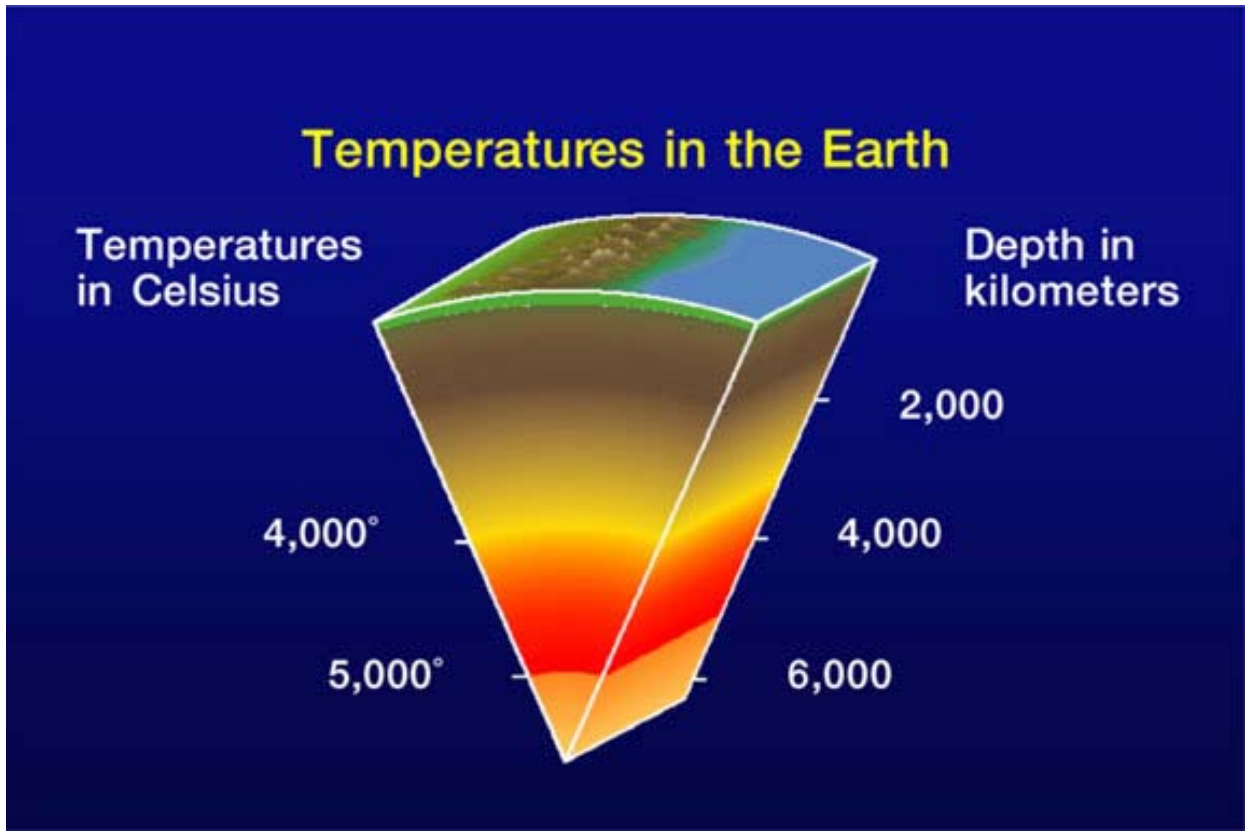
GEOTHERMAL ENERGY

Sustainable Energy Sources

Source: http://geothermal.marin.org/GEOpresentation

Earth's Temperature Profile



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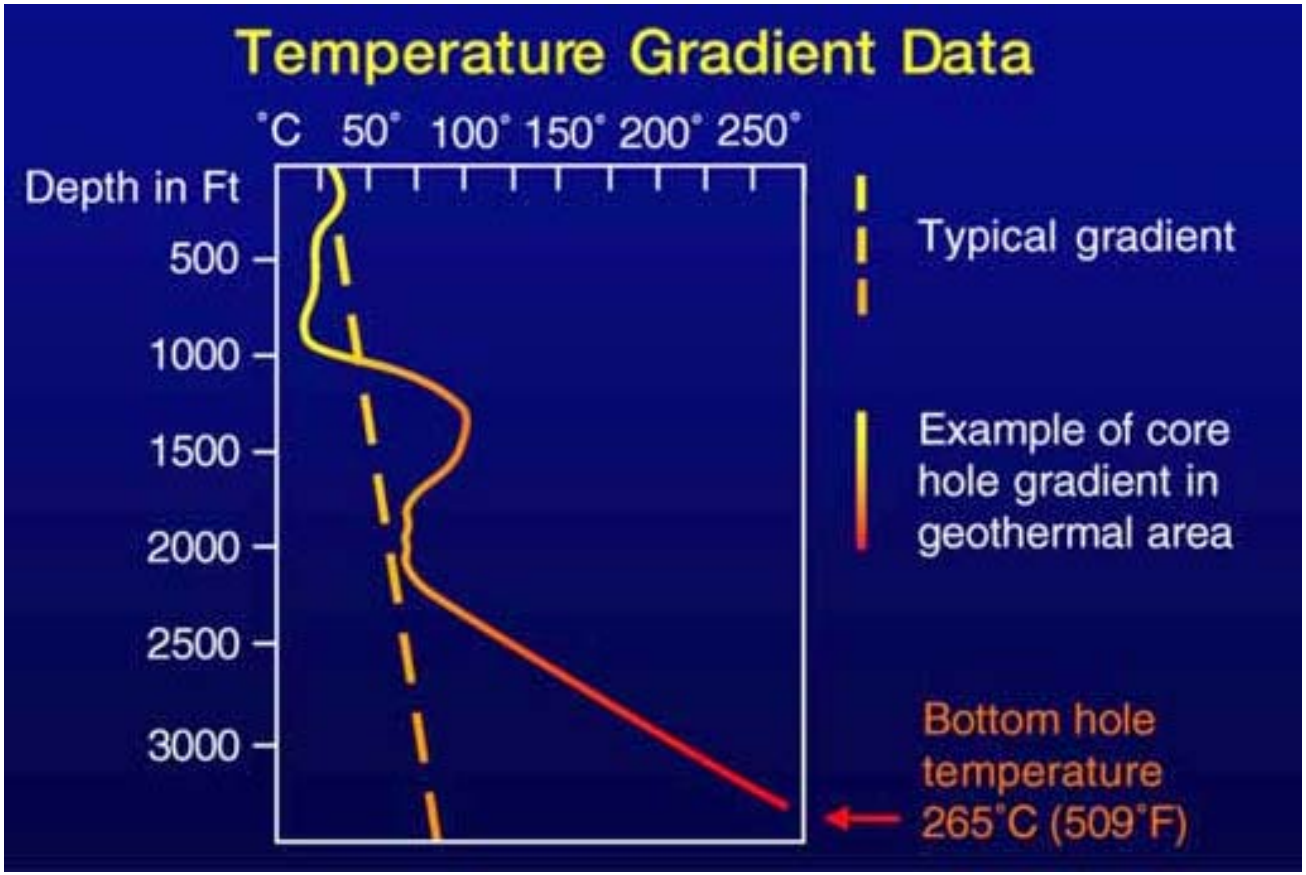

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Plate Tectonics

Earth's crust is broken into huge plates that move apart or push together at about the rate our fingernails grow. Convection of semi-molten rock in the upper mantle helps drive plate tectonics.

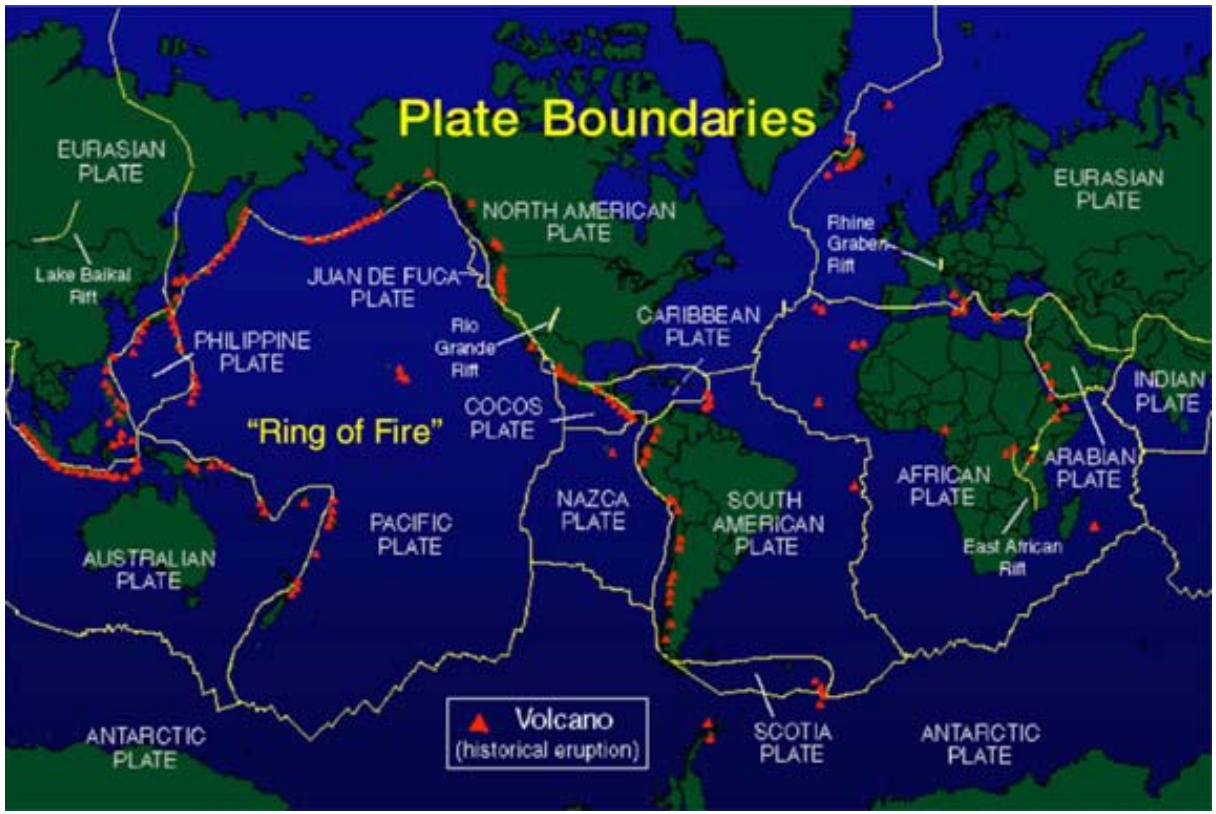

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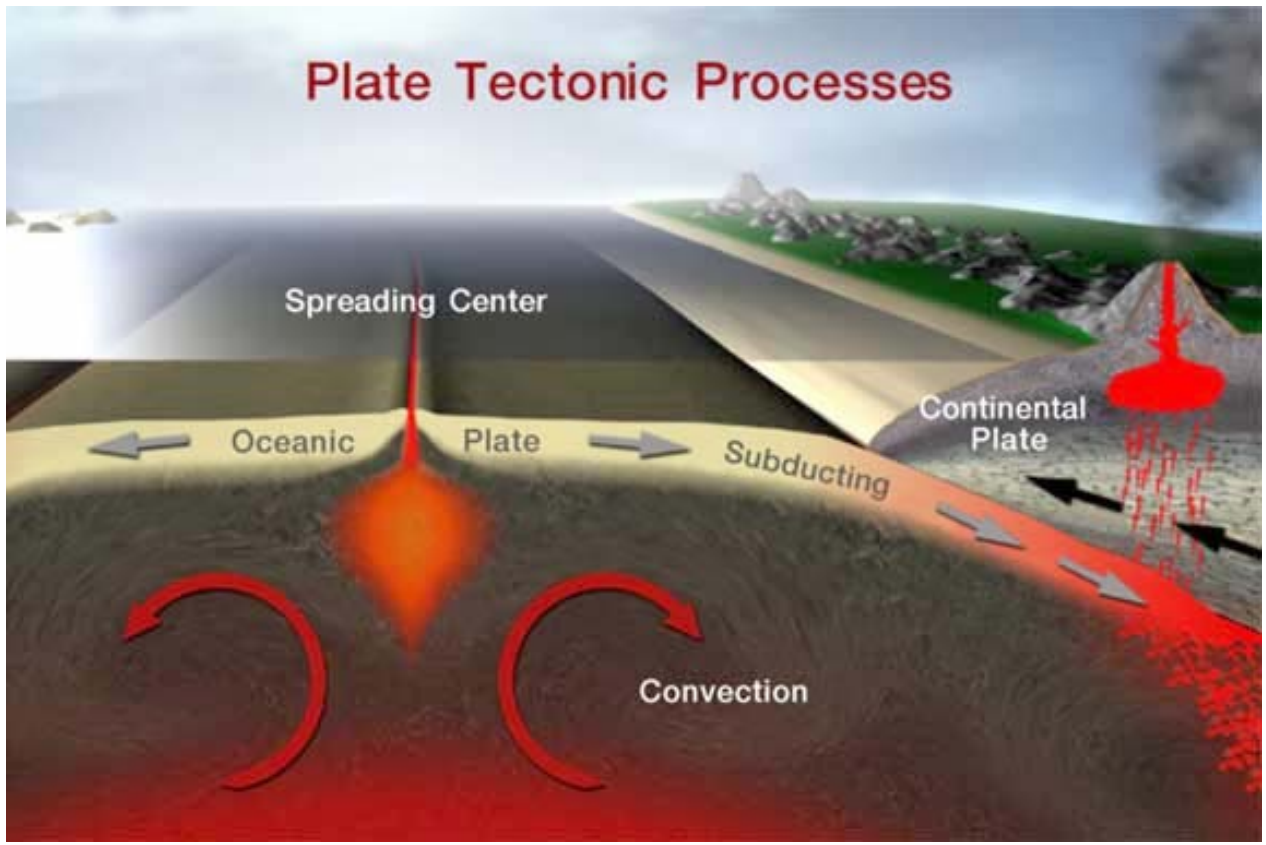
Plate Tectonics

New crust forms along mid-ocean spreading centers and continental rift zones. When plates meet, one can slide beneath another. Plumes of magma rise from the edges of sinking plates.



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Magma

Thinned or fractured crust allows magma to rise to the surface as lava. Most magma doesn't reach the surface but heats large regions of underground rock.

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Rain Water Effect

Rainwater can seep down faults and fractured rocks for miles. After being heated, it can return to the surface as steam or hot water.

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Steaming Ground

This steaming ground is in the Philippines.

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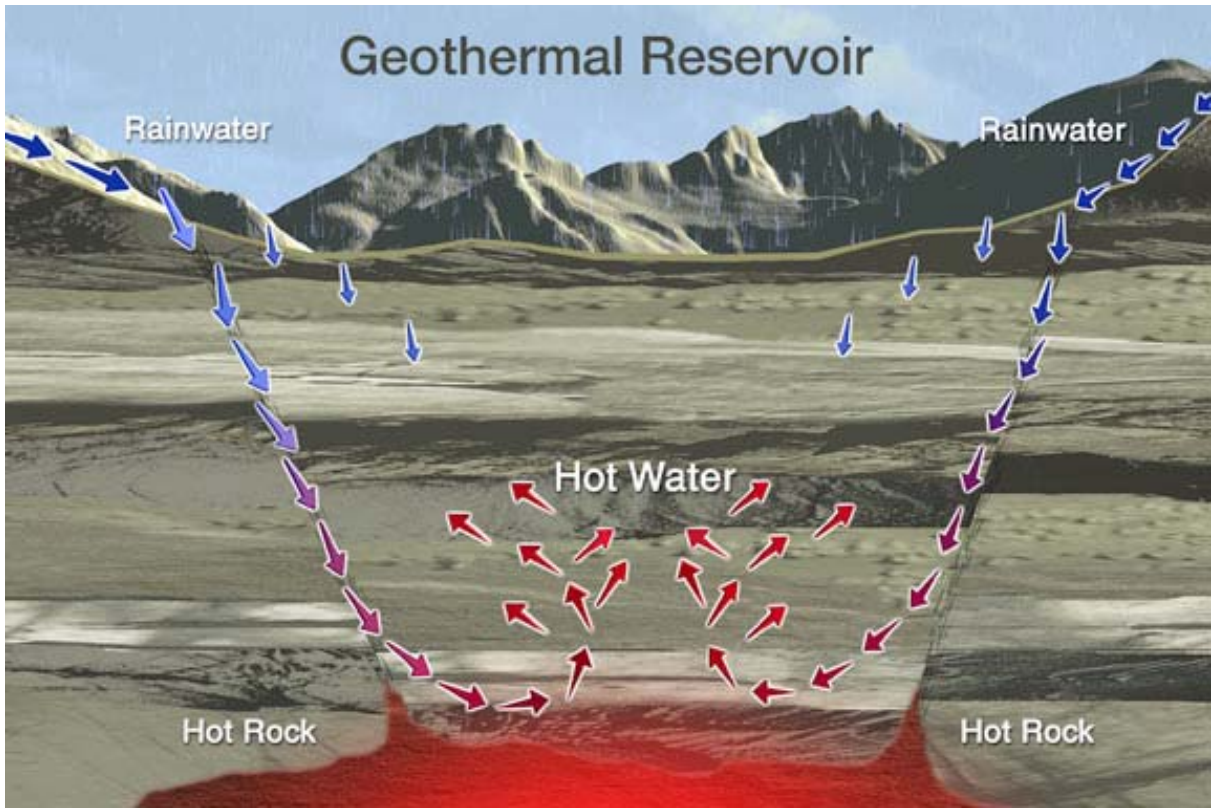
Geysers

- Examples of geothermal heat
- Requirements:
  - Deep subterranean supply of water
  - Source of heat
  - Series of fissures and fractures to surface
- Regular interval geysers are indicators of earthquakes within 500 miles
  - Old Faithful at Yellowstone

Geothermal Reservoir

When the rising hot water and steam is trapped in permeable and porous rocks under a layer of impermeable rock, it can form a geothermal reservoir. Geothermal reservoirs can reach temperatures of 370°C.



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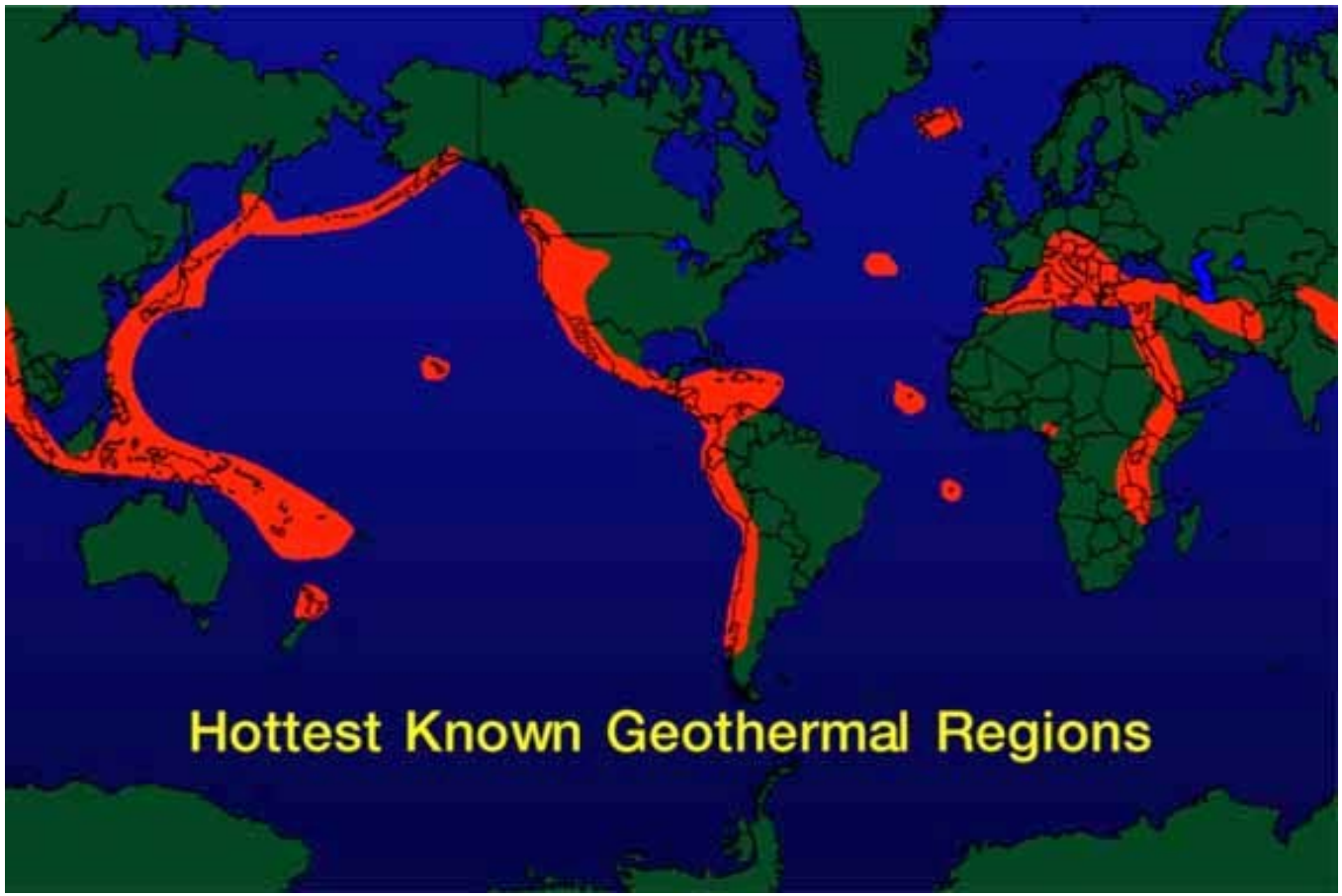

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Geothermal Well

This photograph shows a vertical geothermal well test in the Nevada Desert.

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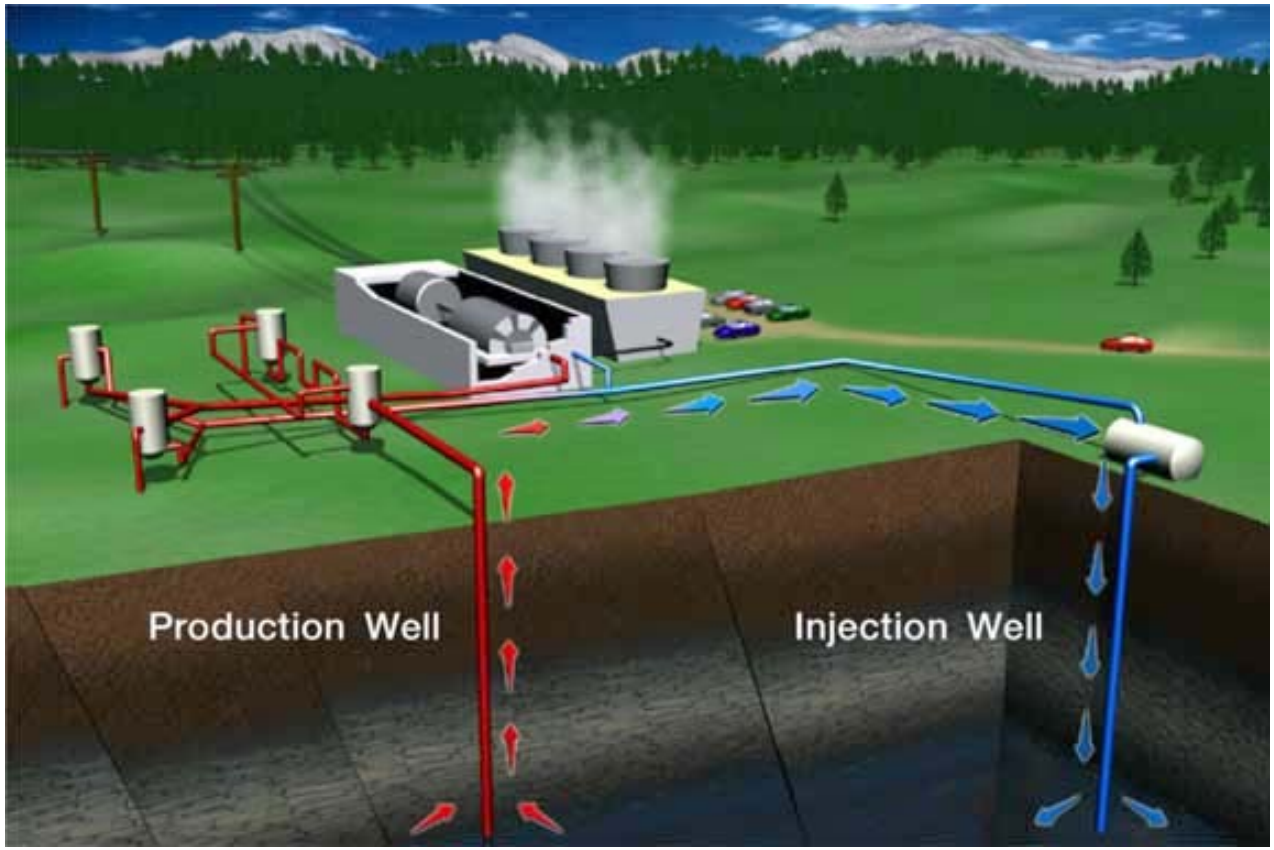
Geothermal Plant

Natural steam from the production wells power the turbine generator. The steam is condensed by evaporation in the cooling tower and pumped down an injection well to sustain production.



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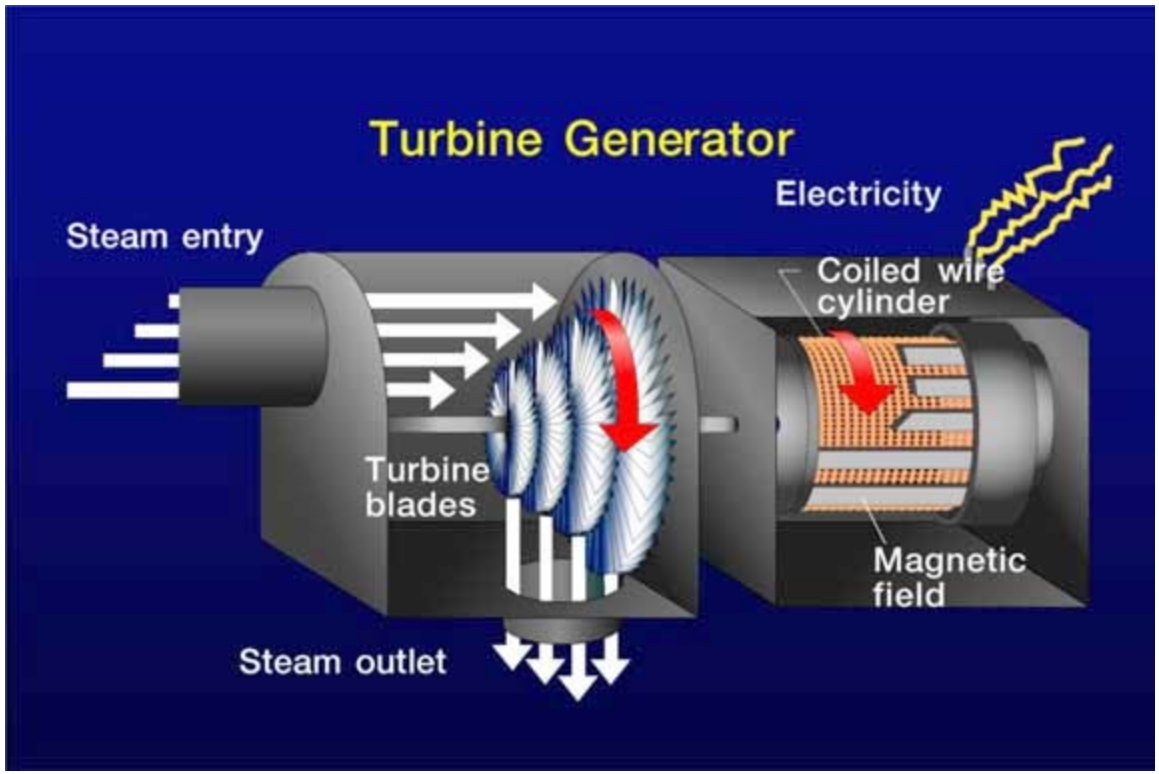
Turbine Generator

Sustainable electricity production with no fuels are burned.



Source: http://geothermal.marin.org/GEOpresentation

Outdoor Turbine Generator

Turbine generator outdoors at an Imperial Valley geothermal power plant in California.

Source: http://geothermal.marin.org/GEOpresentation

Environment

These geothermal plants are operating successfully in a Philippine cornfield, at Mammoth Lakes, Calif., in the Mojave Desert of California, and in a tropical forest, at Mt. Apo, Philippines.

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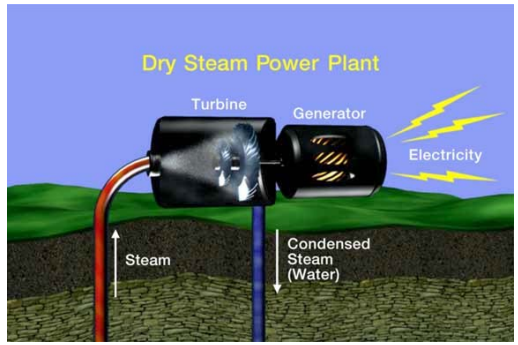
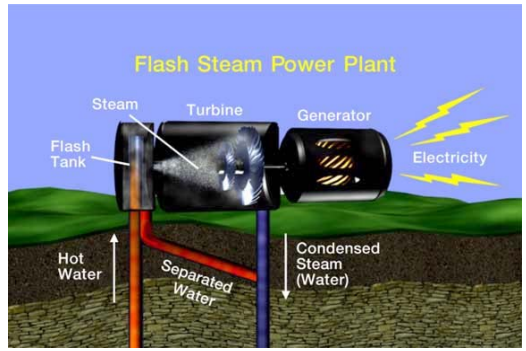
Power Plant Types

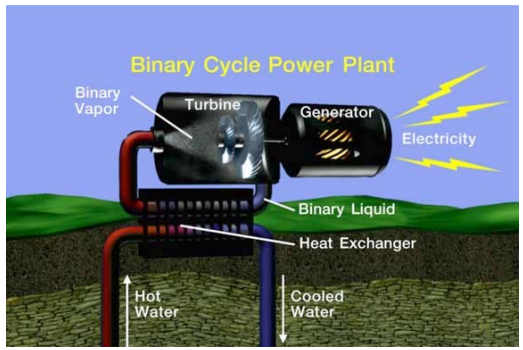
Dry Steam: In dry steam power plants, the steam (and no water) shoots up the wells and is passed through a rock catcher and then directly into the turbine. Dry steam fields are rare.



Flash Stream: Flash steam power plants use hot water reservoirs. In flash plants, as hot water is released from the pressure of the deep reservoir in a flash tank, some of it flashes to steam.



Binary Cycle: In a binary cycle power plant, the heat from geothermal water is used to vaporize a "working fluid" in separate adjacent pipes. The vapor, like steam, powers the turbine generator.



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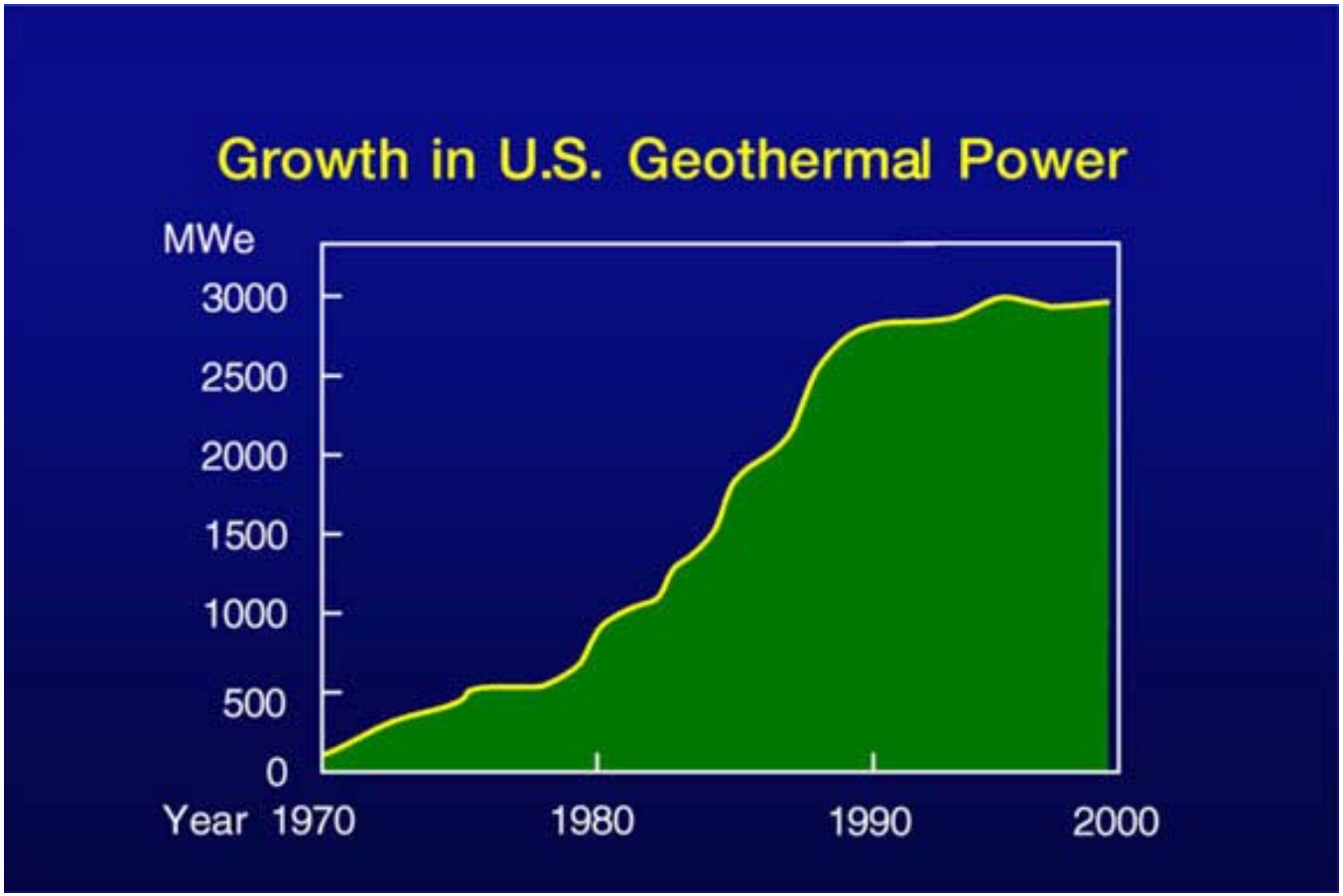
Geothermal Power



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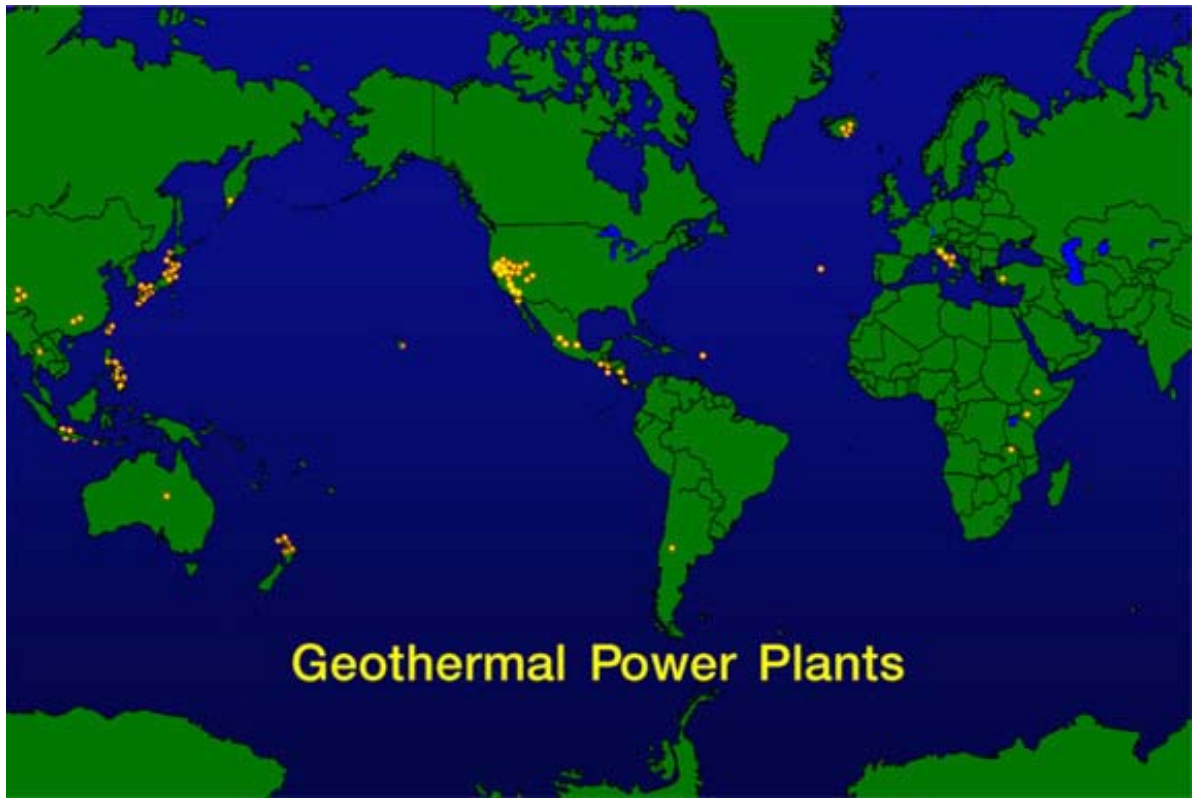
Global Geothermal Power

Geothermal power plants are producing over 8,200 MW of electricity in 21 countries



Source: http://geothermal.marin.org/GEOpresentation

Pollution

Reykjavik, Iceland - picture taken in 1932 when buildings were all heated by burning of (imported) fossil fuels.

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Towards Sustainable Energy

Today, about 95% of the buildings in Reykjavik are heated with geothermal water. Reykjavik is now one of the cleanest cities in the world.

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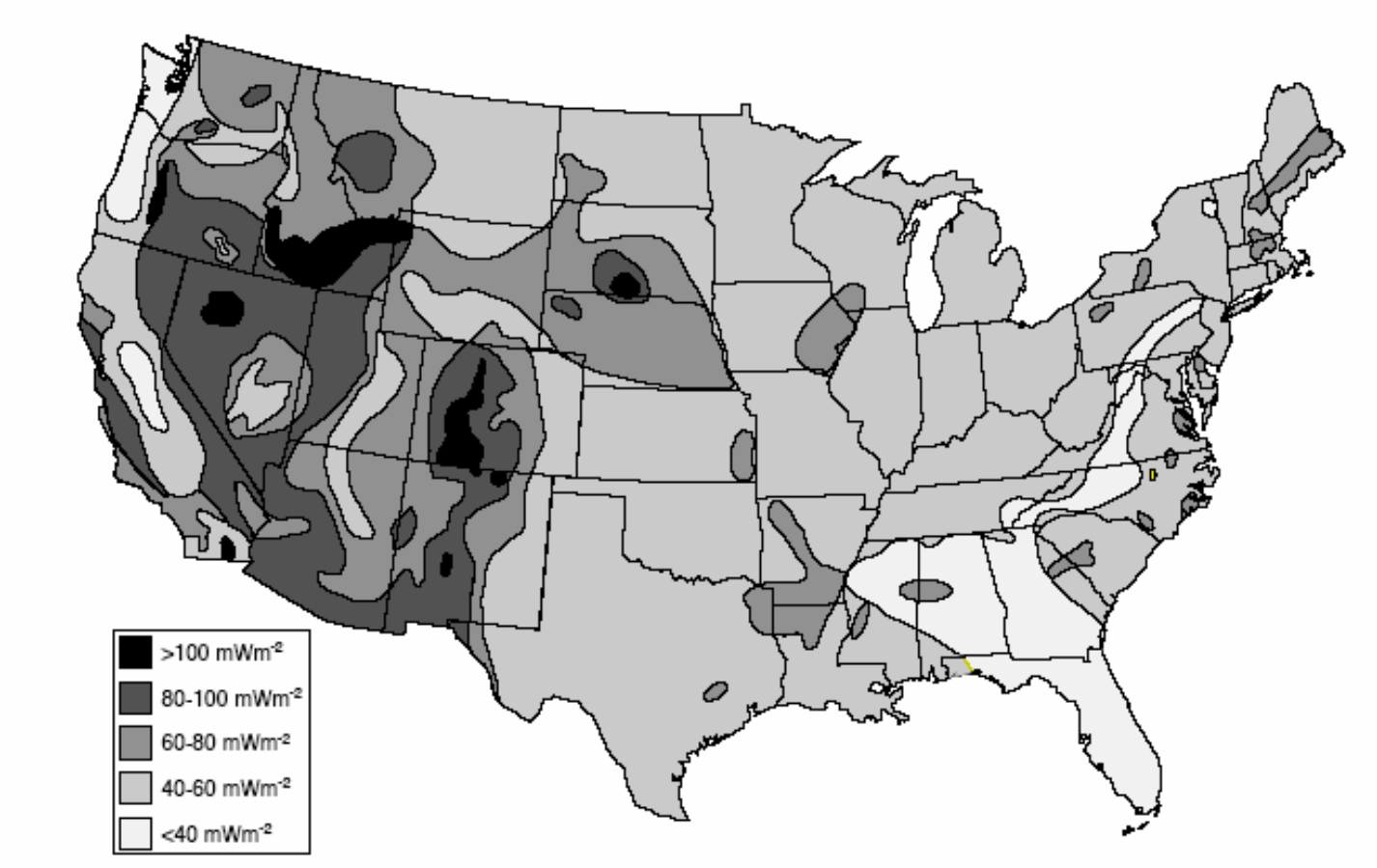
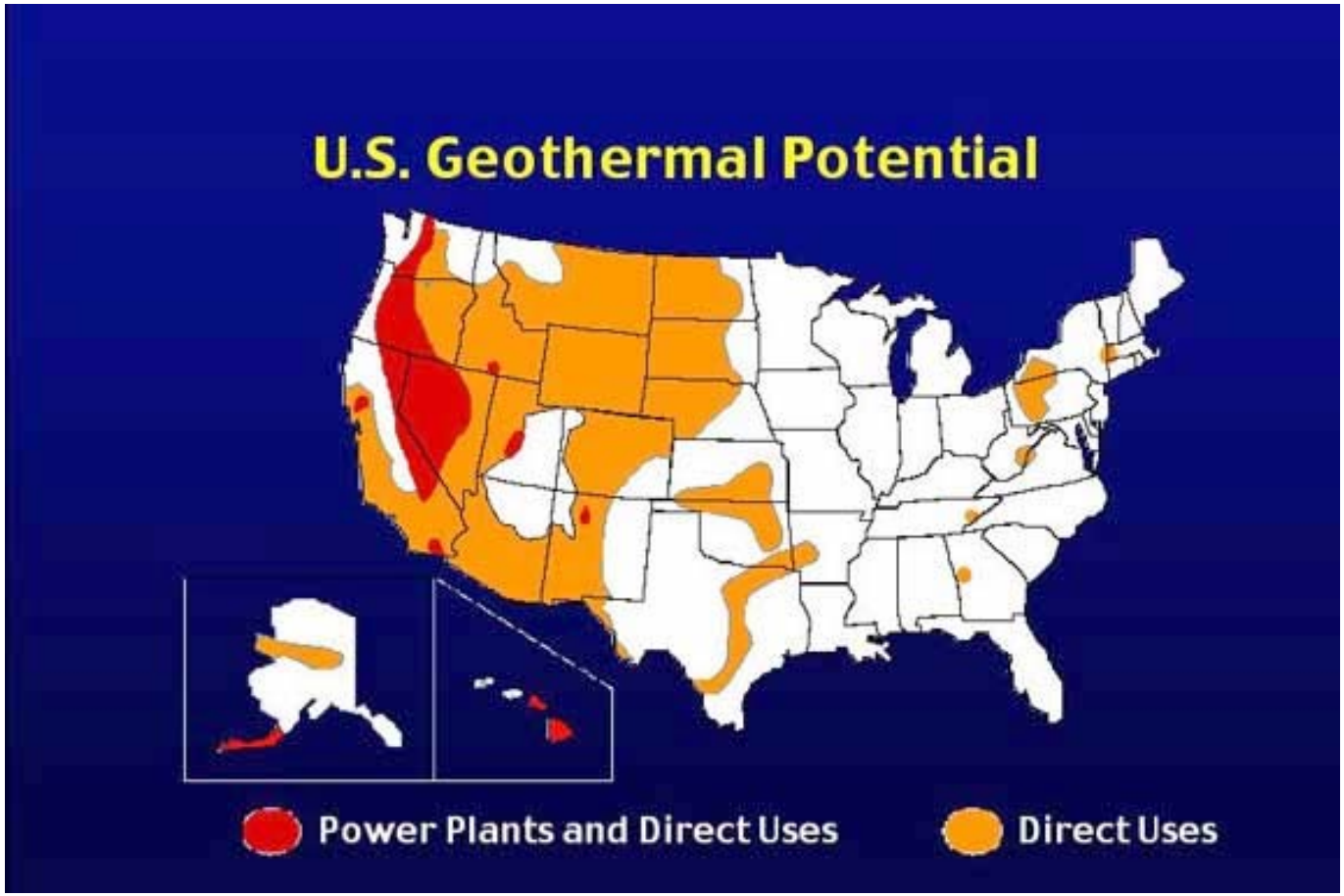
Geothermal Resource



US Geothermal Potential



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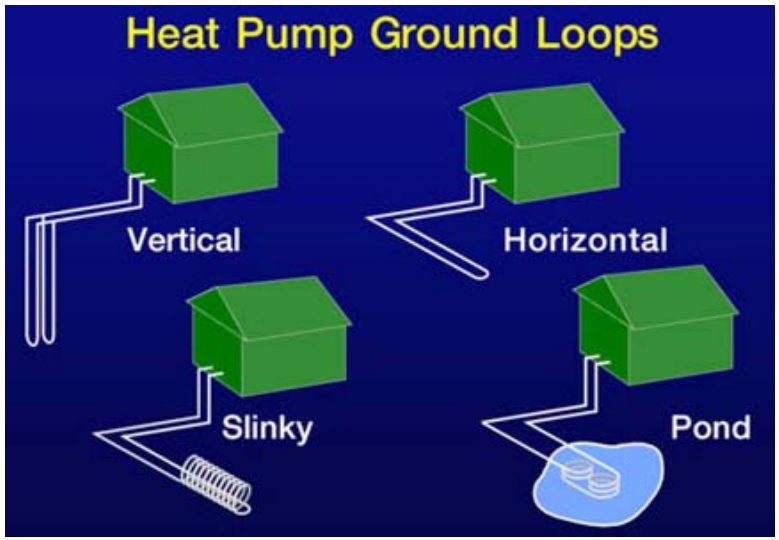
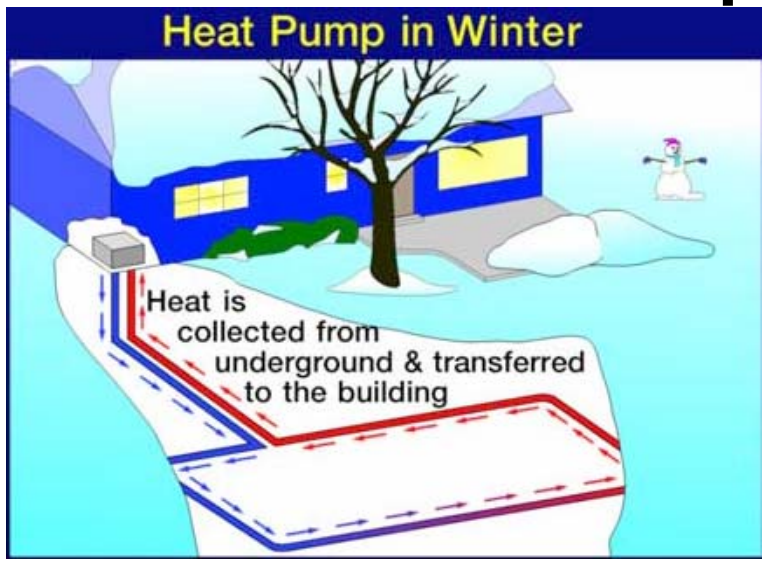
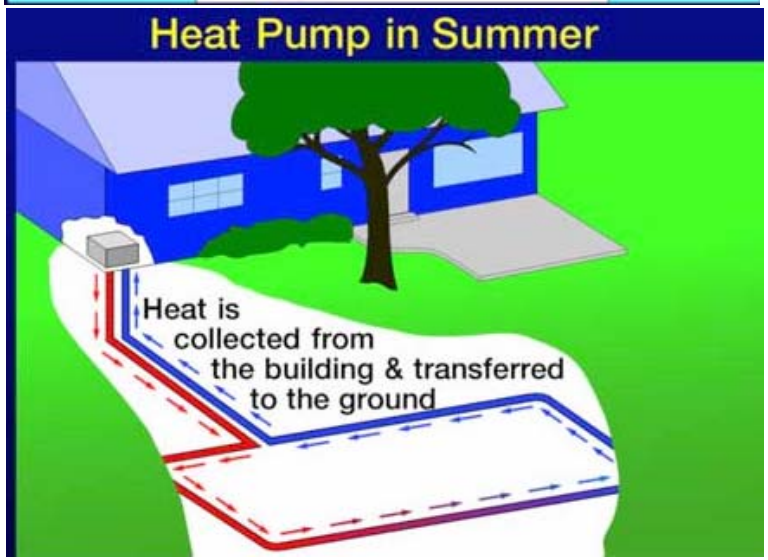
Heat Pumps







Use 40-60% less energy than standard heat pumps

More expensive to install than standard systems

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Drawbacks

Environmental

Dissolved in natural water:

- CO_2 and N_2
- H_2S (oxidizes to SO_2 and H_2SO_4)
- Rn (from rocks containing uranium)
- NH_3
- B
- Hg, HgS

Dissolved in steam:

- CO_2
- H_2S, HCl, HF
- NH_3
- CH_4

Drawbacks

Environmental

- Ground water pollution
  - From system leakage (NH_3)
  - From brines (when discharged into natural waters)
    - Cl^-, F^-, Br^-, I^-
    - SO_4^{2-}
    - HCO_3^-
    - Ca^{2+}, Mn^{2+}, Fe^{2+}
- Land subsidence - from withdrawal of fluids
- Induced seismicity
  - Low-level earthquakes from withdrawal and re-injection of fluids
- Noise - during drilling operations and pump testing

Drawbacks

Sustainability

- Geothermal energy uses stored heat in uppermost crust (~ 5 km) that has accumulated over a long period of heat diffusion and warming
- Average heat flow in the earth is insufficient to sustain geothermal retrieval for long periods of time
  - Long term geothermal retrieval results in slow cooling of the heat exchange region at reservoir depth
  - Exception is in volcanic and sub-volcanic regions
- A 2-hole exchange system with 0.5 to 1.5 km spacing is expected to last 20 years
  - Ambient temperature in the exhausted volume will gradually be restored when it is abandoned
- Heat exchange volumes can also degrade by poor reservoir management, precipitation of minerals, compaction of exhausted volumes.

Summary

Positives

- Exists everywhere
- Low (no) emissions
- Wide range of utilities
- Independent of weather or climate

Negatives

- Expensive exploration
- Requires the use of brines that are corrosive and poisonous
- Sensitive to underground disturbances (earthquakes, volcanism)
- Limited lifetime