Geothermal 101

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Connecting you to clean energy

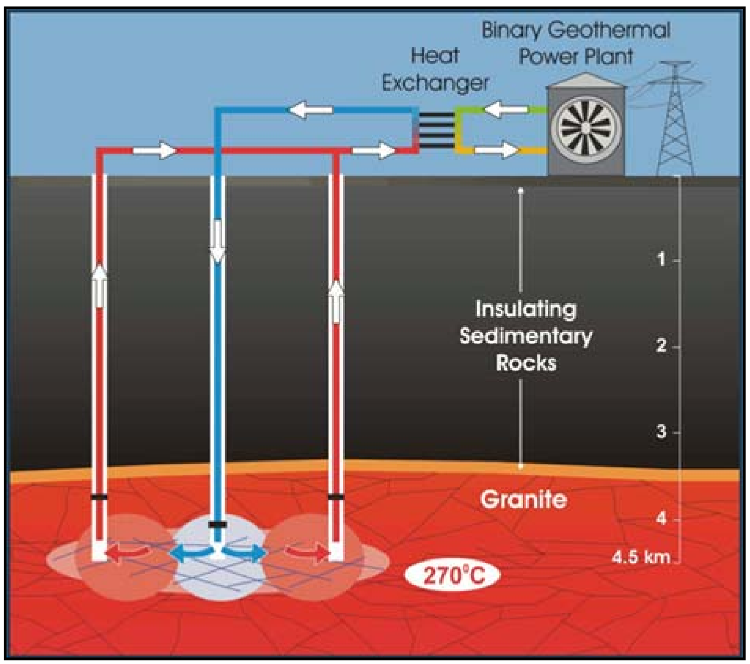
Agenda

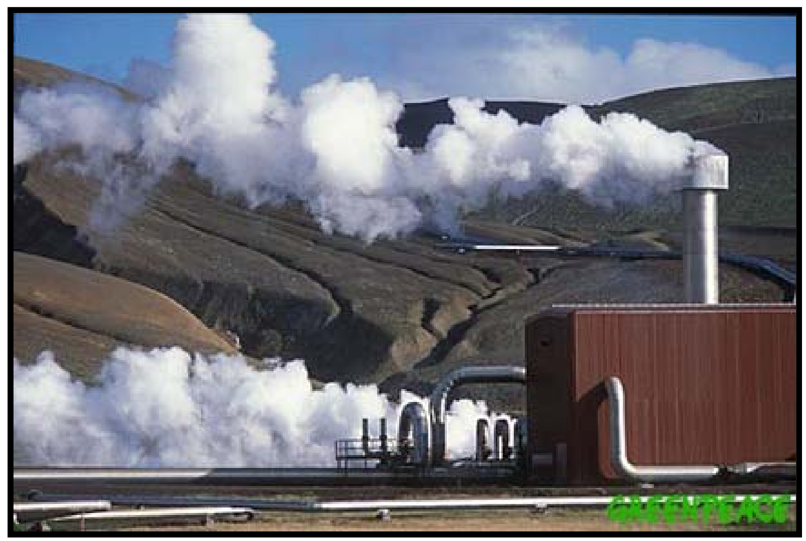
- Basics of Geothermal
- Heat Pumps – How do you get heat from cold water?
- Borehole exchangers vs. performance
- Design considerations impacting heat pump performance

Two Types of Geothermal

A. Hot Rock – Hot Water/Steam

1. Electrical Generation
2. Direct Heating





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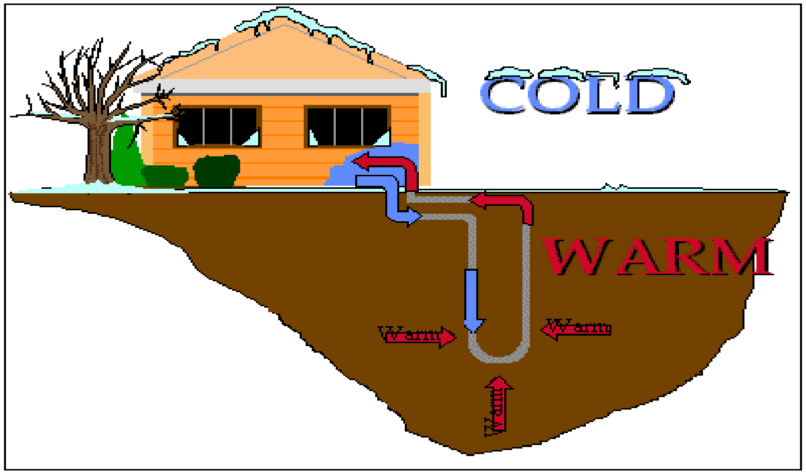
Two Types of Geothermal

B. Low Temperature Thermal Exchange

Ground **S**ource **H**eat **P**umps (GSHP) – Geothermal Heat Pumps

- Exploit the constant temperature of the Earth
- Refrigeration cycle and phase change
- Provides interior climate control
  - Cooling – A/C
  - Heating



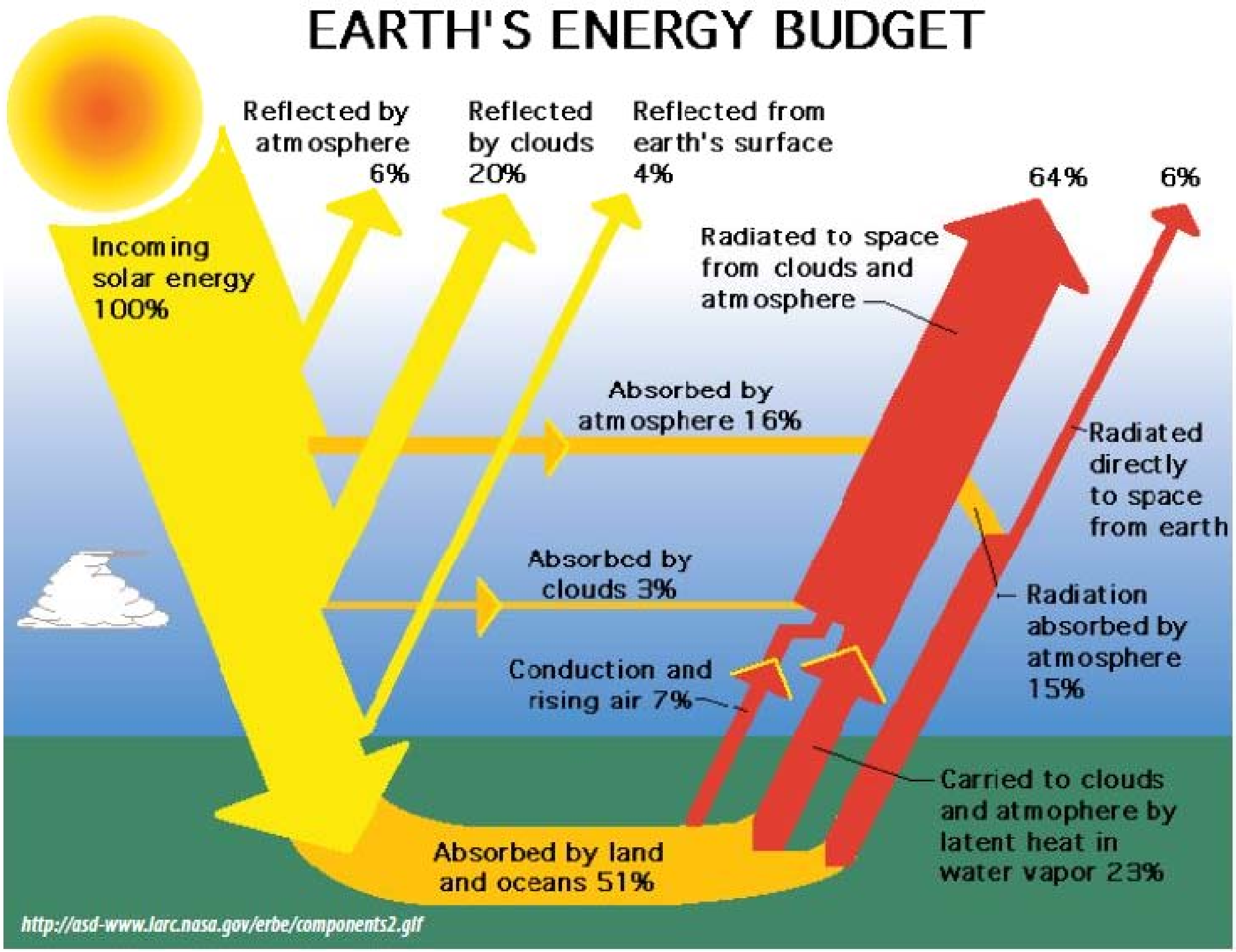
Advantages

- ✓ Reduces
  - ✓ Energy demand
  - ✓ Price volatility
  - ✓ Summer peak demand
- ✓ Available at point of use (most everywhere)
- ✓ Unobtrusive – no eyesores or noise – NIMBY safe

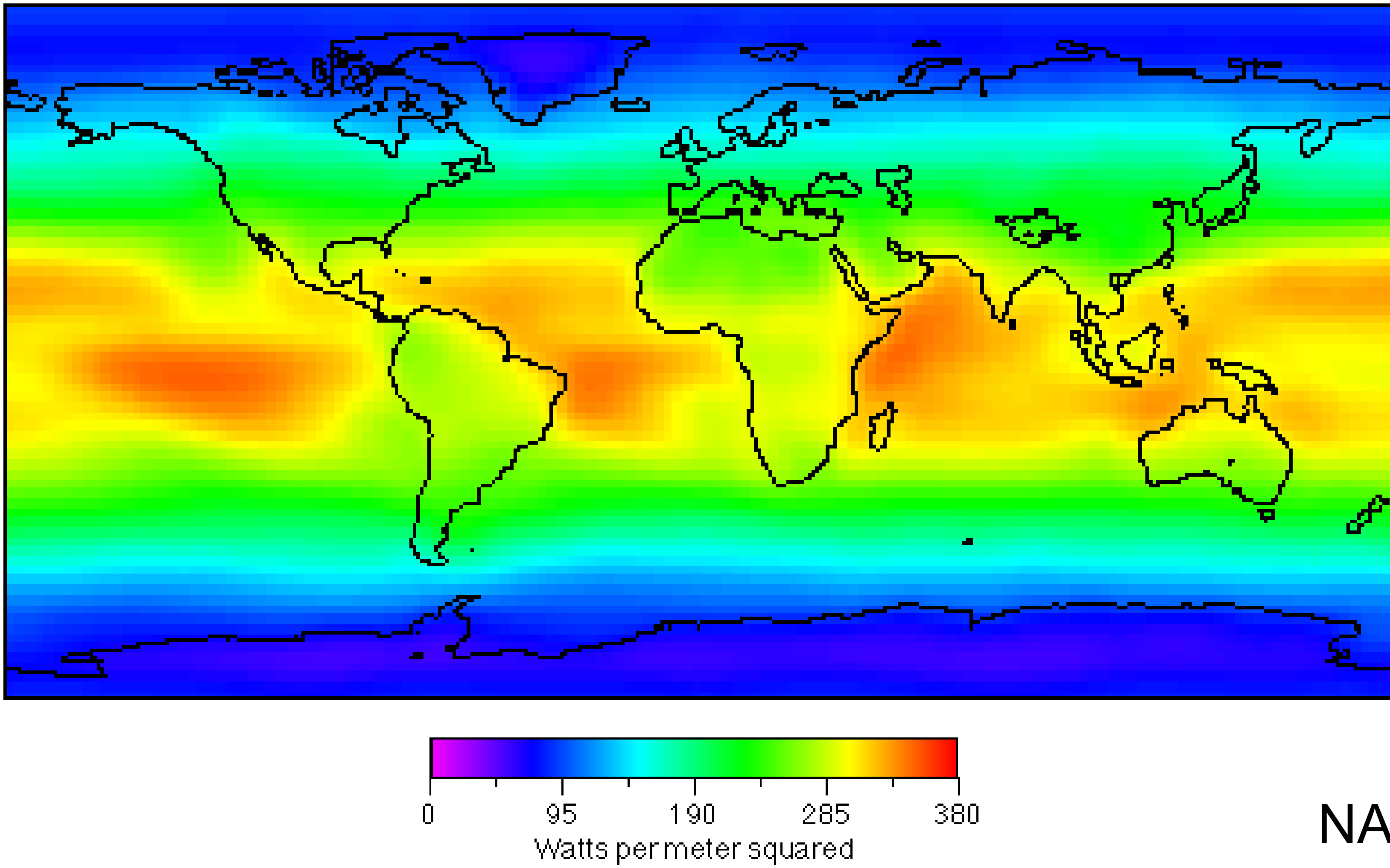
U.S. Environmental Protection Agency (EPA)

- **The most energy-efficient, environmentally clean, and cost-effective space conditioning system available.**

- Significant emission reductions potential
  - When used for both heating and cooling
  - Electricity produced from renewable resources


EARTH'S ENERGY BUDGET
Reflected by atmosphere 6%
Reflected by clouds 20%
Reflected from earth's surface 4%
64%
6%
Incoming solar energy 100%
Radiated to space from clouds and atmosphere
Absorbed by atmosphere 16%
Radiated directly to space from earth
Absorbed by clouds 3%
Radiation absorbed by atmosphere 15%
Conduction and rising air 7%
Carried to clouds and atmosphere by latent heat in water vapor 23%
Absorbed by land and oceans 51%
http://asd-www.larc.nasa.gov/erbe/components2.gif

Absorbed Energy



NASA

Temperature Variation with Depth

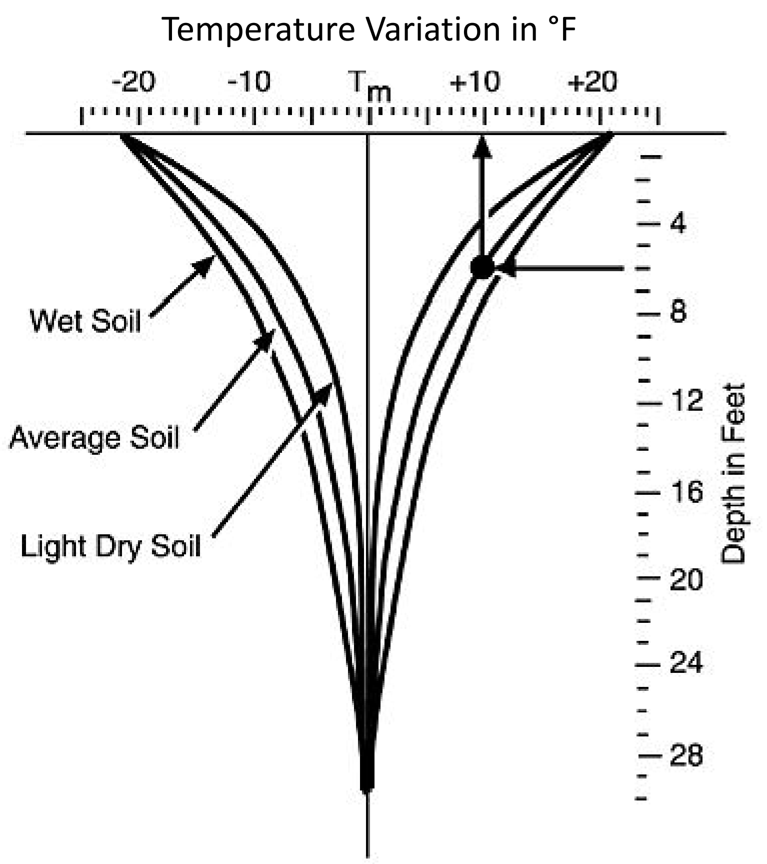


Figure 3. Amplitude of seasonal soil temperature change as a function of depth below ground surface.

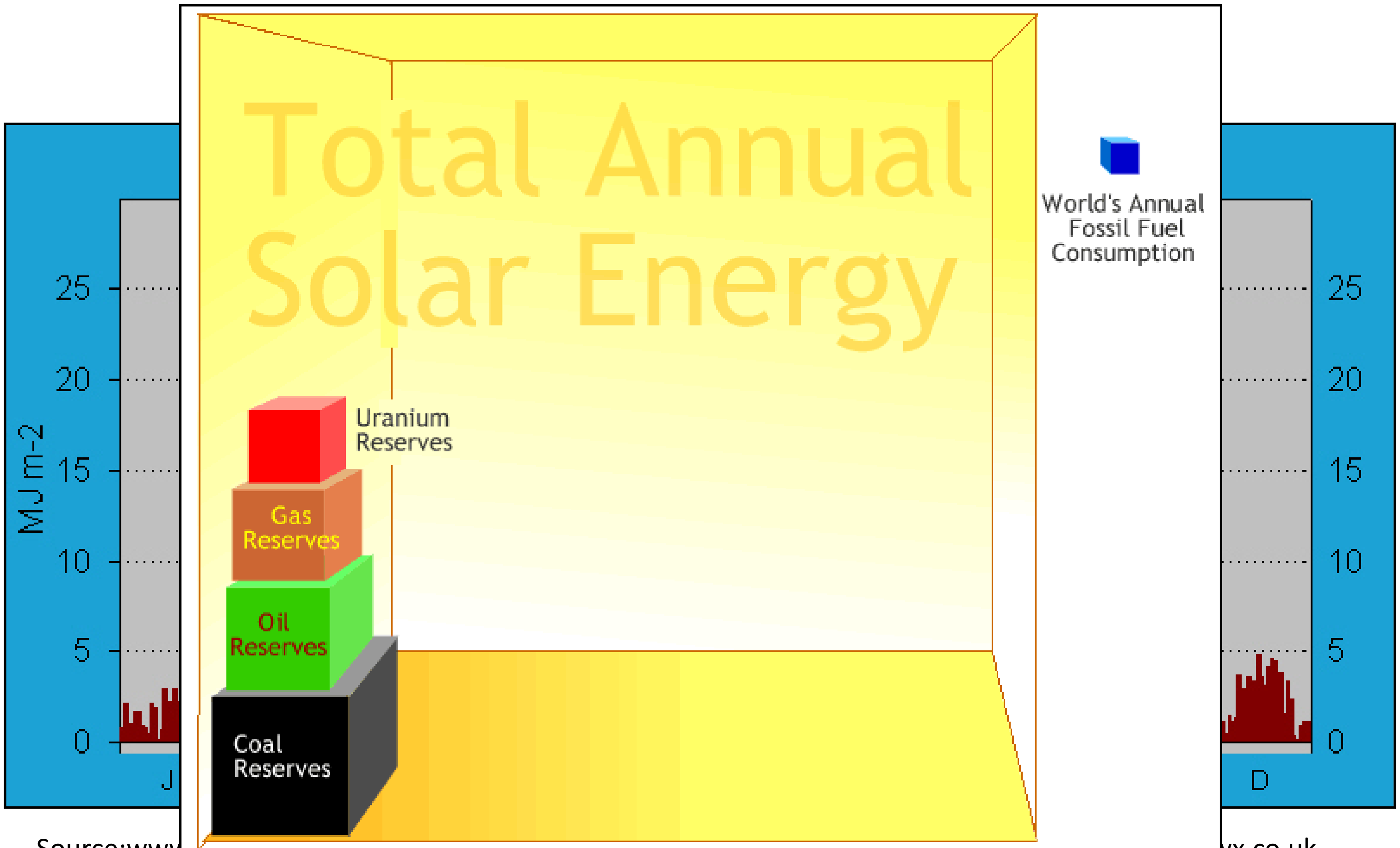
- ET, Conduction, Advective
- HC and λ

- Incoming radiation
- Rainfall
- Seasonal Air Temp
- Vegetation
- Depth

VT Dept Mines, Mineral & Energy

Why Geothermal Heat Pumps

- Long-term solar energy…a sustainable resource



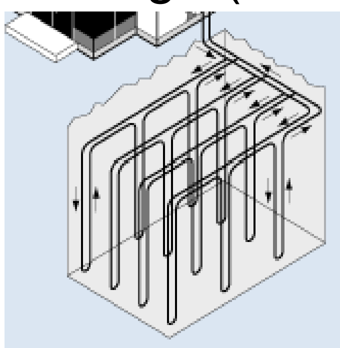
Source:www.

wx.co.uk

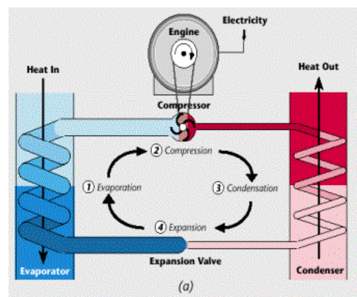
Coupling the Heat Pump

Three main components to the System

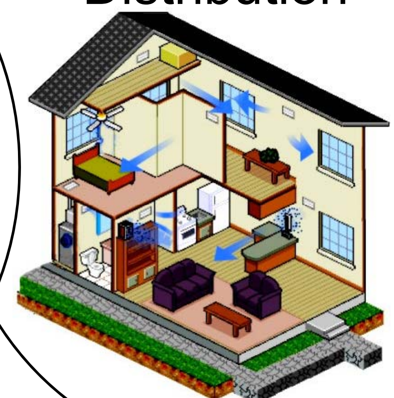
Ground Exchanger(GHEX)



Heat Pump



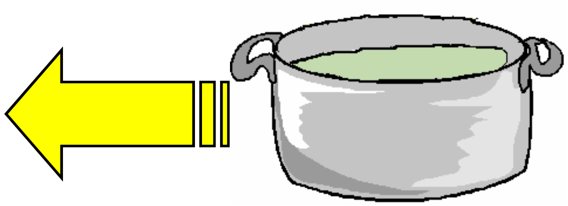
Interior Air Distribution



Movement of Heat

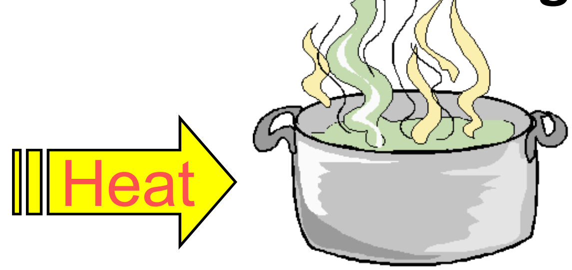
Temperature change

10 Btu's needed to raise temp of 1 lb. of water by 10 degrees



10 Btu's released lowering temp of 1 lb. of water by 10 degrees

Phase change



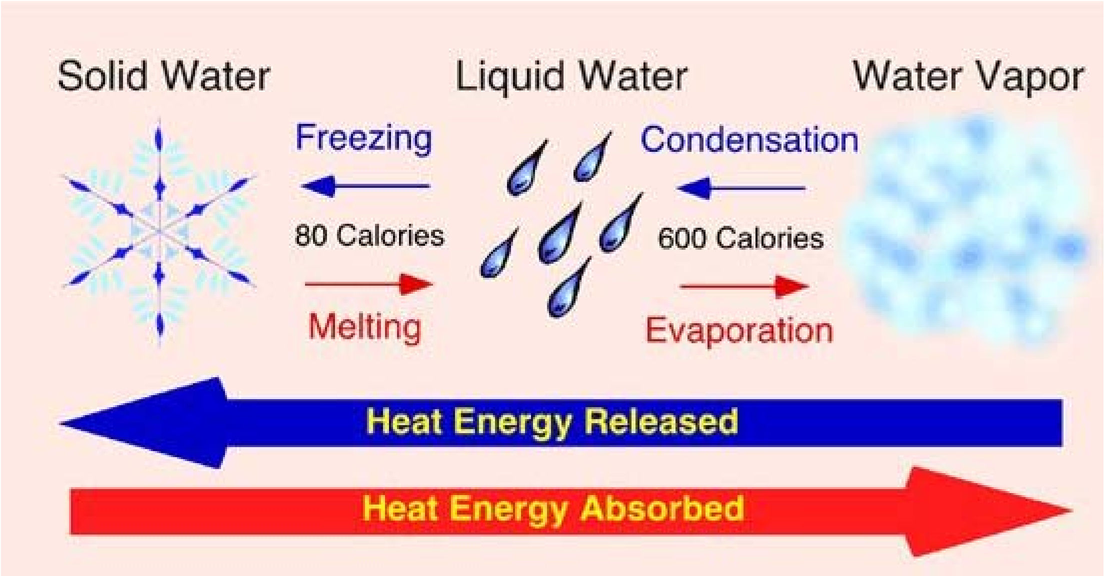
Boiling Water

1060 Btu's needed to change 1 lb. of 212° water to 1 lb. of 212° steam at sea level.

Boiling Point Function of Pressure

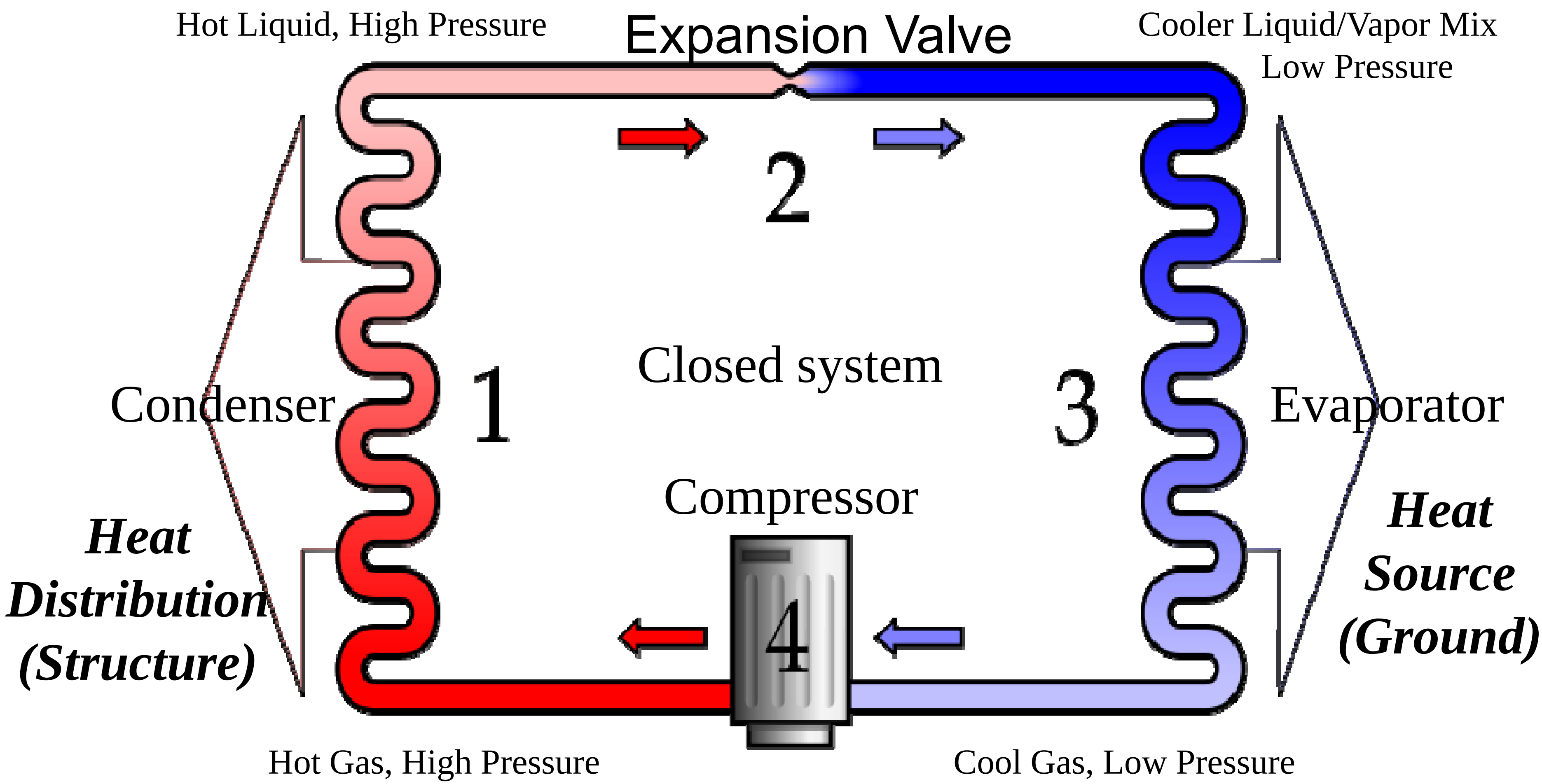
- 10 PSIG, temp = 240°
- 15 PSIG, temp = 250°
- -3 PSIG, temp = 202°

Physics of Heat Pumps



1060 Btu to evaporate 1 lb of water (at 60°F)
1060 Btu is released when that 1 lb of water condenses

Heating



Hot Liquid, High Pressure
Expansion Valve
Cooler Liquid/Vapor Mix
Low Pressure
2
Condenser
1
Closed system
3
Evaporator
Heat
Distribution
(Structure)
Compressor
4
Heat
Source
(Ground)
Hot Gas, High Pressure
Cool Gas, Low Pressure

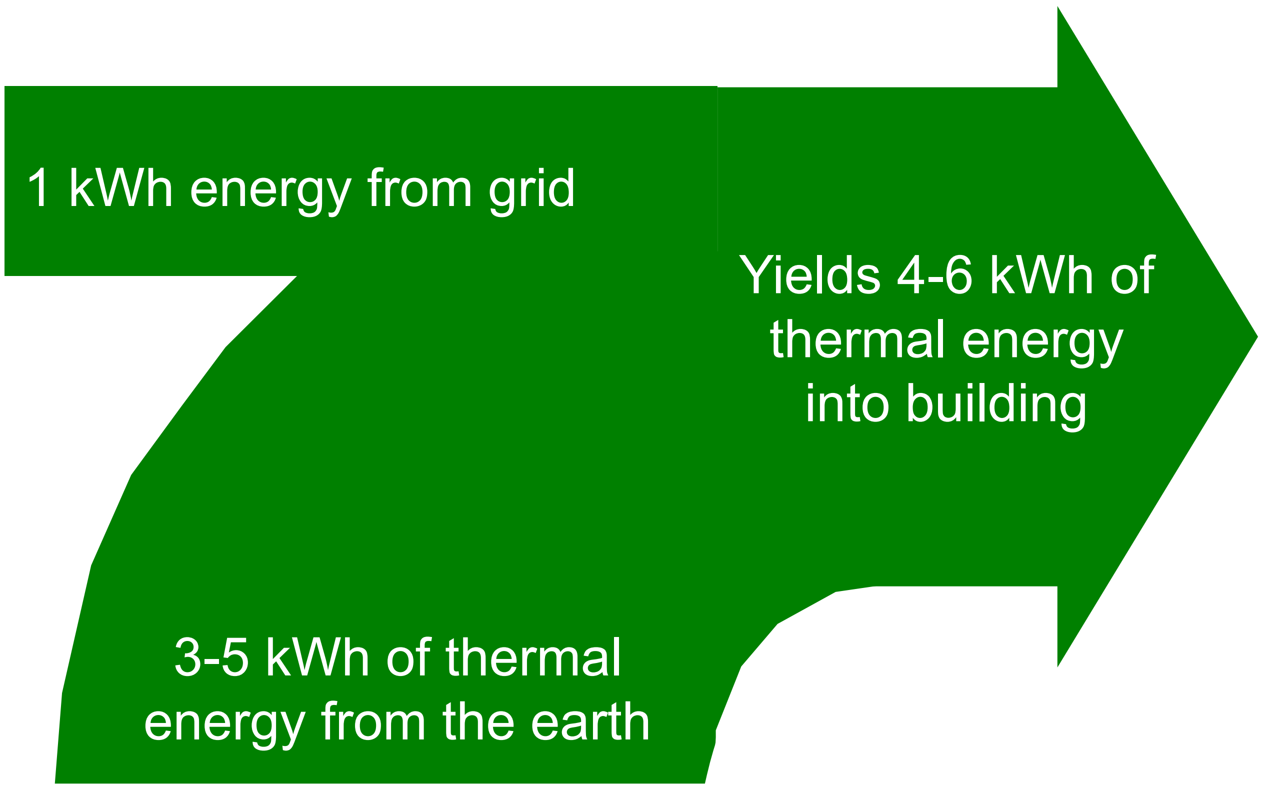
Types of Heat Pumps

Water to Air

Water to Water

High Energy Efficiency

400-600% increase in energy delivery



Coupling the Heat Pump

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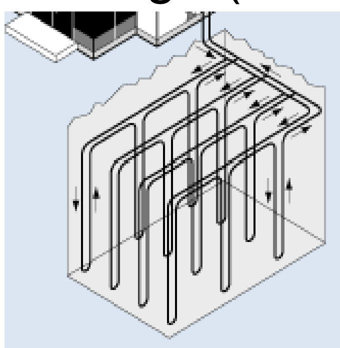
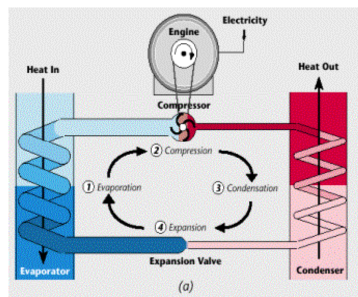
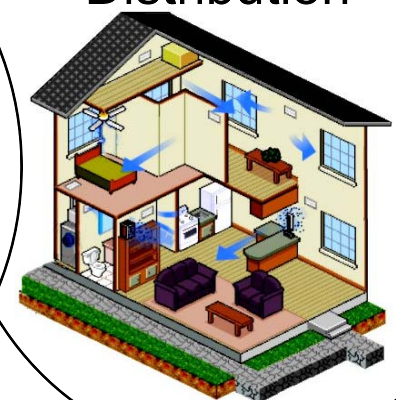
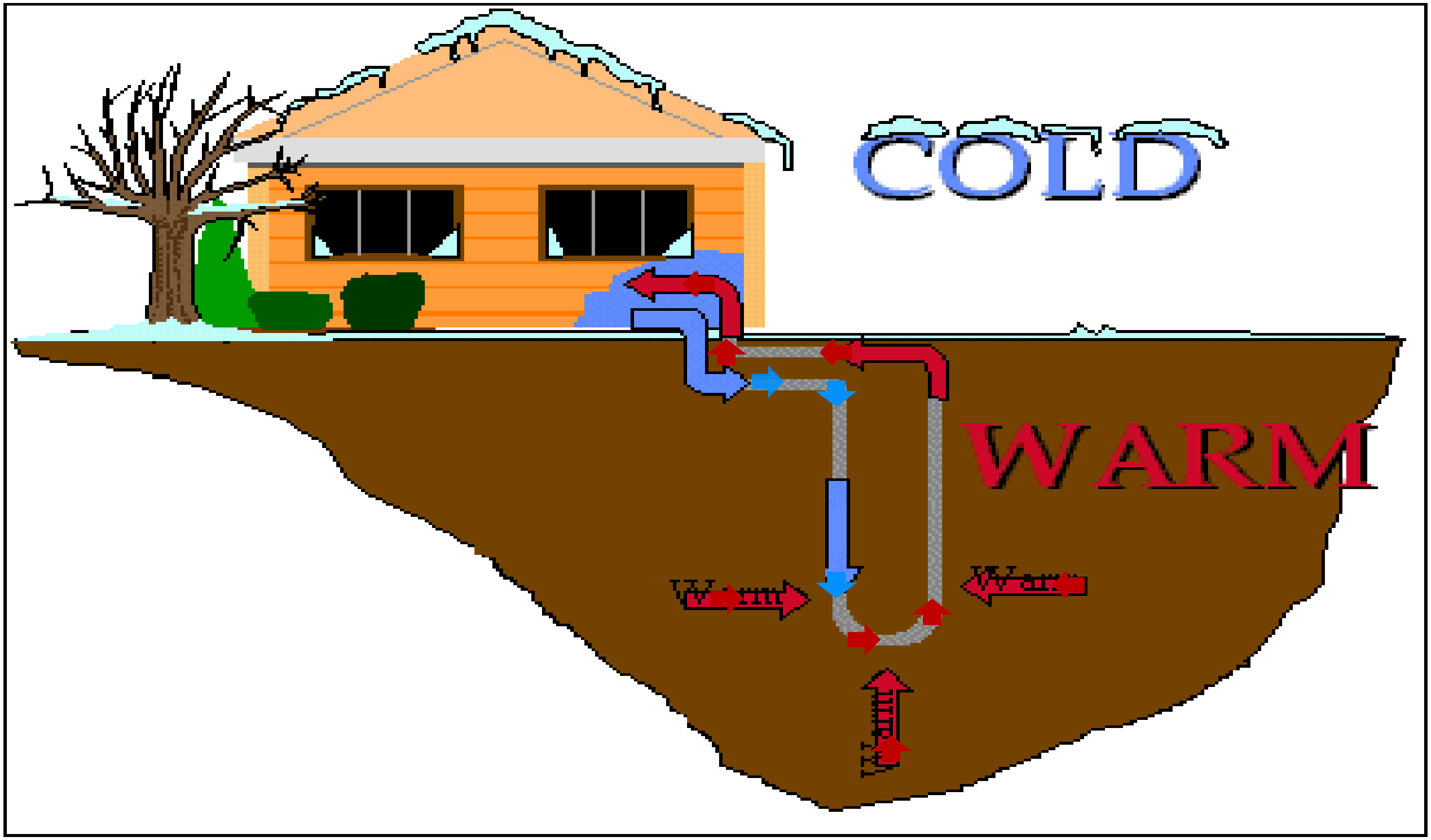


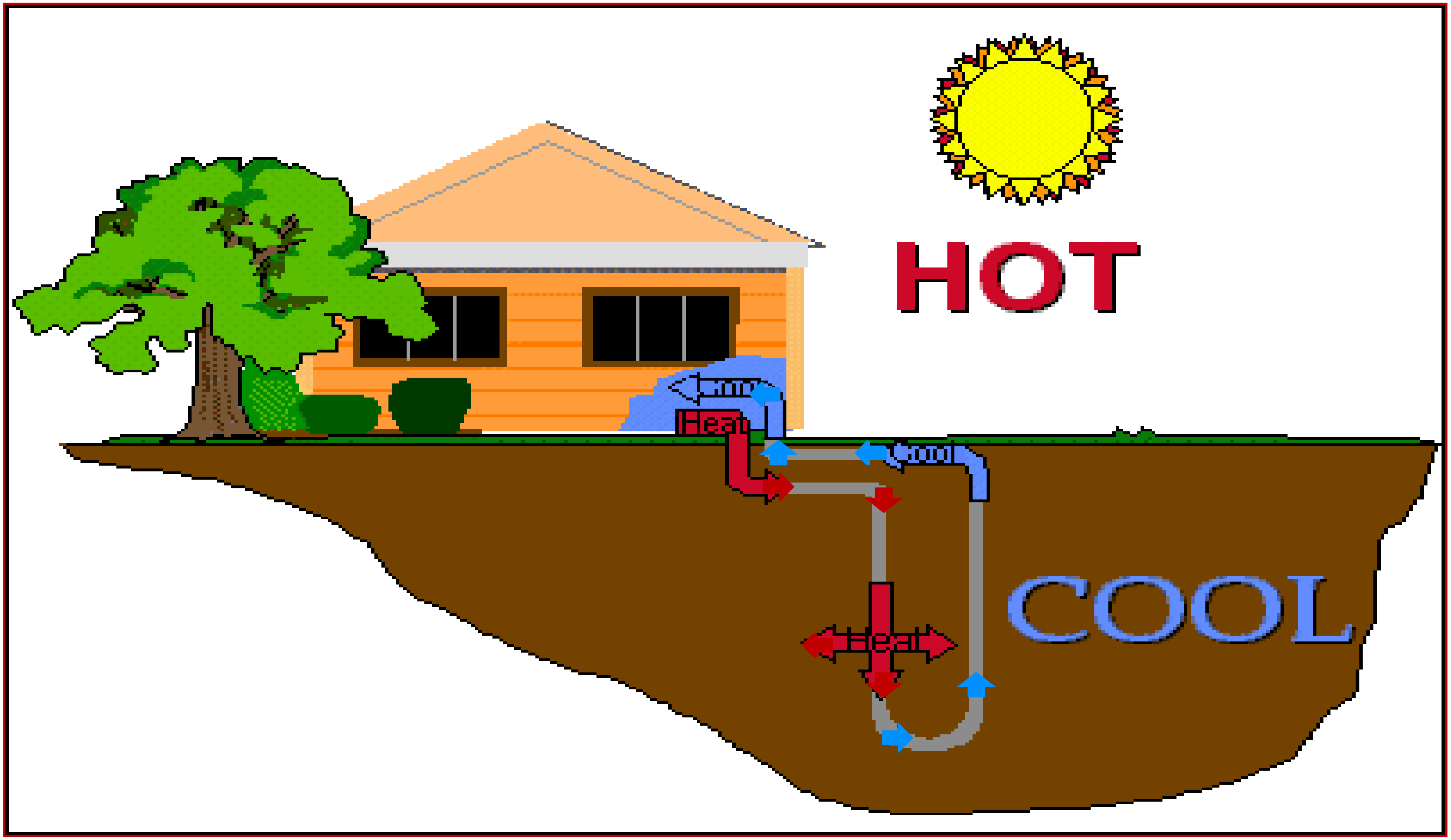
Heat Pump



Interior Air Distribution




COLD
WARM


HOT
Cool
Heat
Cool
Heat
COOL

Types of Ground Heat Exchangers (GHEX)

Water Based

Refrigerant Based

Open

- Pump and Dump (Discharge to surface water)
- Withdrawl-Recharge
- Standing Column

Closed

- U-tube
- Concentric
- Horizontal Slinky
- Vertical Slinky
- Pond Loop

- Direct Exchange (DX)

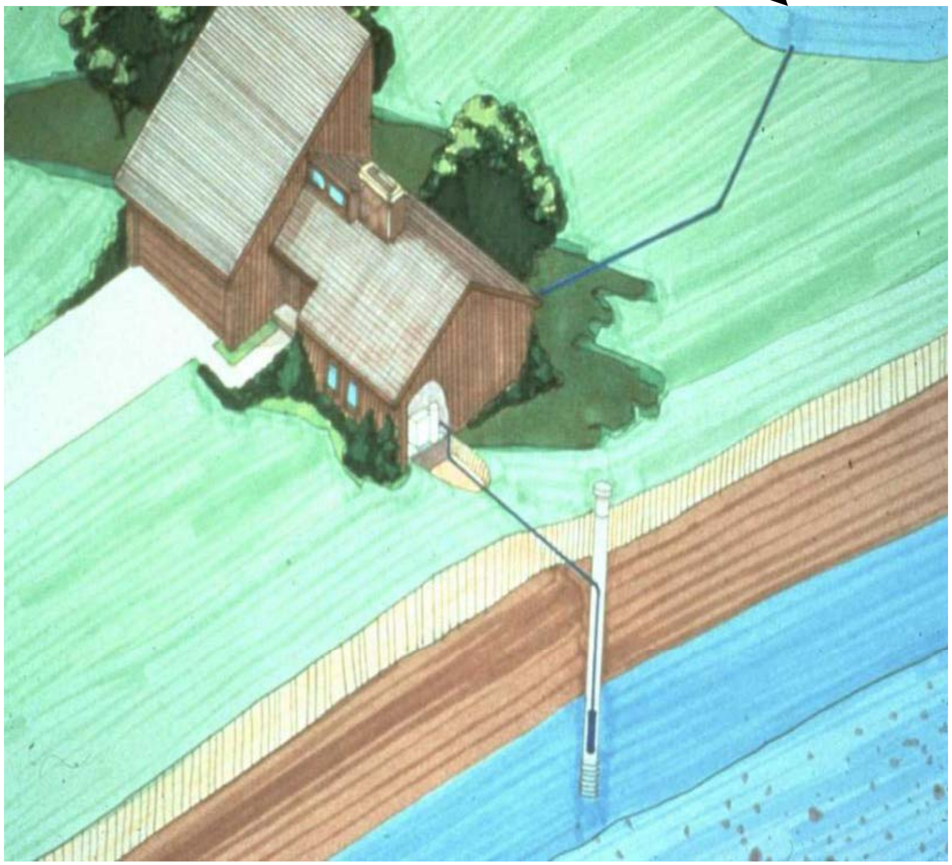
Open Loop – Pump and Dump

Advantages

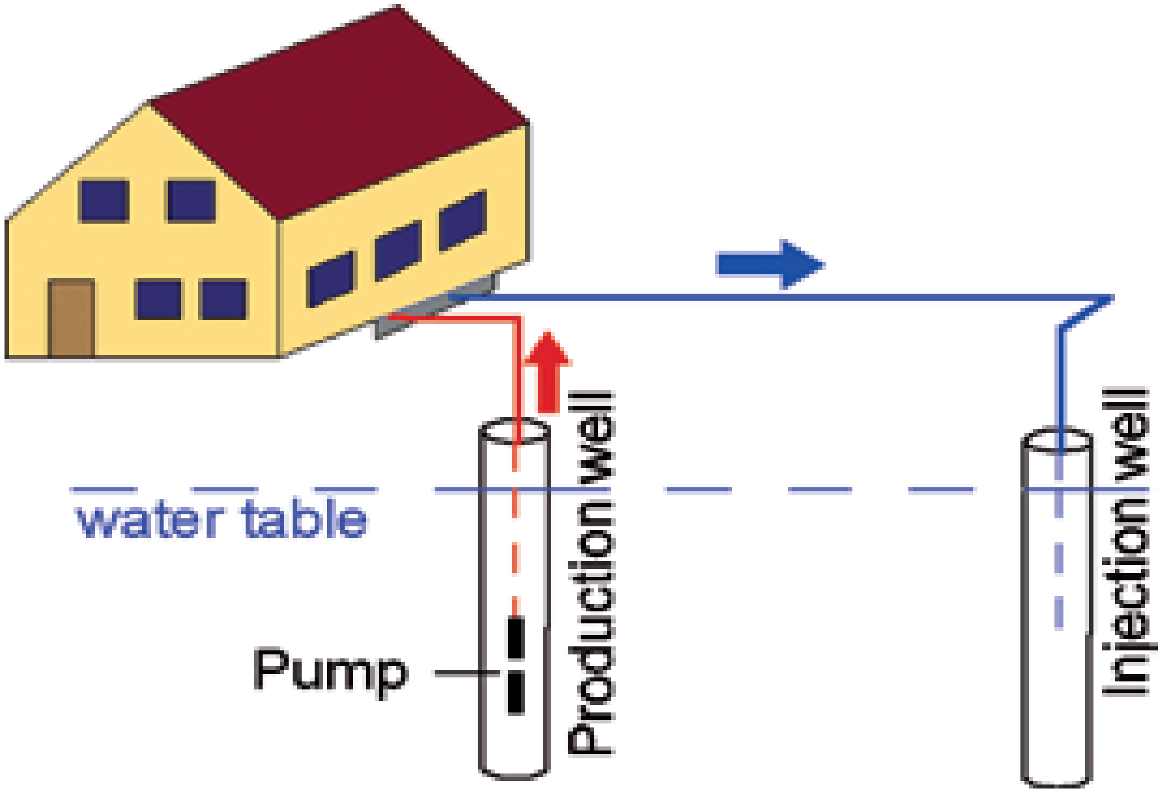
- High Heat Transfer Efficiency
- Constant Water Temperature

Disadvantages

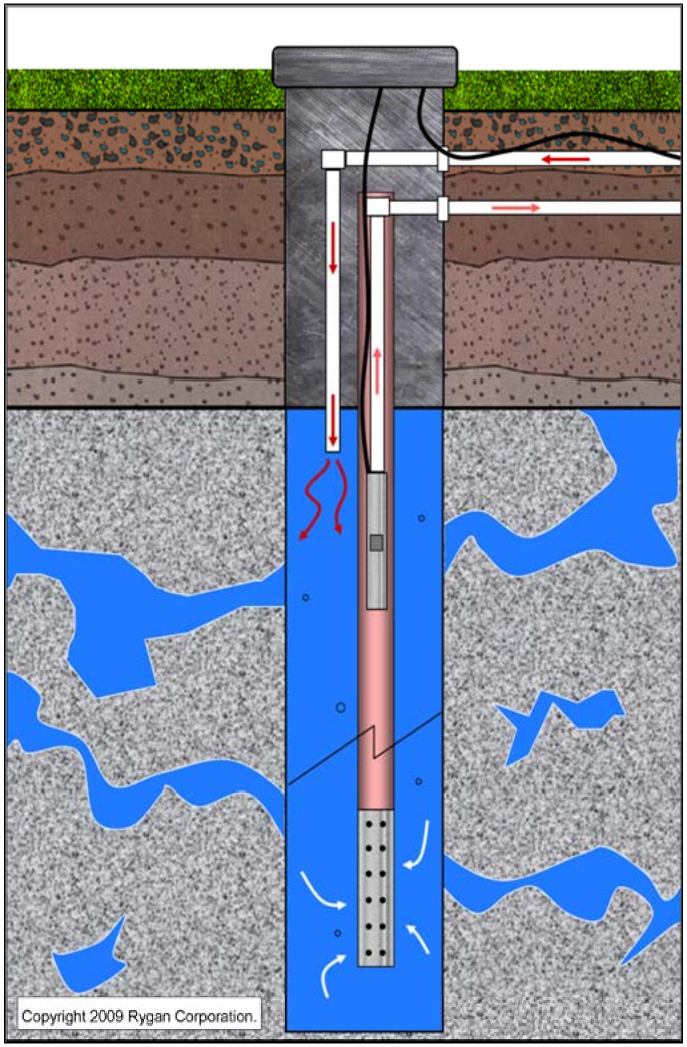
- Water Quality Concerns
- Disposal Issues
- Requires Sufficient Yield
- Regulatory Issues
  - WMA/NPDES/GWDP



Withdrawal/Recharge Wells



Standing Column Wells



- High capacity in a small footprint
- Open design, water re-circulates in borehole
- Typically 1500 ft deep
- In-well pumping equipment
- Efficiency comes from advective heat transfer
- Performance is dependant upon quality of water encountered and ability to bleed

Capacity

5-10% bleed on command = 45-80 ft/ton

No bleed – 100% return = 100-135 ft/ton

Carl Orio – MWUA presentation- 2/09

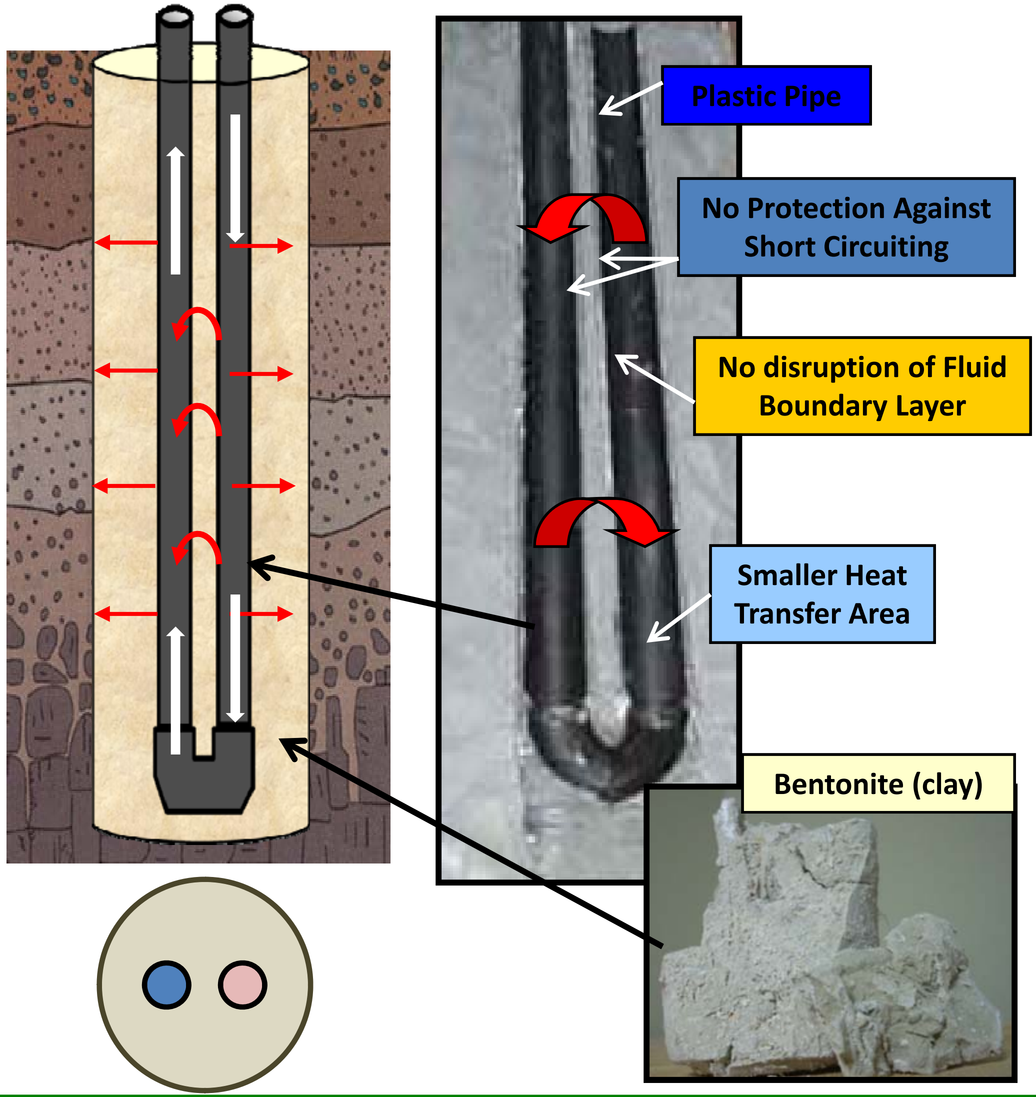
U-tubes – The Industry's Standard for 30 yrs.

Advantages

- Less Environmental Concerns
- No Water Quantity Issues
- No Water Quality Issues
- Lower Maintenance

Disadvantages

- Lower Heat Transfer – Thermally Inefficient
- More Borehole/Ton
- More Land Required
- More Site Disruption
- More Expensive To Install



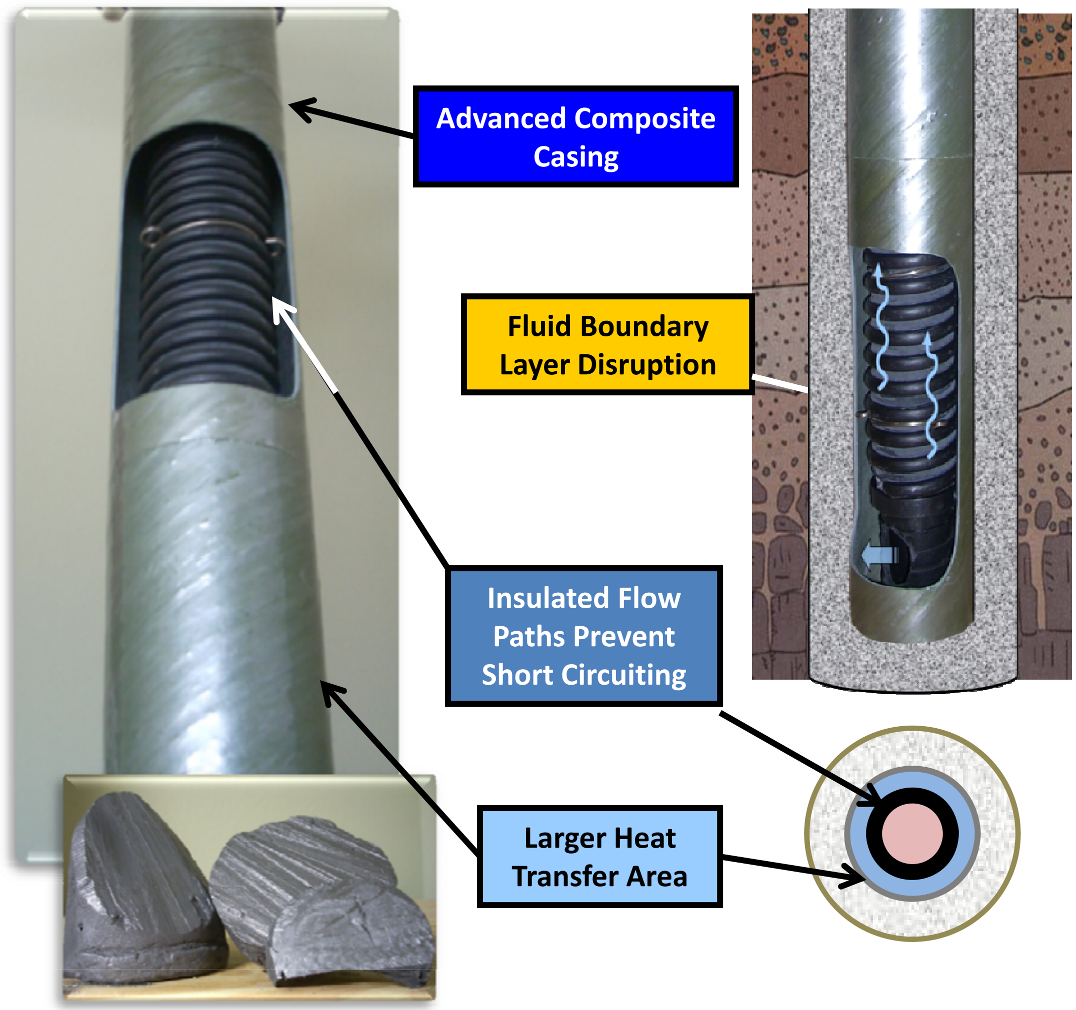
Concentric Closed Loop HPGX

Advantages

- High Heat Transfer
- Improved Heat Pump Performance
- Smaller Wellfield/Less Site Disruption
- Suitable for Salt Water
- Deep Capability

Disadvantages

- Higher Unit Cost
- Relatively New Technology
- Lower Efficiency than Open Loop



Closed Loop - Horizontal

Advantages

- Lower Installation Cost
- Concentrated Heat Transfer Area

Disadvantages

- Lower Tonnage/ ft.
- Significant Site Disruption

http://www.idahogeothermal.com/2010/02/24/6-ton-water-source-heat-pump-and-closed-loop-system/

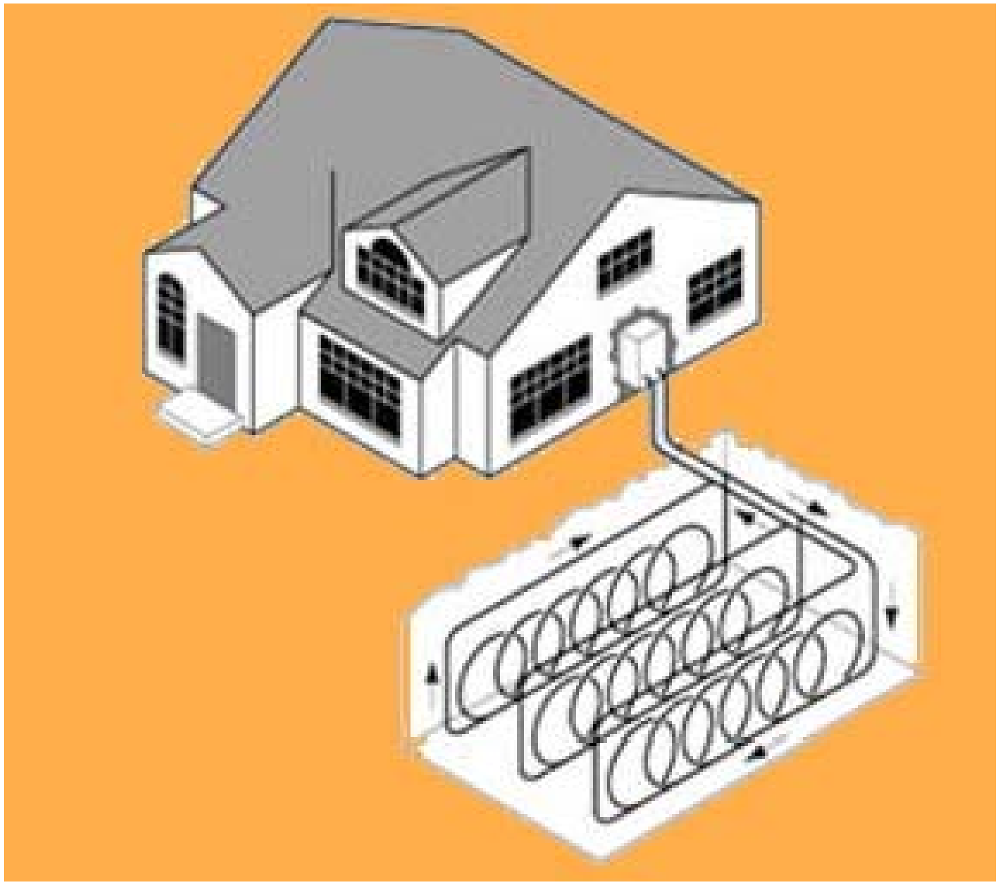
Closed Loop – Vertical Slinky System

Advantages

- Easiest and Cheapest to Install
- Less Site Disruption
- Vertical Trenches

Disadvantages

- Bury Depth Less Than Horizontal Slinky Systems
- Suitable Soils Needed
- Thermally Inefficient
- Long Lengths Needed



http://www.global-greenhouse-warming.com/ground-source-heat-pump.html

Closed Loop – Lake/Pond

Advantages

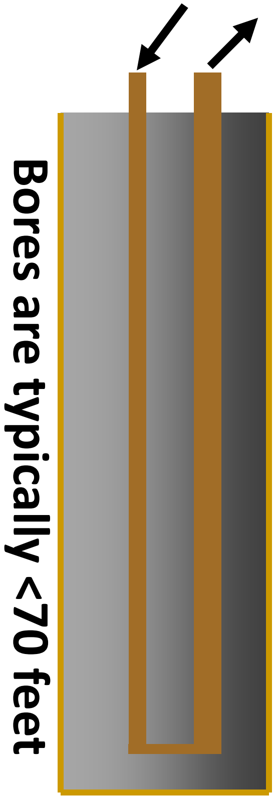
- High Efficiency
- Low Installation Cost
- Easy to Install/Repair

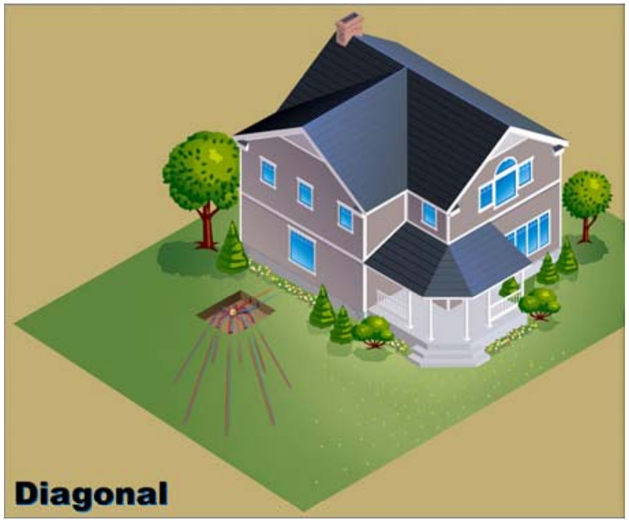
Disadvantages

- Limited Application
- Regulatory Issues
- Environmental Impacts

DX Systems

- Copper Tubing Loop Installed Vertically or Horizontally
- Installed in Small Diameter/Shallow Borehole (>100 ft.)
- Loops Filled with Refrigerant
- Grouted After Copper Tubing is Installed





http://www.earthlinked.com/residential/how-it-works

Choosing a GHEX Depends Upon

GHEX Selection Matrix		Geology	Logistical	Technical	Economic	Risk
Exchanger Types	Closed loop U-tube					
	Concentric					
	DX					
	Horizontal Slinky					
	Hybrid					
	Open Doublet					
	Pond Loop					
	Standing Column					

The Importance of the Ground Connection

Geothermal Success depends upon:

a) Data-driven Design
- Understanding Ground Conditions
  - Hydrogeology
  - Formation Conductivity Testing
- Measuring Exchanger Performance

b) Proper Installation
- Drilling
- Grouting
- Post-installation Pressure and Flow tests

The Immutable Law

Fundamental Theory of Heat Conduction

Fluid temperature is a function of 3 factors

$$T_f = \frac{Q}{4\pi\lambda H}\left(\ln\left(\frac{4at}{r_0^{\,2}}\right) - \gamma\right) + \frac{QR_b}{H} + T_{sur}$$

- Ground response to thermal impulse
- Borehole resistance Rb
- Ground Temp.

Source: C Ecklof and S Gehlin, 1996

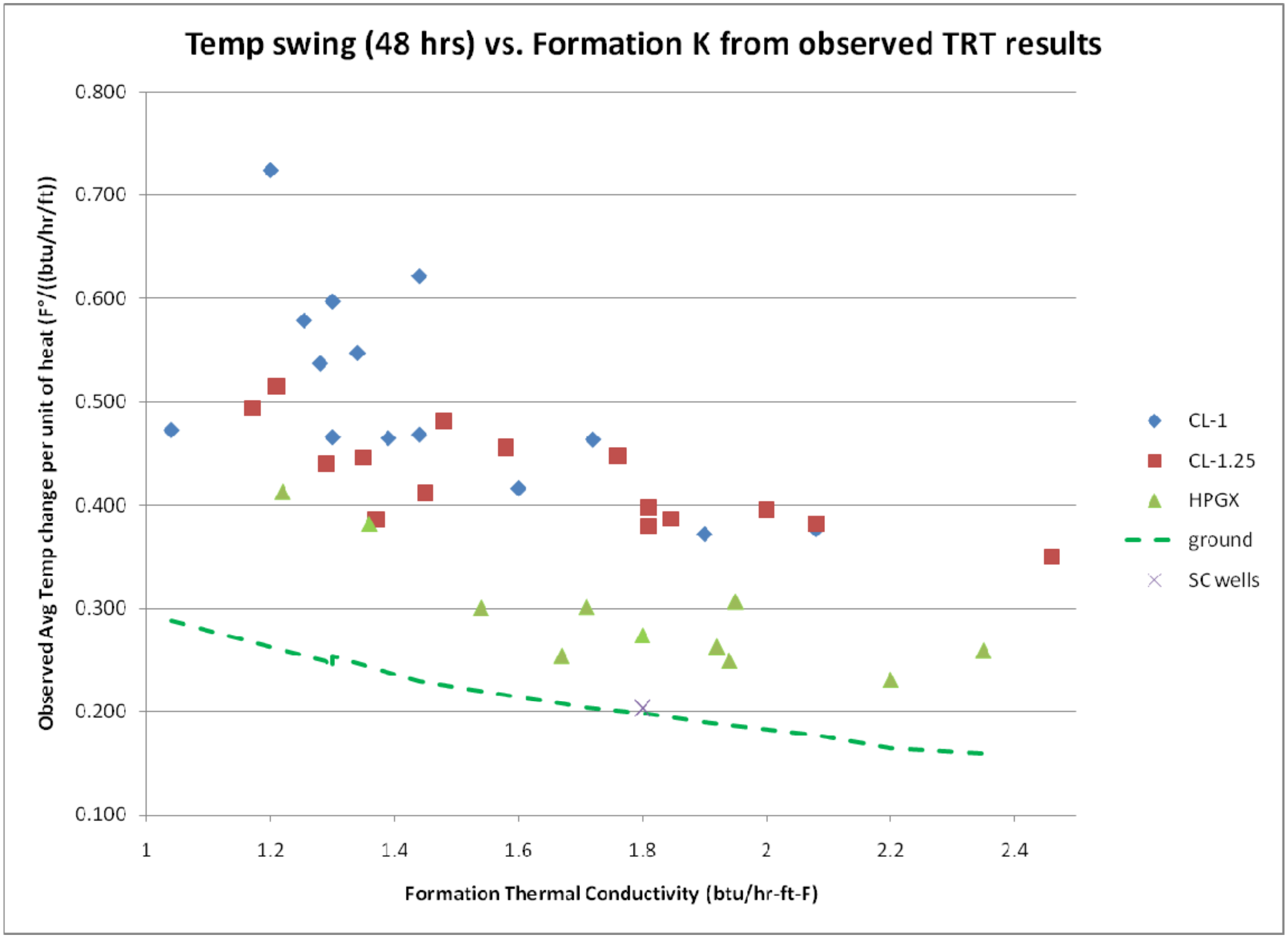
Borehole Resistance

The 'Temperature Tax'

- Inability to conduct heat from the water to the earth
- Cumulative effects from:
  - Thermal conductivity of the materials used
  - Geometry of the exchanger within the borehole
  - Contact time

- Three hurdles:

Thermal Performance by Exchanger Type



Connecting you to clean energy

Economics

High Capital Cost, Low Operating Costs

– First cost hurdle
– 40-60+% annual savings over conventional climate control systems
– ROI is variable, dependant upon
  - Cost of electricity vs. fuel
  - Construction costs
  - Equipment offset (GSHP vs. Conventional)
  - Drilling requirements

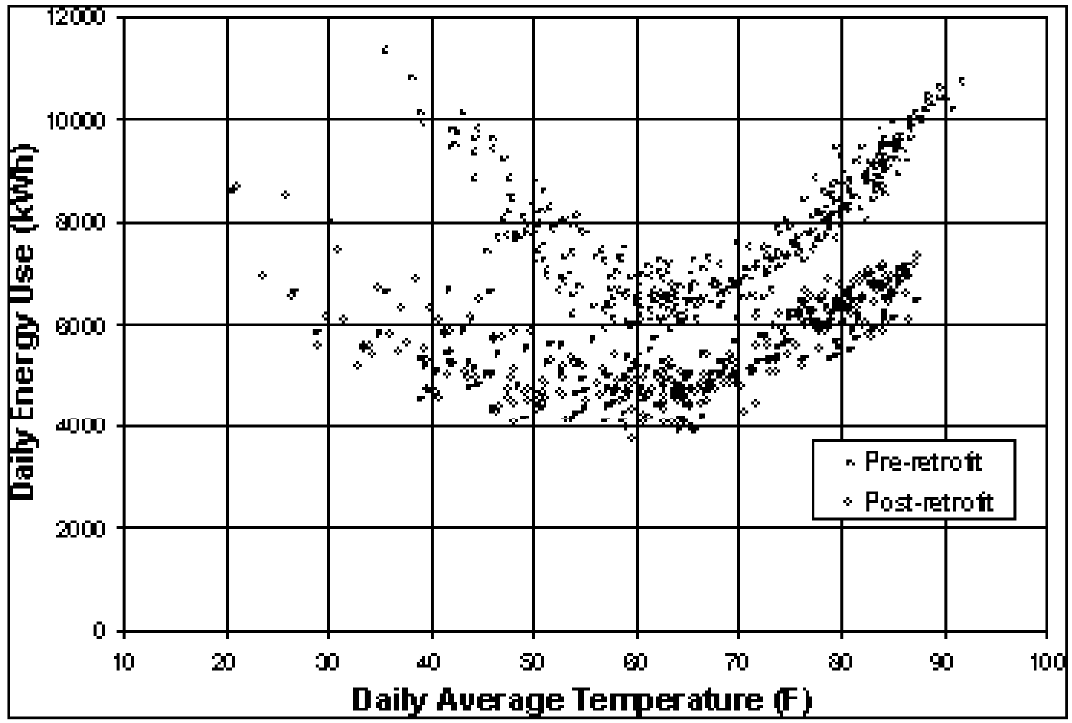
A Commercial Perspective

Fort Polk, LA - US Army - 4,000 units - 5.6 million ft

GSHP's and Energy Upgrades
6,600 Tons
Initial Cost - $19 million

- ✓ 32.4% Electricity savings
- ✓ 40% Peak Reduction
- ✓ Nat Gas reduced 260K therms
- ✓ Maintenance reduced to 77% of pre-retrofit level

Total Savings = $3 million/year
Payback = 6.3 years



Each data point represents the electric use of 200 homes (one electrical feeder) on a given day.

Source: USDOE Fed Energy Management Program

Problems and Pitfalls in the Drilling World

<u>Drilling into the unknown.</u>

Successful drillers are those who understand and respect the challenges that lie beneath their feet, and have plans B and C at the ready.

The challenges are many, the possible solutions are few.

• High yield conditions	• Flowing well conditions
• Highly fractured rock	• Running sands
• Borehole deviation	• Over excavation – Sinkholes
• Loss of Mud	• Methane
• Salt water production	• Incompetency

Wrap-up

Thank you

Questions?

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