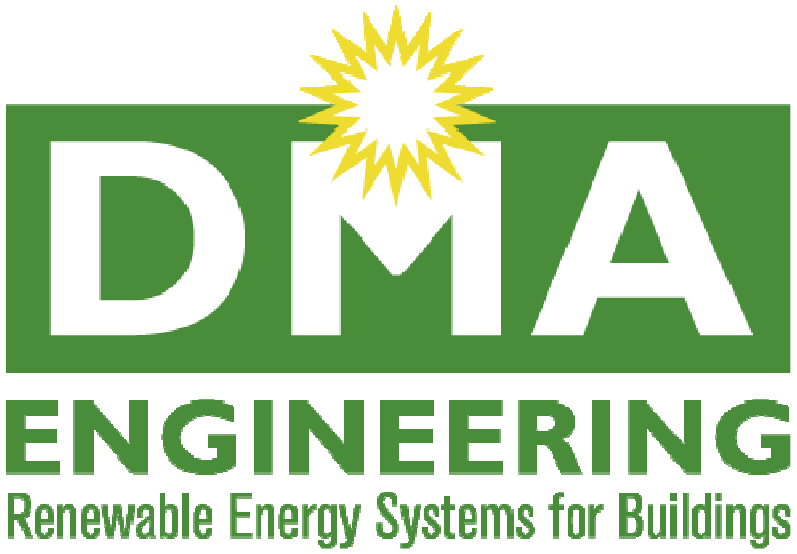


Geothermal Heating and Cooling Using Ground Source Heat Pumps

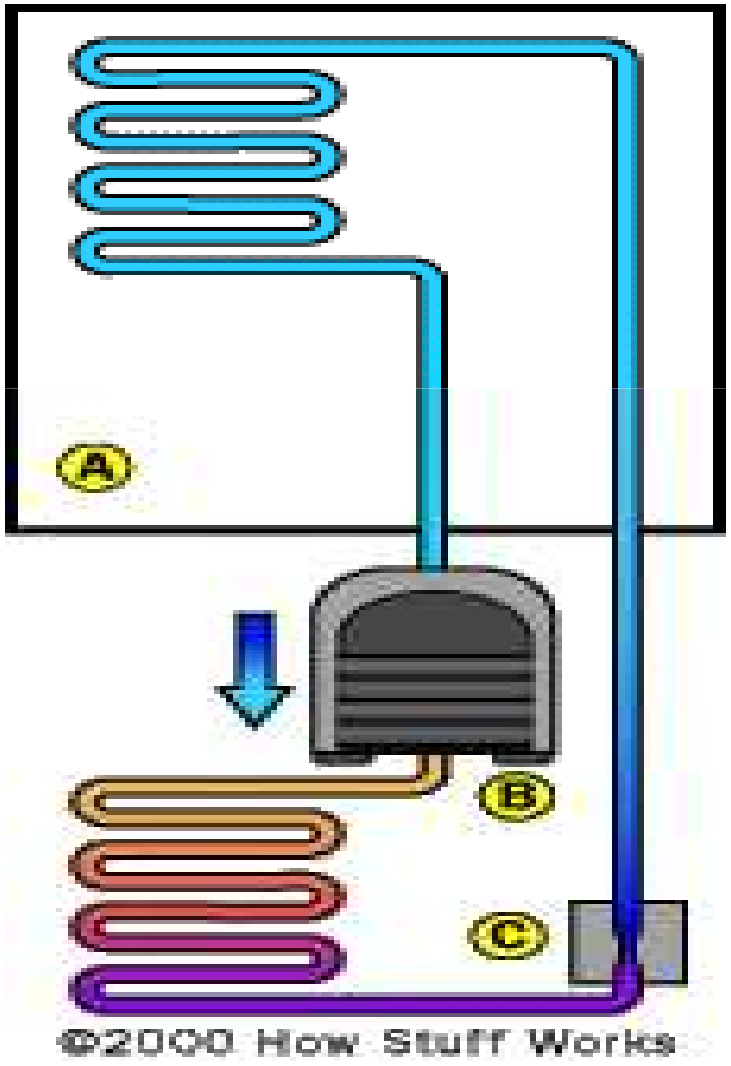
Prepared by: Steven Forrester, P.E. Principal

A Little History on Geothermal and Heat Pumps

- Lord Kelvin came up with the idea for heat pumps in 1852.
- 1940's Robert C. Webber installed first residential system after experimenting with a deep freezer. Professor Carl Nielsen of Ohio State University develops the first ground-source heat pump, for use at his residence. J.D. Krocker, an engineer in Portland, Oregon, pioneers the first commercial building use of a groundwater heat pump.
- 1970's Oil Embargo people start looking for energy alternatives. Dr. Jim Bose puts the math behind the technology to make it more readily usable in America.
- International Ground Source Heat Pump Association (IGSHPA) forms in 1987.

What is a Heat Pump?

It’s a refrigerator. Works off of the vapor-compression cycle.



A Inside the refrigerator
B Compressor
C Expansion valve

What is a Ground Source Heat Pump?

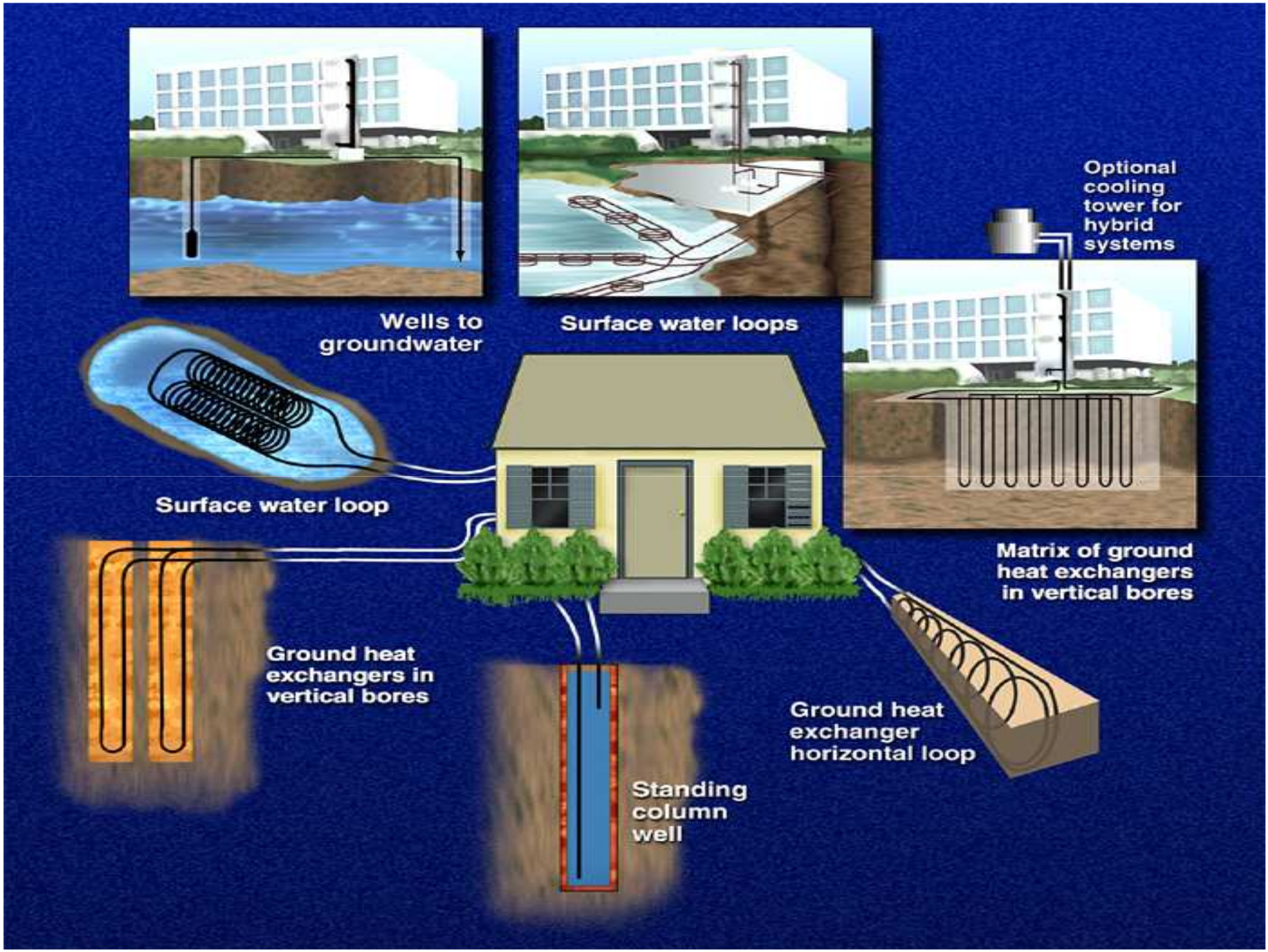
A Ground Source Heat Pump uses the earth or a large body of water as the source (the hot spot of the refrigerator) or sink (the cold spot of the refrigerator).

There are 2 different types of systems used in water source heat pump systems, an open system or a closed system. Direct exchange systems have proven to be too unreliable.

An open system uses ground water or water from a lake or ocean to interact as the heat transfer method. Pump and dump method.

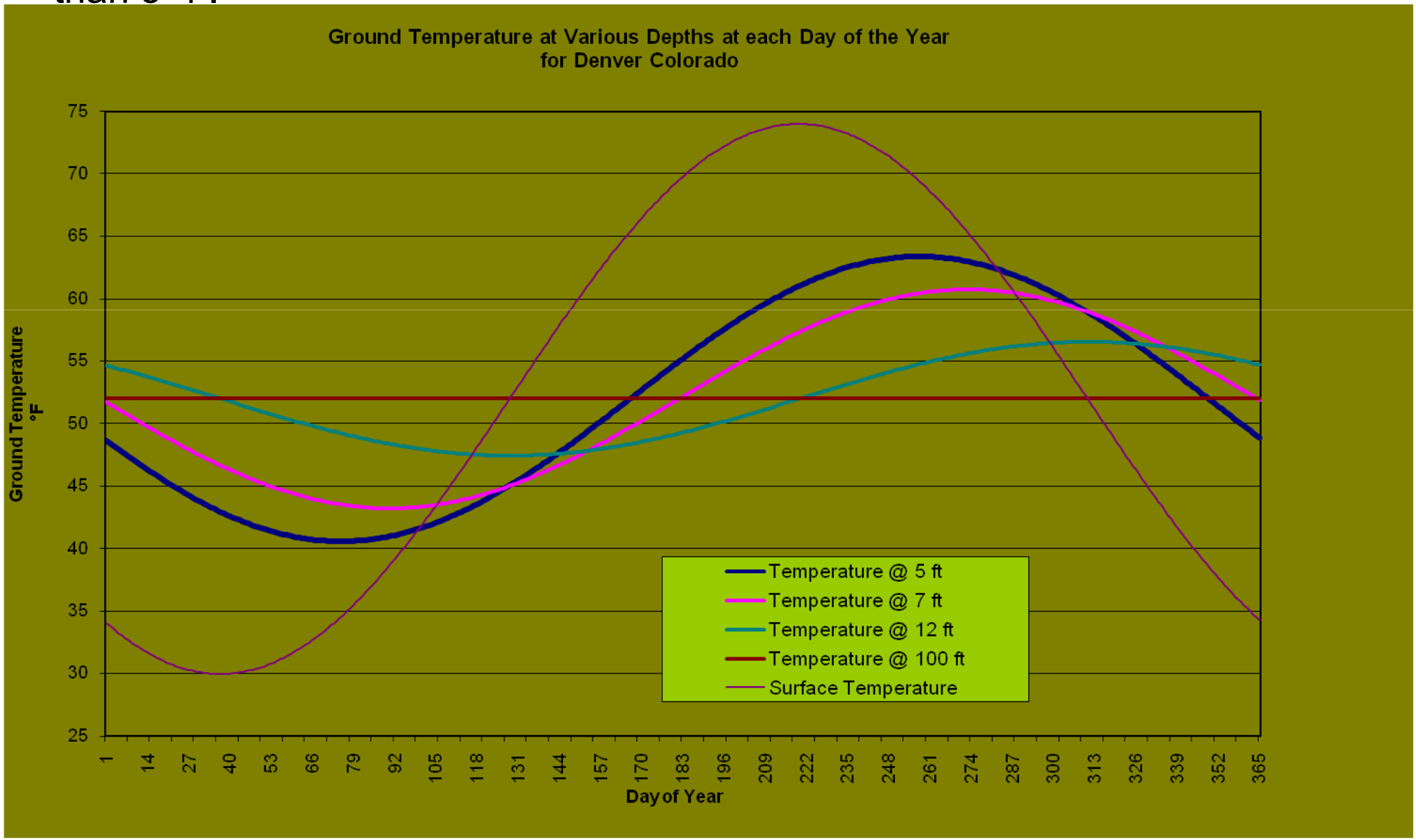
A closed system is just that, closed. A fluid is pumped through a series of pipes that are either buried in the earth or placed in a lake or pond.

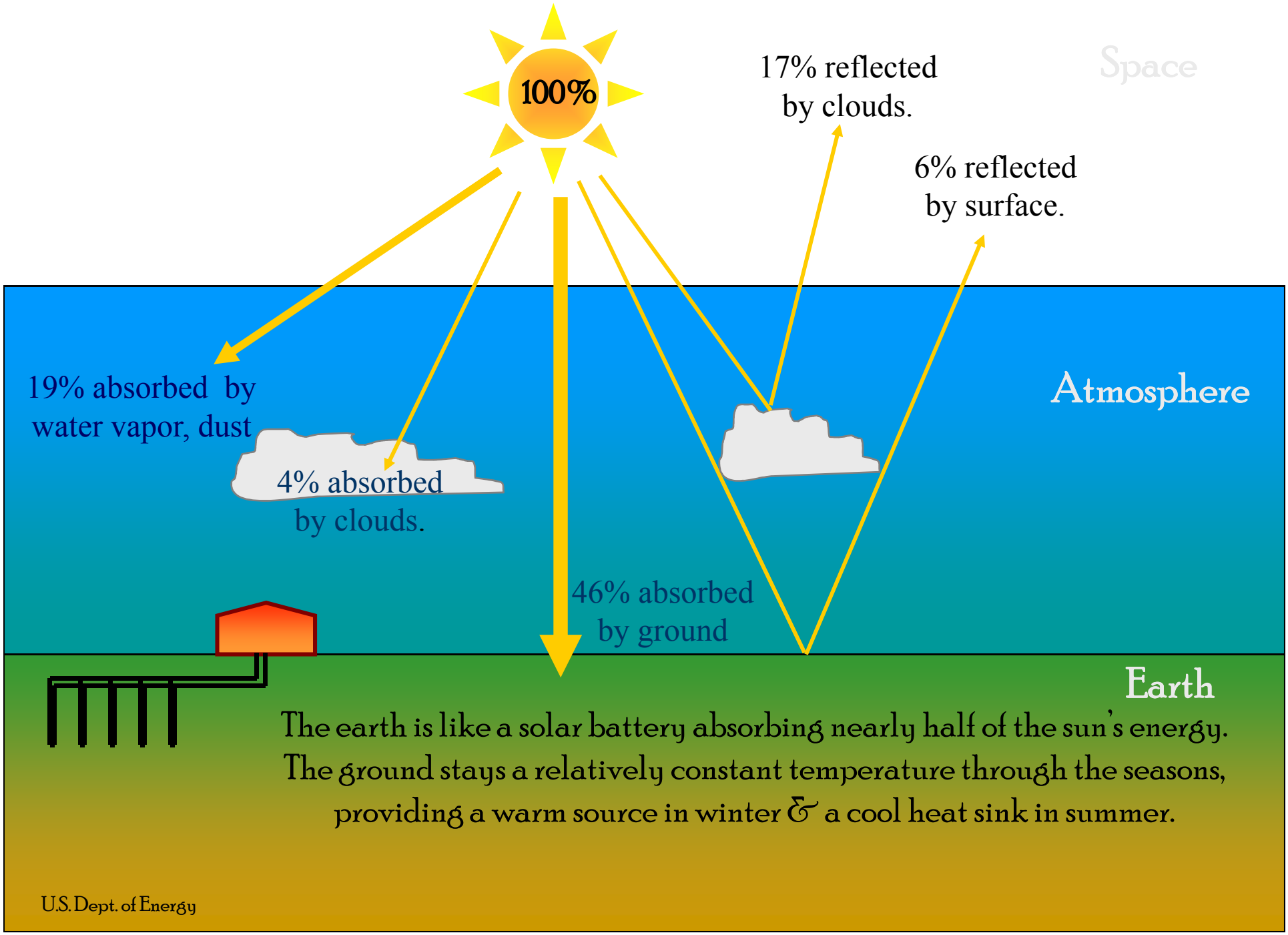
An open system has many variables that can affect it's performance so it is not considered as a viable option unless in a very specific case.


Wells to groundwater
Surface water loops
Optional cooling tower for hybrid systems
Surface water loop
Matrix of ground heat exchangers in vertical bores
Ground heat exchangers in vertical bores
Ground heat exchanger horizontal loop
Standing column well

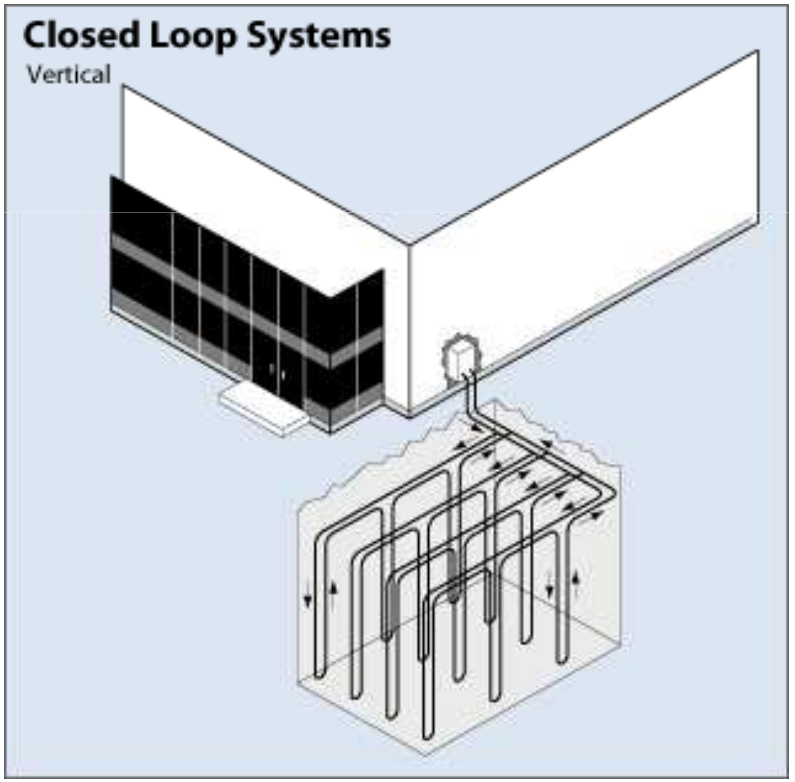
Use the Ground?

Below the earth's surface the temperature doesn't change much. As shown in the graph the temperature below 12 ft doesn't change past 52°F by more than 5 °F.



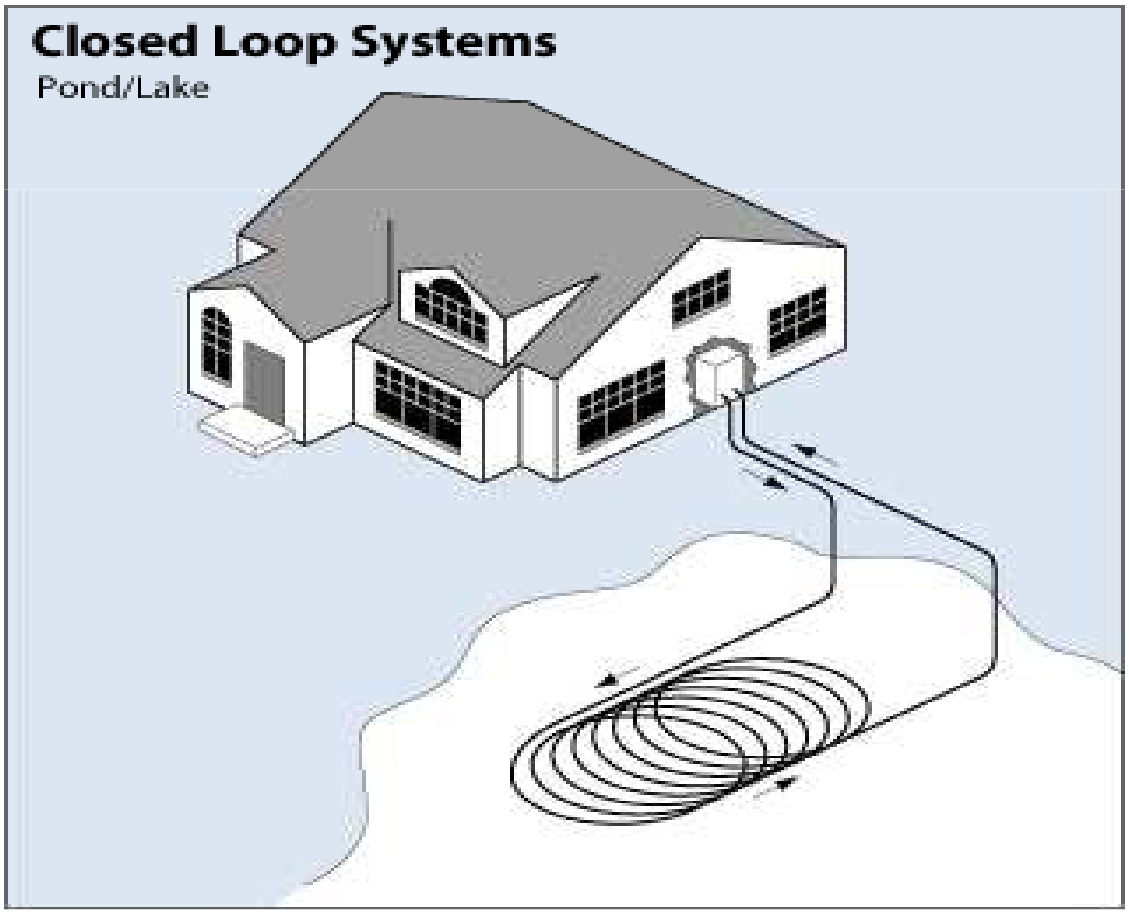

100%
17% reflected
by clouds.
Space
6% reflected
by surface.
19% absorbed by
water vapor, dust
4% absorbed
by clouds.
Atmosphere
46% absorbed
by ground
Earth
The earth is like a solar battery absorbing nearly half of the sun's energy.
The ground stays a relatively constant temperature through the seasons,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

To extract energy from the earth we bury plastic pipes in the earth. Pipes carry an antifreeze fluid solution that is pumped from the ground into the heat pump. Pipes can be can be installed in trenches or a vertical bore hole



Use a Lake, Pond or Ocean?

A large body of water can absorb or give off energy and maintain a balance with the environment through heat exchange with the earth or the atmosphere.



So how does it all work?

How can the earth at 52 °F heat my house or building to 70 °F?

Heat Pump Operation - Heating

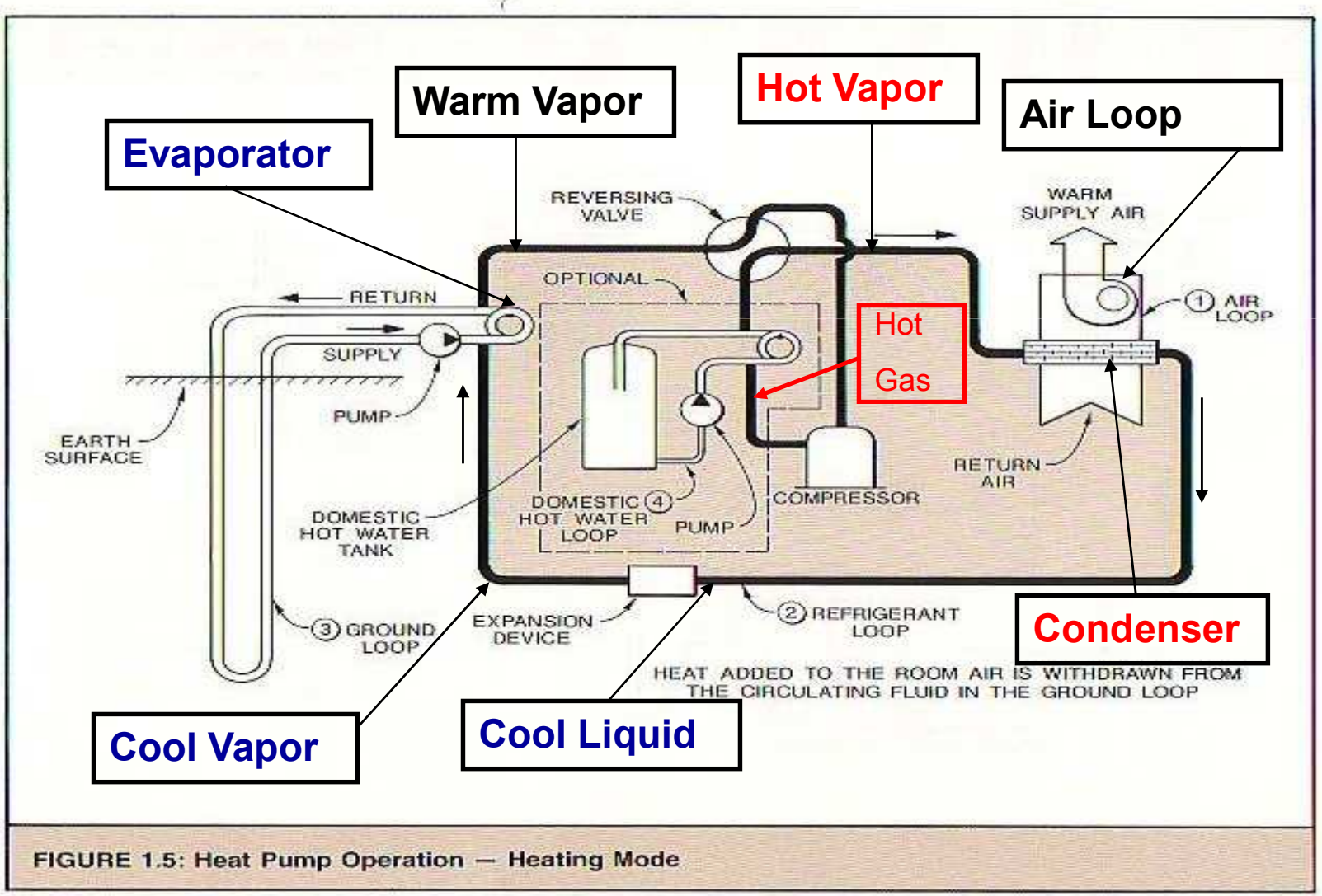


FIGURE 1.5: Heat Pump Operation — Heating Mode

Heat Pump Operation - Cooling

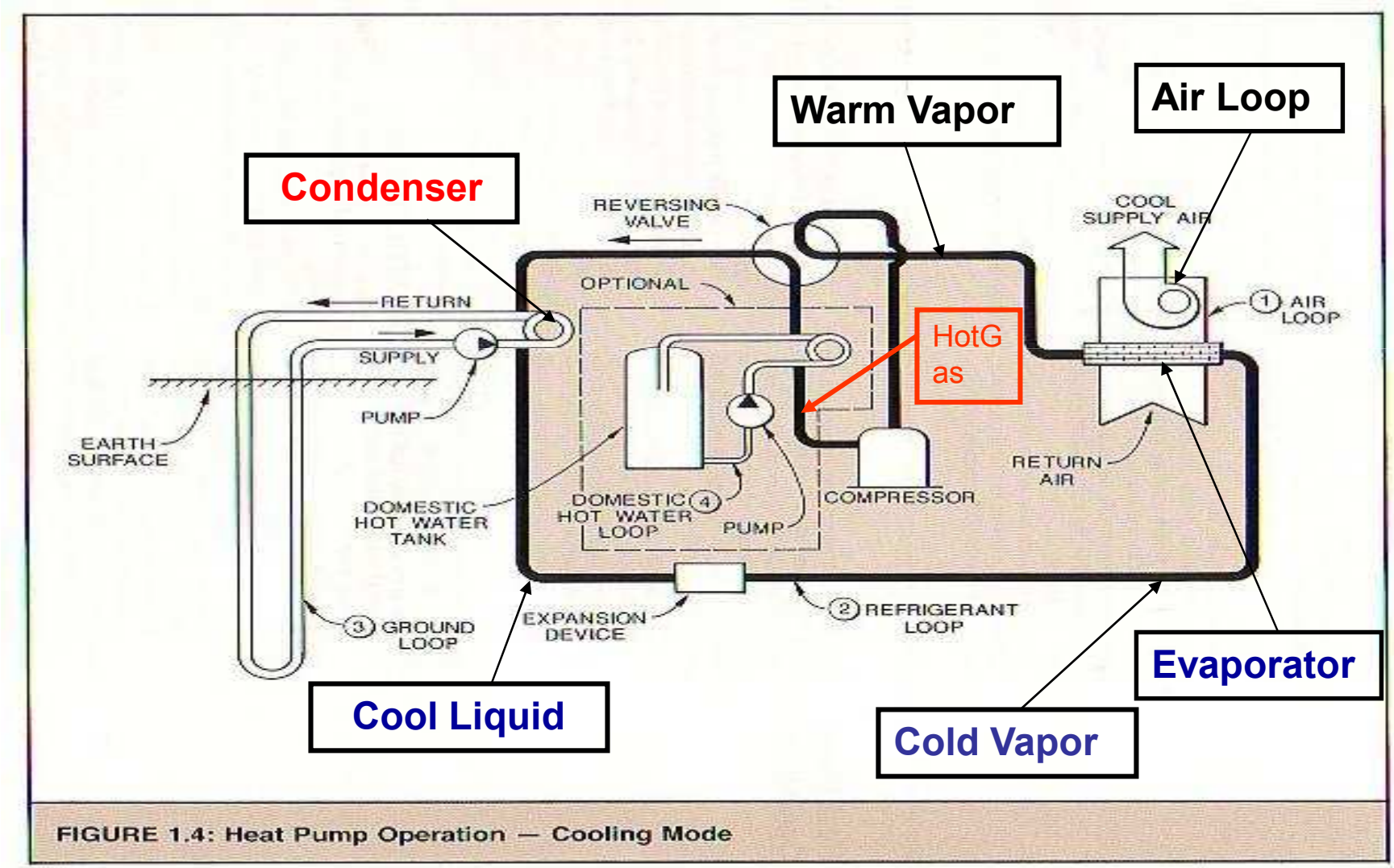
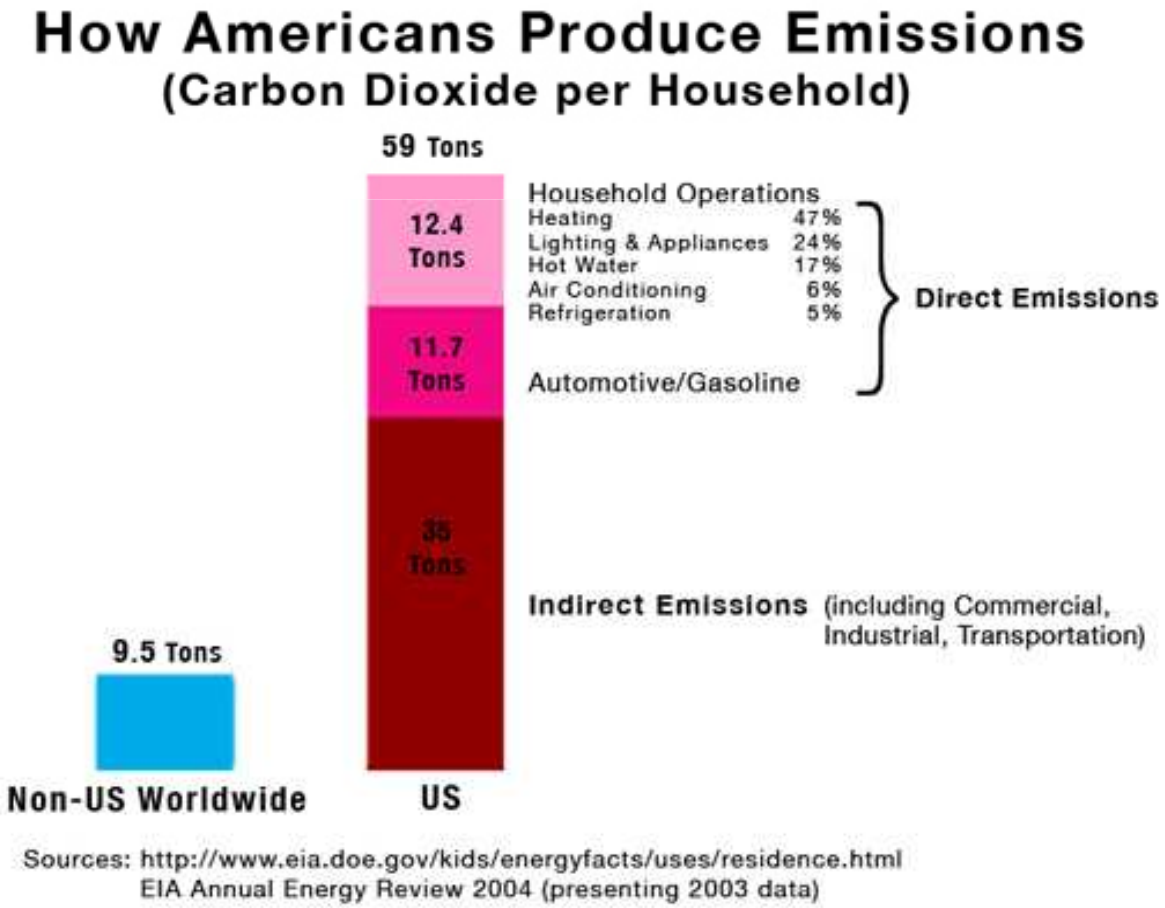


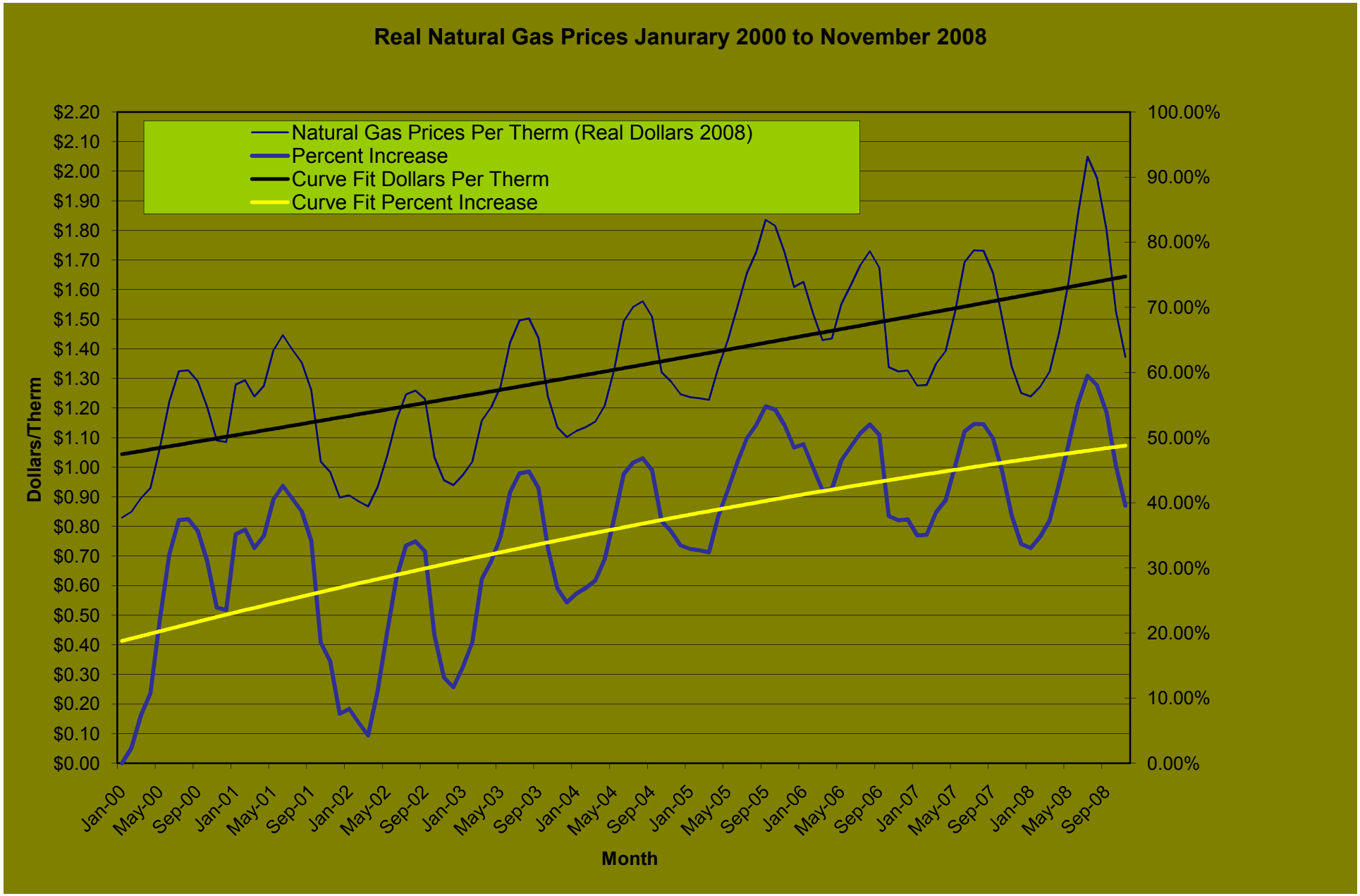
FIGURE 1.4: Heat Pump Operation — Cooling Mode

Why use a GSHP?

A ground source heat pump is 30%-50%+ more efficient than the highest efficiency gas furnace and air conditioner. A 30%-50%+ increase in efficiency means a 30%-50%+ reduction in energy consumption.



Natural Gas Pricing Trend



A Residential Case Study

- New Construction, very well built using high quality windows (SHGC = .33, U= .39) and insulation (R-38 ceiling, R-22 Walls) walk out basement with ICF walls (R-26).
- 3500 sq. ft
- 15.75 Btu/hr/sq. ft Cooling Load (55,125 Btu/hr, 4.6 tons)
- 12.00 Btu/hr/sq. ft Heating Load (42,000 Btu/hr, 3.5 tons)
- Weather Data for Denver area
- Forced air heating and cooling
- 1 ½ Acre lot

Cooling load is dominate factor, due to large picture windows facing southwest for view.

Cost for Conventional System

- One 5 ton air conditioner (Seer = 13)
- One 70,000 Btu/hr furnace (90% efficiency)
- Natural Gas Hot Water Heater
- Ducting
- Plumbing for condensate drain, and humidifier
- Programmable thermostat

System cost = $18,600

Cost for Geothermal System using Horizontal Slinky

- One 5 ton heat pump for both heating and cooling (EER = 16.3, COP = 4.3)
- Ground loop heat exchanger
- Electric Hot Water Heater
- Ducting
- Plumbing for desuperheater, humidifier and condensate drain
- Programmable thermostat

System cost = $31,260

Cost Conventional System vs. GSHP using horizontal slinky

- Difference between GSHP system and conventional system = $12,660
- With natural gas prices at an average of $1.55/therm and electricity at $0.11KW-hr a payback will be realized in 7.9 years.

- Drilling would cost $33,100 yielding a payback of 10.7 years

- With propane at $2.5/gallon a payback will be realized of 4.4 years.

Benefits of the GSHP

- No return on investment for a conventional system.
- Largest cost is the ground heat exchanger, pipes are warranted for 50 years with a service life of 200 years.
- Pipes will outlast structure
- Return on investment dollars increase if natural gas prices continue to rise.
- Produce less green house gases than conventional system, reduce carbon foot print, approximately 2000 lbs per household resident.
- Systems are all electric, can be coupled with Solar Thermal, Solar PV, fuel cells or wind.
- Gain LEED Points, R410 refrigerant, 14 points possible.
- Hydronic units can provide hot and cold water. Use water pipes to move energy instead of duct work. Use with radiant floor, radiant ceiling, and chilled beams.
- More elaborate systems can provide, hot and cold water along with forced air

Commercial Systems

- Load sharing a bigger part of overall building performance. Tie as many systems together as possible. Example, a gas station with refrigeration display cases and hot water for car wash.
- Tie multiple tenants to same ground loop and meter energy usage. Tenant diversification could cancel any load to the ground.
- Hybrid system using chiller to reduce ground loop length, commercial is usually cooling dominated.
- Each zone on own heat pump and pump system provides local control over zone comfort.

Low Maintenance Cost ($/sq.ft.)

- Geothermal Heat Pump
  - $.11-.25
- Water Source Heat Pump
  - $.20-.30
- Fan Coil (2-pipe)
  - $.32-.50
- Air Source Dx/Heat Pump – Split
  - $.23-.33
- Fan Coil (4-pipe)
  - $.40-$.50
- Self-Contained Roof Top

  $.29-.35
- Thru-Wall
  - $.28-.32

Construction First Cost ($/sq.ft.)

based on 400 sq.ft per ton and approx 10k-50k sq.ft bldg.

Unitary Systems

- Geothermal Heat Pump 14 - 23
- Water Source Heat Pump 12 - 18
- Air Source Heat Pump – Split 7 - 15
- Self-Contained DX Roof Top 5 - 9
- Thru-wall 3 - 7

Central Station Systems

- Fan Coil (2-pipe) 14 - 21
- Fan Coil (4-pipe) 16 - 25