Introductory Overview of Ground Source Heat Pump Technologies

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Introduction to Ground Source Heat Pumps
Virginia Cooperative ExtensionBioenergy Engineering Education Program
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VirginiaTech

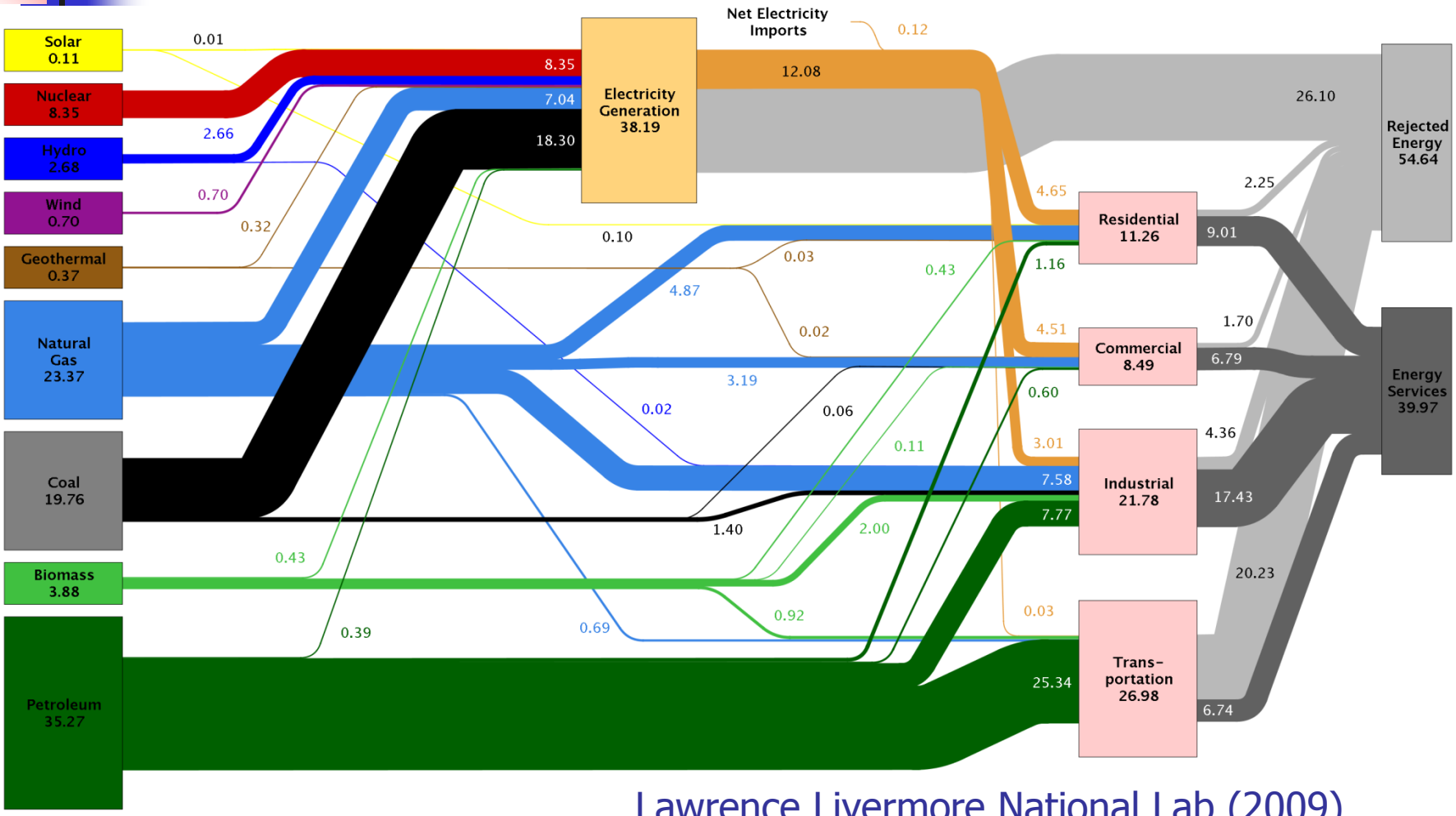
Outline

- Background
  - Energy demand
  - Geothermal systems
- State of the GSHP industry
- Types of GSHP systems
  - Closed loop systems
  - Open loop systems

Learning Objectives

- Gain background on ground source heat pump (GSHP) systems
- Identify the basic principles of GSHP systems
- Identify different GSHP systems (closed loop vs. open loop, vertical vs. horizontal loop systems)
- Discuss advantages and disadvantages of GSHP systems
- Discuss cost related information on GSHP systems
- Learn about different applications of GSHP systems

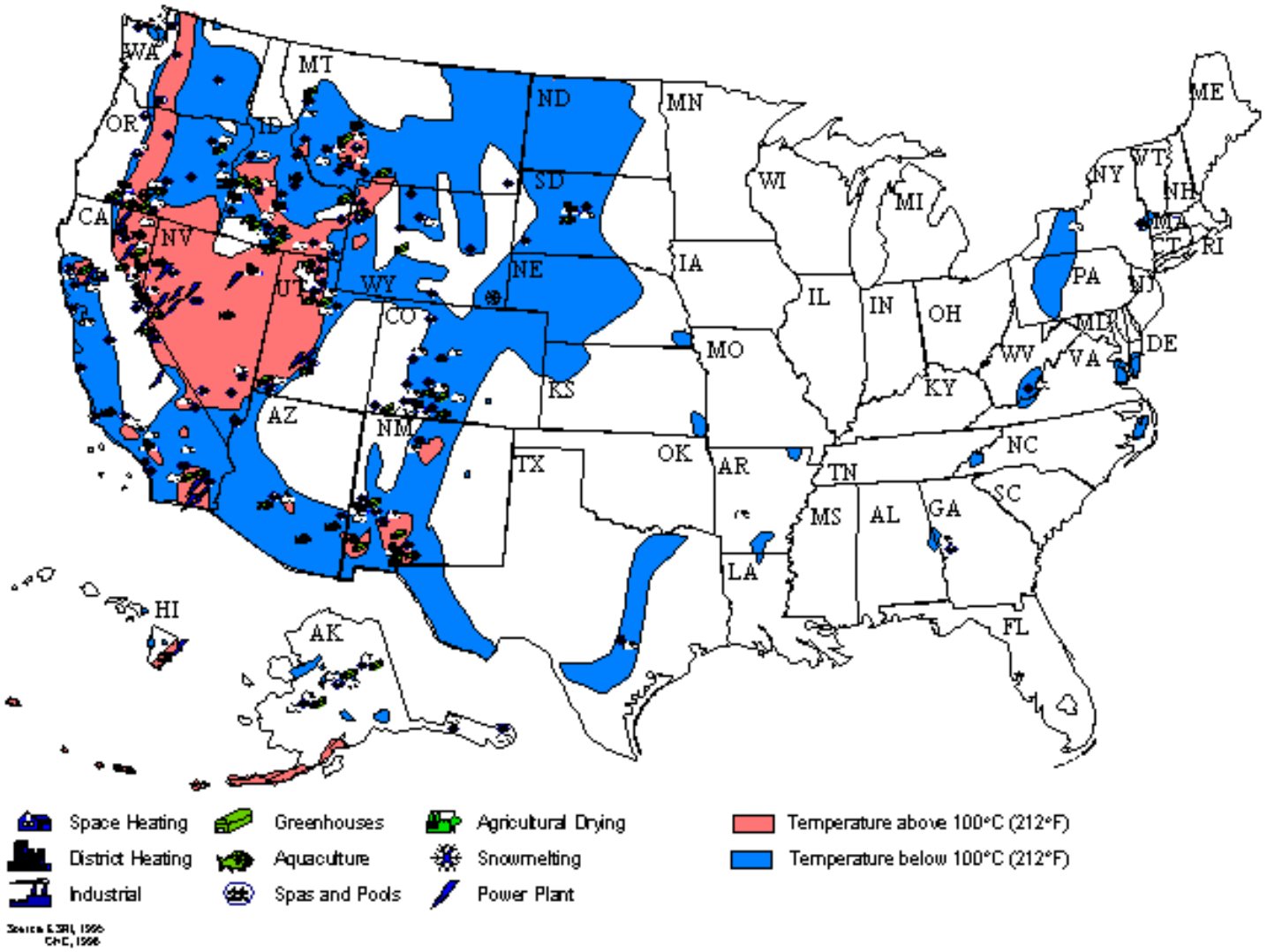
U.S. Energy Flow Chart



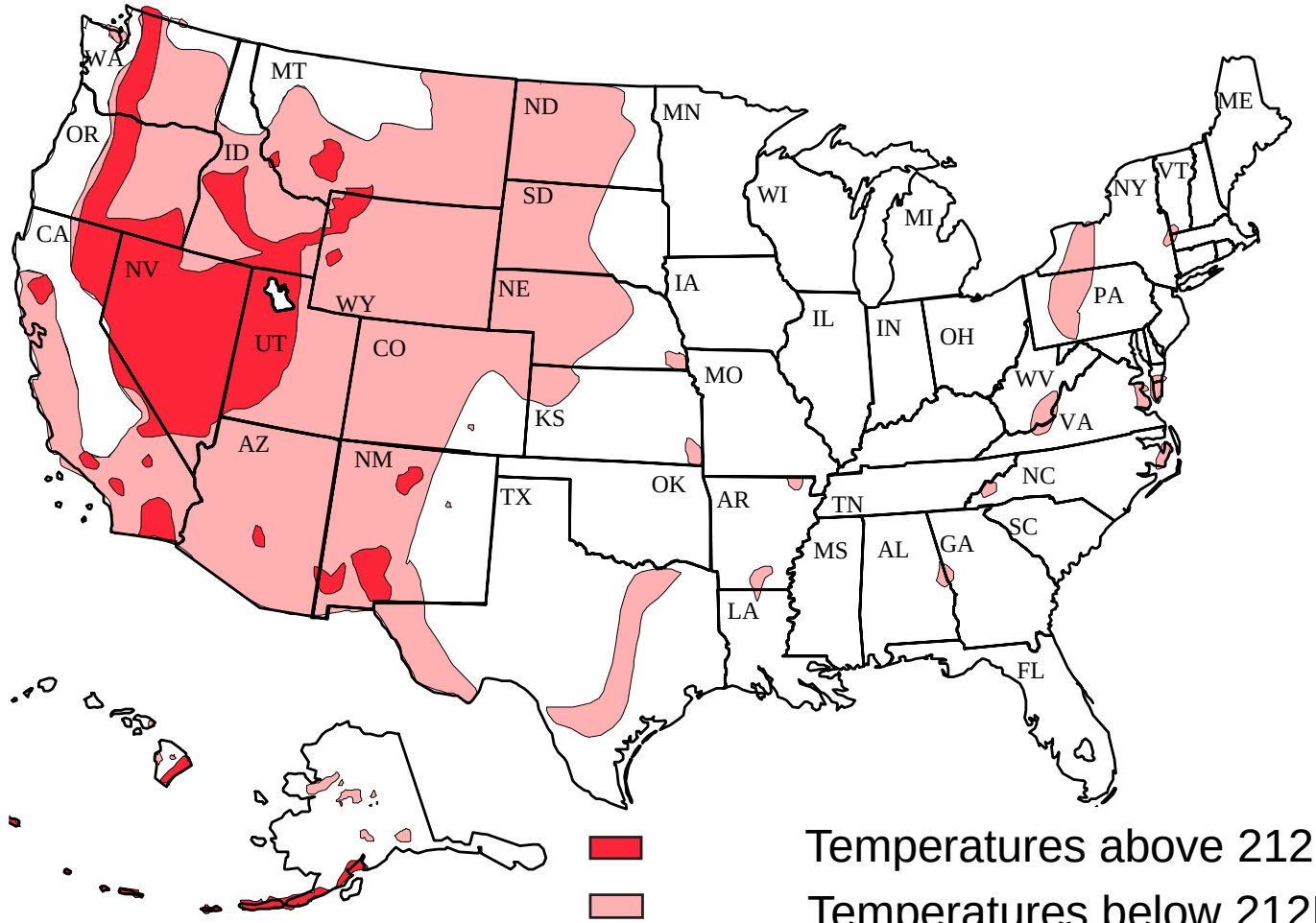
Lawrence Livermore National Lab (2009)

Significant energy consumption in buildings mainly for heating and cooling

U.S. Geothermal Resources & Projects



U.S. Geothermal Resources



Temperatures above 212F

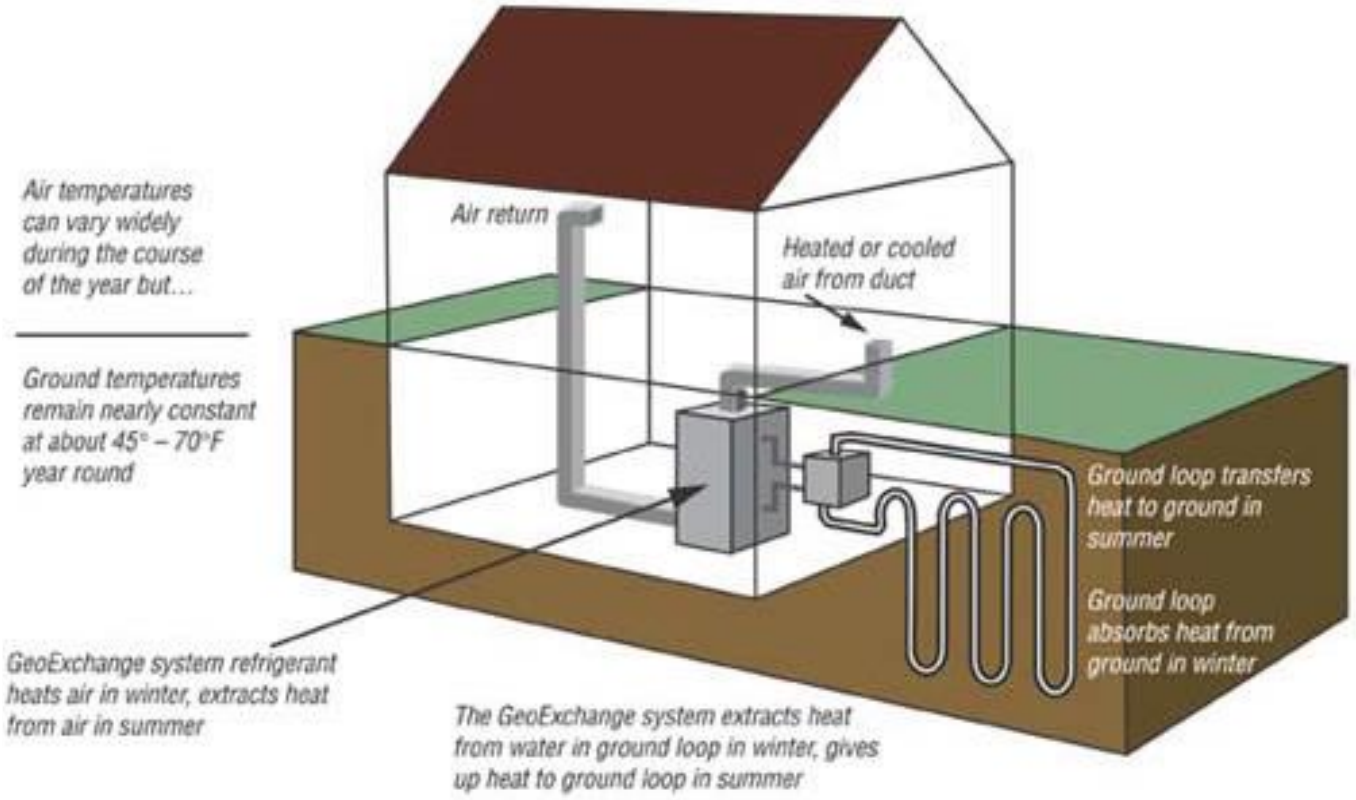
Temperatures below 212F

Suitable for geothermal heat exchange (entire U.S.)

What is a Ground Source Heat Pump (GSHP)?

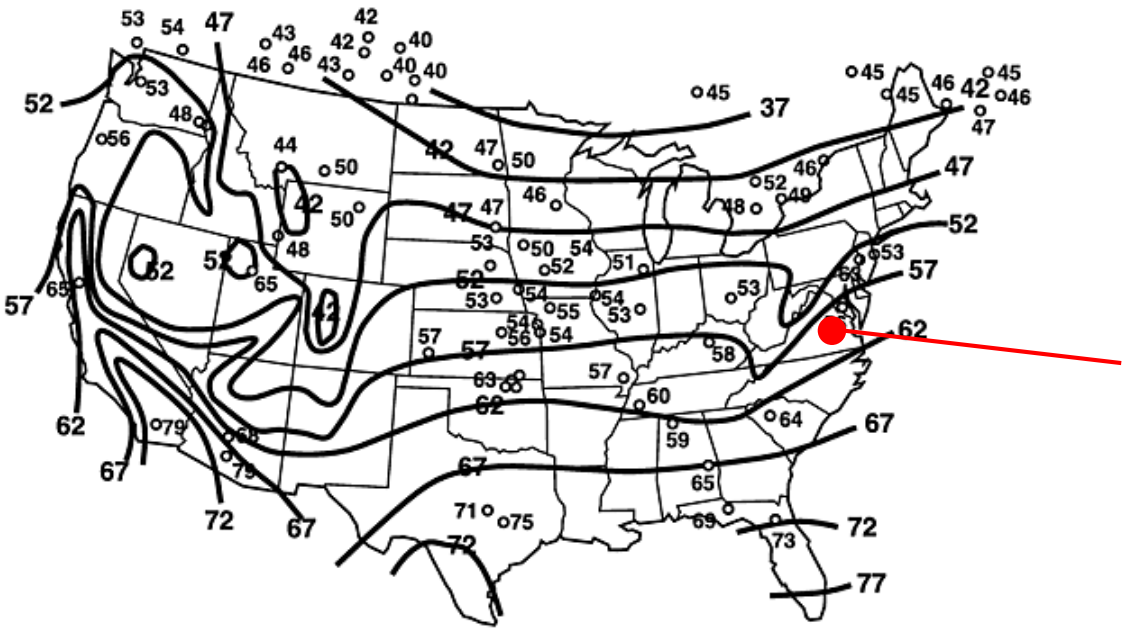
- GSHP is a electrically powered system that utilizes the relatively constant ground or groundwater temperatures to provide heating, cooling, and hot water
- Instead of burning fossil fuels to create heat like conventional systems, GSHPs move heat that already exists
- In heating mode, a GSHP moves heat from the ground or groundwater into the building
- In cooling mode, a GSHP moves heat from the building and deposits it into the ground or groundwater.

Ground Source Heat Pump Systems

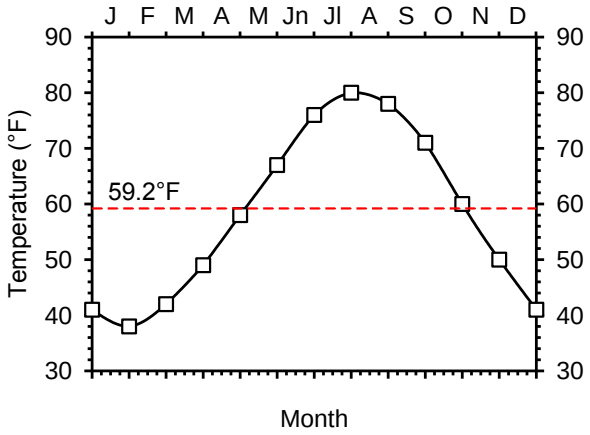


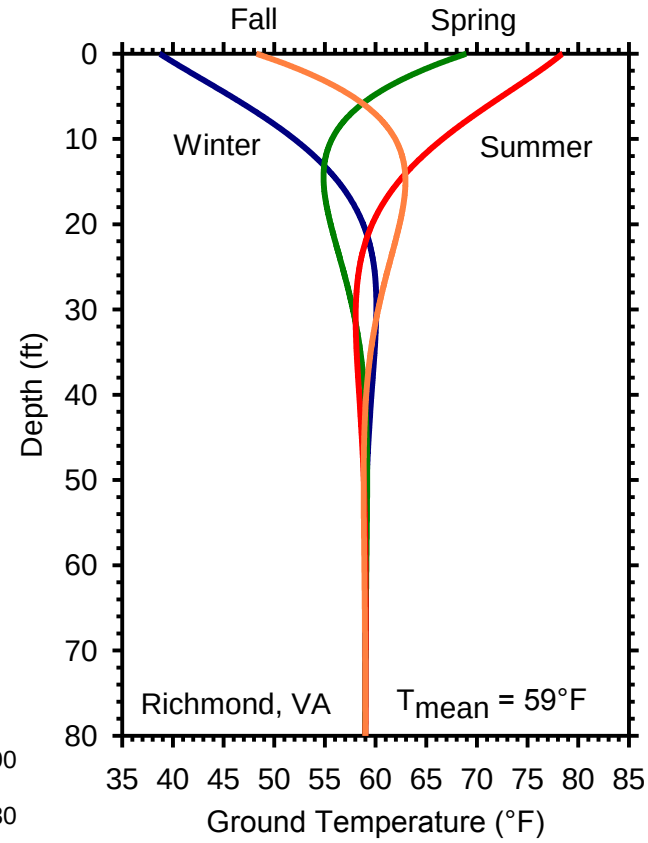
1. Ground or groundwater heat exchanger
2. Heat pump
3. Interior heating/cooling distribution system
4. Domestic hot water heating (optional)

Ground Temperature Profile

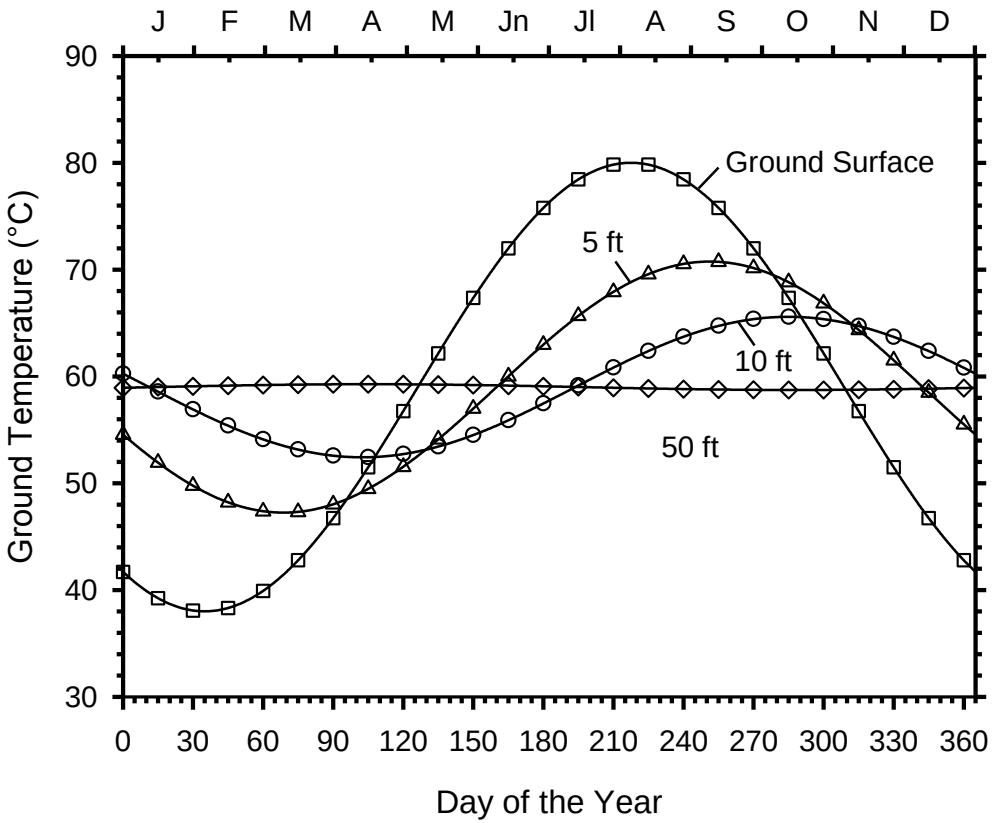


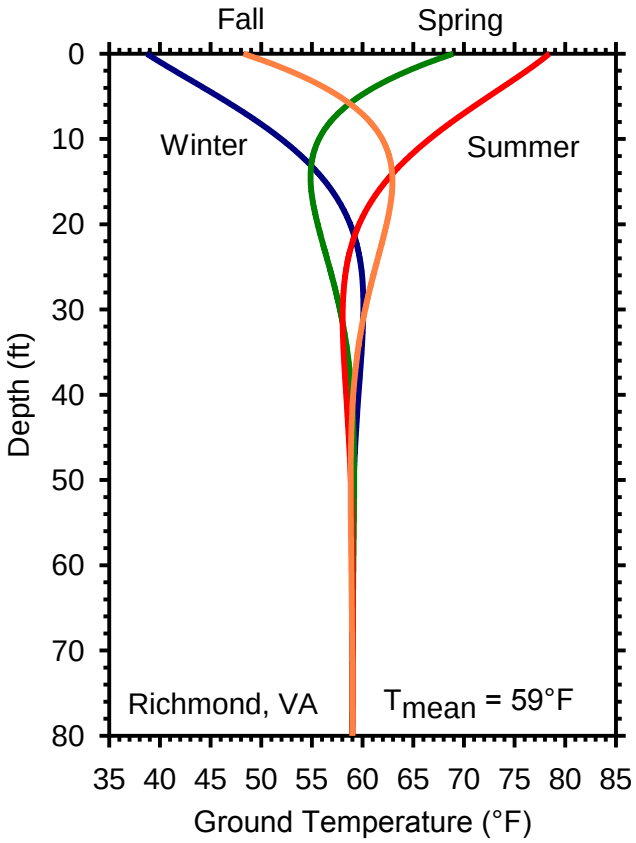
Mean ground temperature





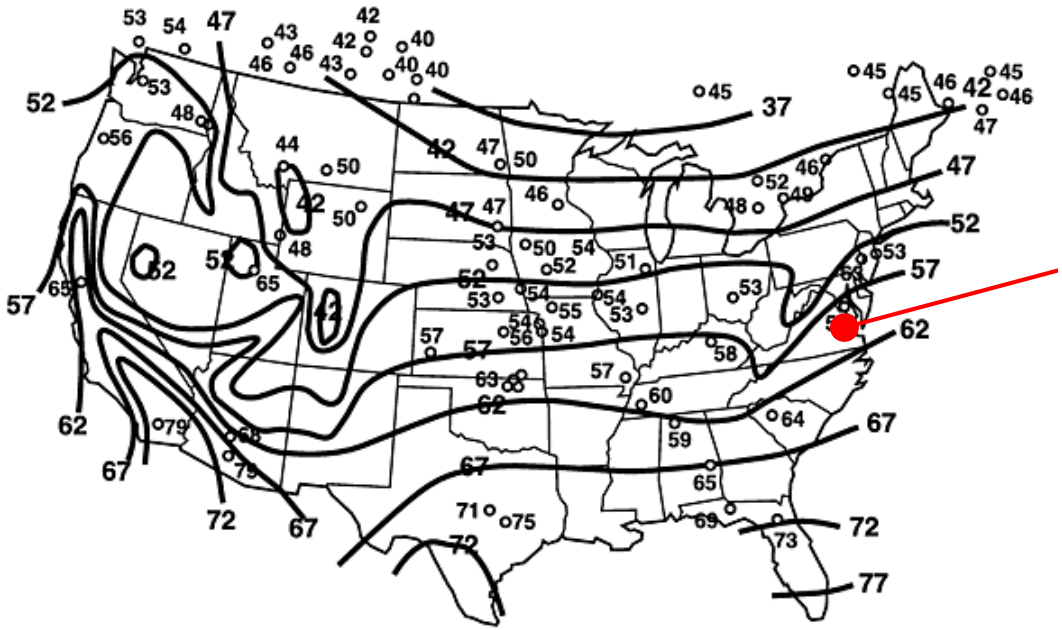
Ground Temperature Profile

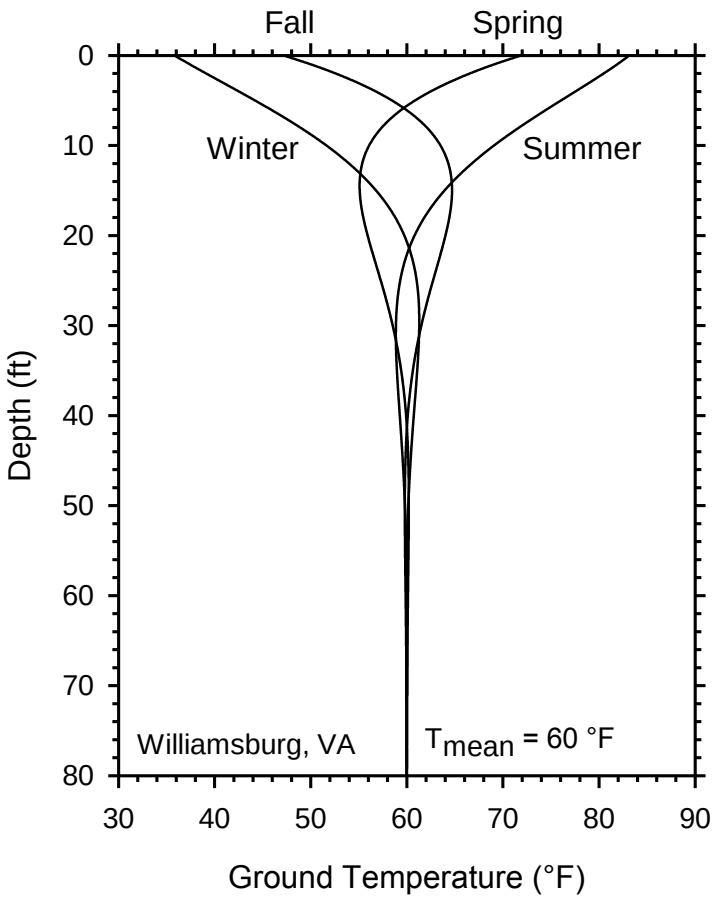




Ground temperature fluctuations

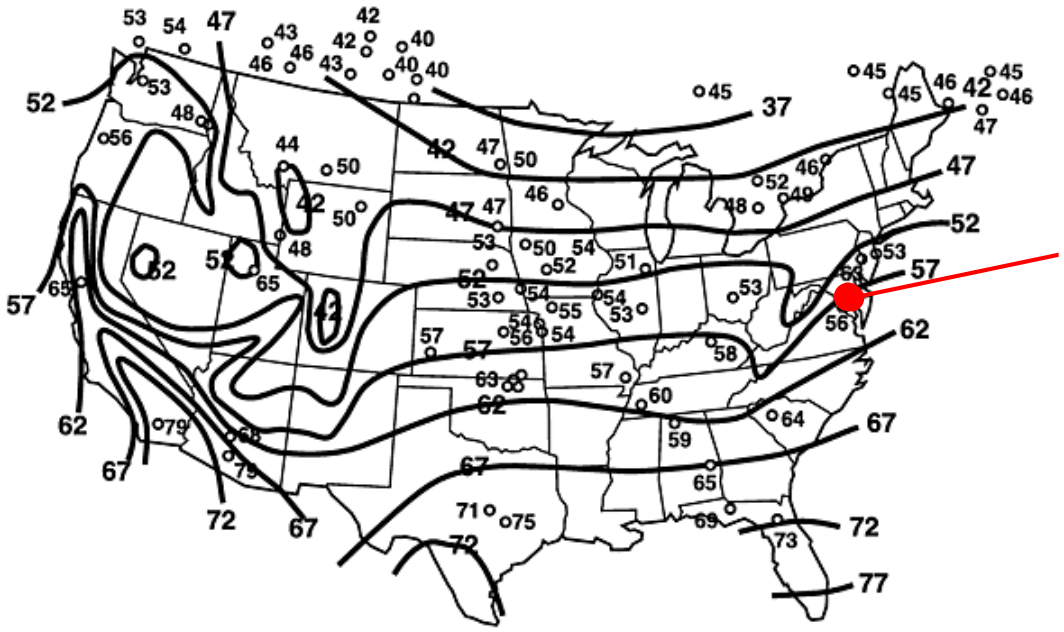
Ground Temperature Profile



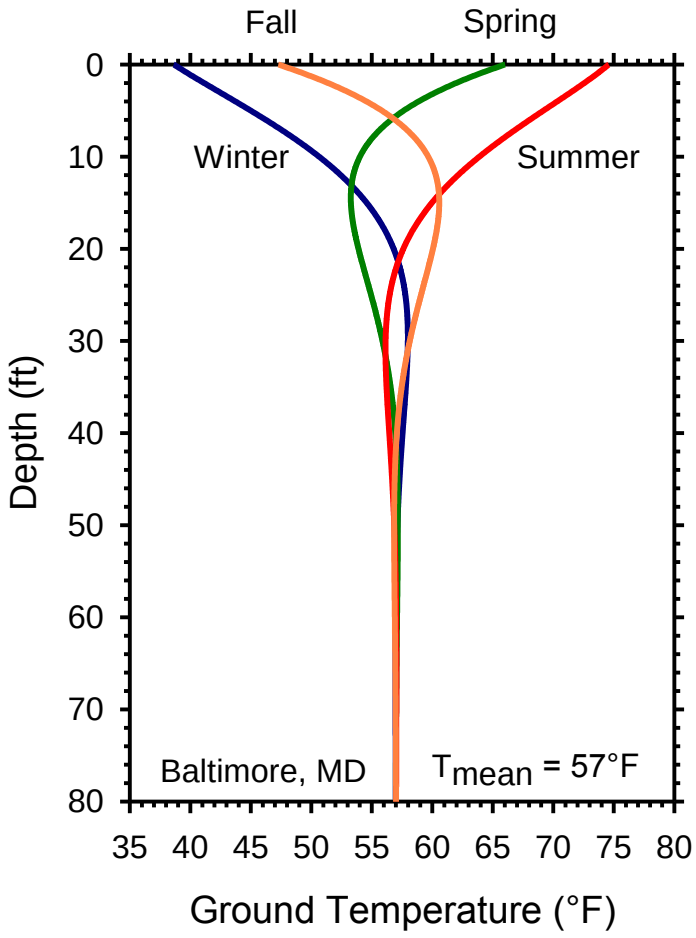


Mean ground temperature

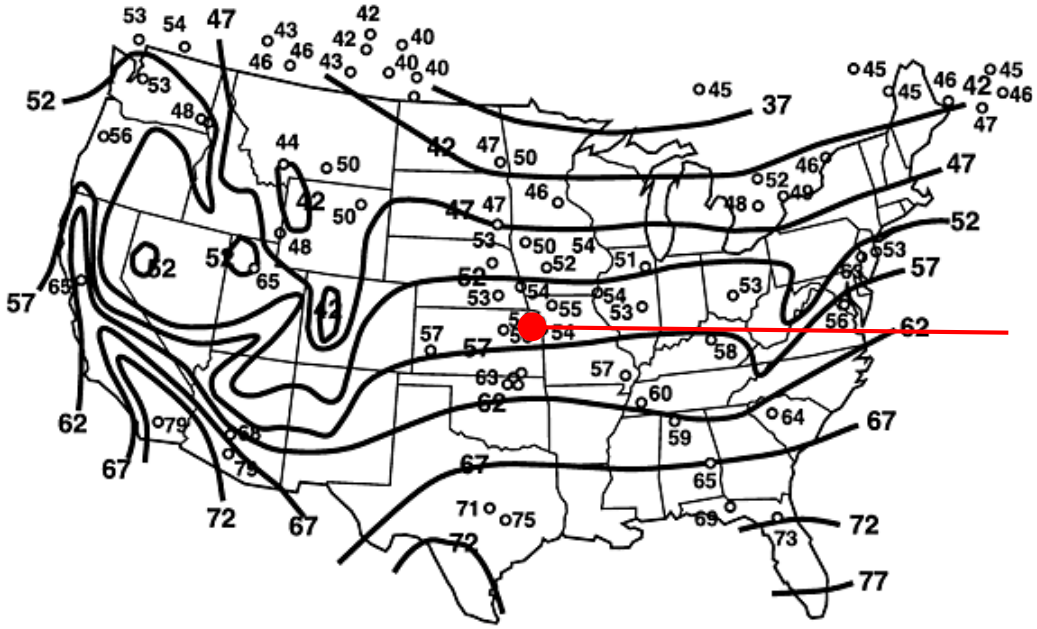
Ground Temperature Profile



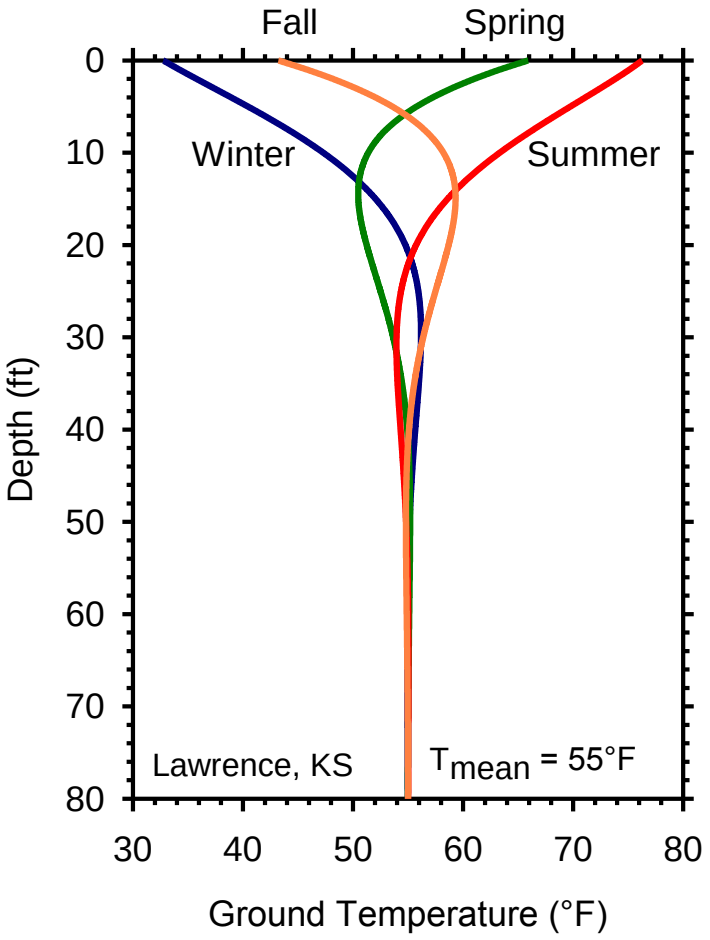
Mean ground temperature



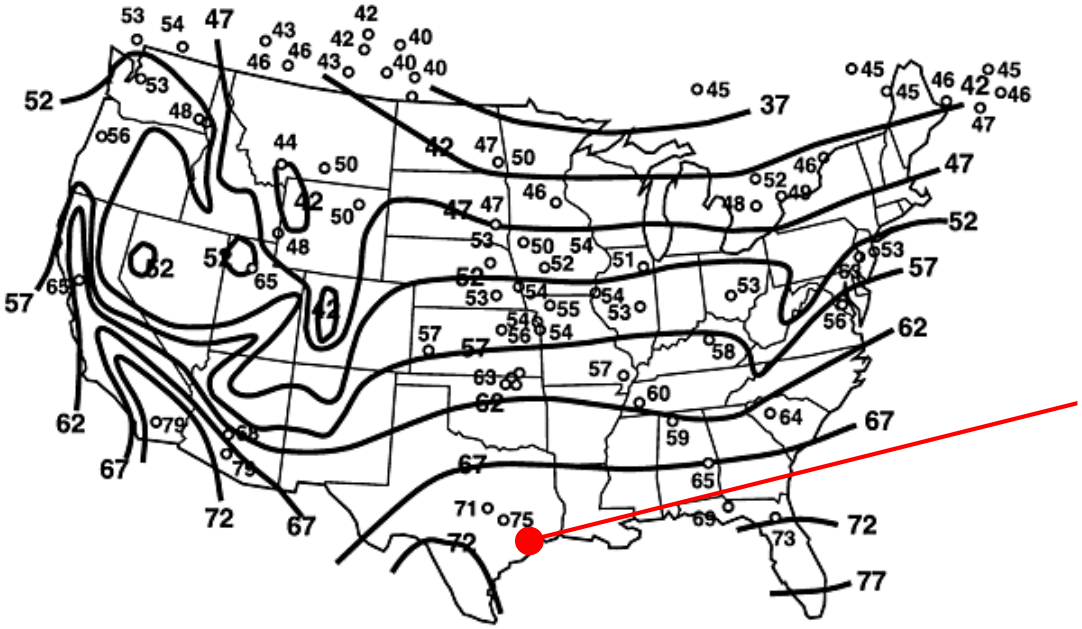
Ground Temperature Profile



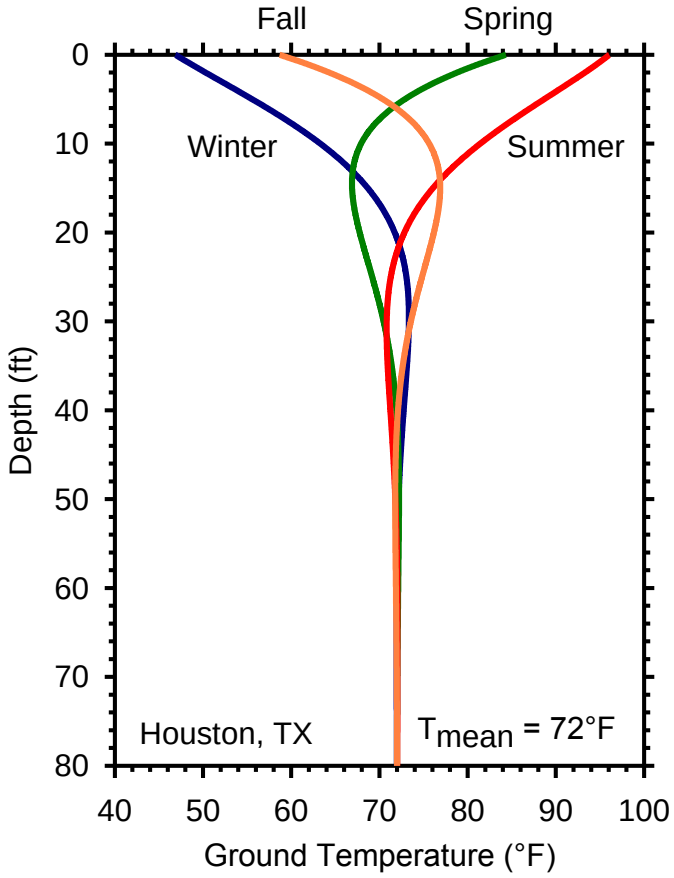
Mean ground temperature



Ground Temperature Profile



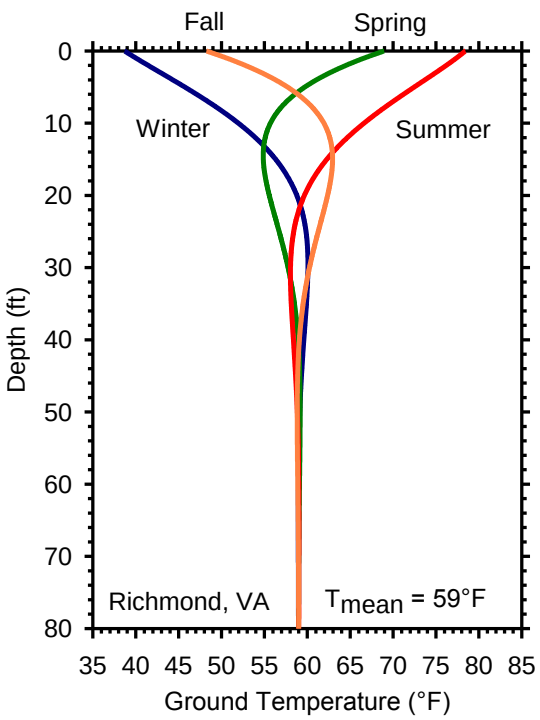
Mean ground temperature

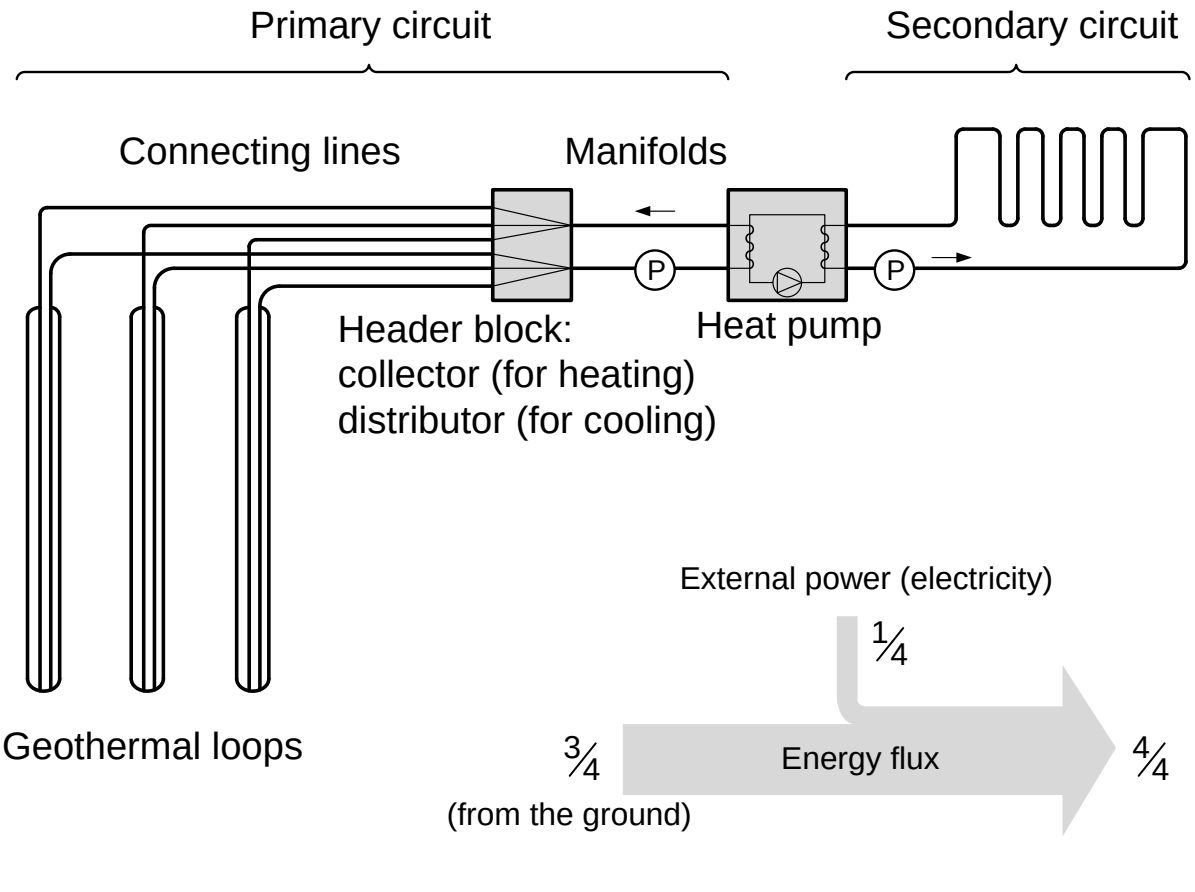


Terminology

- Ground source heat pumps (GSHP)
- Geothermal heat pumps (GHP)
- Ground coupled heat pumps (GCHP)
- GeoExchange systems
- Earth energy systems

Ground Source Heat Pump Systems





Utilize the relatively constant temperature of the ground and use it for heating in the winter and cooling in the summer

GSHP Heating/Cooling

- Geothermal heat exchange systems provide ground-source energy for heating and cooling
- The use of ground-source systems for heating and cooling has increased exponentially especially in Europe
- Basic idea been around for long time – make use of the heat energy stored in the ground; access this energy using heat exchangers buried in the ground (fluid-filled HDPE loops)
- In ideal conditions these systems can provide majority of required heating/cooling energy and significantly reduce costs and carbon footprint

Common Comments on GSHPs

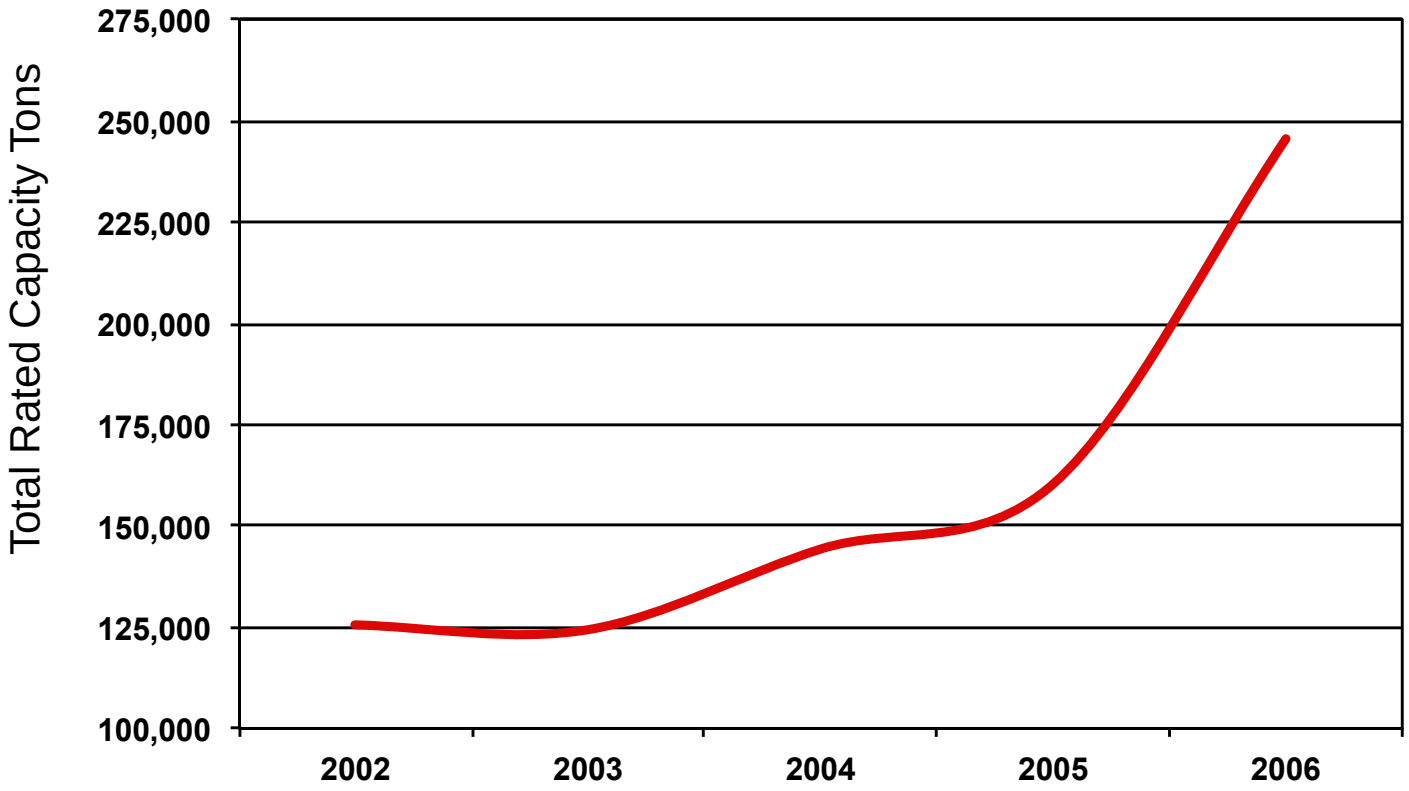
Advantages

- High efficiency results in lower energy consumption cost
- Lower maintenance cost
- Lower life cycle cost
- No outdoor equipment
- Greater occupant comfort
- All electric - can be powered by renewable energy

Disadvantages

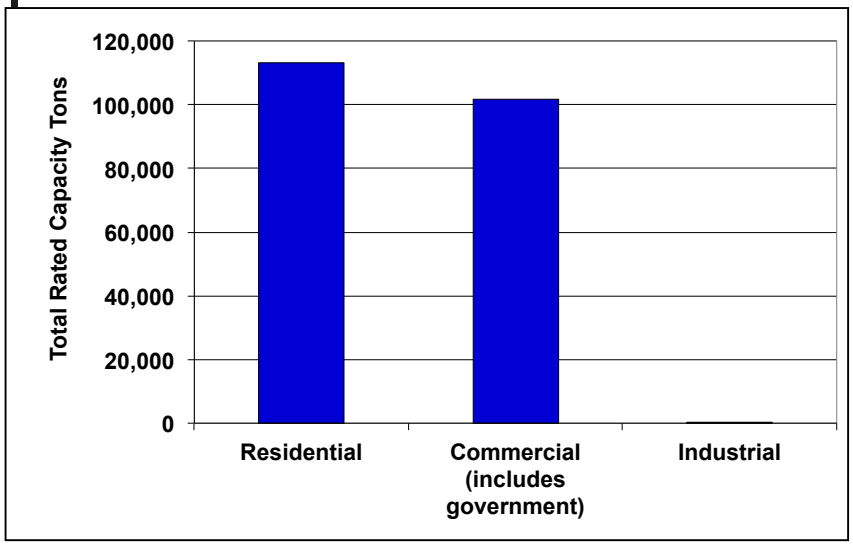
- First cost can be significantly higher than conventional systems
- Not all system types feasible in all locations
- Limited pool of qualified designers and installers in many locations

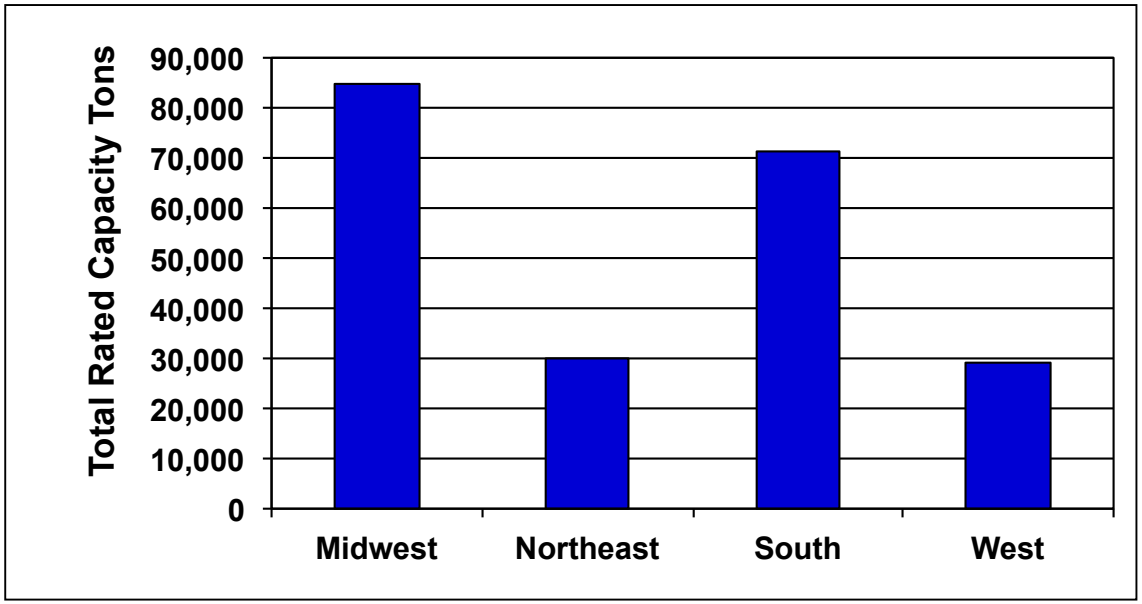
GSHP Domestic Shipments, 2002-2006



Source: EIA, Survey of Geothermal Heat Pump Shipments, 2006

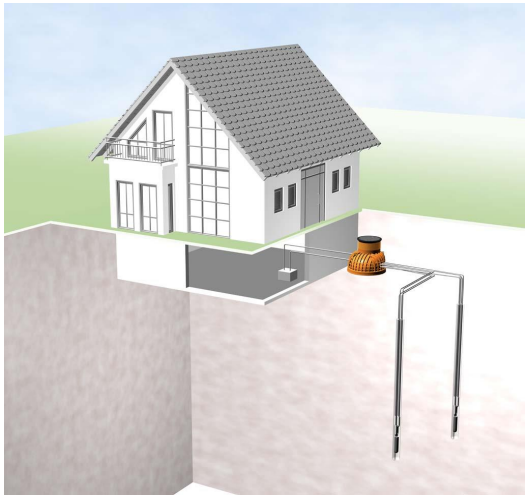
GSHP Domestic Shipments, 2002-2006



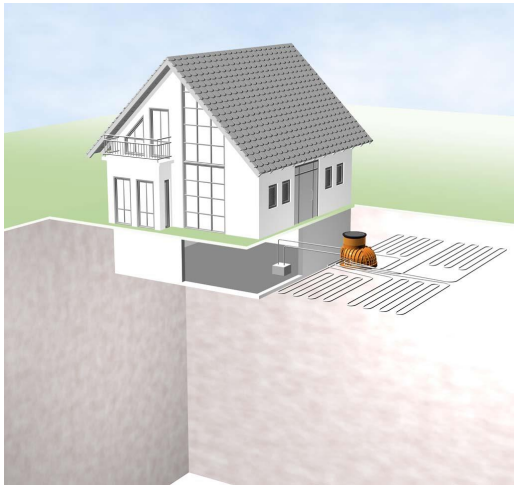


Source: EIA, Survey of Geothermal Heat Pump Shipments, 2006

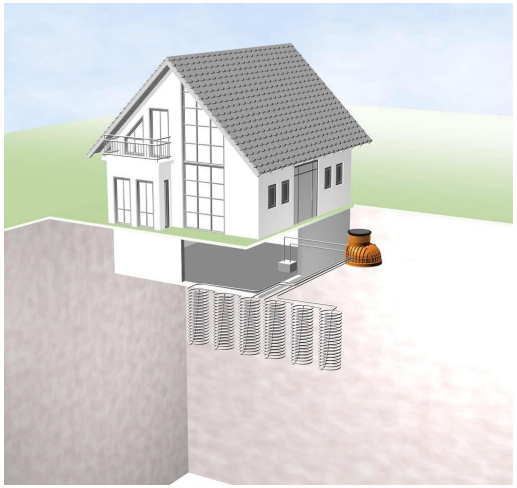
GSHP : Closed Loop Systems



Borehole Wells



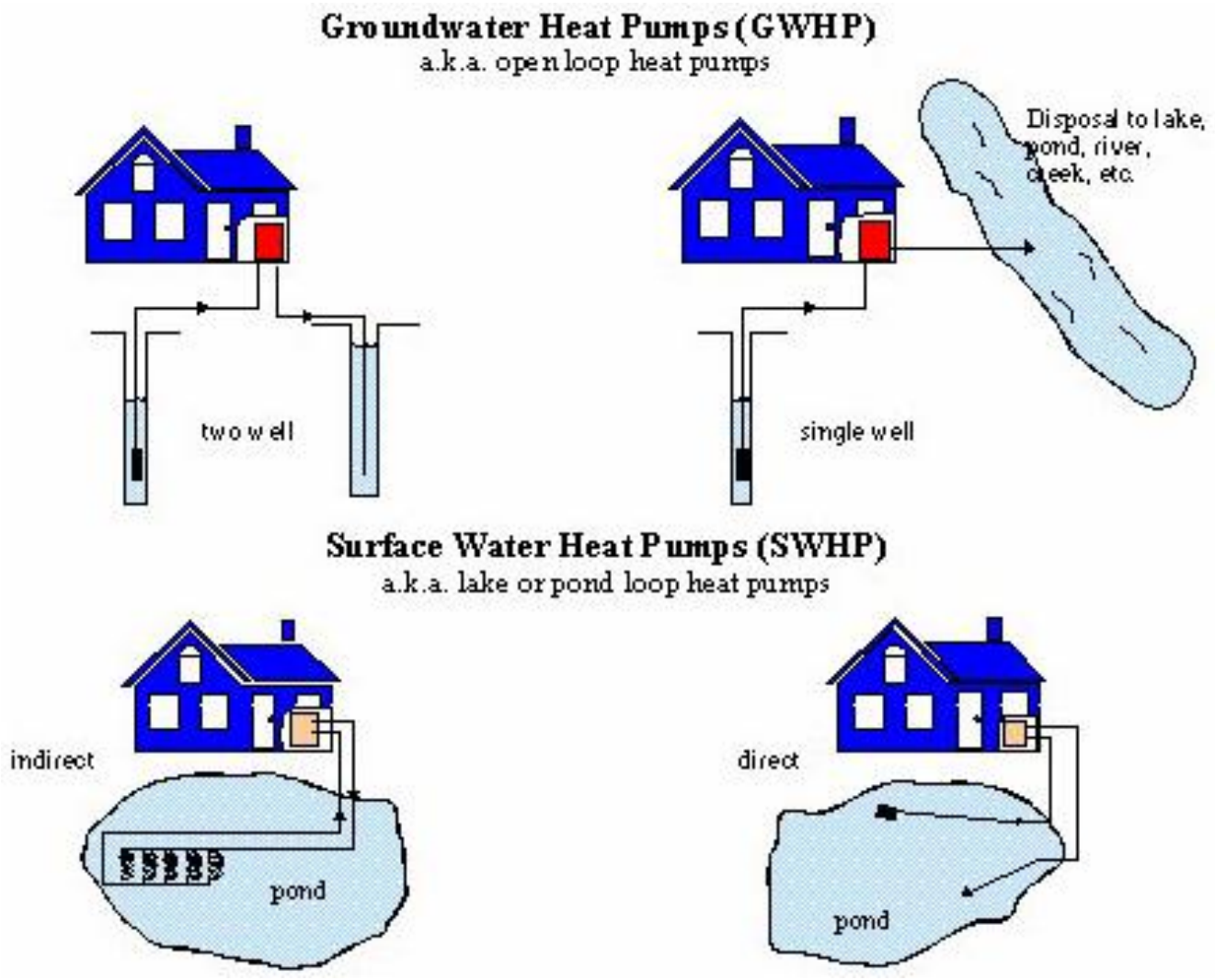
Horizontal Loops



Helical Coils

Energy Piles

Open Loop Systems

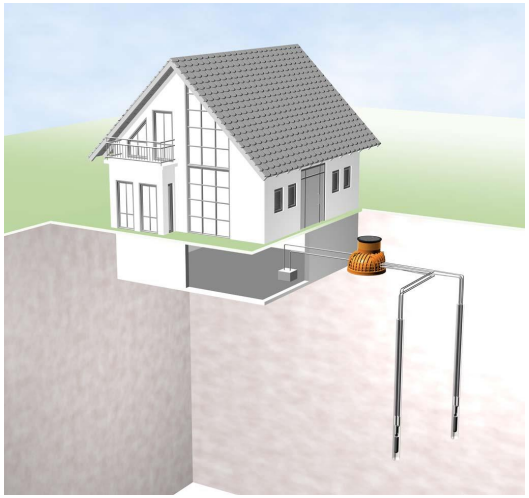


Source eere.energy.gov

Barriers to wider GSHP Implementation

- Tend to have significantly higher first costs compared with conventional systems
- Generally longer paybacks when replacing natural gas heating systems
- Lack of awareness
- Lack of uniform standards – design and installation accreditation has yet to receive nationally standardized accreditation
- Shortage of qualified designers and installers.

GSHP : Closed Loop Systems



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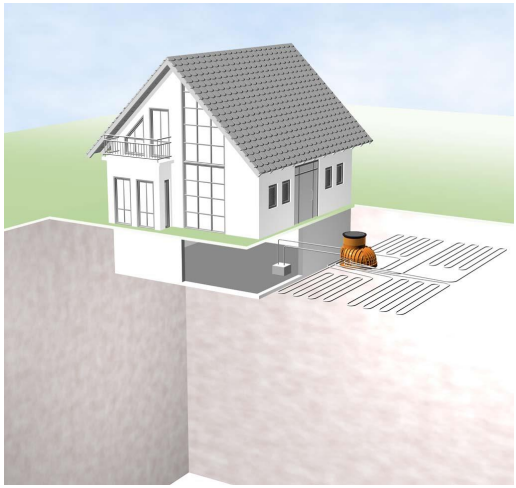

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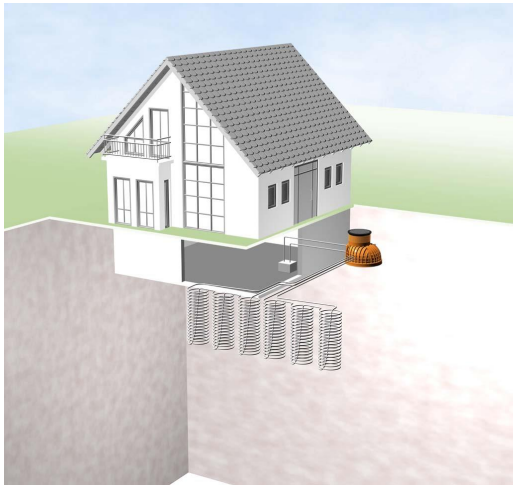
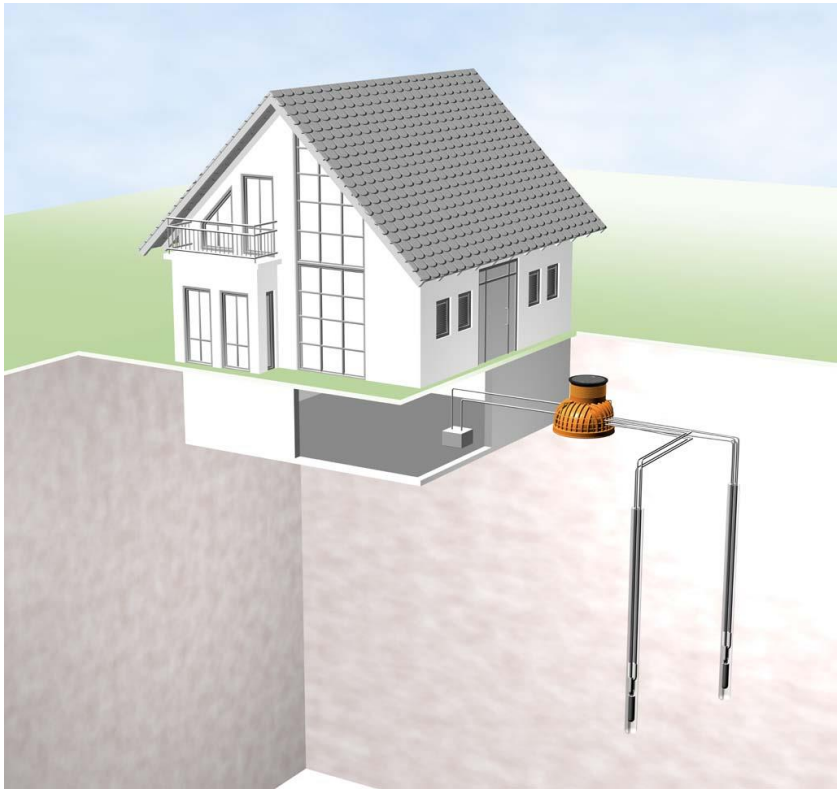


Helical Coils

Energy Piles

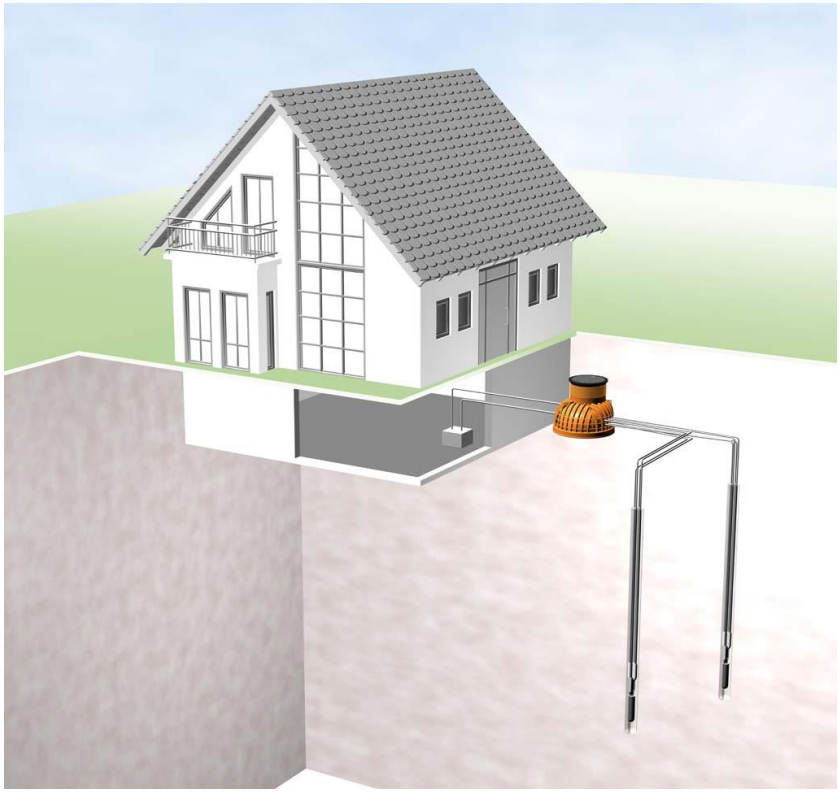
Borehole Wells



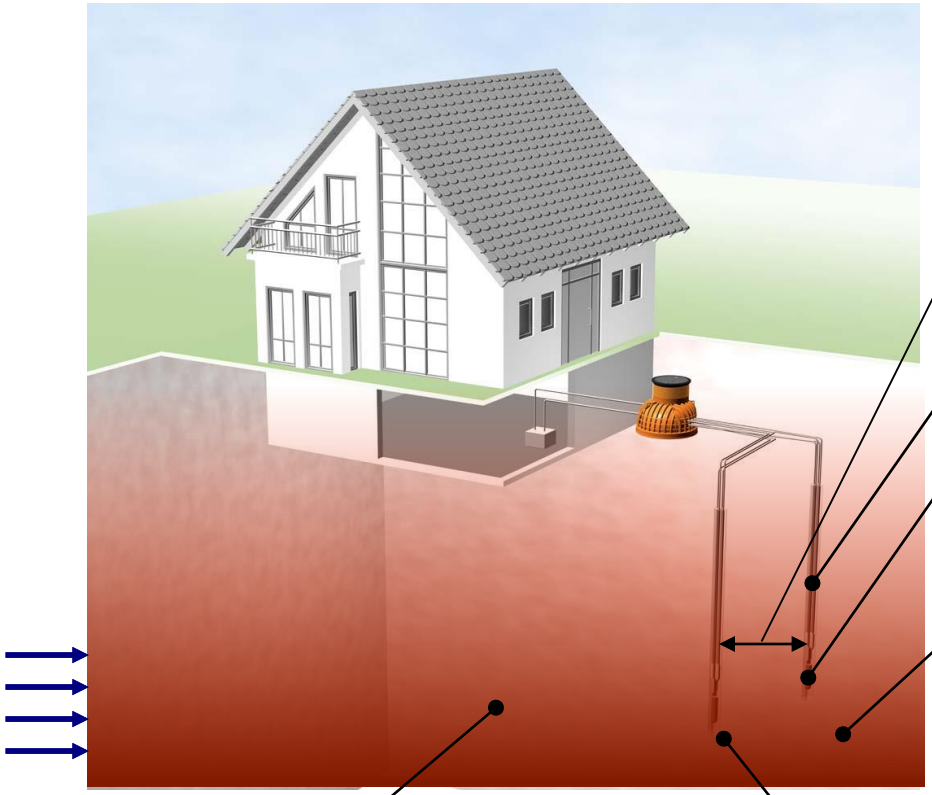
Major cost is drilling and materials

- 200 ft - 500 ft deep
- Small residential to large commercial

Borehole Wells



Borehole Wells – Design Considerations



Spacing

Grout Type

Single U-bend or
Double U-bend

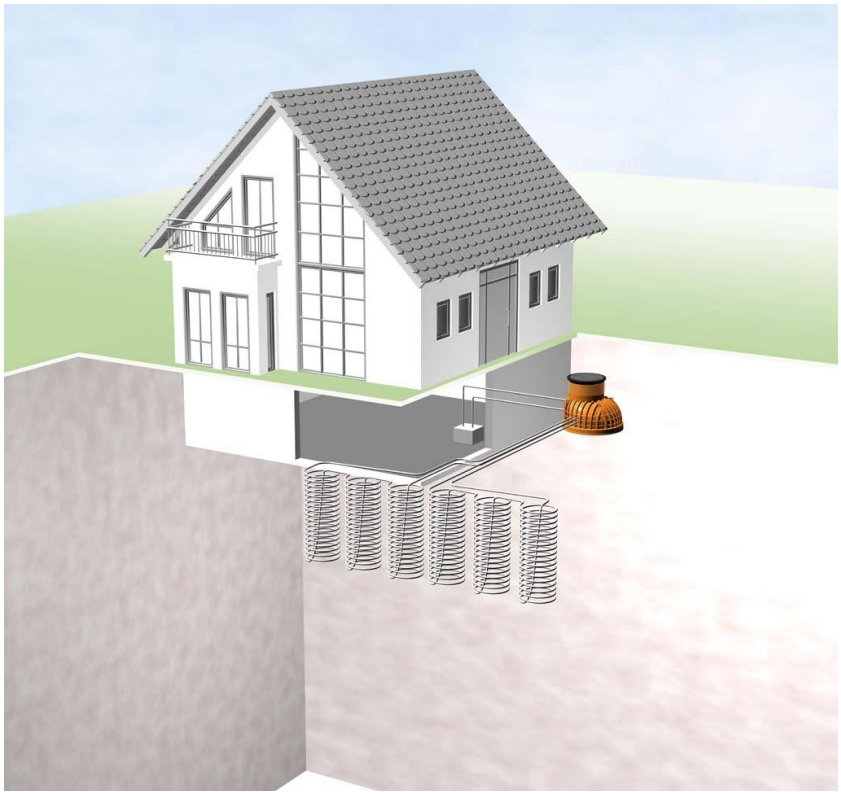
Ground properties:

- Temperature
- Thermal conductivity
- Thermal diffusivity

Ground water

Long-term effects

Helical Coils



Energy Piles

gy pile

return pipes
for the liquid
heat carrier

Vertical Ground Source Heat Pump Systems

Piping is inserted to deep vertical boreholes. Boreholes are grouted to improve heat transfer and protect groundwater.

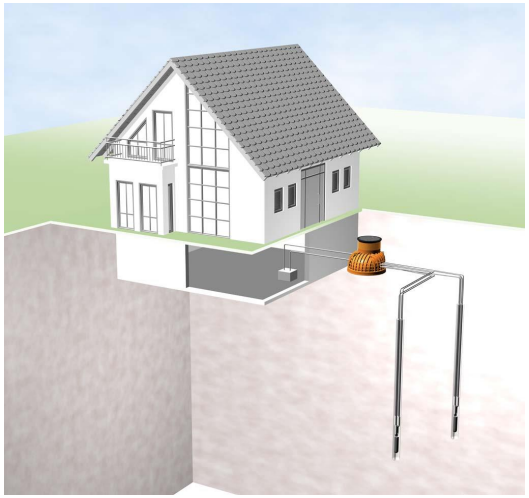
Advantages

- Requires less land than other closed loop systems
- Requires smaller amounts of pipe and pumping energy
- Likely to yield the most efficient performance of closed loop systems

Disadvantages

- Higher initial cost due to the drilling of boreholes
- Problems in some geological formations (an issue in parts of MA)
- Limited availability of experienced drillers and installers

GSHP : Closed Loop Systems



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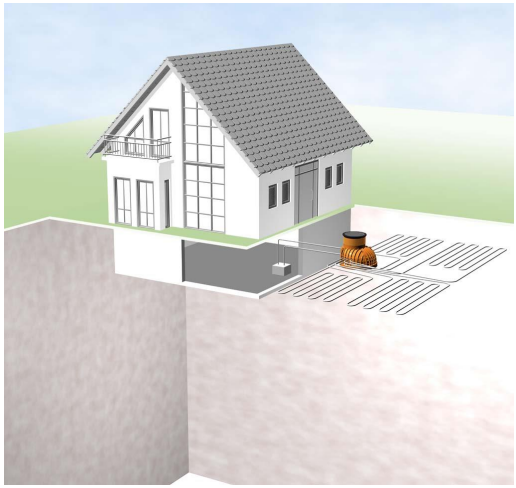
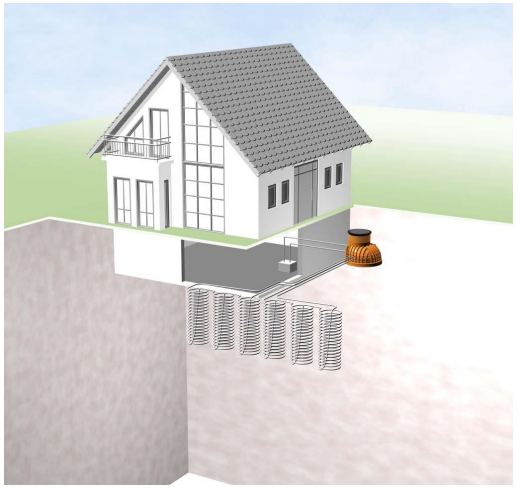


Horizontal Loops



Helical Coils

Energy Piles

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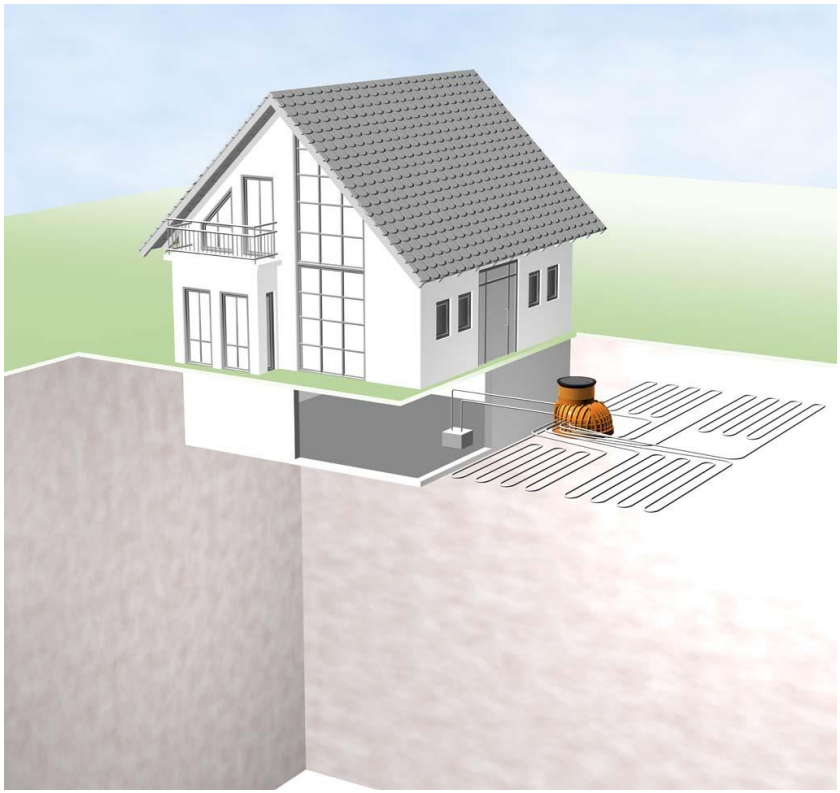
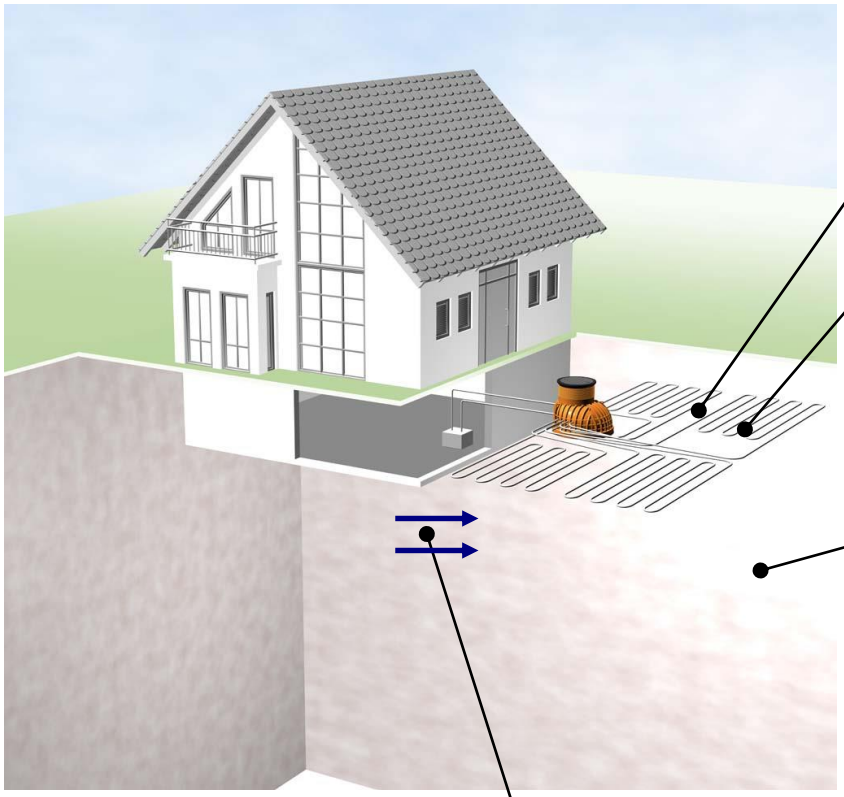


6-10 ft

Horizontal Loops



Spacing

Pipe configuration:

- Straight
- Horizontal Slinky
- Vertical Slinky

Soil properties:

- Temperature (seasonal variation)
- Thermal conductivity
- Thermal diffusivity

Shallow ground water

Horizontal Loops

Recently built house in Blacksburg VA with a trench loop system

Horizontal Loops

Horizontal loop systems within/beneath slabs

Horizontal Loops

Energy slab (Messe U2 metro station, Vienna)

Horizontal Loops – Deicing

Horizontal Ground Source Heat Pump Systems

Placement of straight or "slinky" piping in shallow (6-8ft) horizontal trenches.

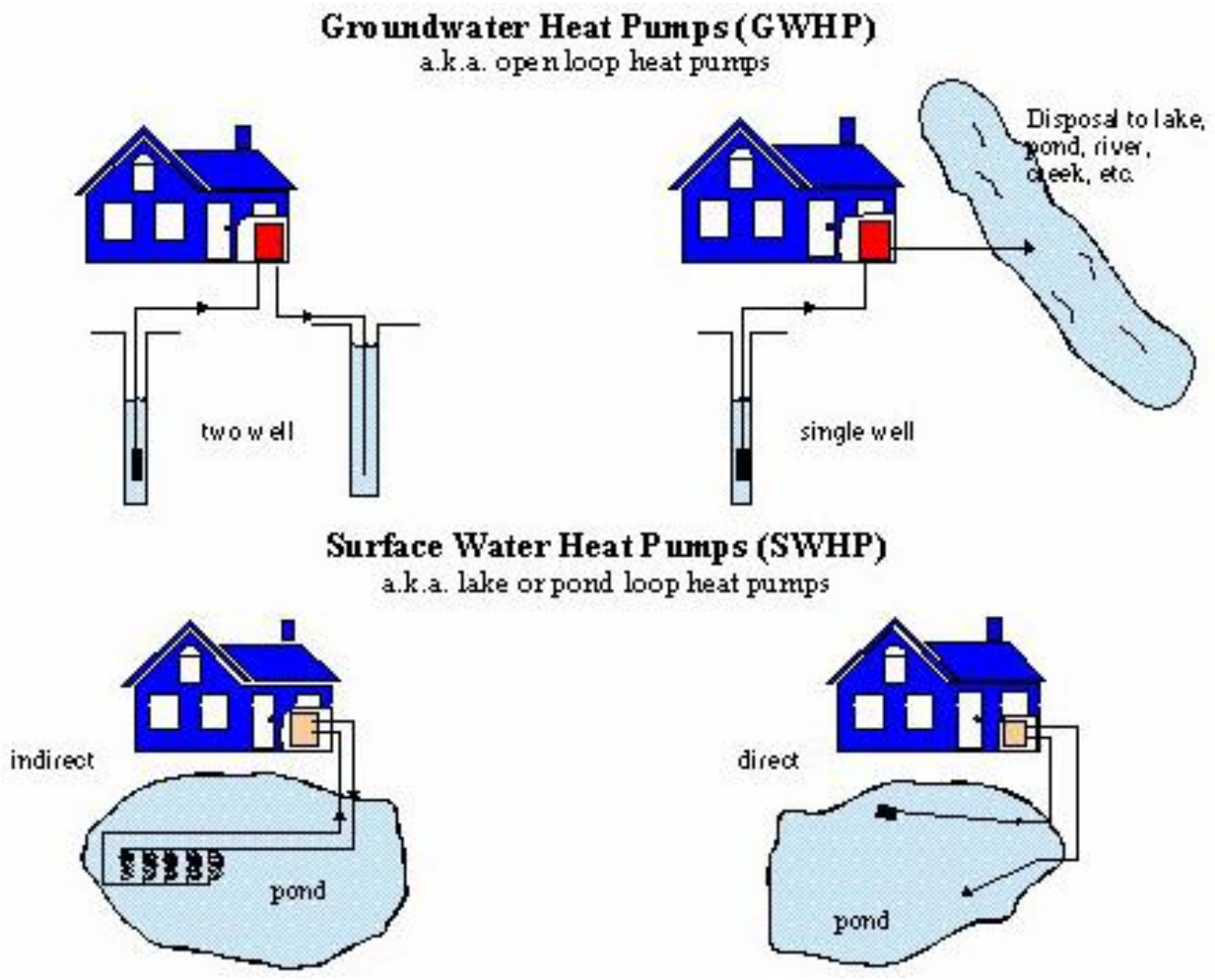
Advantages

- Likely less expensive to install vertical closed loop
- Requires less specialized skill and equipment to install, so contractors are more widely available

Disadvantages

- Need more space
- Ground temperature and thermal properties fluctuate with season, rainfall, and burial depth
- Lower efficiency

Open Loop Systems

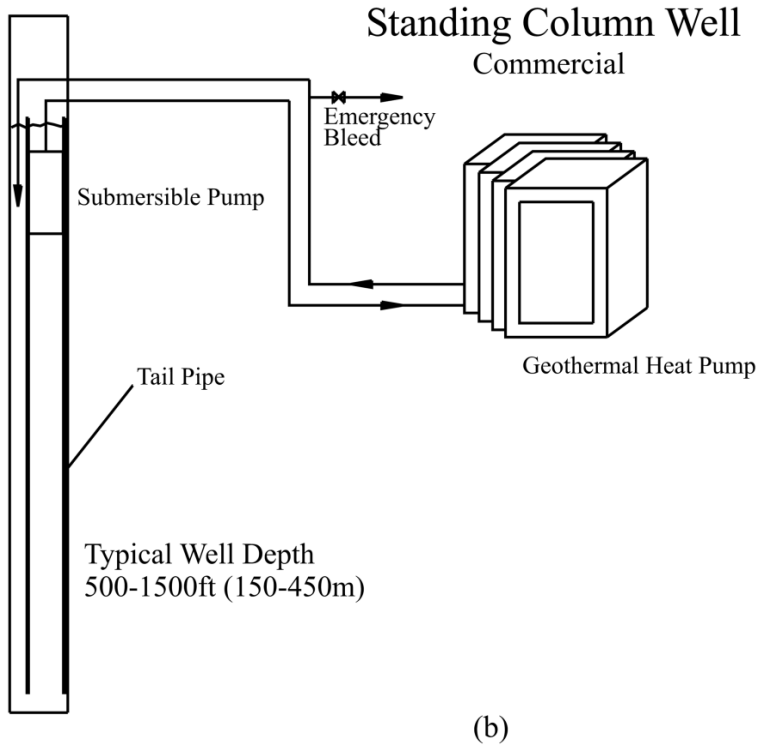


Source eere.energy.gov

Open Well Systems

Water is pumped from bottom of well and re-injected at the top

- Heat exchange rate is enhanced by the pumping action
- Often utilized where little land is available or the bedrock is close to the surface
- During peak heating and cooling, the system can use a bleed cycle to control the column temperature



Source: Orio, 2005. "A Survey of Standing Column Well Installations in North America," ASHRAE Transactions.
Information for Evaluating Geoexchange Applications, prepared for NYSERDA by the Geothermal Heat Pump Consortium.

Groundwater Heat Pump Systems

Uses groundwater as heat sink and source.
Water is pumped through the system, then discharged.

Advantages

- Have the lowest installed cost, especially in larger applications
- Uses less space
- Well water contractors are widely available
- Long track record in large commercial applications

Disadvantages

- Local water and environmental regulations may restrict use
- Limited water availability
- May need fouling precautions
- High pumping energy required if system poorly designed or water pulled from deep aquifer

Source: 2003 ASHRAE Applications Handbook

Surface Water Heat Pump Systems

The piping is anchored to the bottom of a nearby body of water

Advantages

- Low cost due to reduced excavation costs
- Low maintenance
- Low operating costs

Disadvantages

- Possible damage to piping in public lakes
- Significant temperature variation if lake is small/shallow

Hybrid Systems

- Use several different geothermal resources, or a combination of a geothermal resource with outdoor air (most often, a cooling tower)
- Particularly effective where cooling needs are significantly larger than heating needs.
- Cooling tower used to reject excess heat
- Main benefits:
  - Reduces loop field size, and thus costs, by allowing for the ground loop to be undersized for the cool load, but sized for the smaller heating load
  - Avoid increase in ground temperature due to seasonal load imbalances

Source: Federal Energy Management Program, Assessment of hybrid geothermal heat pump systems, 2001

Thank You !