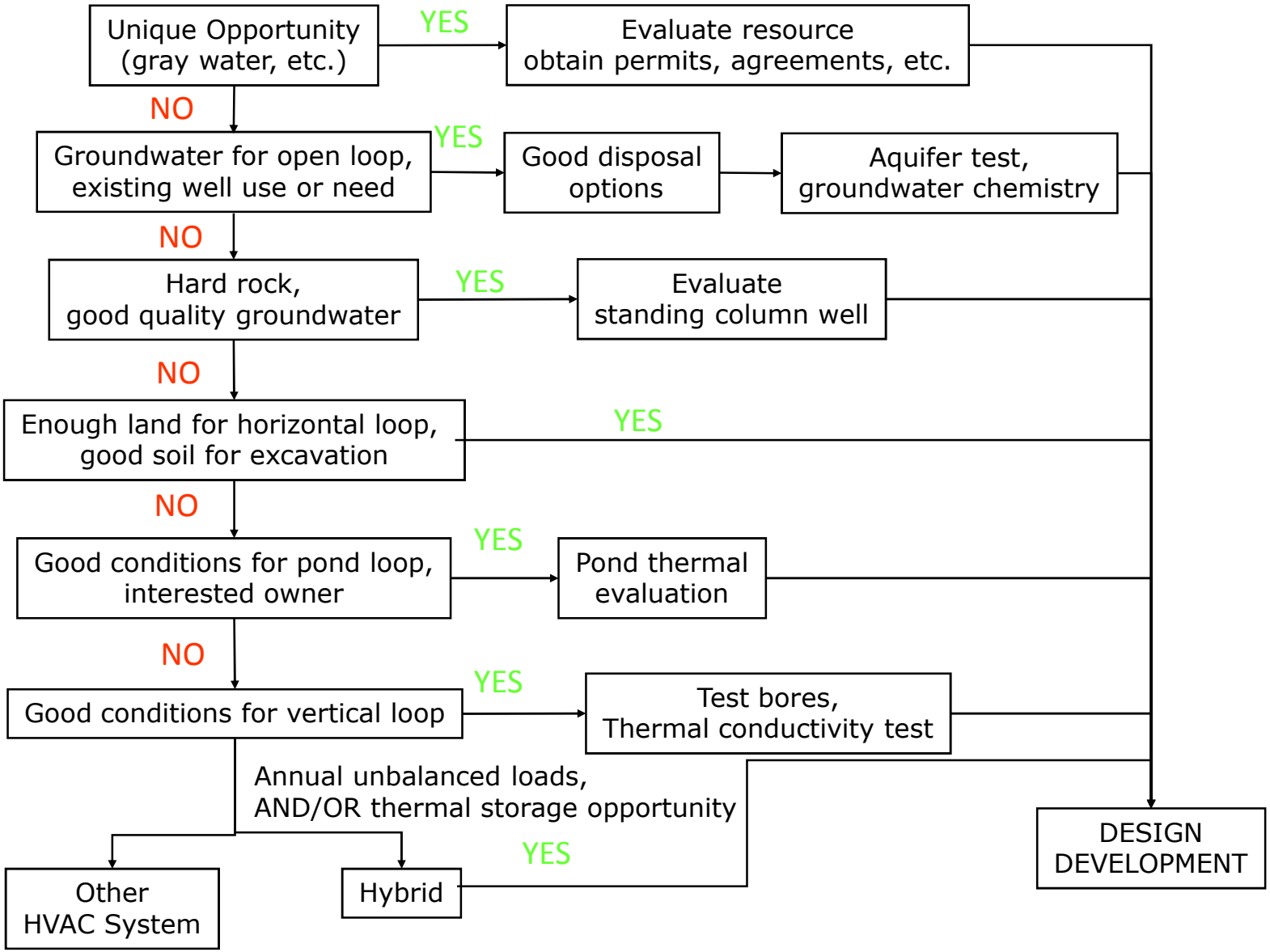

SYSTEM DESIGN

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- Building Load Analysis
- Site Specific Data Collection
- Equipment Selection
- Geoexchange Design
- Select construction team

SYSTEM DESIGN

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- RULES OF THUMB ARE **NOT** RECOMMENDED FOR FINAL DESIGN

SYSTEM DESIGN

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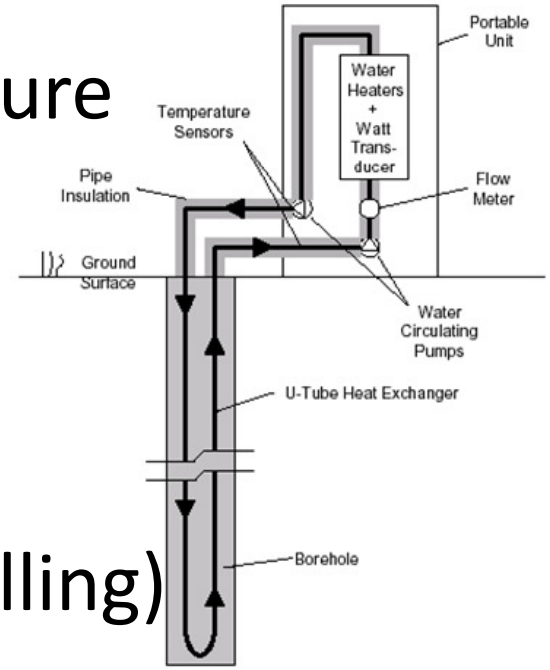
Formation Thermal Conductivity Testing

- Measures In-situ Conductivity
- Measures Deep Earth Temperature
- Test borehole improves design
- Eliminates guess work
- Improves efficiency
- Reduces cost (operating and drilling)



Conclusion

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- Cost Competitive
- Site Specific Data is required for good design
- Pennsylvania's geology and climate are well suited for geothermal systems

Thank You!