

Renewable Energy Technologies

Geothermal Energy



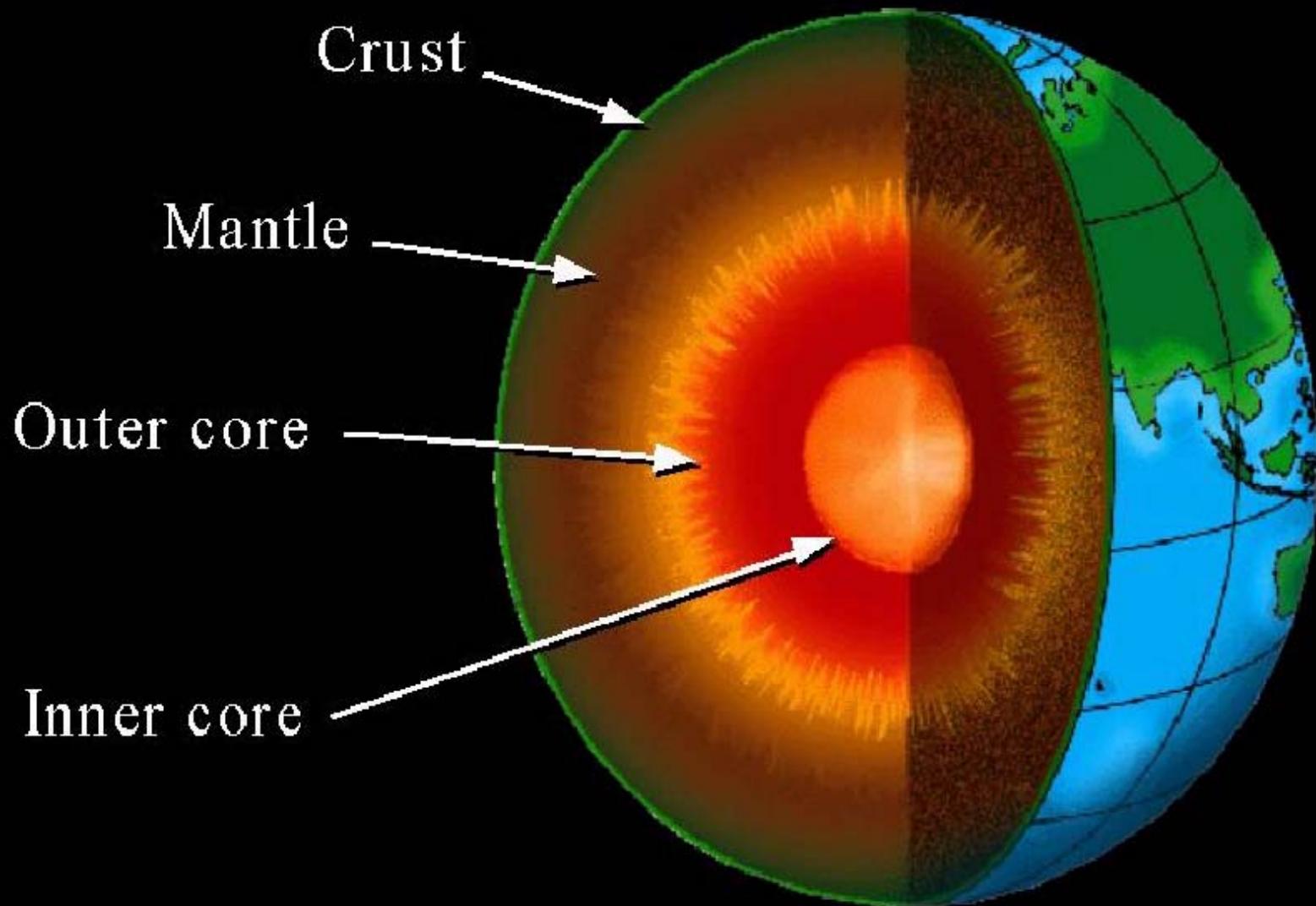
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Geothermal Energy is Heat from the Earth.

How Geothermal Energy is Used:

- Electricity Generation
- Direct Thermal Use
- Geothermal Heat Pumps, also called Geoexchange Units or Ground-Coupled Heat Pumps.

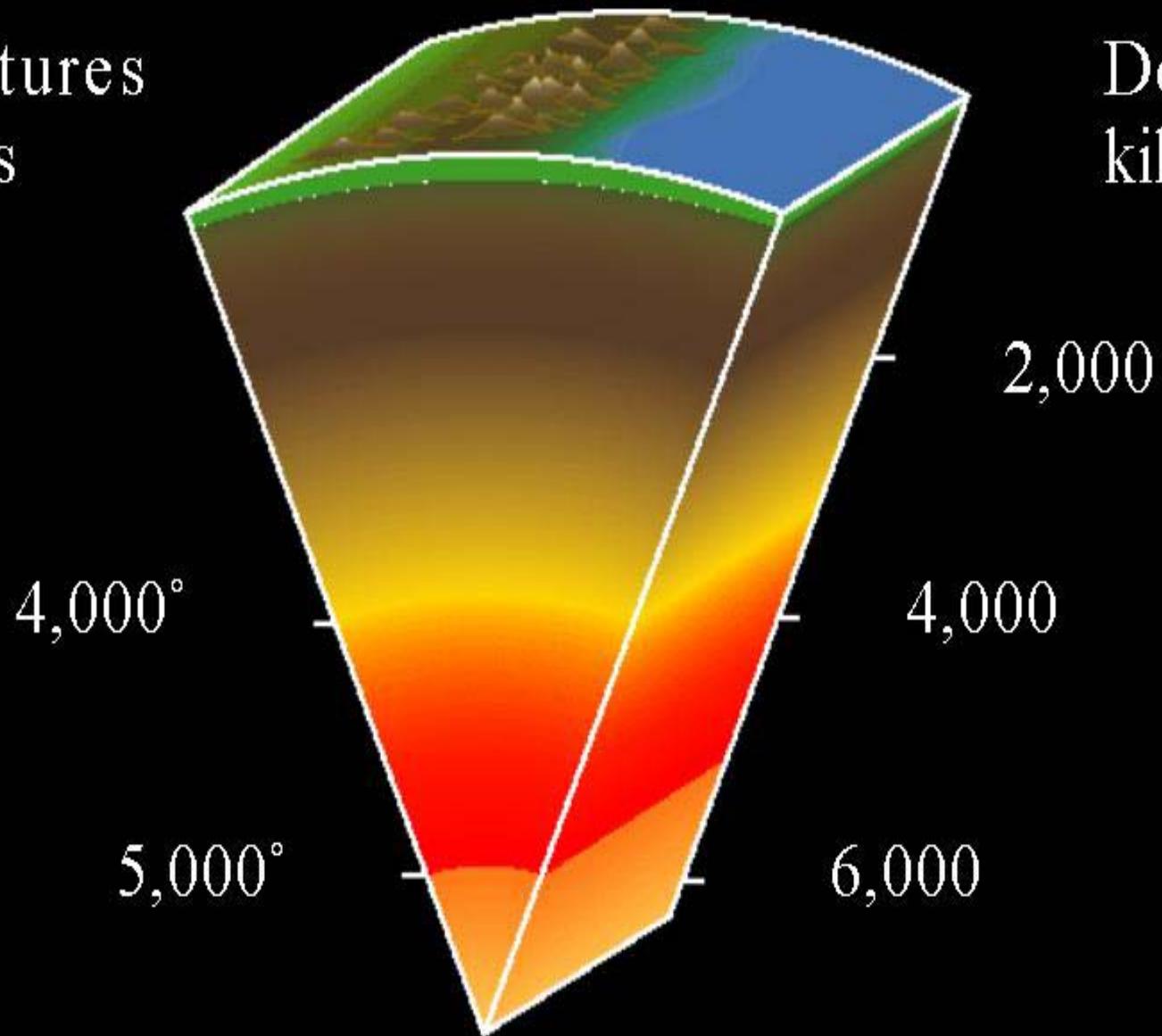
The Earth

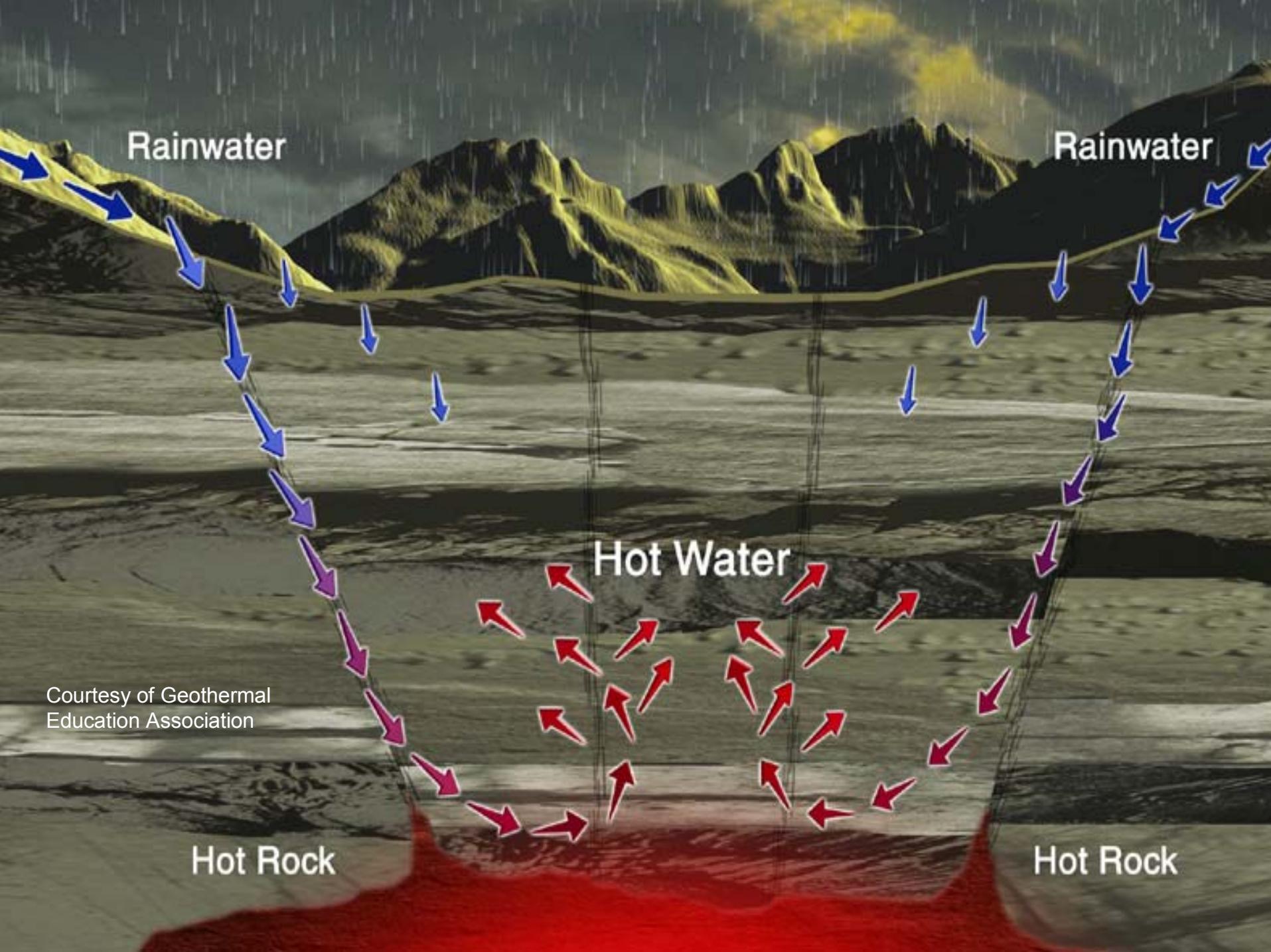


Temperatures in the Earth

Temperatures
in Celsius

Depth in
kilometers





Courtesy of Geothermal
Education Association

Rainwater

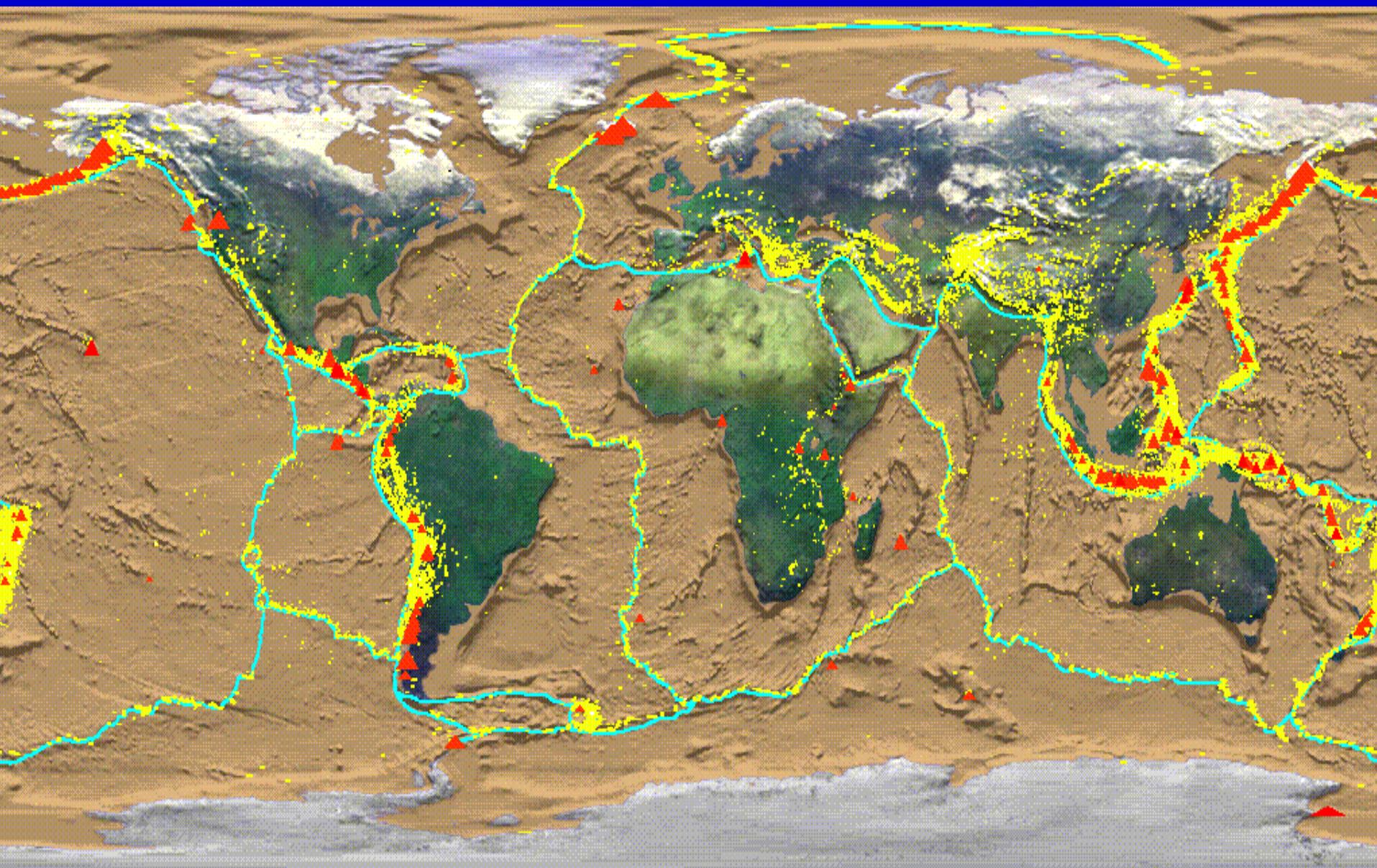
Rainwater

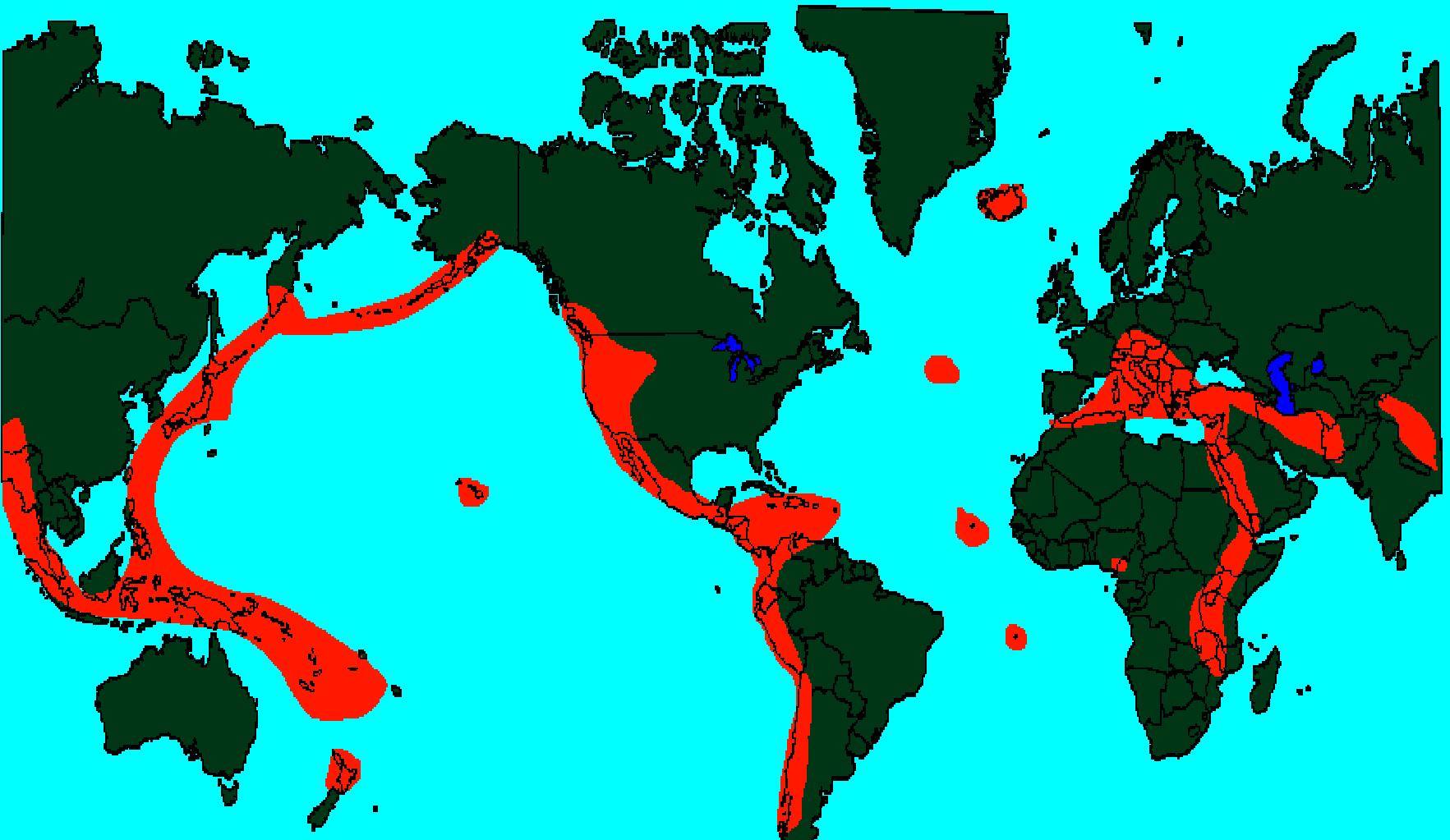
Hot Water

Hot Rock

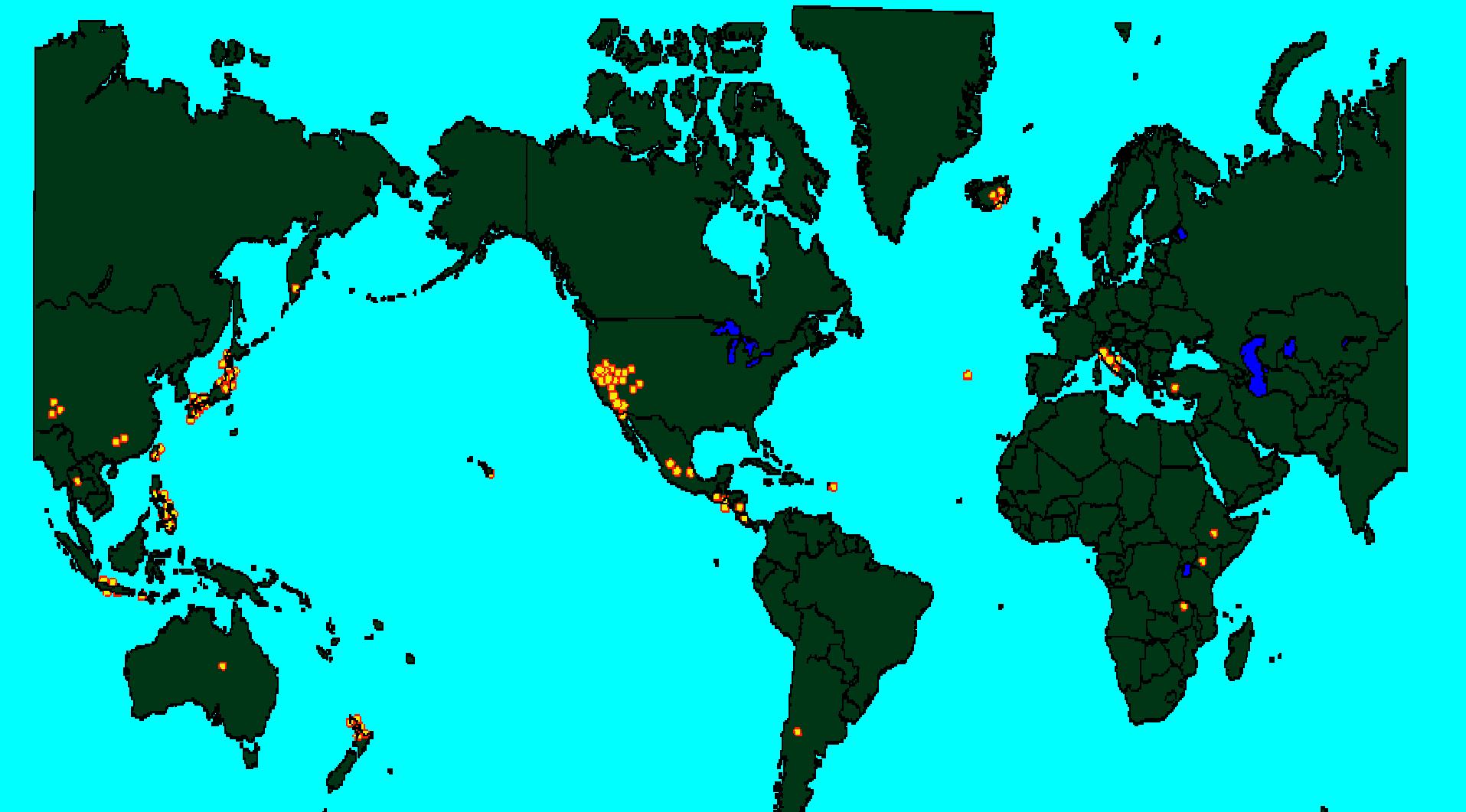
Hot Rock

Tectonic Plate Boundaries





Hottest Known Geothermal Regions

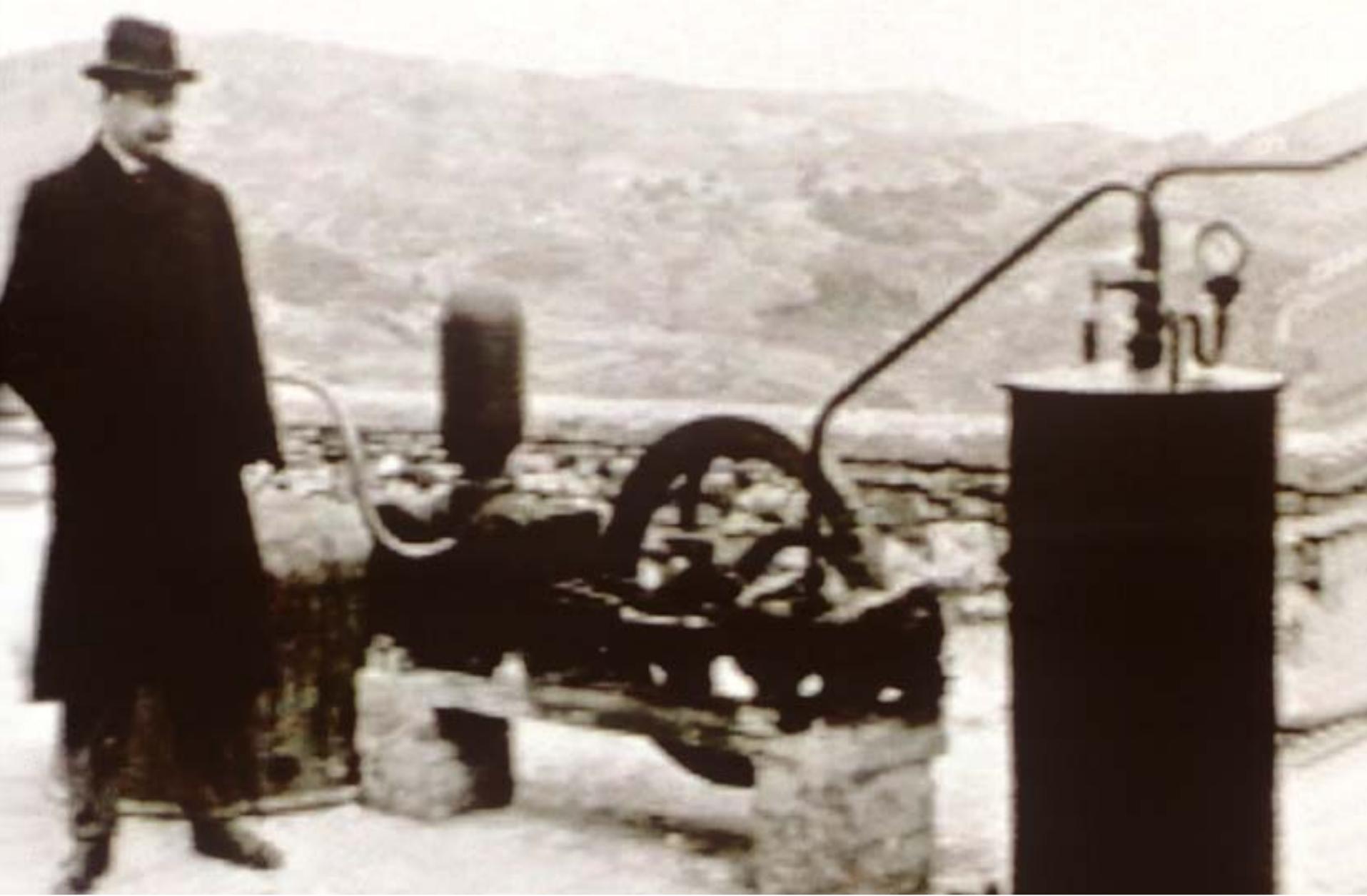


Geothermal Power Plants

History of Geothermal Electricity

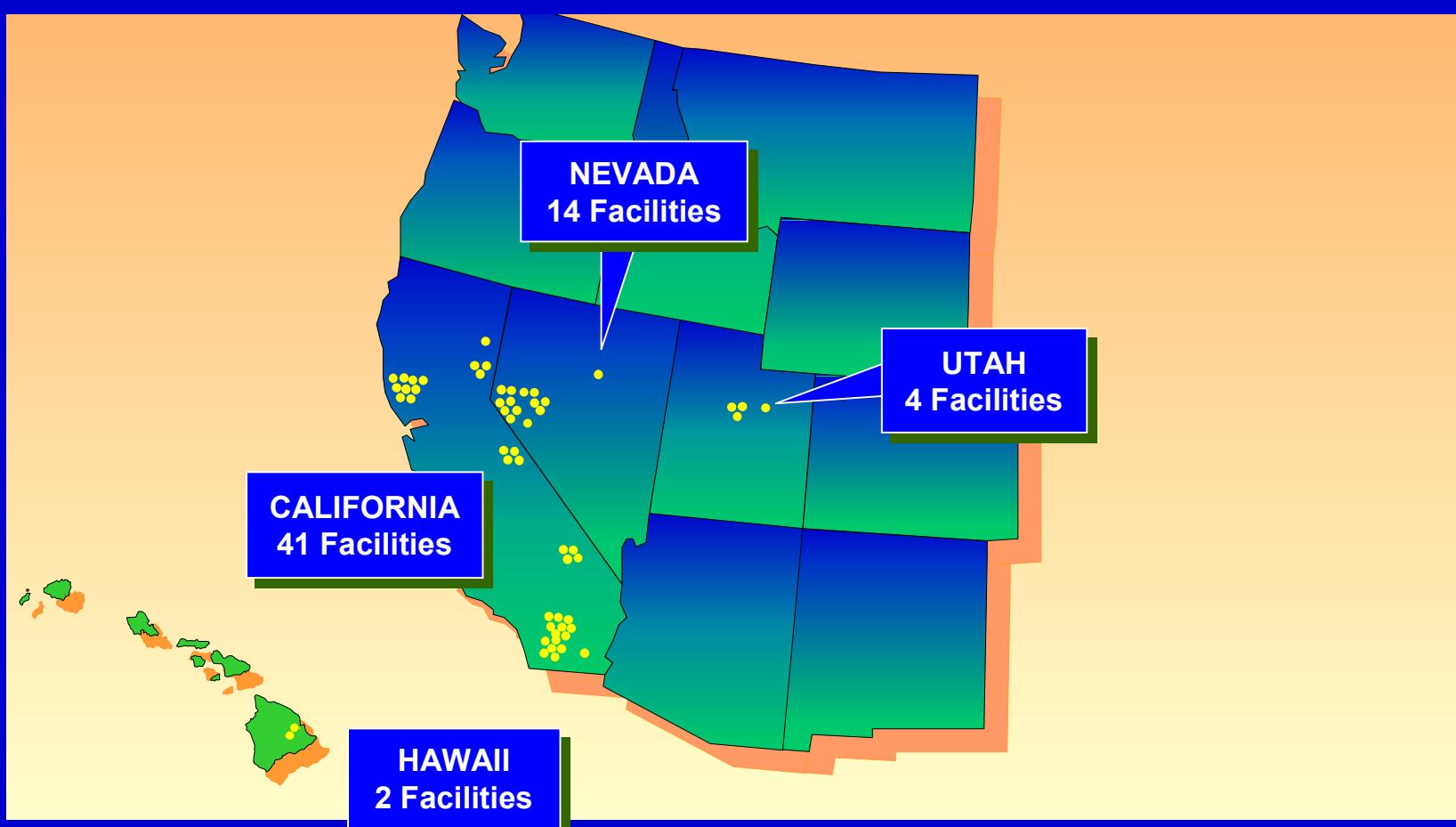
- Experiments began in Lardarello, Italy in 1904
- First U.S. plant at The Geysers in 1920s; first commercial plant in 1960





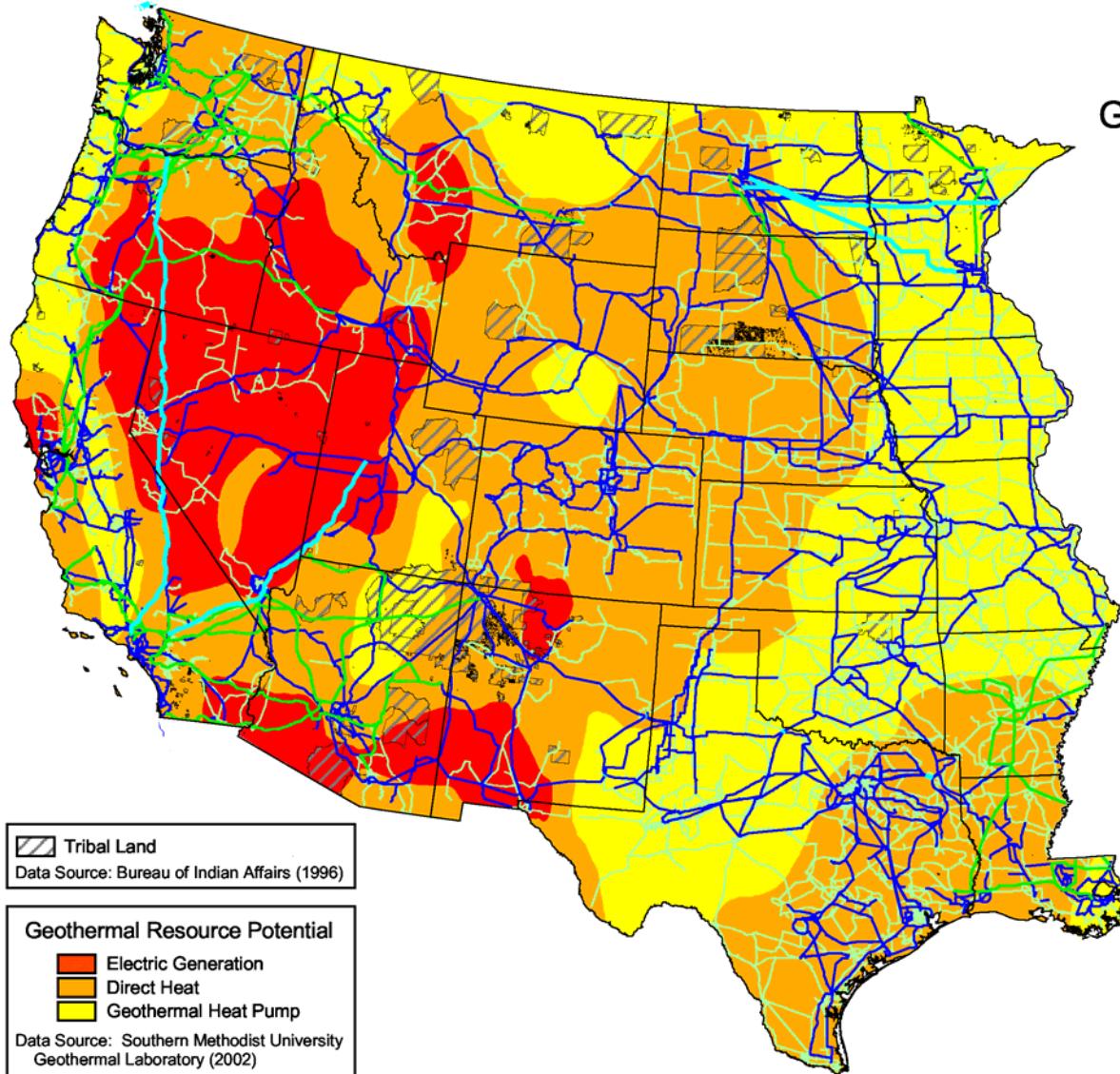
First Geothermal Power Plant, 1904, Larderello, Italy.

U.S. Geothermal Power Generation Sites





Native Americans have been using geothermal energy for many years.



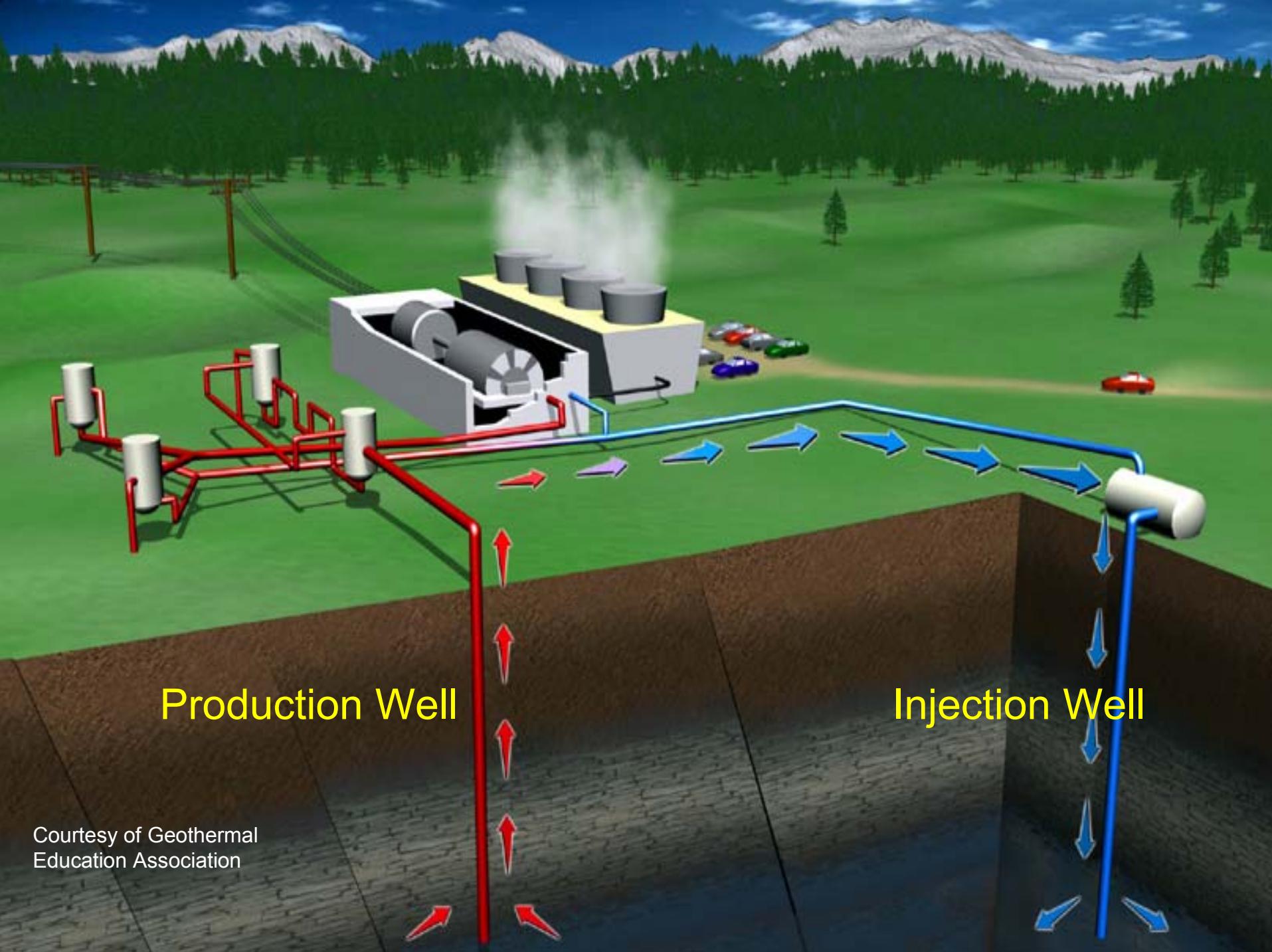
Geothermal Resource and Tribal Lands

Western and Great Plains Regions of the United States

- Transmission Line* Voltage
- △ DC (1000 kV)
 - ▽ 500 - 765 kV
 - ▲ 230 - 400 kV
 - ◆ 69 - 161 kV

Data Source: PowerMap,
© 2002 Platts, a division
of the McGraw-Hill Cos.

U.S. Department of Energy
National Renewable Energy Laboratory



Production Well

Injection Well

Advantages

- Dispatchable, 24-hour, base-load electricity
- Very reliable
- 90 to 95% availability
- Environmentally sound (e.g., low emissions)
- Virtually inexhaustible with smart resource management practices
- Relatively low cost (~4 to 8 cents/kWh)

Geothermal Energy Getting Cheaper

1980: 10-16 cents/kWh

2000:
4-7 cents/kWh

- Improved technology
- Reduced drilling costs
- Experience reduces risk



2007 Goal: 3-5 cents/kWh

Significant Energy Production

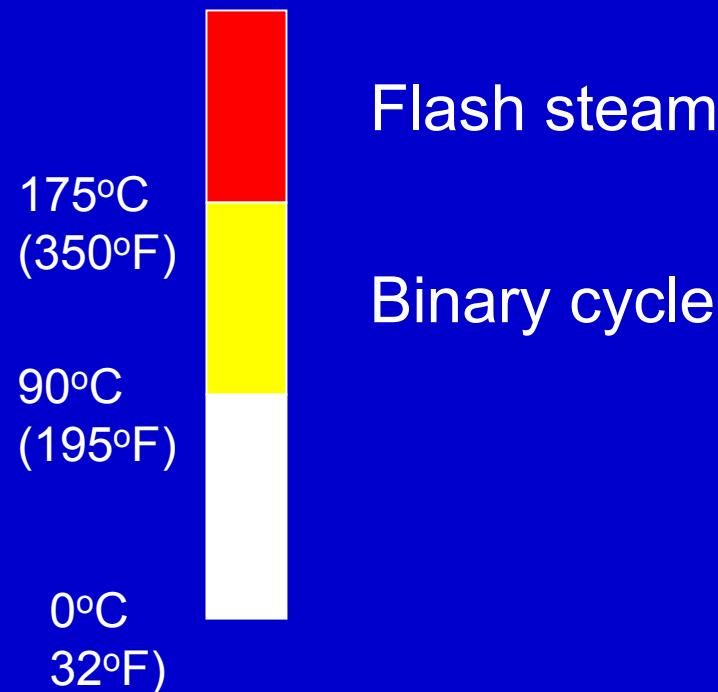


Geothermal power plants produce almost 5% of California's electricity (12.8 million MWh in 1999)

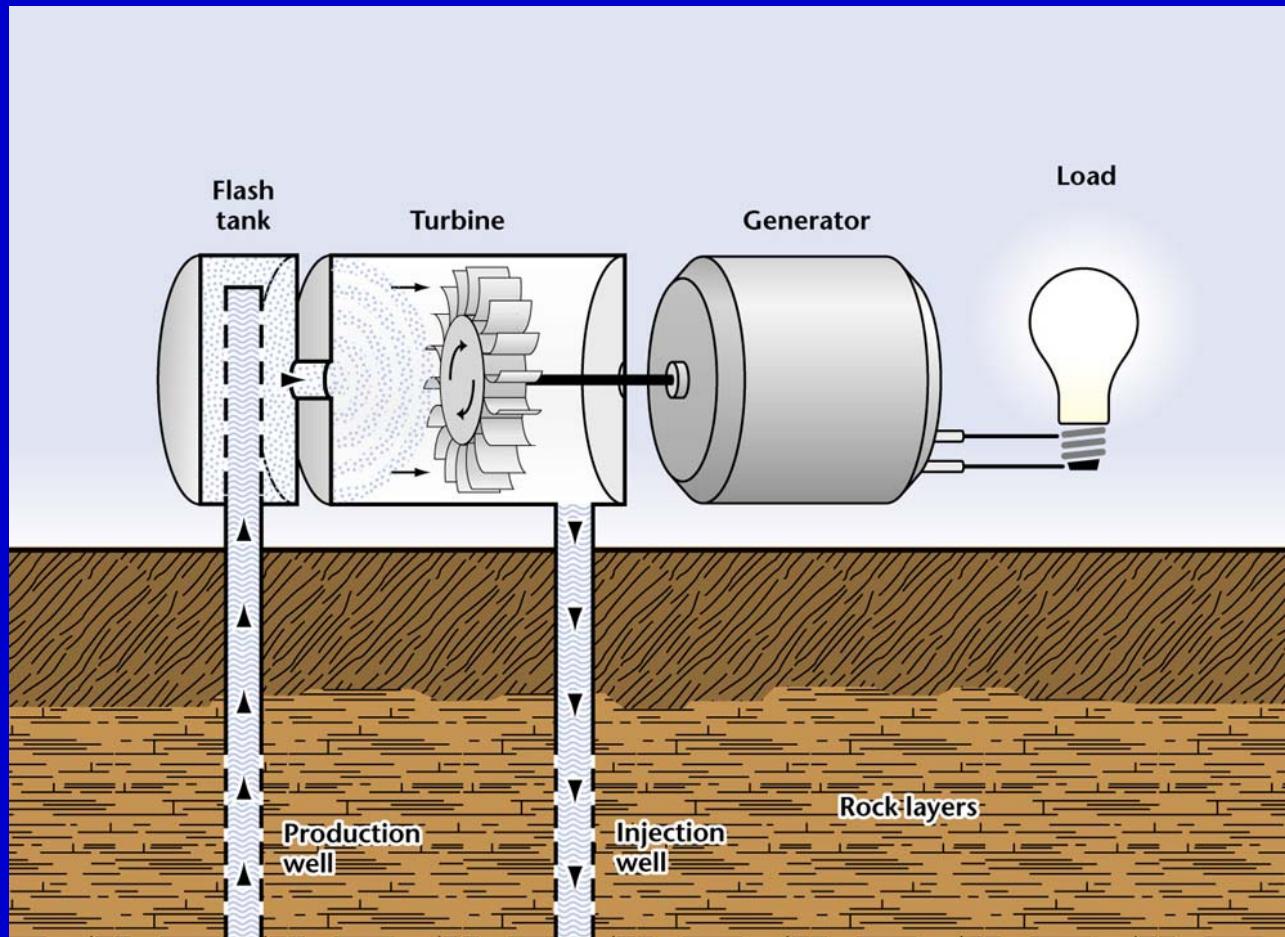
This hybrid binary/flash power plant provides about 25% of electricity demand on the Big Island of Hawaii



Plant Type vs. Temperature



Flash Steam Power Plant

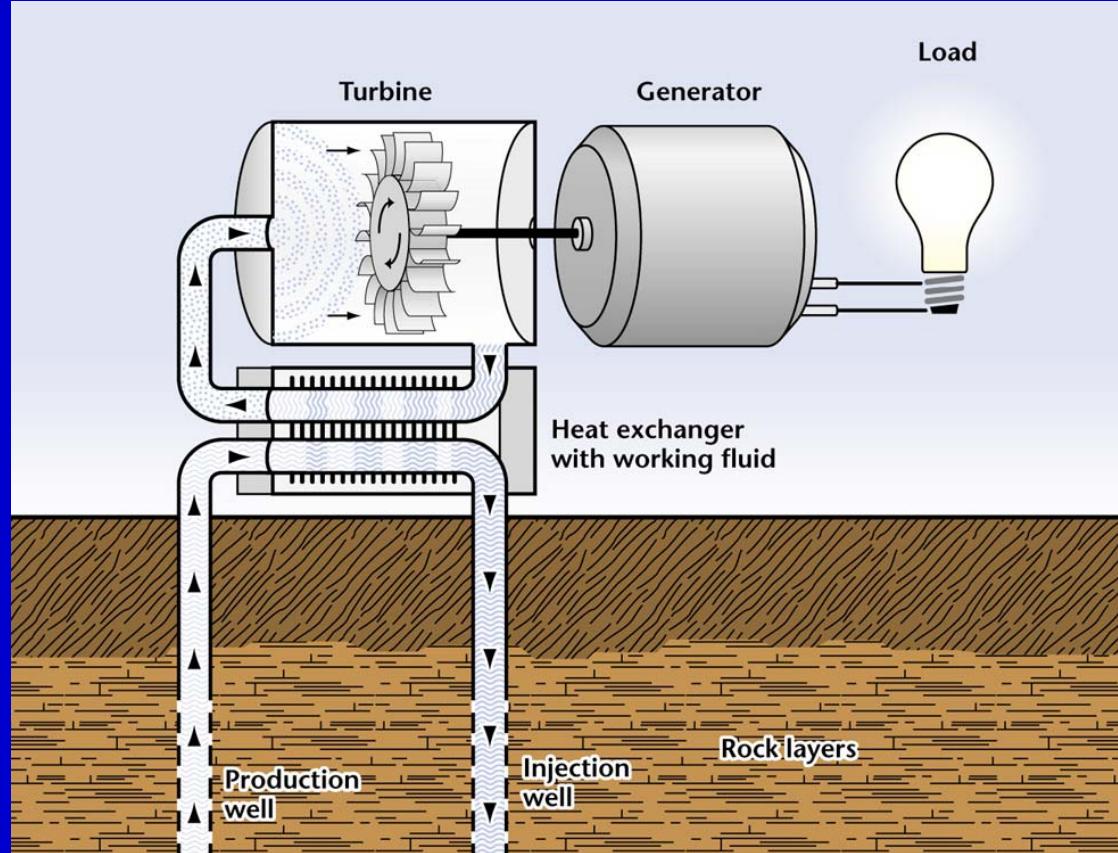


NREL

As this hot water flows up through wells some of the hot water boils into steam. The steam is then separated from the water and used to power a turbine/generator. Leftover water and condensed steam are injected back into the reservoir.

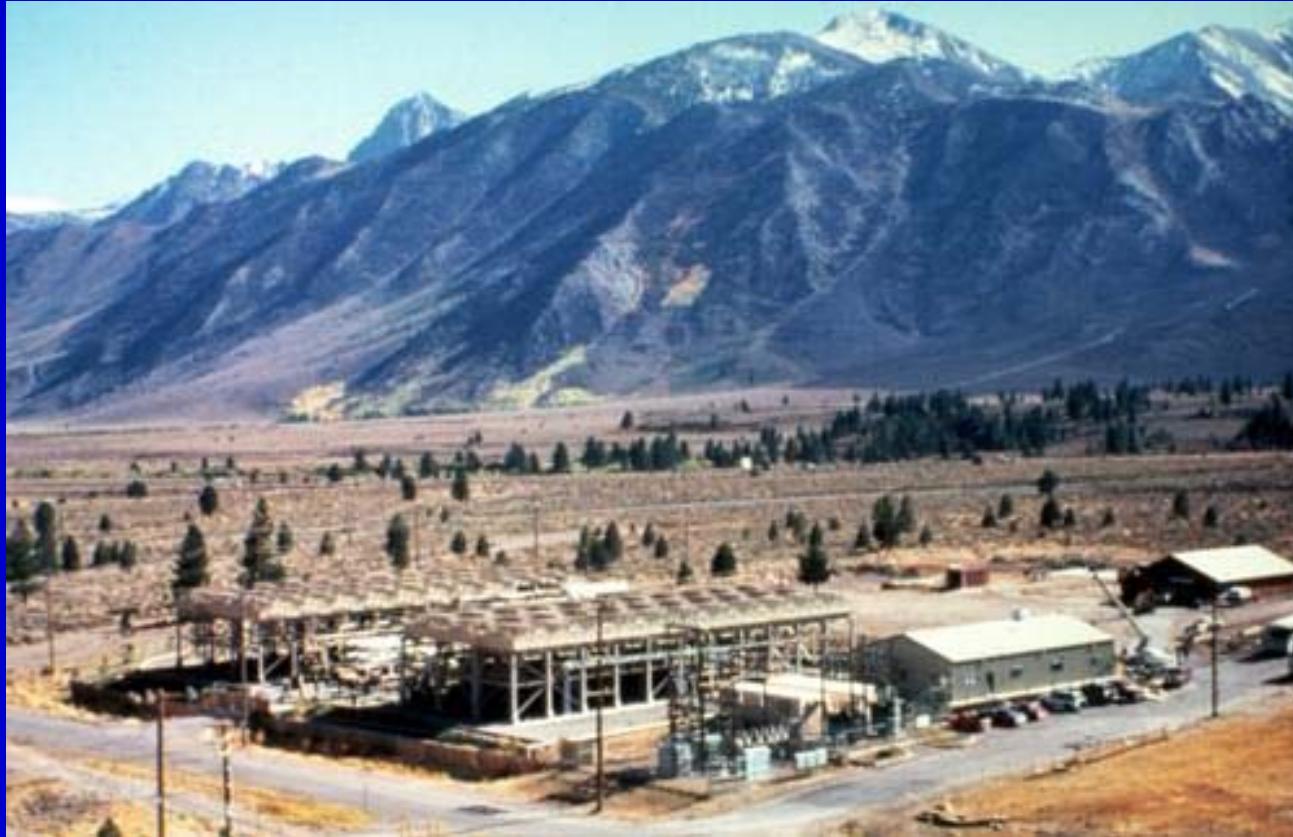


The Geysers, near San Francisco. The largest geothermal field in the world – has successfully produced power since the early 1960s.



NREL

Operates on water at lower temperatures of about 225°– 350°F (107°– 175°C). These plants use the heat from the hot water to boil a *working fluid*, usually an organic compound with a low boiling point. The working fluid is vaporized in a *heat exchanger* and used to turn a turbine. The water and the working fluid are kept separated during the whole process, so there are little or no air emissions.

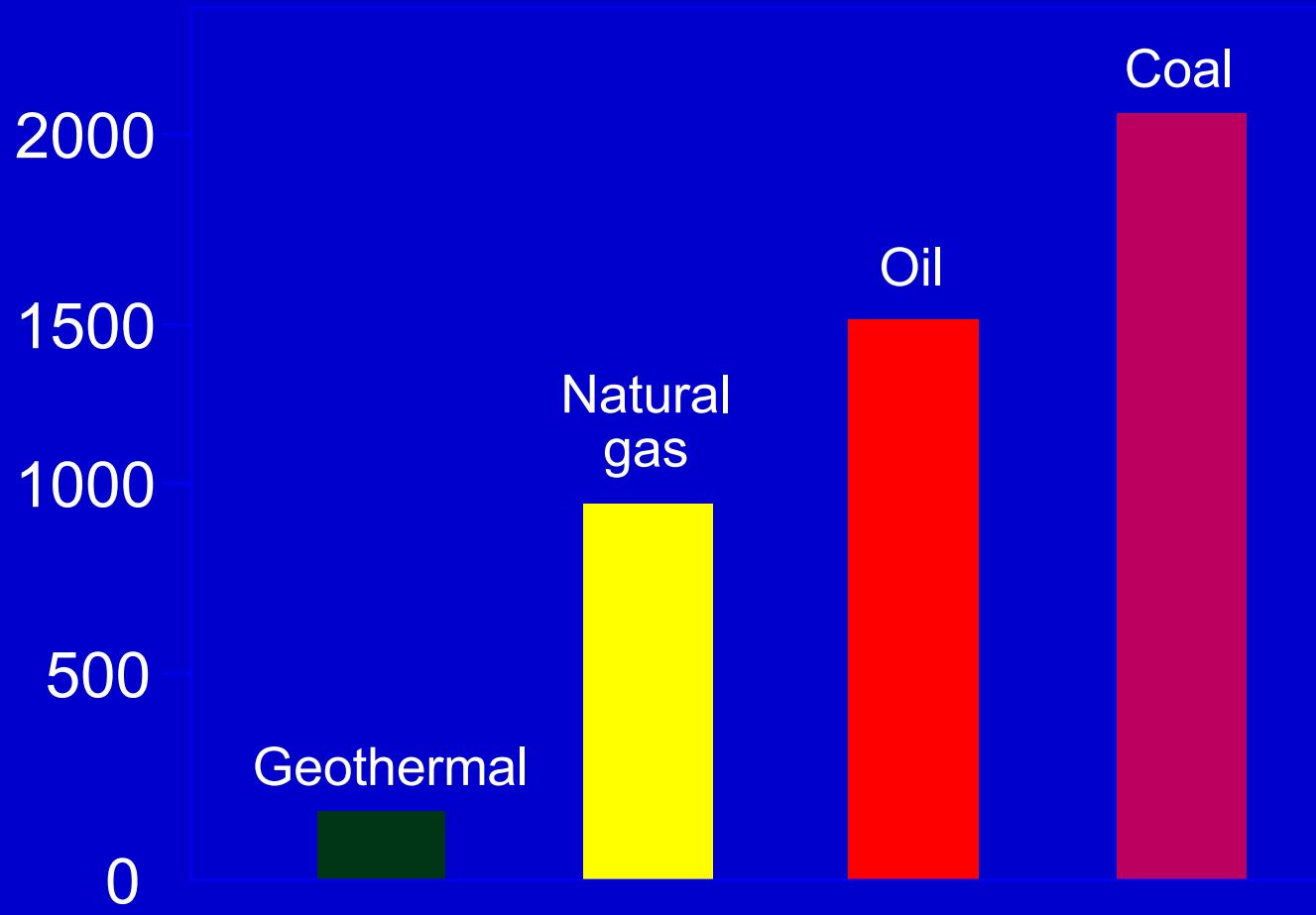


The Mammoth geothermal plant -- Located in the eastern Sierra Nevada mountain range in California, showcases the environmentally friendly nature of geothermal power. Three air-cooled binary units generate a total of 28 megawatts of electricity, and release essentially no emissions into the atmosphere or land surface.



Imperial Valley, California. The drilling of production wells, such as this one in southern California, results in one-third to one-half of the cost of a geothermal project.

CO₂ Emissions Comparison (lbs/MW-hr)



Source EIA 1998; Bloomfield and Moore 1999

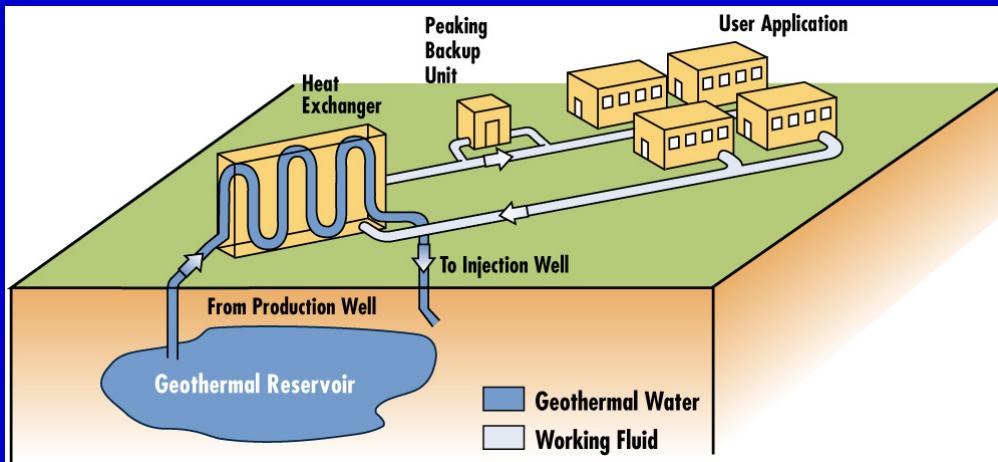


Direct Uses

- **Agriculture (greenhouse and soil warming)**
- **Aquaculture (fish, prawn, and alligator farming)**
- **Industrial Uses (product drying and warming)**
- **Residential and District Heating**
- **Balneology (hot spring and spa bathing)**



Direct Uses



Greenhouses

District Heating



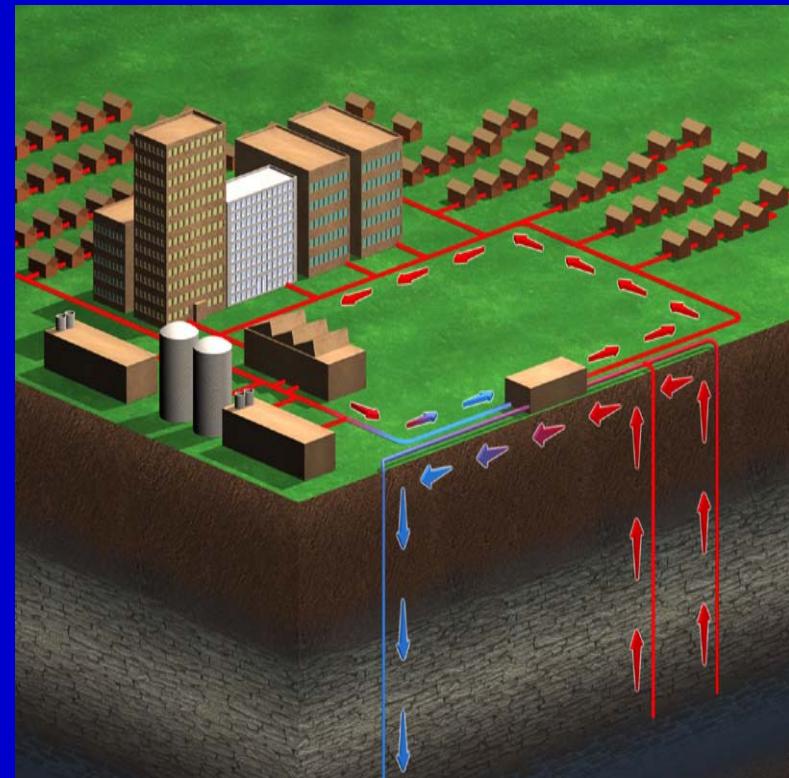
Space Heating



Snow Melting

District Heating in Western U.S.

- There are 18 district heating systems operating in the western United States.
- Over 270 cities in the western U.S. are close enough to geothermal reservoirs to use district heating.



District Heating in Western U.S.



The Idaho State Capital Building (Boise) uses geothermal energy.



The Ada County Courthouse (Boise) uses the city geothermal district-heating system.

Geothermal Heat Pumps

Heating Mode

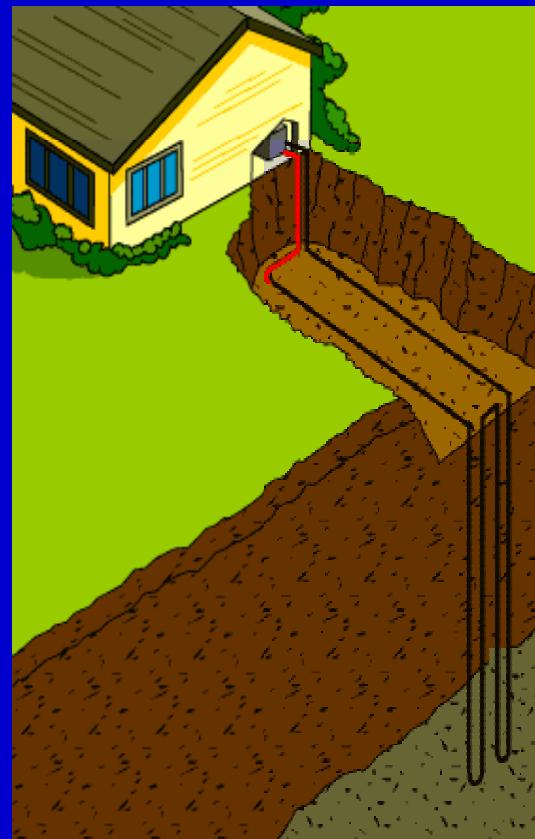


NREL

Geothermal heat pumps use the stable temperatures of the ground (often vertical boreholes typically are 100 to 400 feet deep) as a heat source to warm buildings in winter and as a heat sink to cool them in summer. Also called ground-source heat pumps or Geoexchange units.

Geothermal Heat Pumps

Cooling Mode

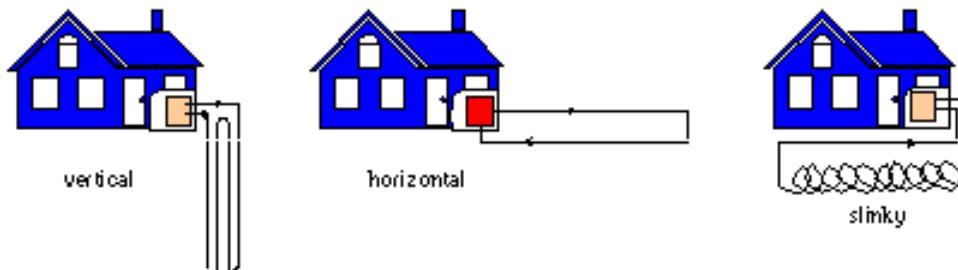


GEOTHERMAL HEAT PUMPS (GHP)

a.k.a. Ground Source Heat Pumps (GSHP)

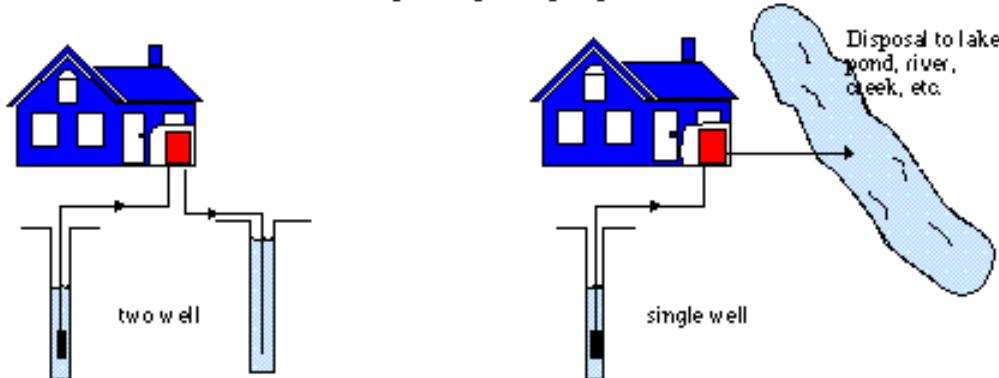
Ground Coupled Heat Pumps (GCHP)

a.k.a. closed loop heat pumps



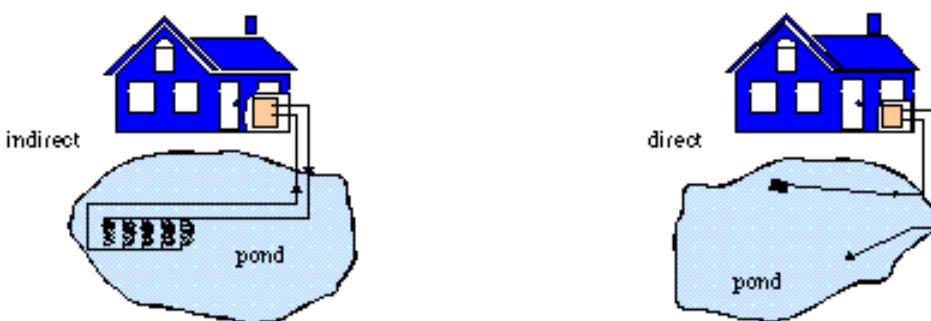
Groundwater Heat Pumps (GWHP)

a.k.a. open loop heat pumps



Surface Water Heat Pumps (SWHP)

a.k.a. lake or pond loop heat pumps



Geo-Heat
Center



**Residential application
in Colorado – a happy
homeowner.**



**Commercial application
in Idaho showing two
36-ton units.**

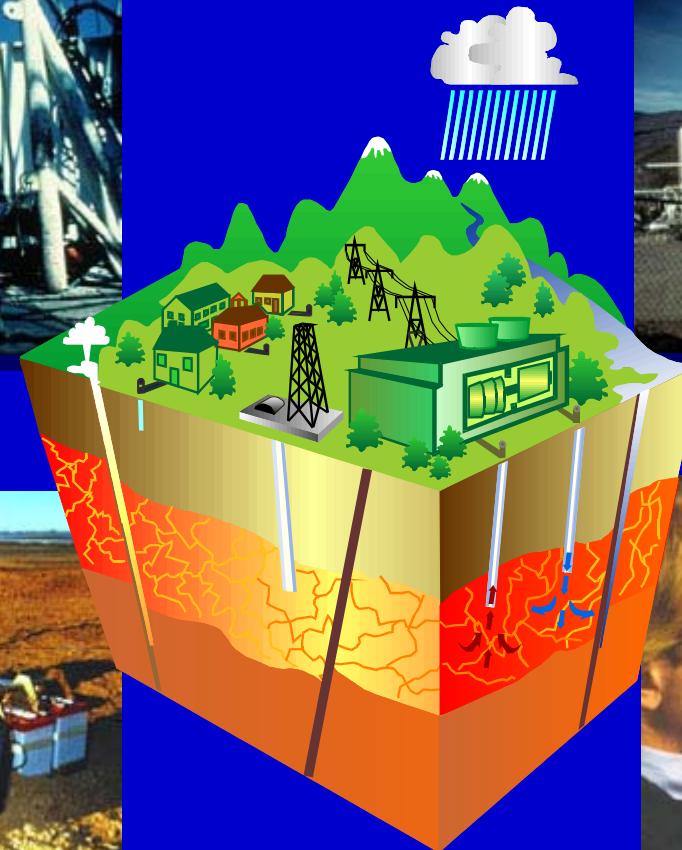
Summary of Geothermal Energy Use in the U.S.

- **2,200 megawatts of electricity supplying 4 million people in western U.S. and Hawaii**
- **650 thermal megawatts of direct use for heating and cooling**
- **3,700 thermal megawatts geothermal heat pumps, about 750,000 in use today.**

Developing Geothermal Technology



Drilling



Exploration



Energy Conversion



Reservoir Technology

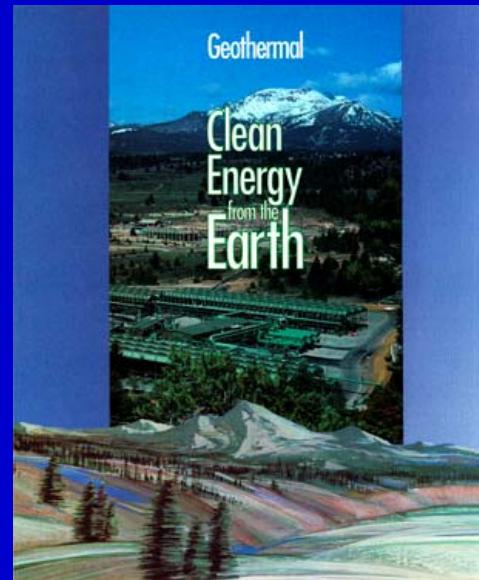
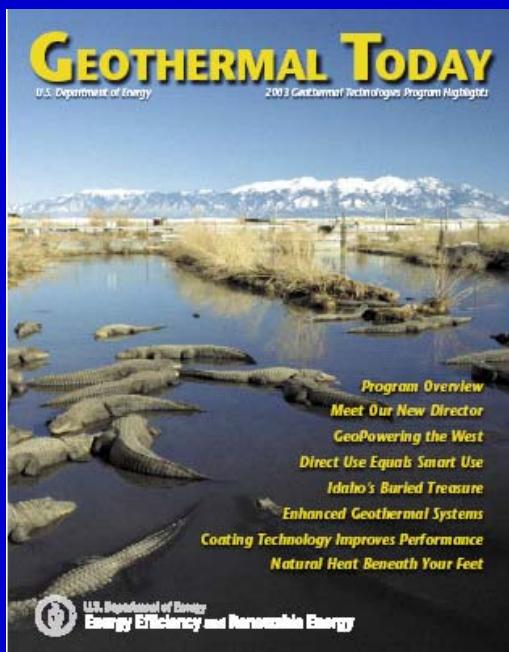
DOE Role

- R&D and deployment activities to enable expanded geothermal energy use
- Support technical assistance and replicable field verification projects
- Outreach and removal of barriers are important activities: GeoPowering the West

Sources of Information and Technical Assistance*

- General; Department of Energy, Geothermal Technologies Program* www.eere.energy.gov/geothermal
- Direct Use; GeoHeat Center, Oregon Institute of Technology*
www.geoheat.oit.edu
- General Information; Geothermal Education Office
www.geothermal.marin.org/
- National Labs* e.g. www.nrel.gov, www.inel.gov,
www.sandia.gov.
- Geothermal Heat Pump Consortium, www.geoexchange.org

Geothermal Energy Outreach Materials and Activities



Geothermal technologies
U.S. Department of Energy

DOE Geothermal Funding Increased by Congress

Georges has appropriated \$27 million for the U.S. Department of Energy's Geothermal Energy Program for fiscal year 2001, which began October 2000. This is an increase of \$1 million over last year's funding and will provide additional support for the Program's mission to work in partnership with U.S. industry to establish geothermal energy as an economically competitive contributor to the U.S. energy supply.

The Program has three goals:

- (1) By 2006, double the number of states with geothermal electric power facilities to eight.
- (2) By 2007, reduce the levelized cost of generating geothermal power to 3-5 cents per kilowatt-hour.
- (3) By 2010, supply the electrical power or heat energy needs of 7 million homes and businesses in the U.S.

To attain these goals, the Program funds three principal areas of research:

GEOSCIENCE AND SUPPORTING TECHNOLOGIES	BUDGET
Geoscience and Supporting Technologies	\$11.0 million
Drilling Research	\$1.0 million
Energy Systems Research and Testing	\$3.7 million
Total	\$22.7 million

GEOSCIENCE AND SUPPORTING TECHNOLOGIES

DOE funds core research in the area of reservoir models, geochemistry, geophysics, rock properties, and modeling to ensure that the U.S. continues to lead the world in geothermal energy sciences. This core research promotes understanding of complex geothermal processes and facilitates development of technology to maximize geothermal resources.

DOE also funds cost-shared Enhanced Geothermal Systems (EGS) projects that employ rock fracturing, water injection, and well circulation techniques to map and exploit impermeable rock layers that generate geothermal energy from new fields that lack sufficient production capacity. Projects have been completed in several areas, and two or three of the most promising designs will be selected for further development and field testing.

Work also is performed in heat flow and temperature gradient, R&D, reservoir dynamics and two-phase flow, and stress and thermal history of fractures. In addition, funds will be devoted to further development of the borehole circulation logging tool, and to detecting and mapping open fractures and permeable zones to improve overall productivity of geothermal wells.

[continued on page 2]

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