Geothermal (Ground-Source) Heat Pump Systems for Building Heating, Cooling, and Hot Water

SUNY/Small Business Development Center – Geothermal Workshop,
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3 Categories of Geothermal Systems

- High Temperature Electric Power Production
- Low Temperature Direct Use Applications
- *Ground Source Heat Pump Applications (this presentation)*

What You Should Learn:

- Better understanding of the technology
- Clear up misconceptions, confusion with “hot rock” geothermal
- Pros and cons
- How ground source differs from PV and wind
- Costs and incentives
- Local operating systems
- ***Opportunities for job growth with the variety of trades and professions involved***

What is “Geothermal”?

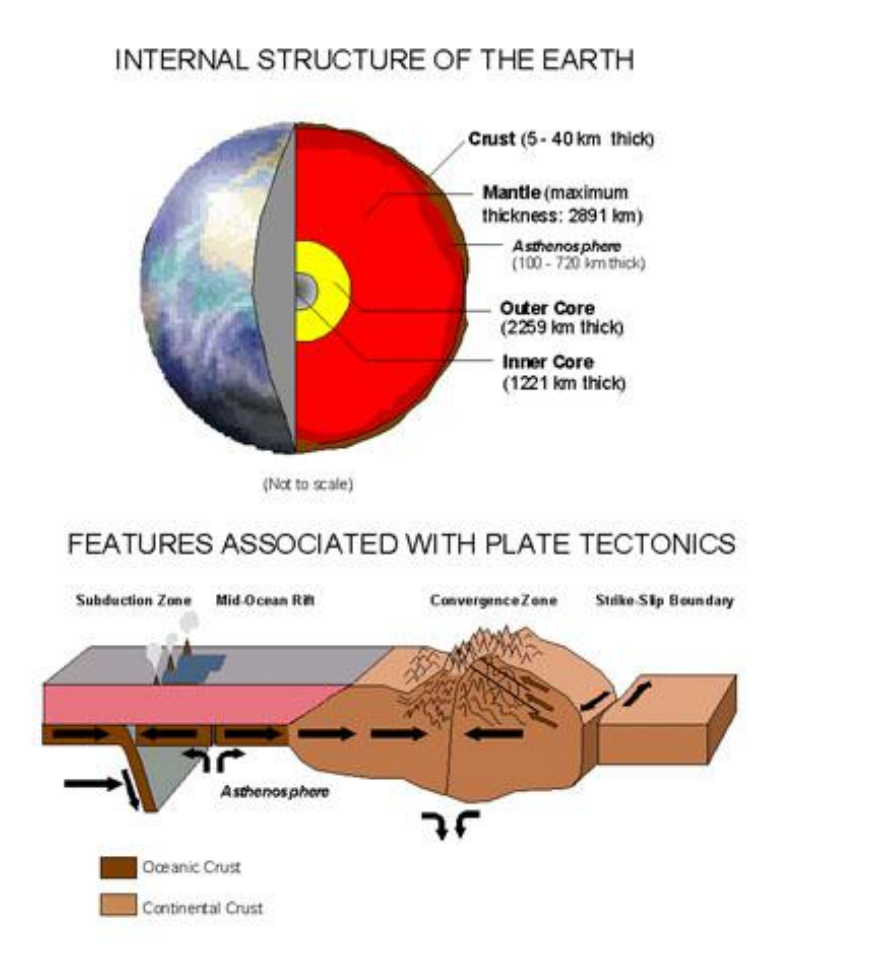
- Technically, means “earth heat”
- Several varieties of “geothermal”
- Local variety is used for space heating and cooling
- In our area, average earth temps. are 50-55 degrees F
- Limitless amount of heat energy contained in earth materials beneath us for heating
- For cooling, these same earth materials serve as a “sink” to reject and store excess heat

Geothermal (NOT Ground-Source Heat Pumps)

Yosemite National Park

Geothermal Power Plants, Northern CA

Geothermal vs. Ground Source



"Geothermal" taps into magma and hydrothermal fluids generated from tectonic activity within the Crust

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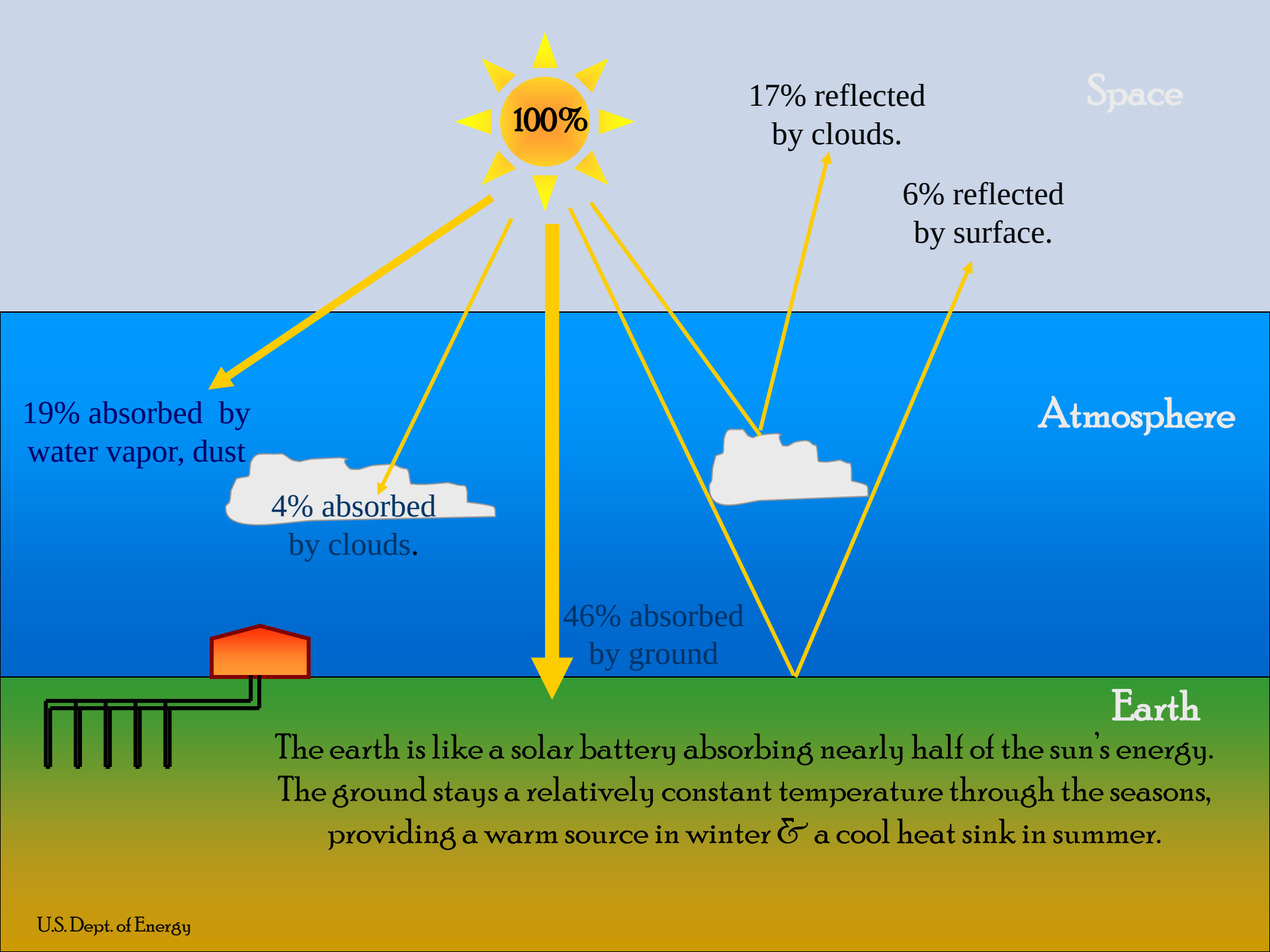
"Ground Source" taps into the moderate ambient earth temperatures in the shallow Crust…unrelated to tectonic activity and NO MAGMA REQUIRED


100%
17% reflected by clouds.
Space
6% reflected by surface.
19% absorbed by water vapor, dust
Atmosphere
4% absorbed by clouds.
46% absorbed by ground
Earth
The earth is like a solar battery absorbing nearly half of the sun's energy.
The ground stays a relatively constant temperature through the seasons,
providing a warm source in winter & a cool heat sink in summer.
U.S. Dept. of Energy

Why Isn't Ground Source More Widely Used on LI

- General higher first cost than other HVAC systems
- Gets overlooked…it's underground and a dirty drilling rig makes a lousy photo op
- Current focus on solar, wind, CHP, etc.
- General lack of knowledge of technology
- Misinformation and hearsay about "problem" systems…that it doesn't work
- ***Shortage of infrastructure…trained, experienced installers, drillers, designers, architects and engineers.***
- Actual or perceived subsurface risks/issues
- Actual or perceived regulatory hurdles

THE FACTS

- Can be used anywhere people live, from the Arctic to the Equator
- Can supply all the heating and cooling needs of a building
- A single mechanical system replaces the two separate systems
- USEPA has concluded that ground source heat pumps are the cleanest, most energy-efficient heating and cooling systems on the market.
- Fully endorsed by USDOE and Energy Star
- All electric-powered system; eliminates on-site fossil fuel use
- Can provide simultaneous heating and cooling

THE FACTS (cont'd)

- Can be suited for any type or size building, religious facilities, schools, and private homes
- Demonstrated lowest life-cycle cost of all other HVAC systems
- ***SIMPLY PUT, THE EARTH SERVES AS YOUR BOILER FOR HEATING, AND AS THE COOLING TOWER, CHILLER, OR CENTRAL AIR CONDITIONING SYSTEM FOR COOLING***
- May not be a good fit at every site; conduct appropriate due diligence
- Each system is an engineered solution…no cookie cutter approach

How does Ground Source Compare to Solar and Wind

- PV's and wind are used to generate electricity and heat water
- Ground Source is used exclusively for indoor space heating and cooling, and domestic hot water production
- However, designated in same category as "energy property" under US Tax law in the bailout bill (Oct. 2008)
- Ideal goal to integrate with PV/wind towards zero energy buildings

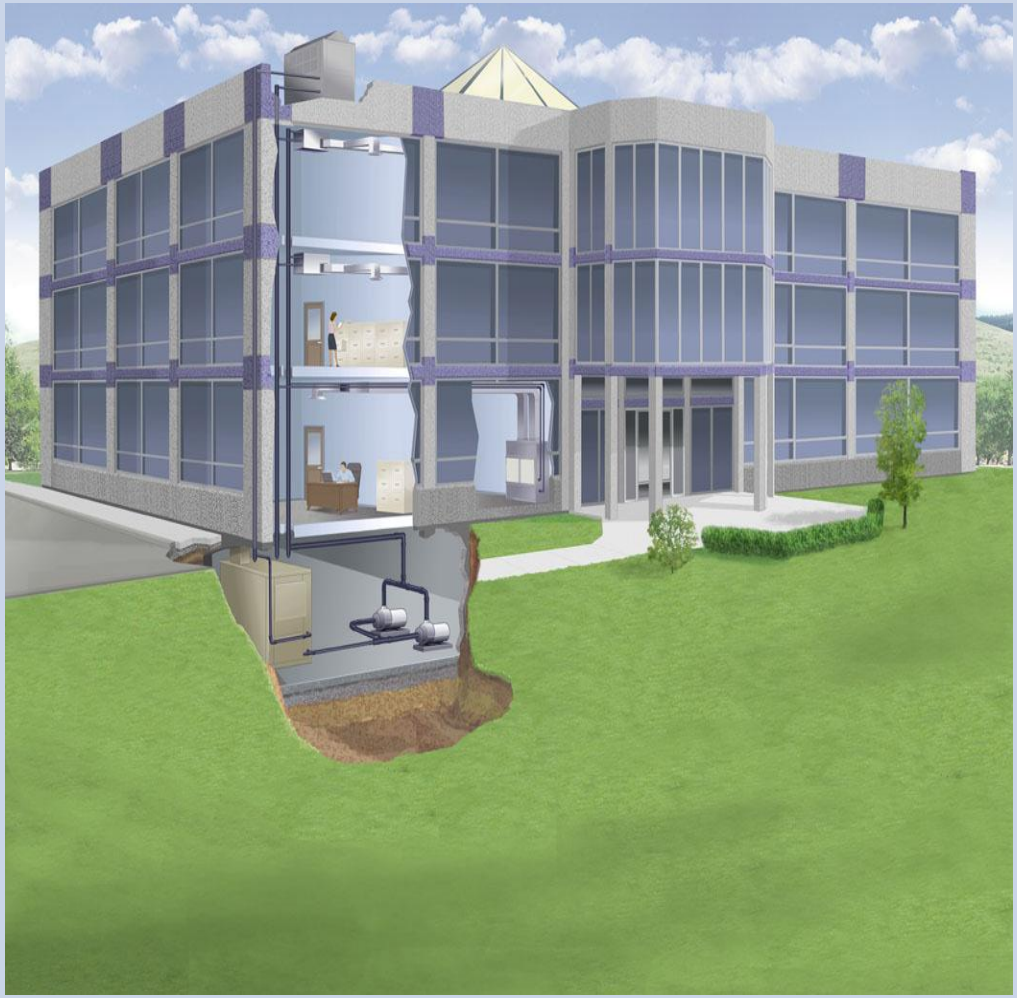
Basic System Layout and Operation

Conventional Boiler/Tower System

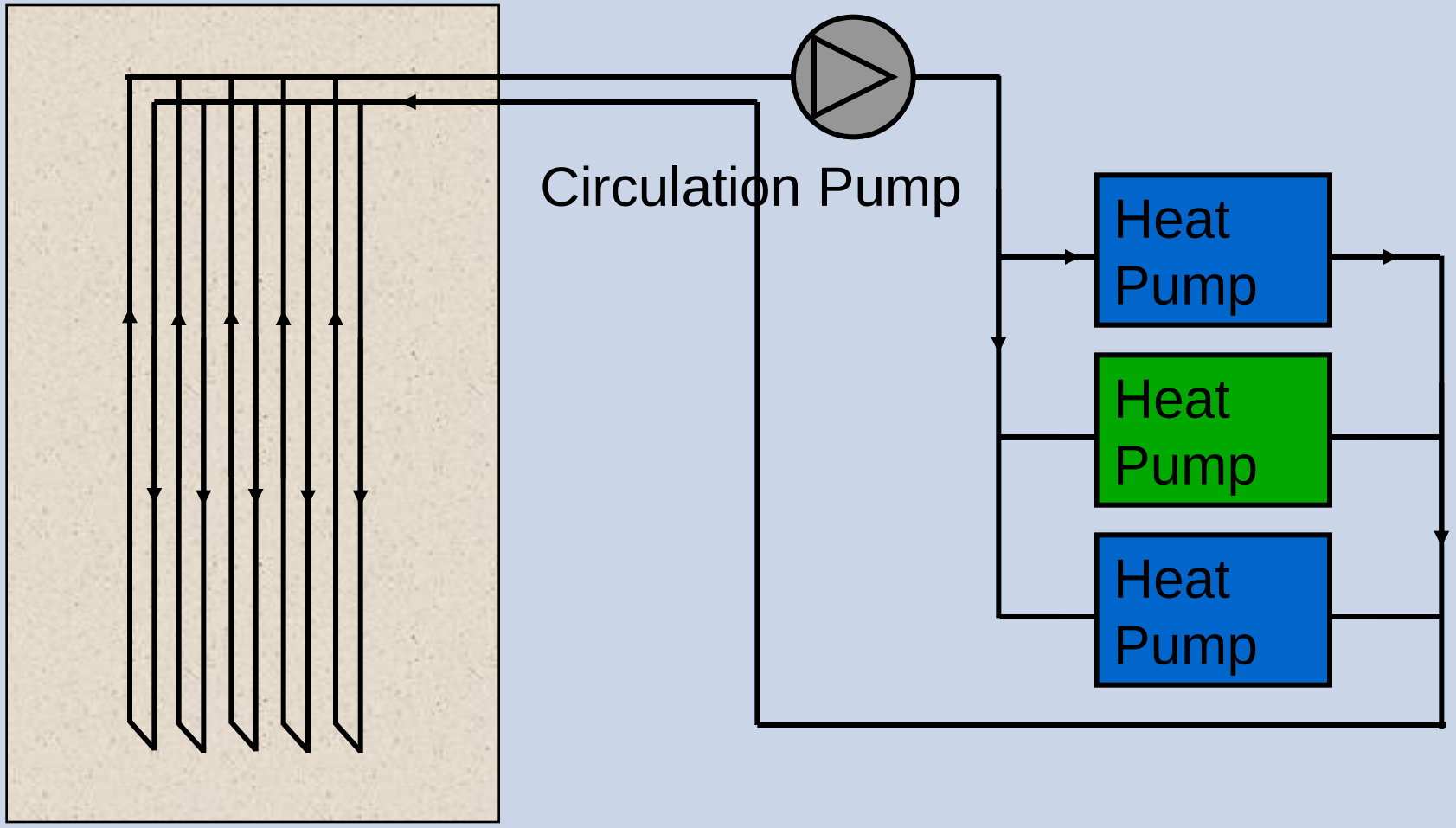
- Two independent mechanical systems, one for heating, one for cooling

- Two separate piping and/or duct systems

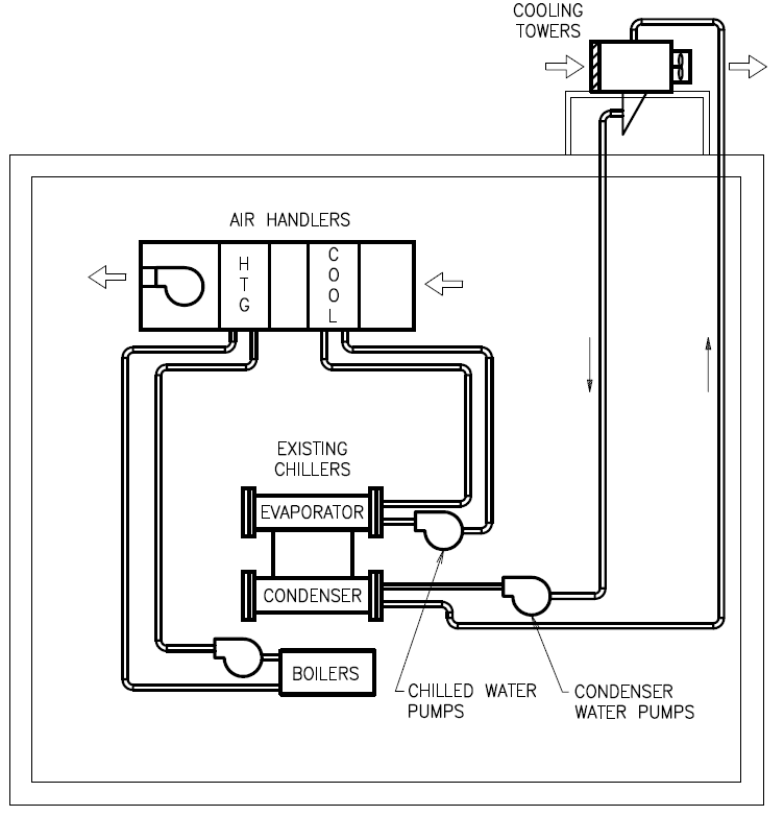
- Two separate fuel/energy sources

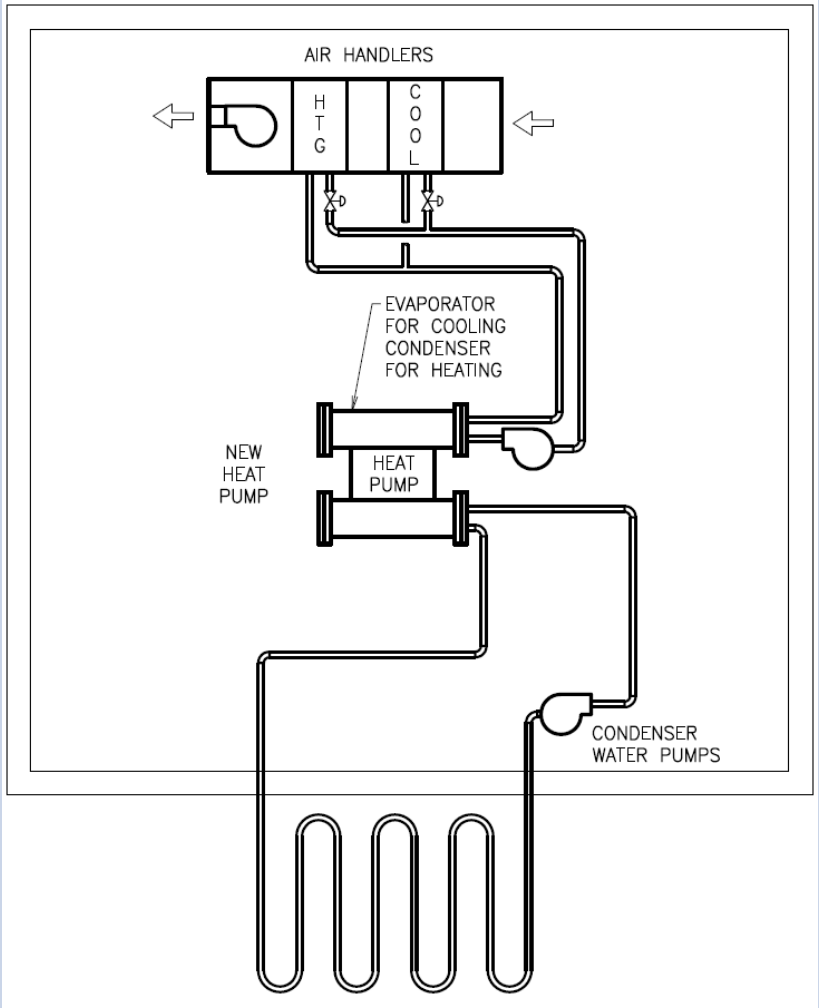


Basic System Layout

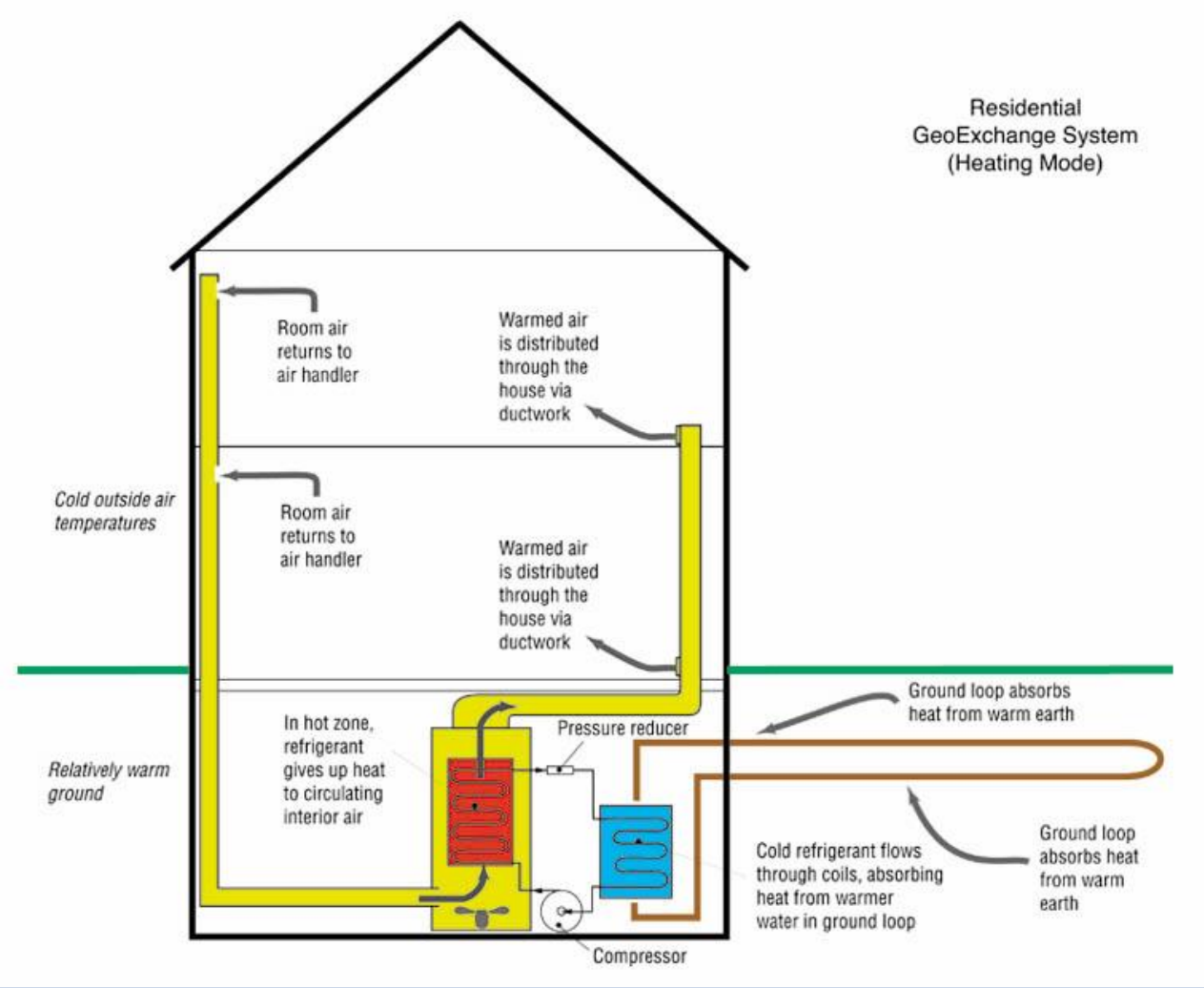


Conventional vs Geothermal

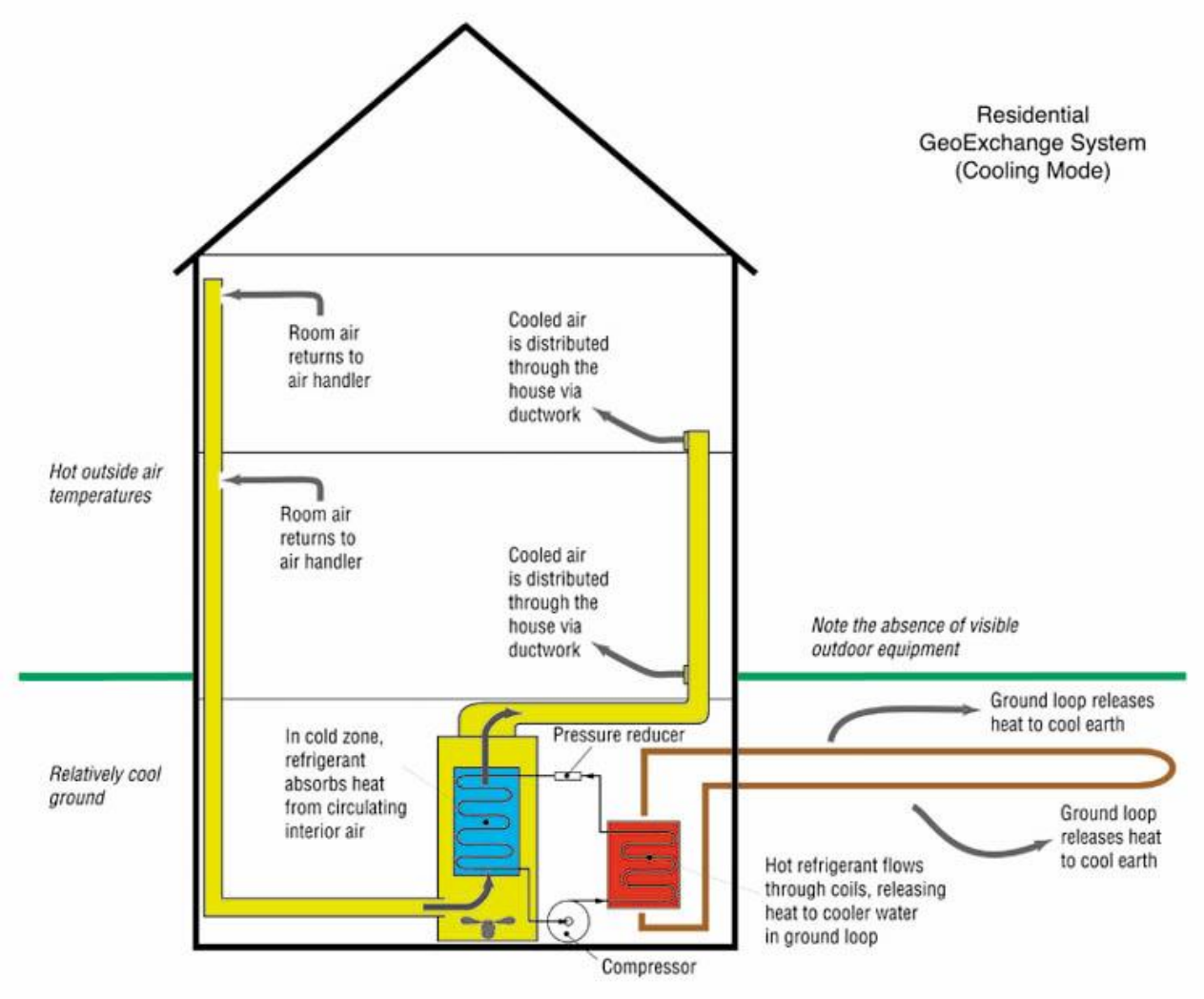




Basic Operation - Heating Mode



Basic Operation - Cooling Mode



Benefits

GHP Benefits

- Energy efficiency - 25-40% lower energy costs
- Simplicity
- Low maintenance - 1/3 to 1/2 of Conventional Costs
- Enhanced safety, security – no oil storage tanks, oil deliveries, source of combustion
- No auxiliary heat (in most cases)
- No outdoor equipment
- Simultaneous heating & cooling (diversification)
- Educational opportunities for students and the public
- Lowers peak demand
- Low life-cycle cost
- Allows more architectural freedoms
- Better zone comfort control

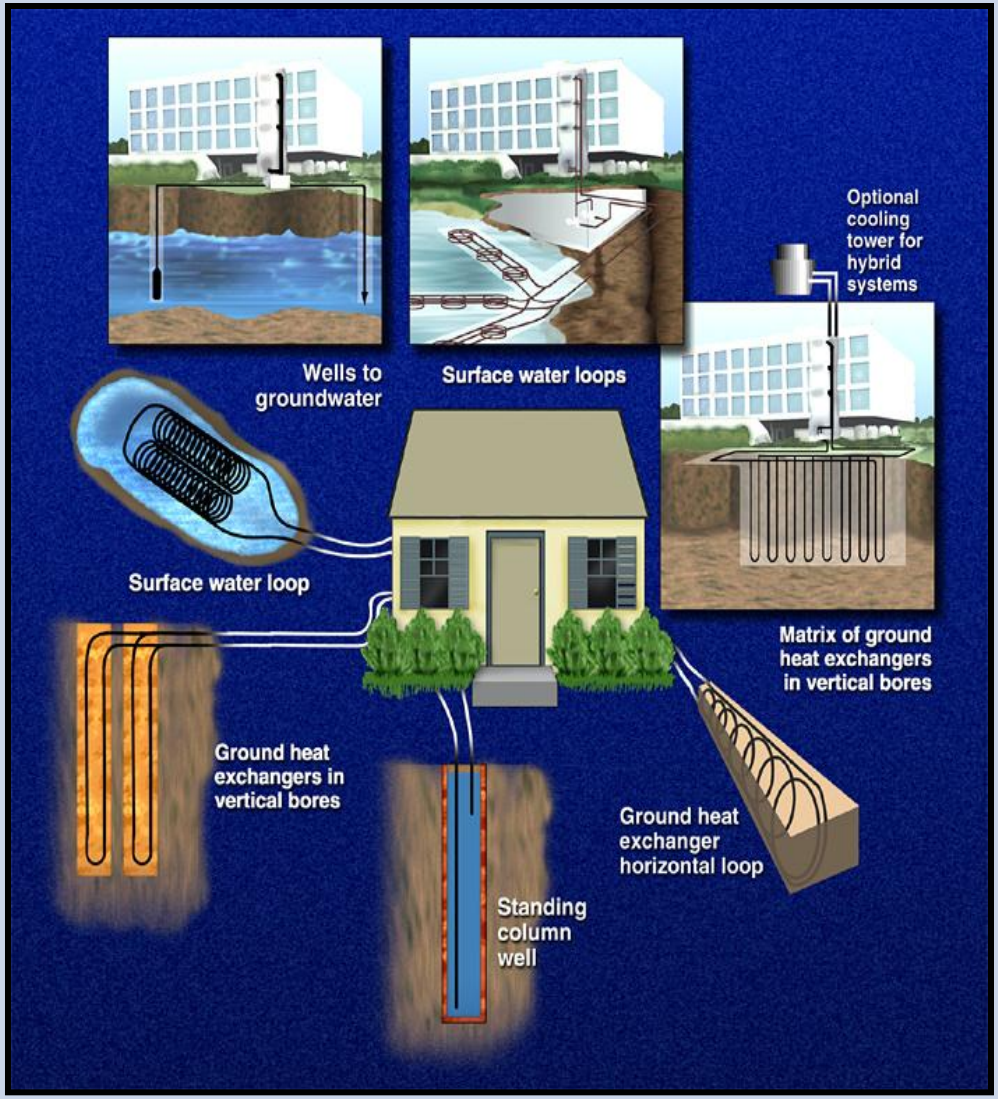
GHP Disadvantages

- 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

The “Ground Coupling”

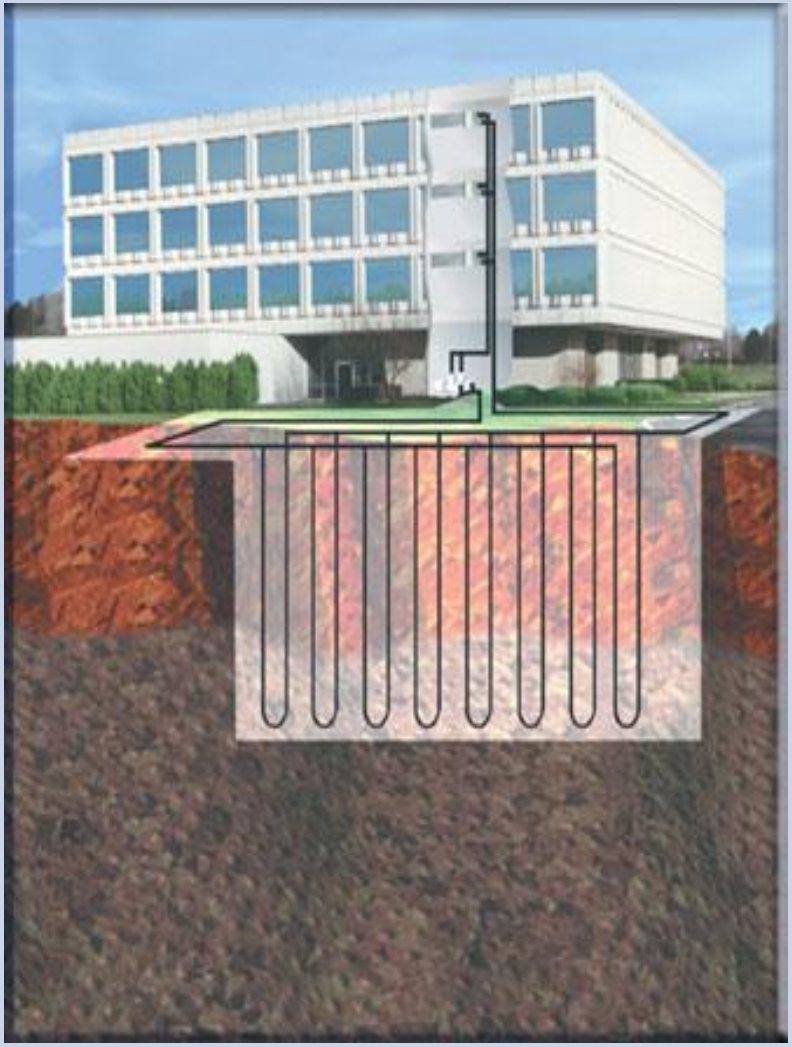
We Tap the Resource Using a Variety of ”Ground Couplings”

The Type of Ground Couplings Depends on Site Conditions



Source: US Dept. of Energy

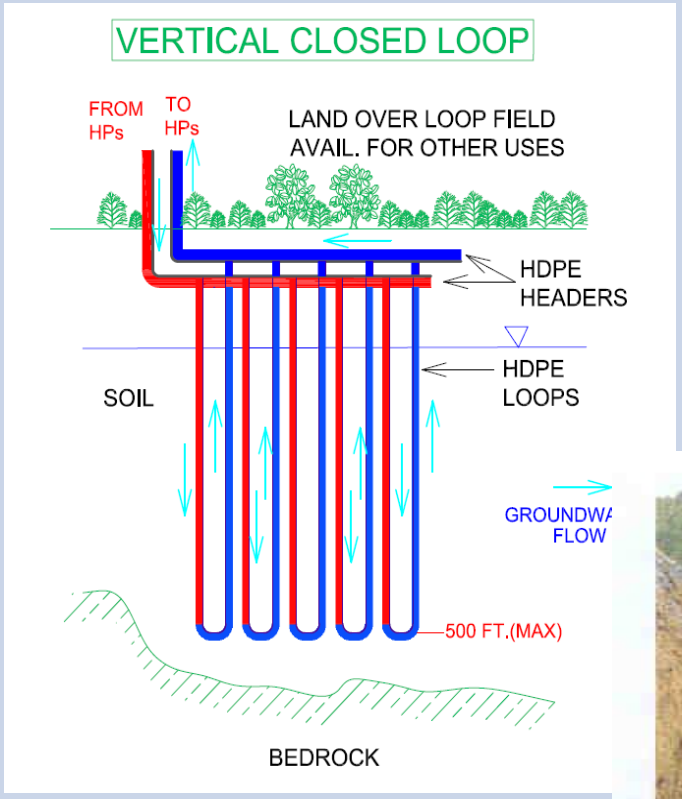
Vertical Closed Loop Systems



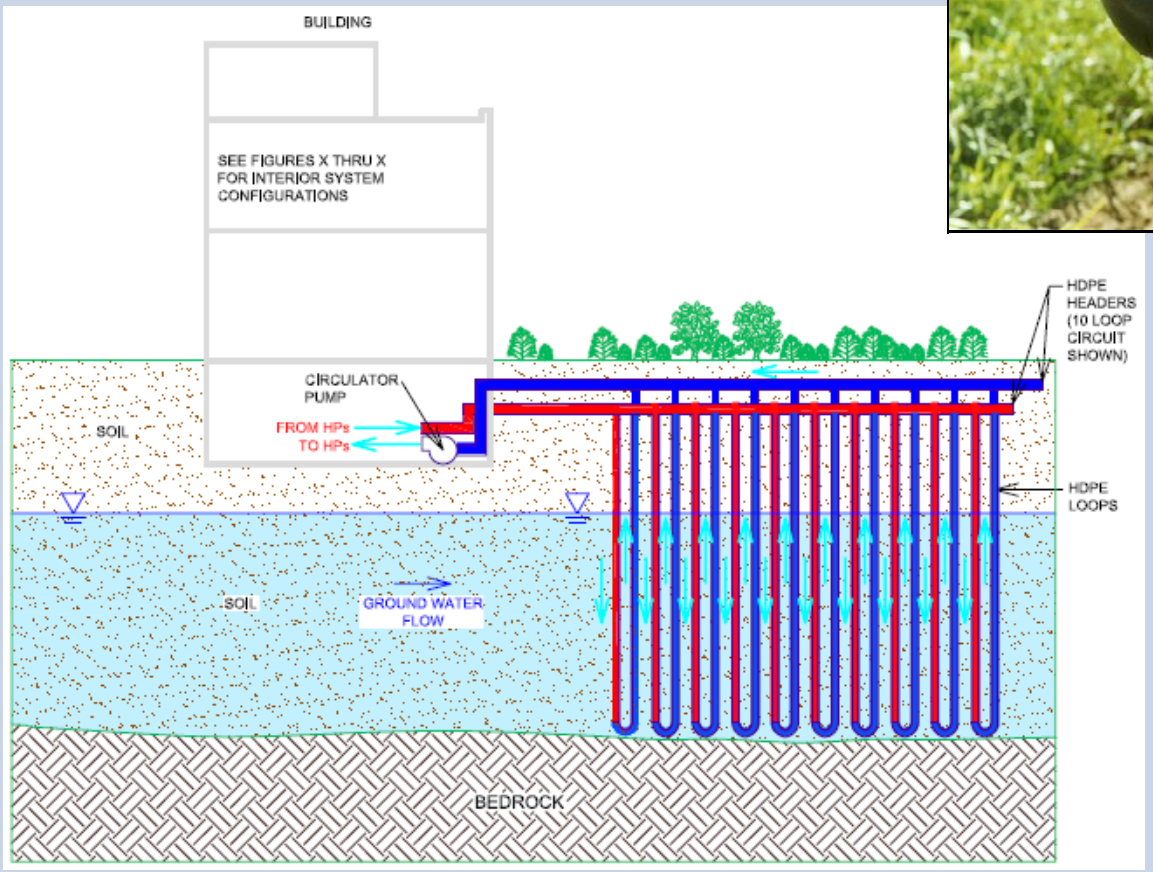
- **Rule of Thumb: 150-200 linear ft. of loop per ton of cooling/heating load.**
- **Each bore 150 - 400 ft deep.**
- **Typ. 20 ft. spacing in grid layout.**
- **¾”, 1”, 1-1/4” HDPE loops.**
- **Fluid filled with water or water with biodegradable, non-toxic antifreeze (ethanol, propylene glycol).**
- **Thermal grout annulus fill**
- **Loop piping is heat-fused to headers by IGSHPA-certified technicians**

Conductive thermal exchange from circulating fluid to earth materials, through the HDPE and grout backfill

Vertical Closed Loop



Vertical Closed Loop Installation



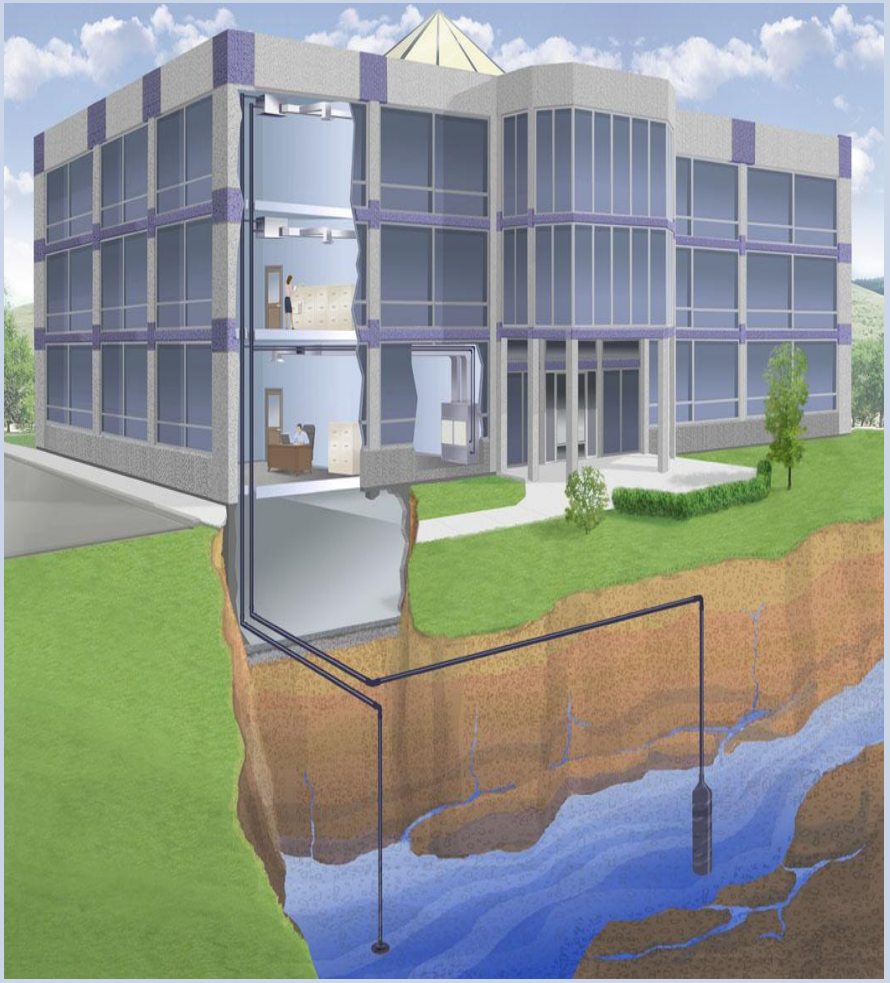
Loop Pressure Test

Slinky® Heat Exchanger Field

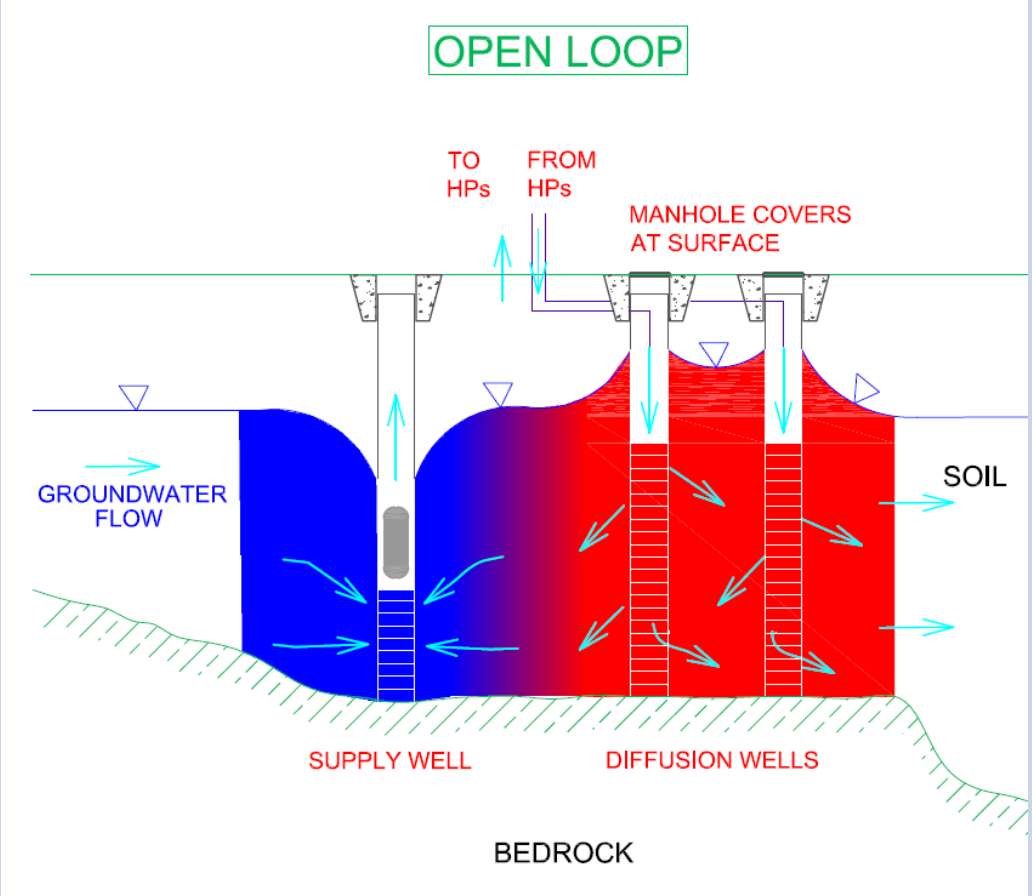
Slinky Heat exchanger in 6-inch wide trench

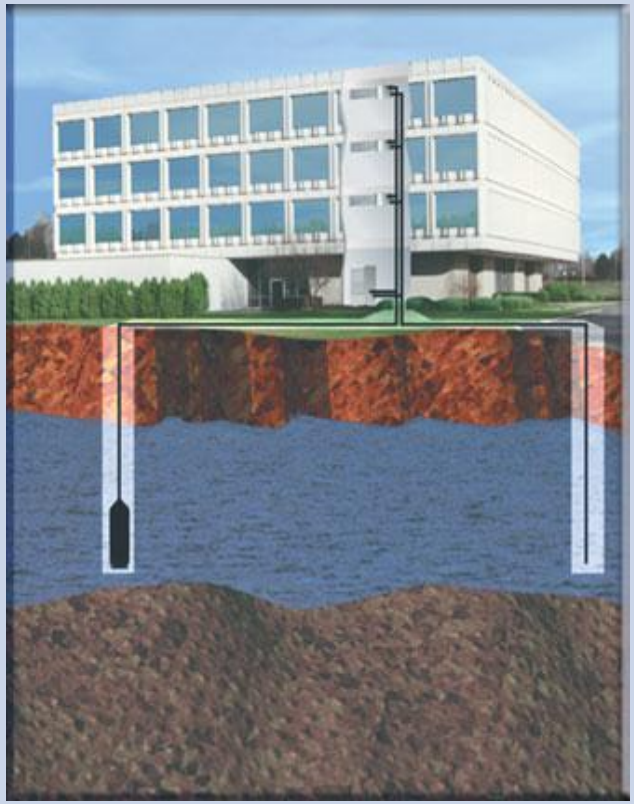
Ground Water “Open Loop”

- Entering groundwater temperature on LI ranges from 50 to 55 degrees F
- Poor water quality can increase maintenance costs; can be project killer (iron, pollutants, TOC)
- NYSDEC requires extract and return to same aquifer
- Plate-frame heat exchanger advisable between well loop and building loop

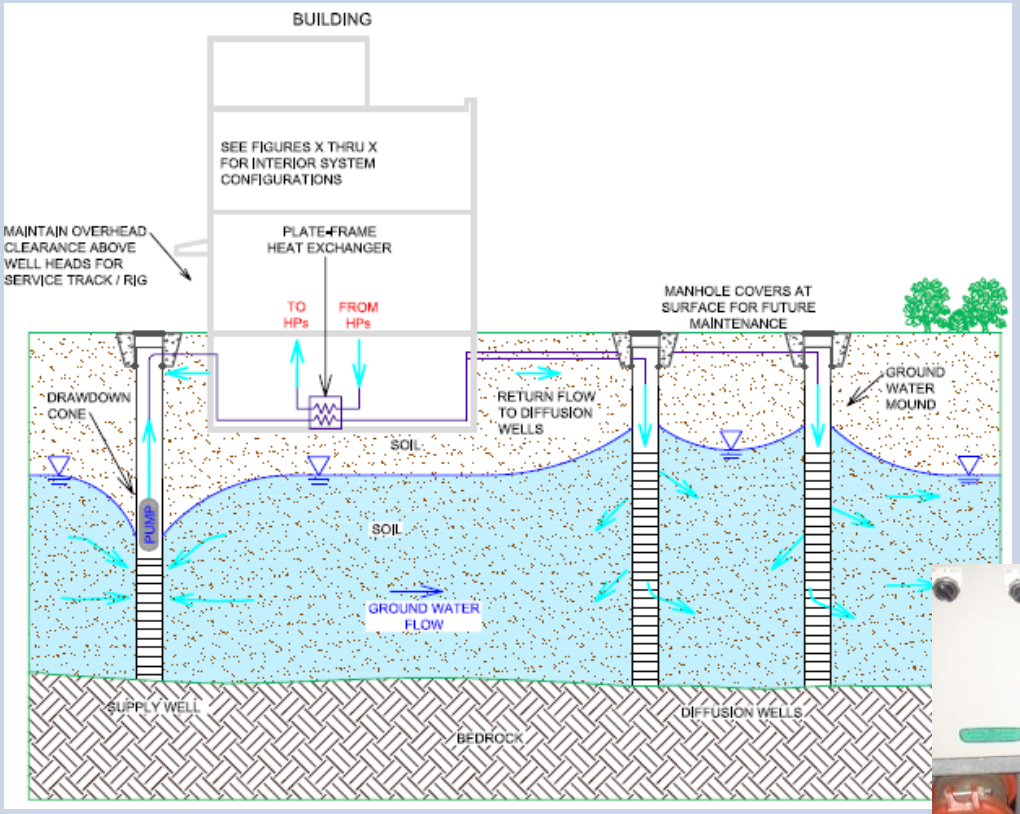


Open Loop


OPEN LOOP
TO HPs
FROM HPs
MANHOLE COVERS AT SURFACE
GROUNDWATER FLOW
SOIL
SUPPLY WELL
DIFFUSION WELLS
BEDROCK



Open Loop


BUILDING
SEE FIGURES X THRU X FOR INTERIOR SYSTEM CONFIGURATIONS
MAINTAIN OVERHEAD CLEARANCE ABOVE WELL HEADS FOR SERVICE TRACK / RIG
PLATE-FRAME HEAT EXCHANGER
TO HPs
FROM HPs
MANHOLE COVERS AT SURFACE FOR FUTURE MAINTENANCE
GROUND WATER MOUND
DRAWDOWN CONE
RETURN FLOW TO DIFFUSION WELLS
SOIL
PUMP
SOIL
GROUND WATER FLOW
SUPPLY WELL
BEDROCK
DIFFUSION WELLS

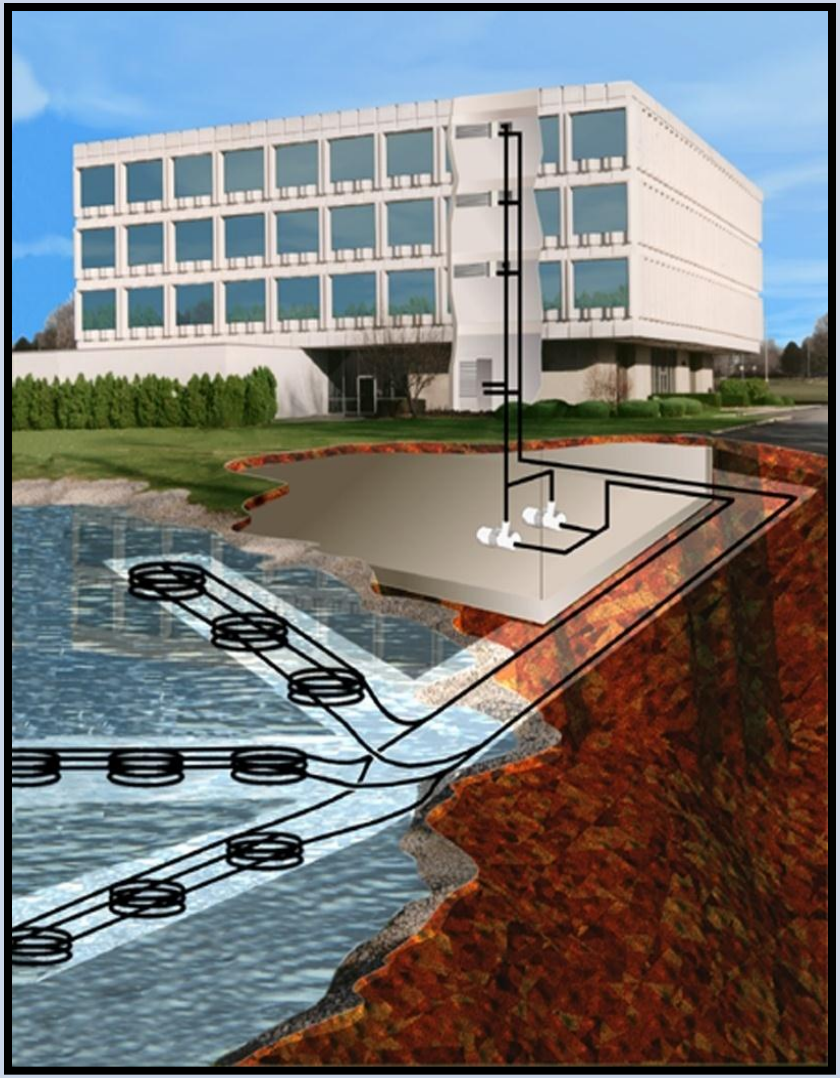
Due Diligence and Feasibility Analysis

- Subsurface Geologic Conditions--The earth is not a BLACK BOX!
- Which ground couples are suited for site?
- What's the depth to groundwater?
- What are the heating/cooling loads?
- Is there enough land area to drill to meet building peak demand?
- Is site large enough to separate wells and avoid thermal short-circuiting.
- Any environmentally bad neighbors?

Ranking Ground Heat Exchangers

Considerations	Geothermal System Type		
	Vertical Closed Loop	Open Loop	Standing Column Well
Efficiency	LOWEST	HIGHEST	INTERMEDIATE
Reliability	HIGHEST	INTERMEDIATE	LOWEST
Drilling Cost	INTERMEDIATE	LOWEST	HIGHEST
Amount of Trenching	HIGHEST	LOWEST	INTERMEDIATE
Land Area Affected	HIGHEST	LOWEST	INTERMEDIATE
Amount of Field Testing	LOWEST	HIGHEST	INTERMEDIATE
Soft Costs	LOWEST	HIGHEST	INTERMEDIATE
Maintenance	LOWEST	HIGHEST	INTERMEDIATE
Effected by Ground Water Quality	NO	YES	YES

Pond Loops



Pond Loops

Copper Pipe

Slim Jim

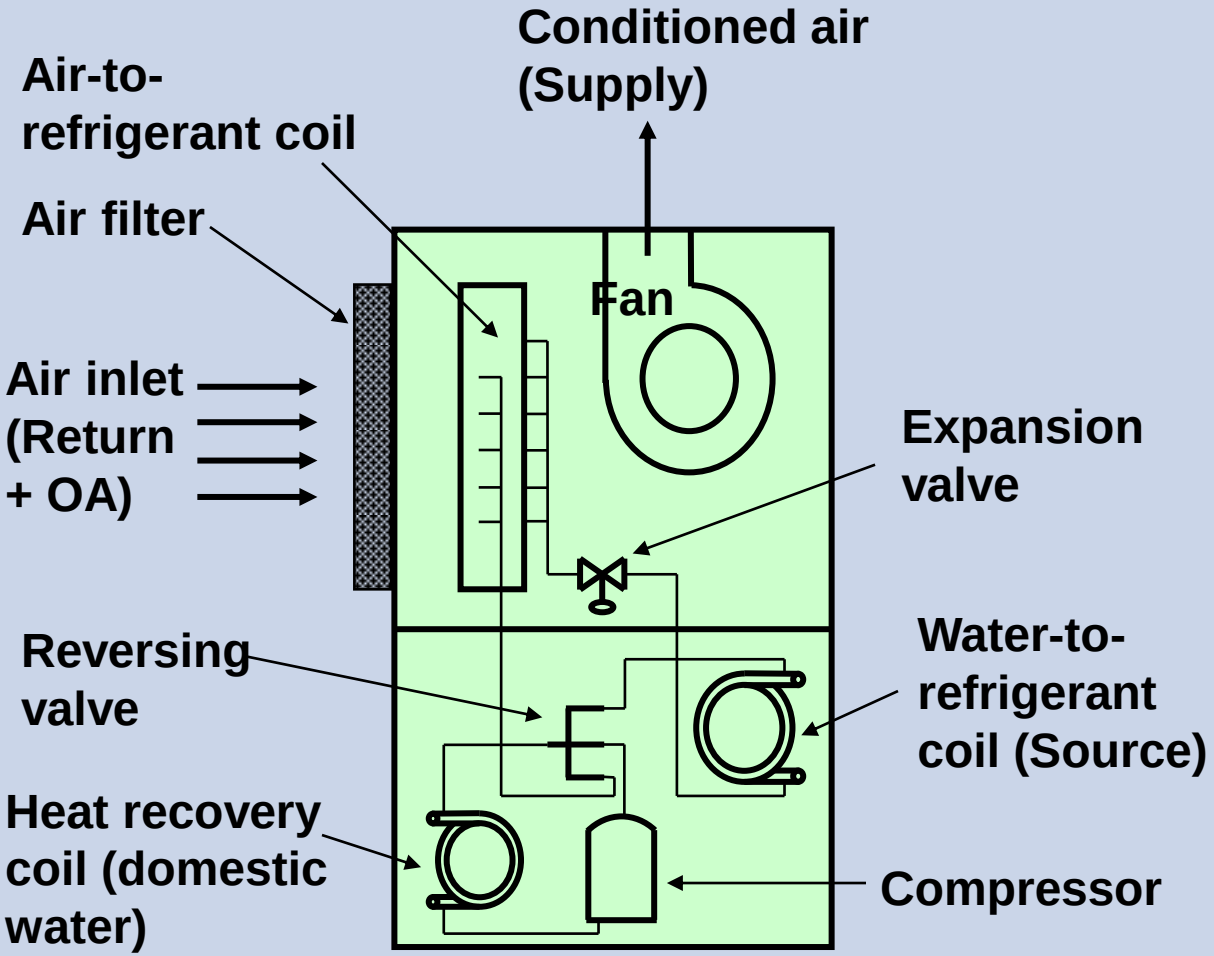
HDPE Pipe

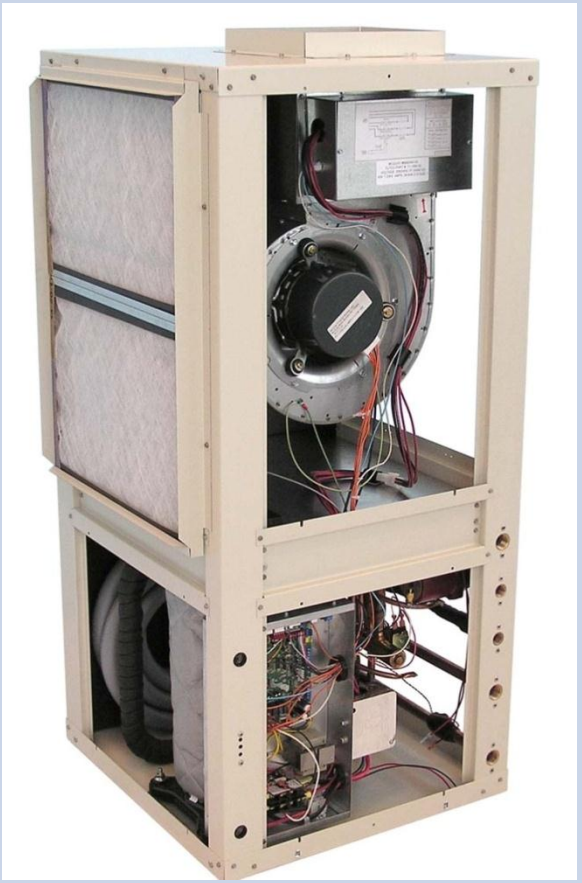
Copper Spiral Pond Loop

The Heat Pump

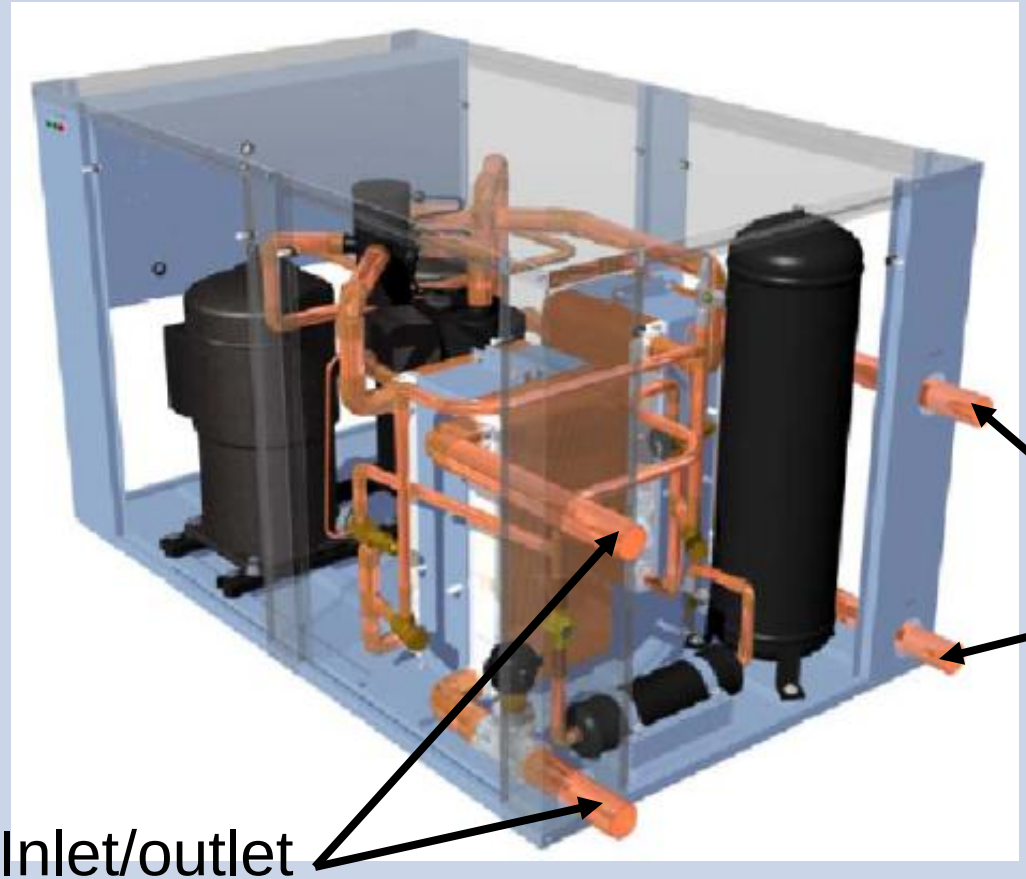
30-Ton Geothermal Heat Pump

Water-Air Heat Pump





Water-Water Heat Pump

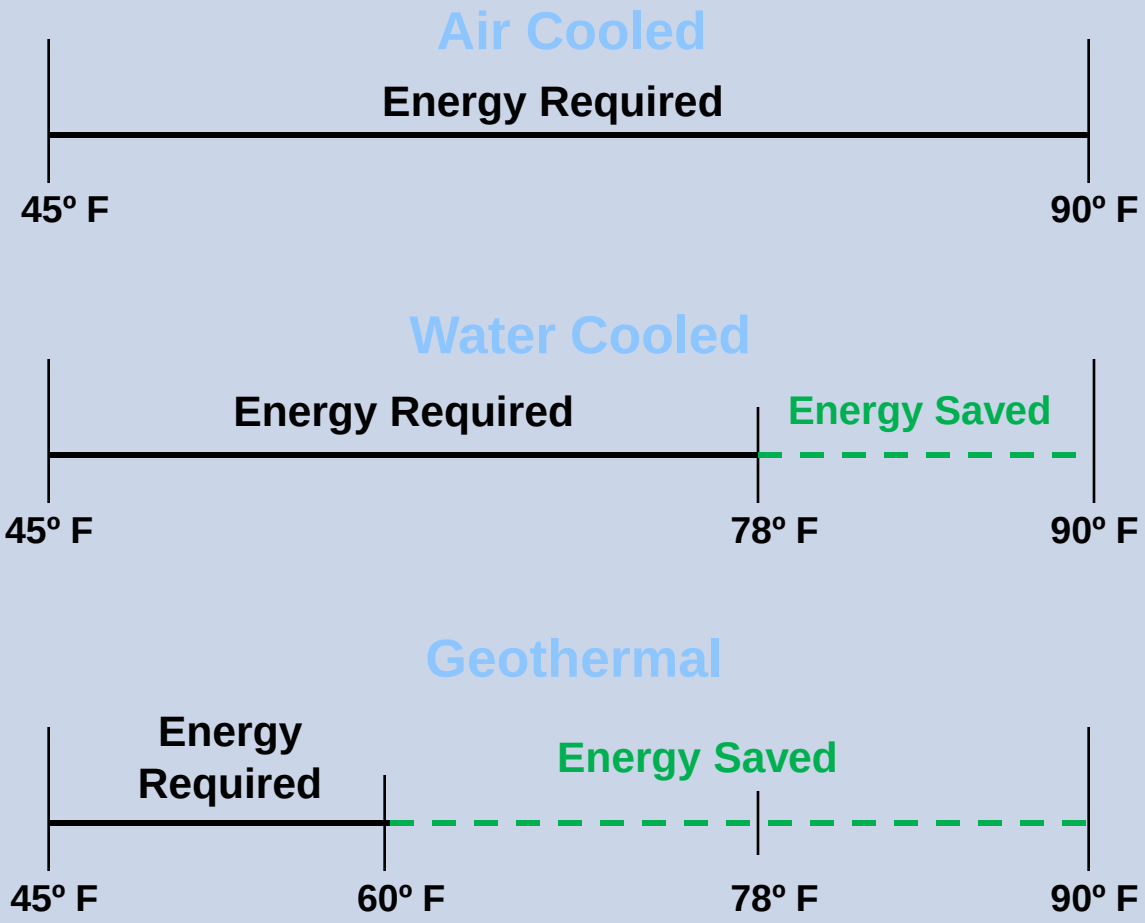


Inlet/outlet to fan coils, air handlers, VAV, etc.

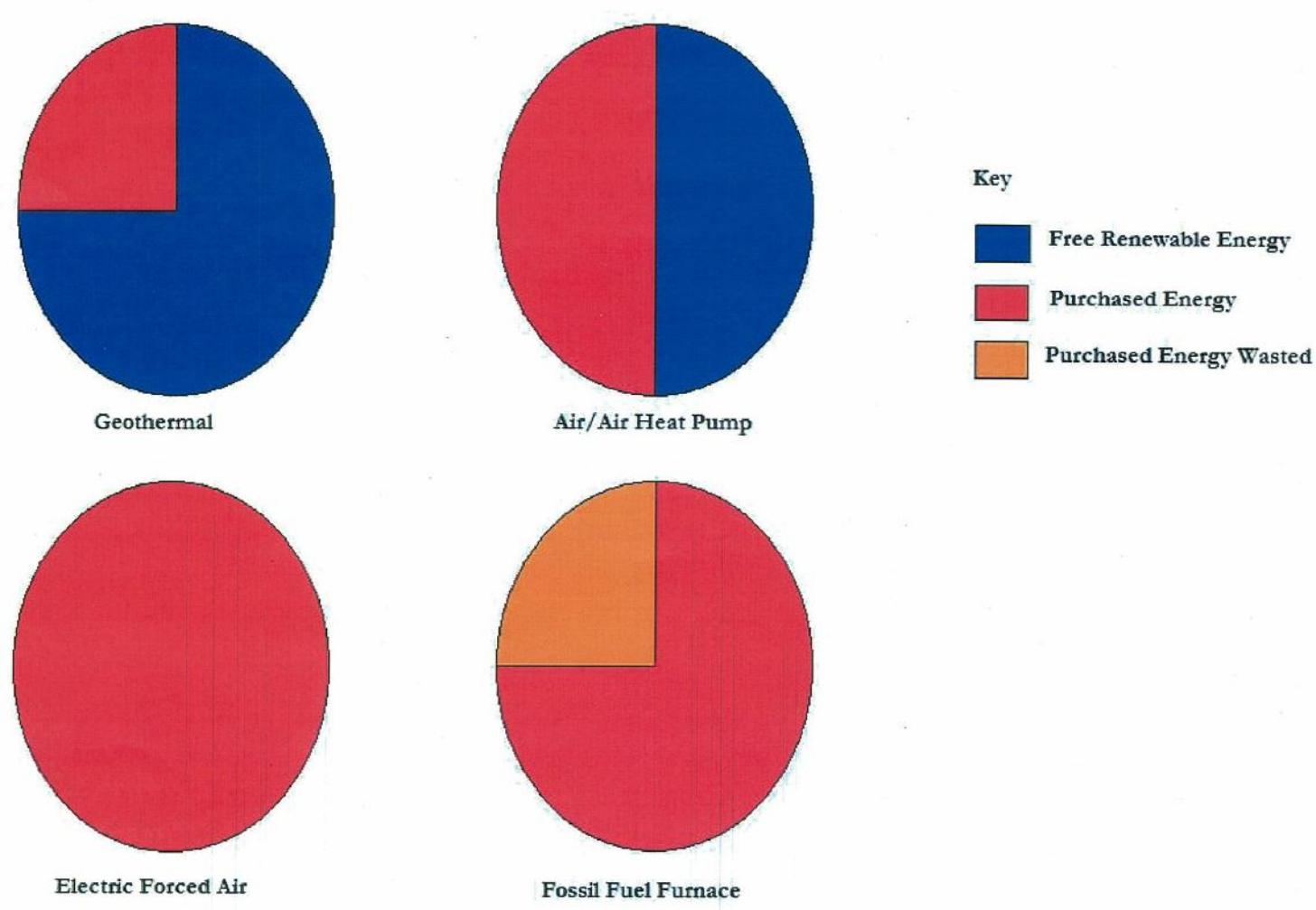
Inlet/outlet to ground loop

Energy Efficiency

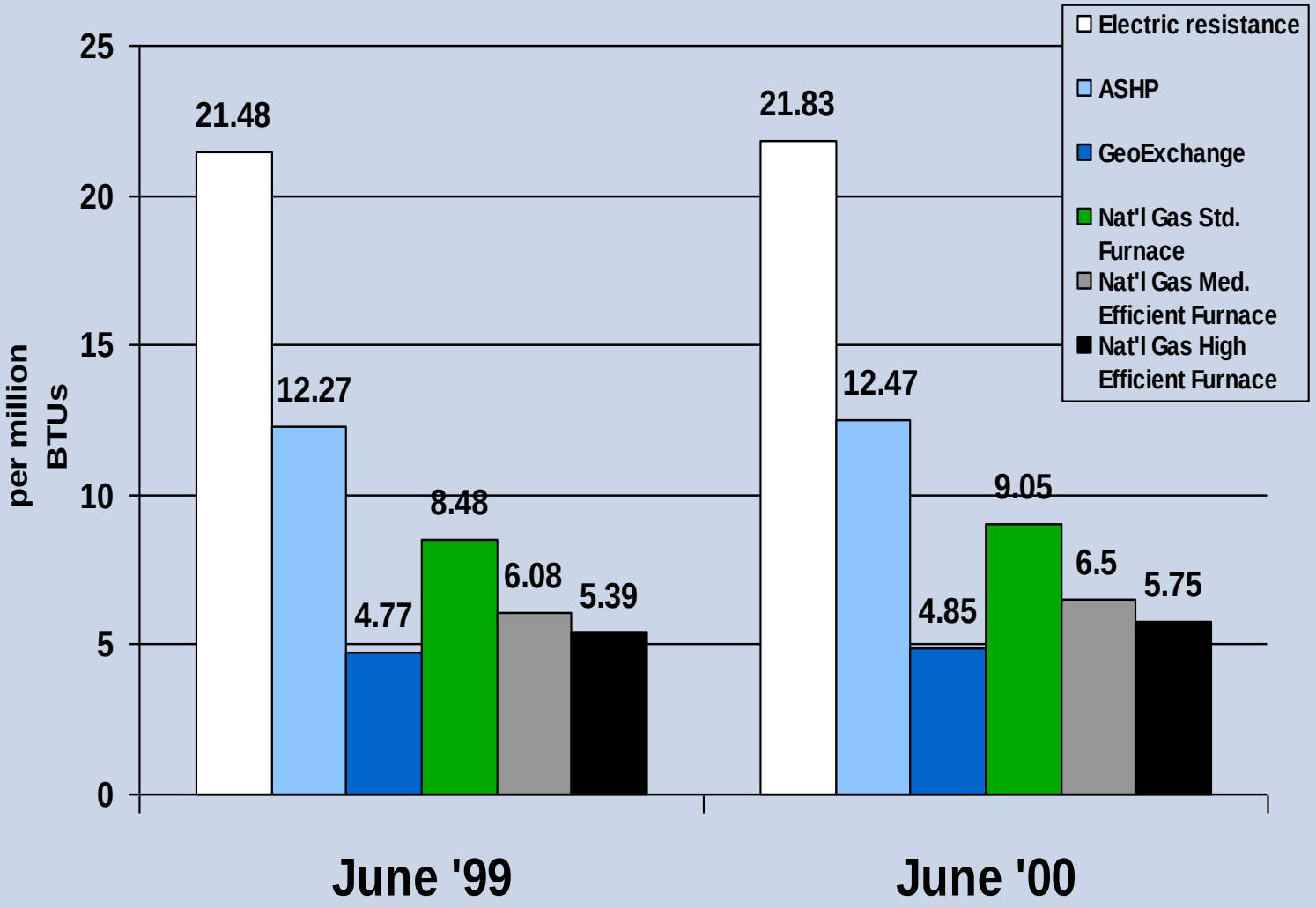
Energy Use / Savings by HVAC System Type - Cooling



Free vs. Purchased Energy



Relative Operating Costs



Local Operating Systems and Applications

Long Island Schools and Universities with Geothermal Systems

OPEN LOOP SYSTEMS (PWGC)

- Ross School, East Hampton – 3 buildings
- C.W. Post, Brookville – administration building

CLOSED LOOP SYSTEMS

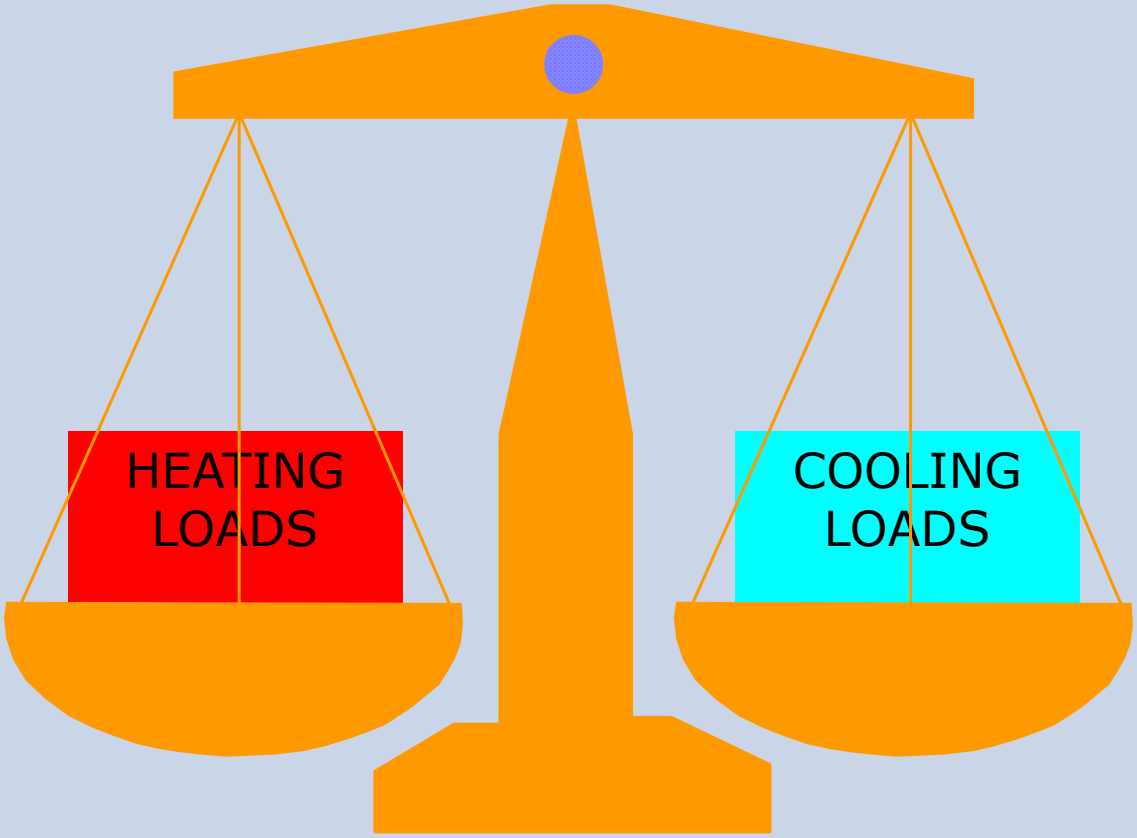
- Hewlett High School, Hewlett - 164K sf building with new addition
- Adelphi University – multiple buildings, dorm
- Kings Point Merchant Marine Academy – multiple dormitories
- Tuckahoe School (K-8), Southampton, 65K sf building with new addition
- SUNY/Southampton College Campus

Long Island Commercial Facilities with Geothermal Systems

- Glen Cove Hospital, NSLIJ (PWGC)
- SUNY/Stony Brook, Simons Center for Geometry and Physics
- Guild Hall, East Hampton
- Amityville Village Hall, Amityville
- Nature Conservancy, Cold Spring Harbor
- Southampton Village Police Station
- The Inn at Fox Hollow, Woodbury
- Peconic Landing Assisted Living Center
- Sayville Library
- Renaissance Center, Setauket
- Sisters of St. Dominick, Amityville

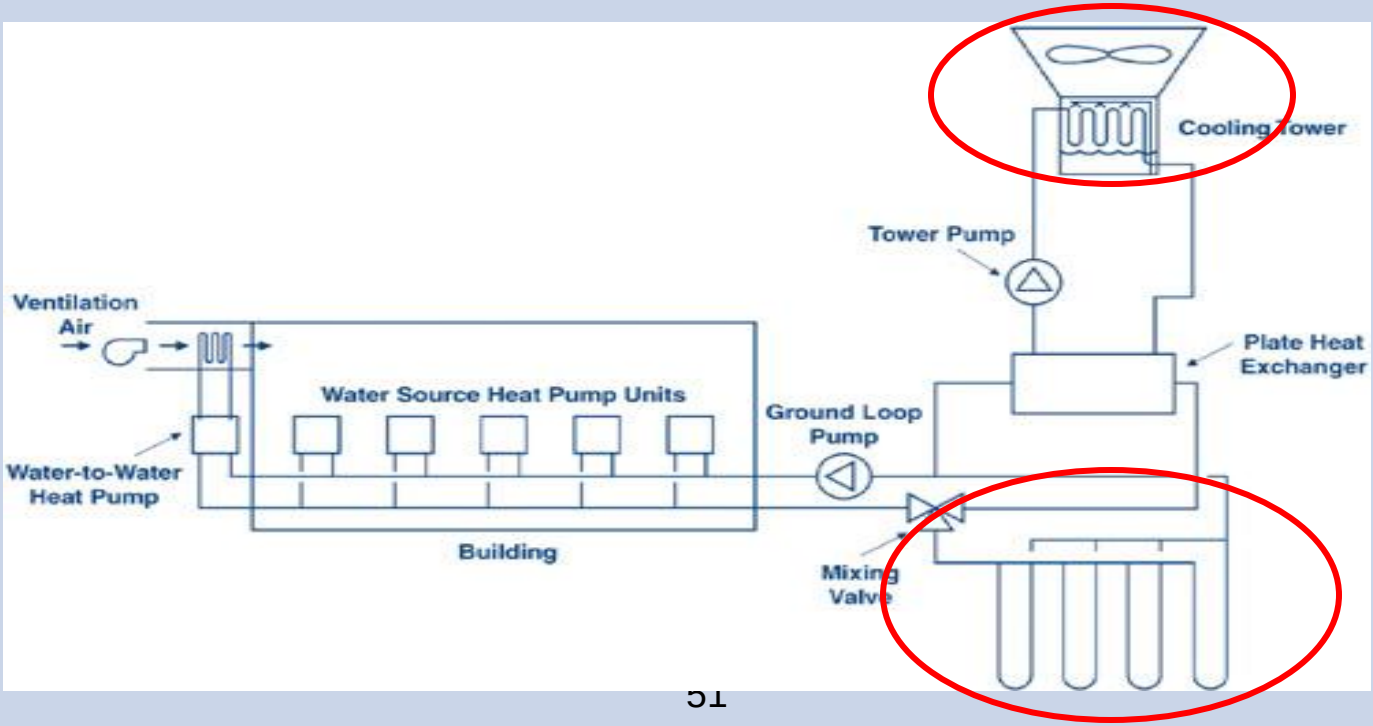
Hybrid Systems

- *Reduce loop field construction premium*
- *If not enough land area for full loop field*
- *Protect against thermal buildup or deficiency*

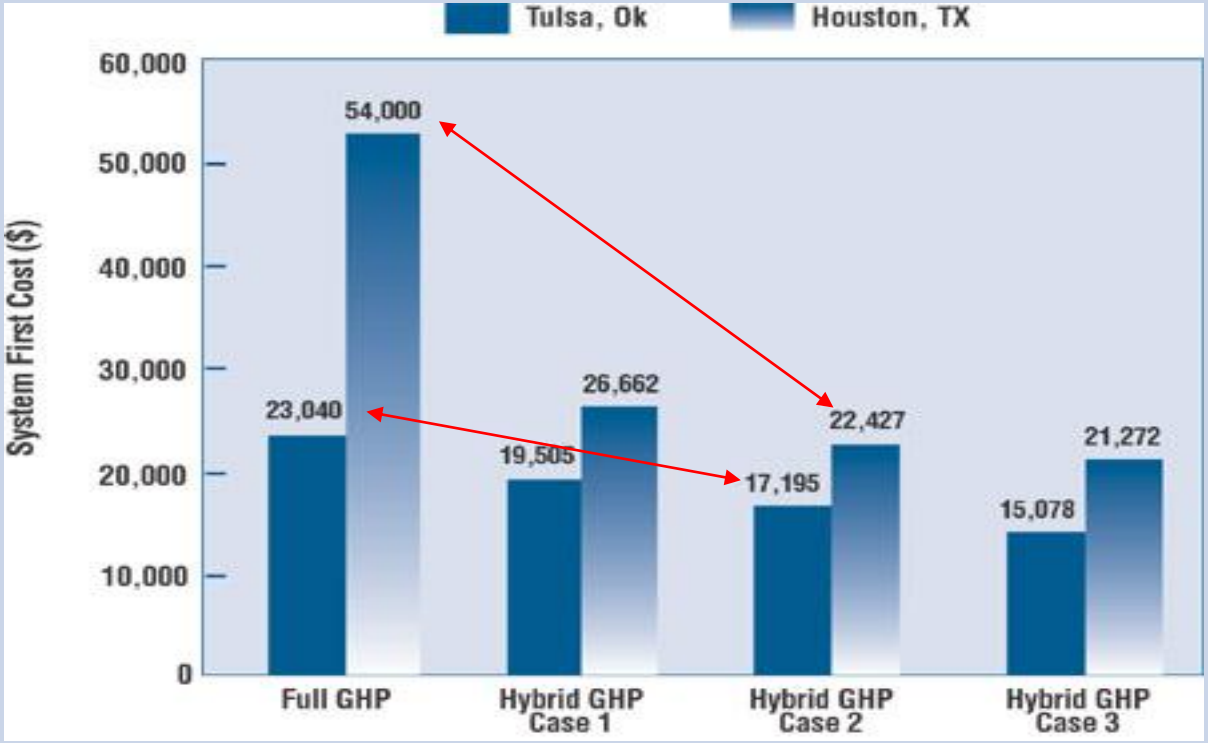


What Is A “Hybrid” Design?

- “Low cost” alternative to a full GHP design
  - Cooling Dominant – size loop field for heating load and supplement with a cooling tower for peak cooling load
  - Heating Dominant – size loop field for cooling load and supplement with a boiler for peak heating load



Hybrid Design – Reduced First Cost Analysis



Full GHP	No tower
Case 1	Tower on when exiting heat pump LWT is 96.5ºF
Case 2	Tower on when LWT to “air wet bulb” temp exceeds 3.6ºF diff. Off @ 2.3ºF
Case 3	Tower on operates midnight to 6:00 a.m.(max LWT 96.5ºF)

Data from McQuay

Costs and Incentives

Construction Costs

- Inside mechanical equipment, ductwork, controls, etc. and costs are comparable to a conventional HVAC system
- The wells or loop field represent a cost premium over conventional HVAC systems…but
- For ***new construction***, geo can be competitive
- For ***retrofits***, geo can be comparable to a 4-pipe conversion
- Otherwise, paybacks are typ. under 10 years

Relative Maintenance Costs

Type of Equipment	Median Cost
Geothermal In-house	15.03
Geothermal Contractor O&P	16.78
Water source heat pump	45.00
Packaged air-to-air heat pump	27.00
Split system heat pump	35.10
Reciprocating chiller	35.10
Single-stage absorption chiller	37.20
Two-stage absorption chiller	33.95

Data compiled from ASHRAE RP-929 and Caneta Research report for July, 2000 ASHRAE publication.

Geo vs Traditional HVAC Retrofit Cost Analysis – Residential Ex.

	Traditional Gas Boiler & Central Air (Replacement)	Retrofit to Geothermal Heating & Cooling System
Initial Investment	$25,000	$45,000
Federal Tax Credit (30%)	-	($13,500)
LIPA Rebate	-	($1,000)
Net Investment	$25,000	$30,500
Increased Up Front Investment for Geothermal	-	$5,500
Annual Operating Cost	$5,000	$2,800
Annual Savings	**-**	**$2,200**
Payback	**-**	**2.5 years**
Annual ROI*	n/a	**40%**

*Return on Investment = Annual savings divided by the increased investment

Above assumes no or only minor change to ductwork

Federal Incentives

- On Oct. 3, 2008, geothermal heat pumps were added to definition of “energy property” (Bailout Bill), ushering in tax credits
- Under Stimulus Bill, prior caps were eliminated
- *Residential - 30% Tax Credit for total system cost*
- *Commercial - 10% tax credit or grant available*
- Can be used to offset alternative minimum tax (AMT)
- 5-year “bonus” depreciation period allowed
- Can be combined with solar and wind tax credits
- Good for systems installed through 2016
- Lease-back or energy purchase arrangements are allowable for non-taxable organizations

LIPA Incentives

Current LIPA Incentives:

- Residential – through 12/09, LIPA will pay up to $1,000 per new heat pump and $250 per replacement heat pump, depending on EER
- Commercial – incentives based on whole building analysis, no prescriptive incentives

“Word on the street” is LIPA is returning to prescriptive incentives based on system size

Questions?

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PWGC
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