Larger Wind turbines

- China, Germany, Spain, the United States, India, and Denmark have made the largest investments in wind generated electricity

Smaller Wind turbine

- This rooftop-mounted urban wind turbine charges a 12 volt battery and runs various 12 volt appliances within the building on which it is installed.

How much does wind energy cost?

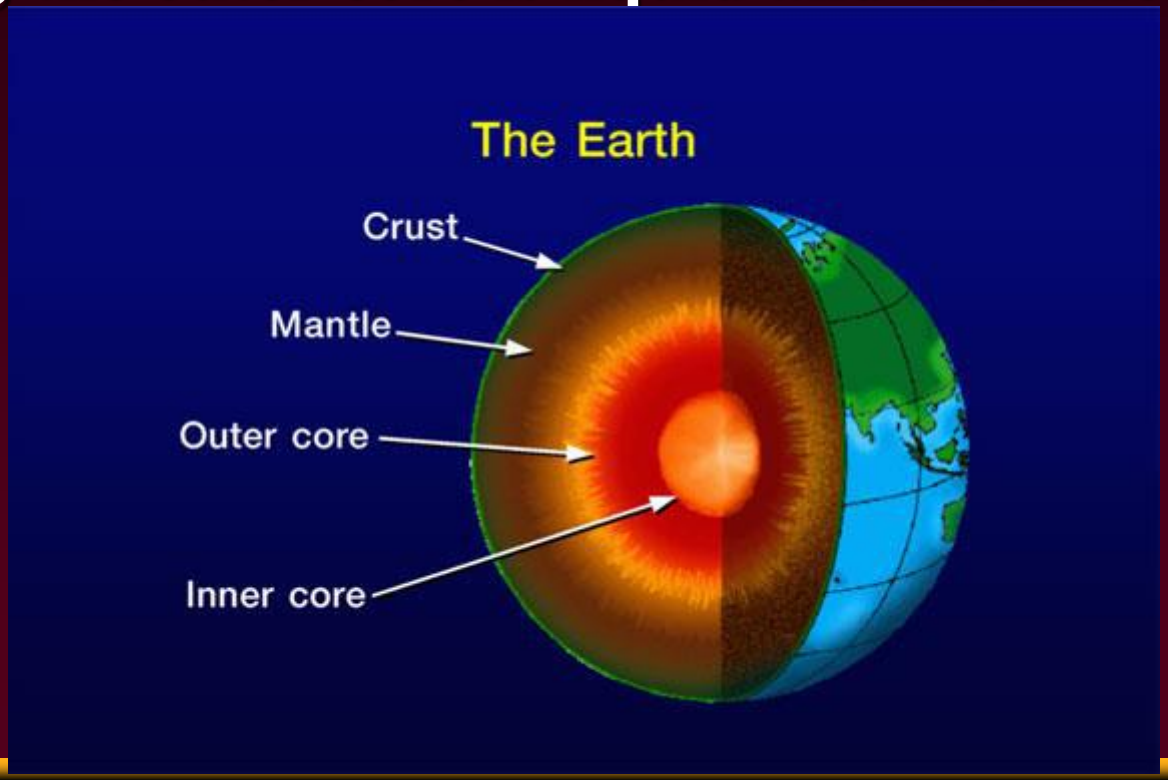
- Over the last 20 years, the cost of electricity from utility-scale wind systems has dropped by more than 80%.
- In the early 1980s, when the first utility-scale turbines were installed, wind-generated electricity cost as much as 30 cents per kilowatt-hour.
- Now, state-of-the-art wind power plants can generate electricity for less than 5 cents/kWh with the Production Tax Credit in many parts of the U.S., a price that is competitive with new coal- or gas-fired power plants.

Sustainable Energy Technologies

Geothermal Energy

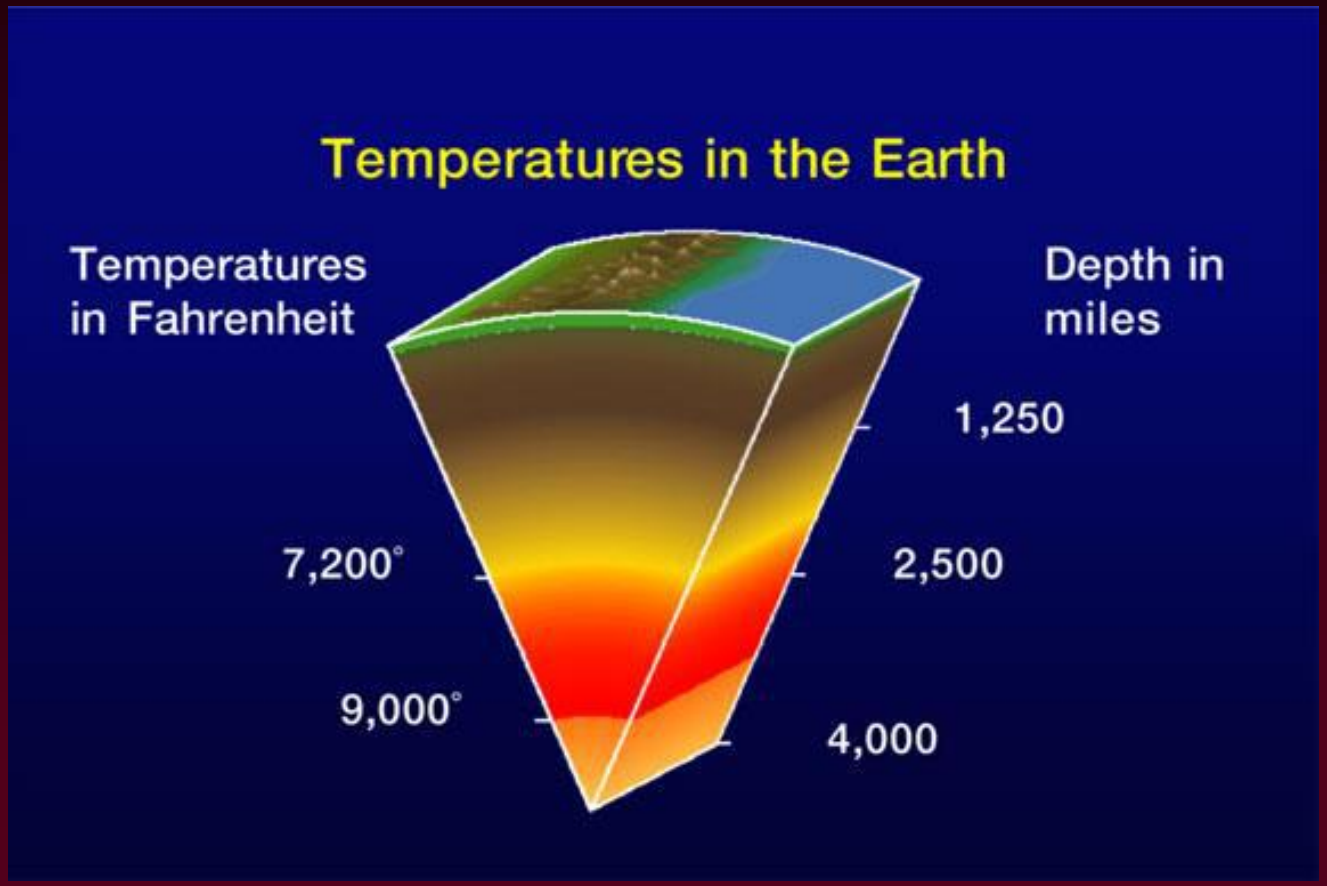
Earth

- Heat flows outward from Earth's interior. The crust insulates us from Earth's interior heat. The mantle is semi-molten, the outer core is liquid and the inner core is solid.



Heat and Depth

- **The deeper you go, the hotter it gets (in Fahrenheit and miles).**



Lava

- 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.

Rain Water

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

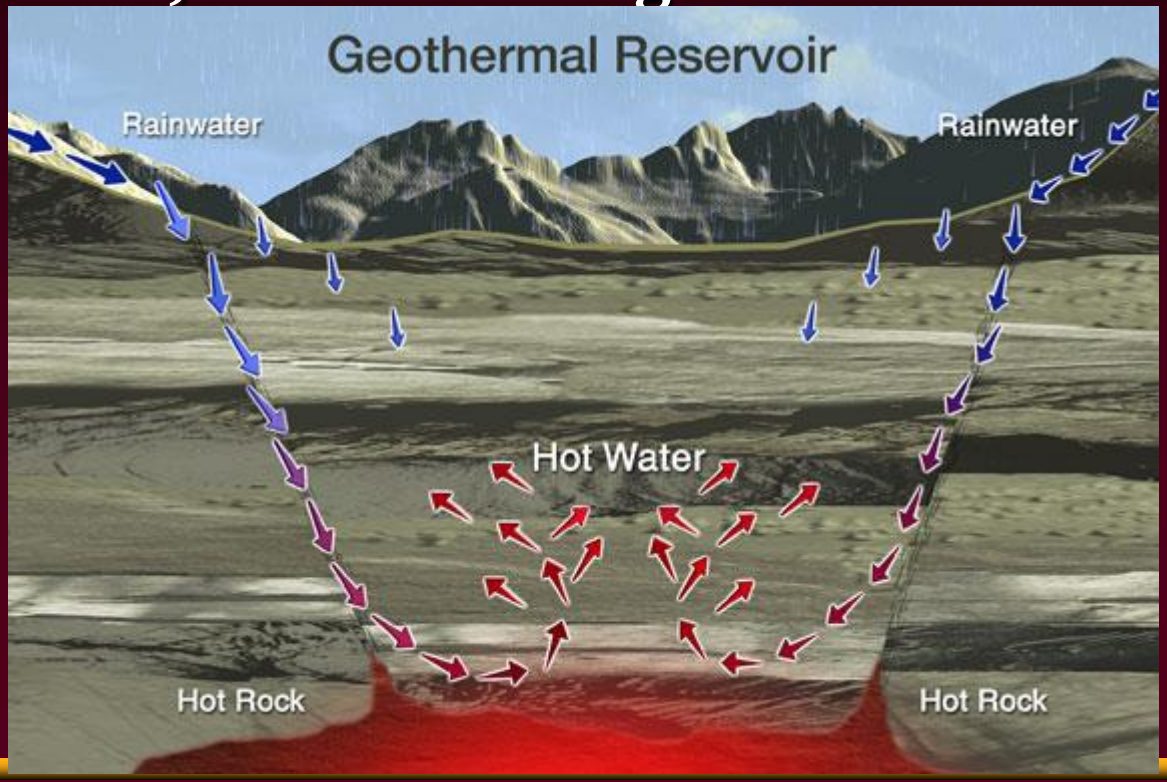
Steaming ground in the Philippines

Steam/Hot water

- When hot water and steam reach the surface, they can form fumaroles, hot springs, mud pots and other interesting phenomena.

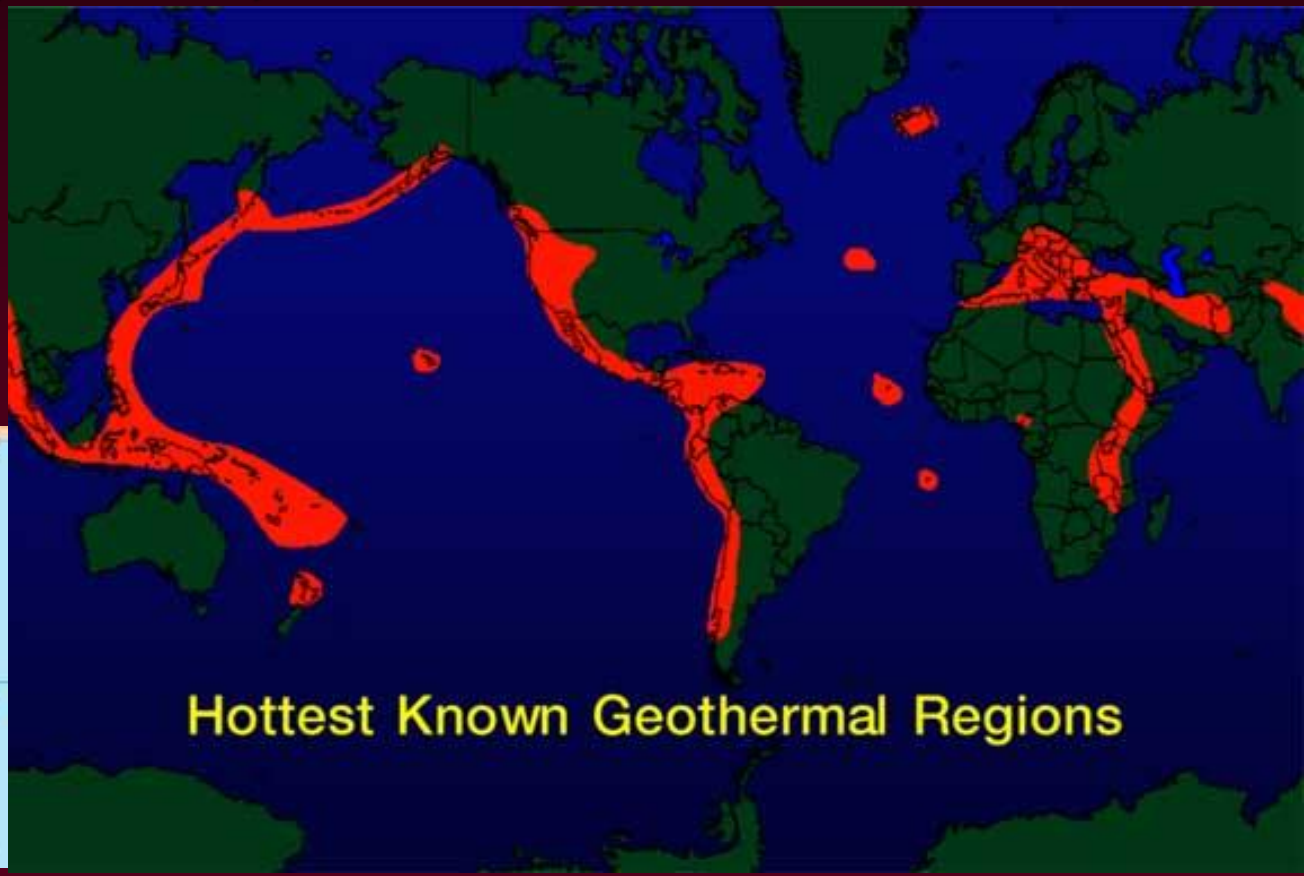
Geothermal Reservoir

- 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



Hottest known areas

- Many areas have accessible geothermal resources, especially countries along the circum-Pacific "Ring of Fire," spreading centers, continental rift zones and other hot spots.



Exploration

- Geologists explore volcanic regions to find the most likely areas for further study, like this steaming hillside in El Hoyo, Nicaragua (Central America)

Exploration

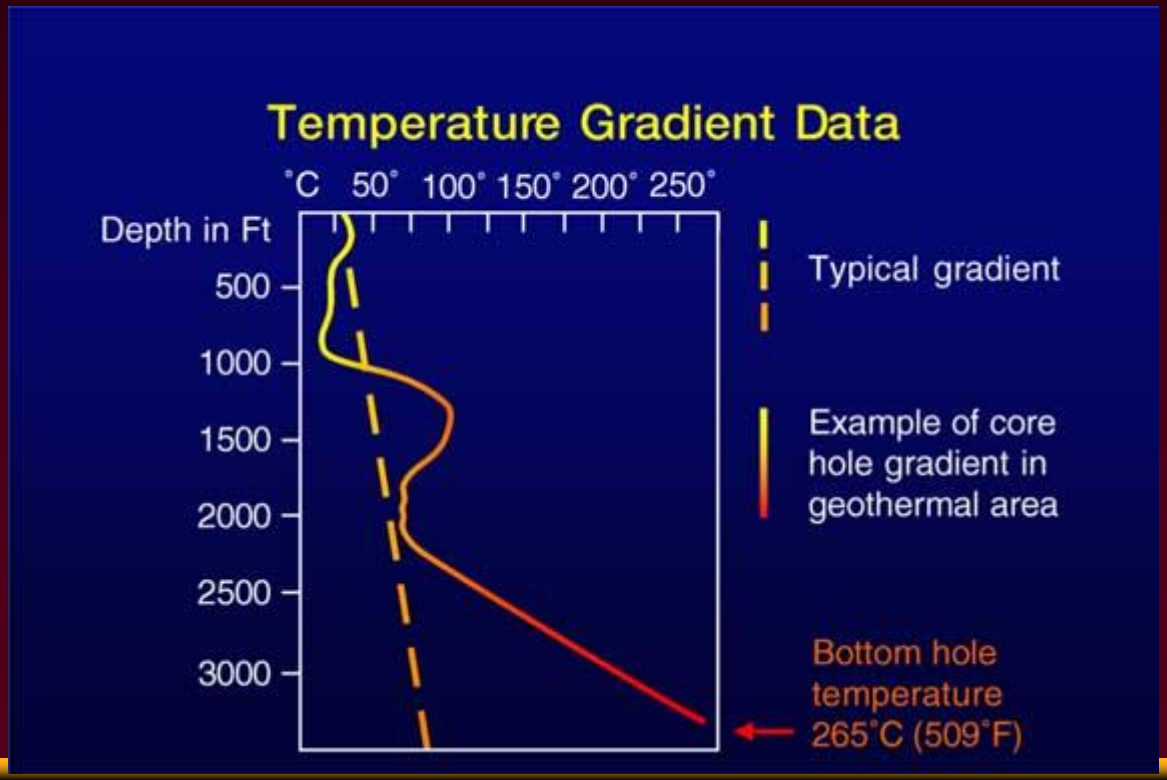
- Data from electrical, magnetic, chemical and seismic surveys is gathered in the field

Exploration

- First, a small- diameter "temperature gradient hole" is drilled (some only 200' deep, some over 4000 feet deep) with a truck-mounted rig to determine the temperatures and underground rock types

Temperature Profile

- Temperature results like this would definitely encourage the drilling of a larger, deeper well to try to find a hydrothermal reservoir



Exploration

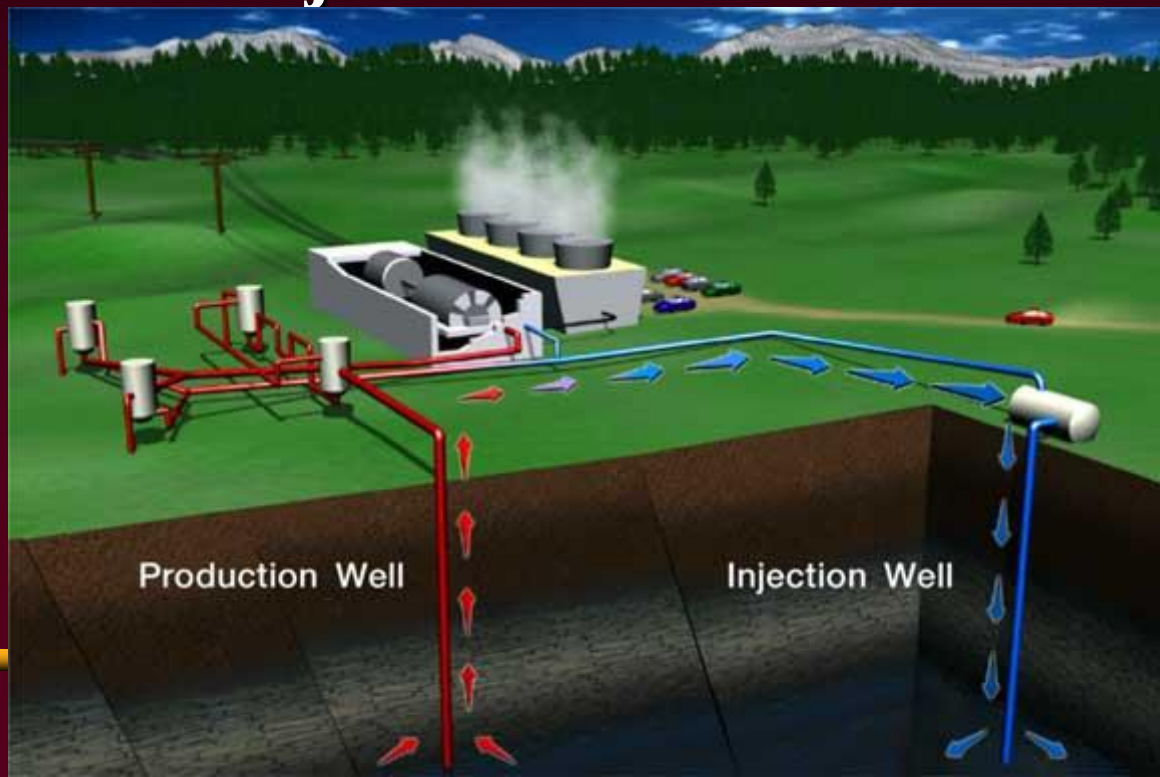
- Production-sized wells require large drill rigs like these and can cost as much as a million dollars or more to drill. Geothermal wells can be drilled over two miles deep.

Well test

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

Operating Principle

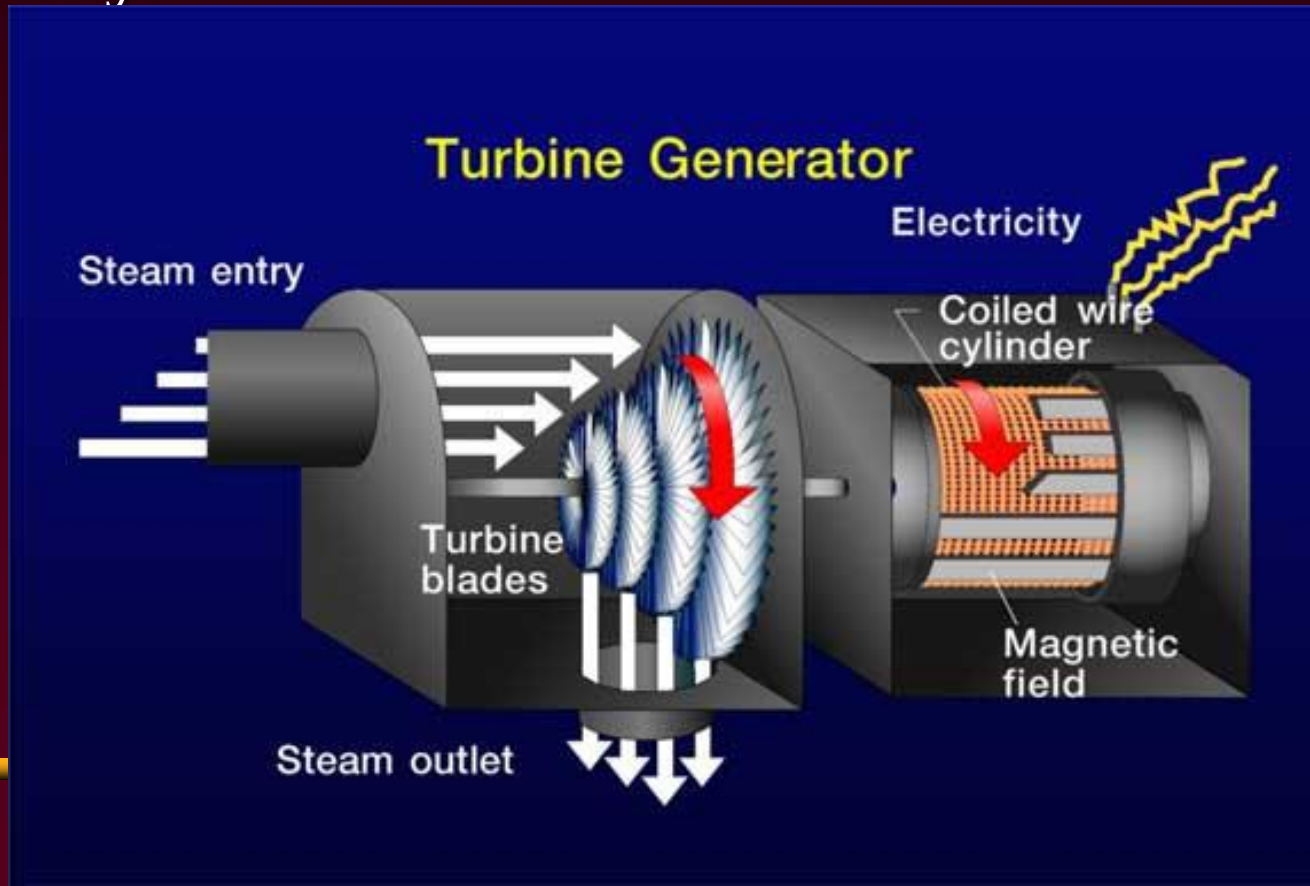
- Natural steam from the production wells power the turbine generator.
- The steam is condensed by evaporation in the cooling tower and pumped down an injection well to sustain production



Turbine Generator

- Like all steam turbine generators, the force of steam is used to spin the trubine blades which spin the generator, producing electricity.

With geothermal energy, no fuels are burned.

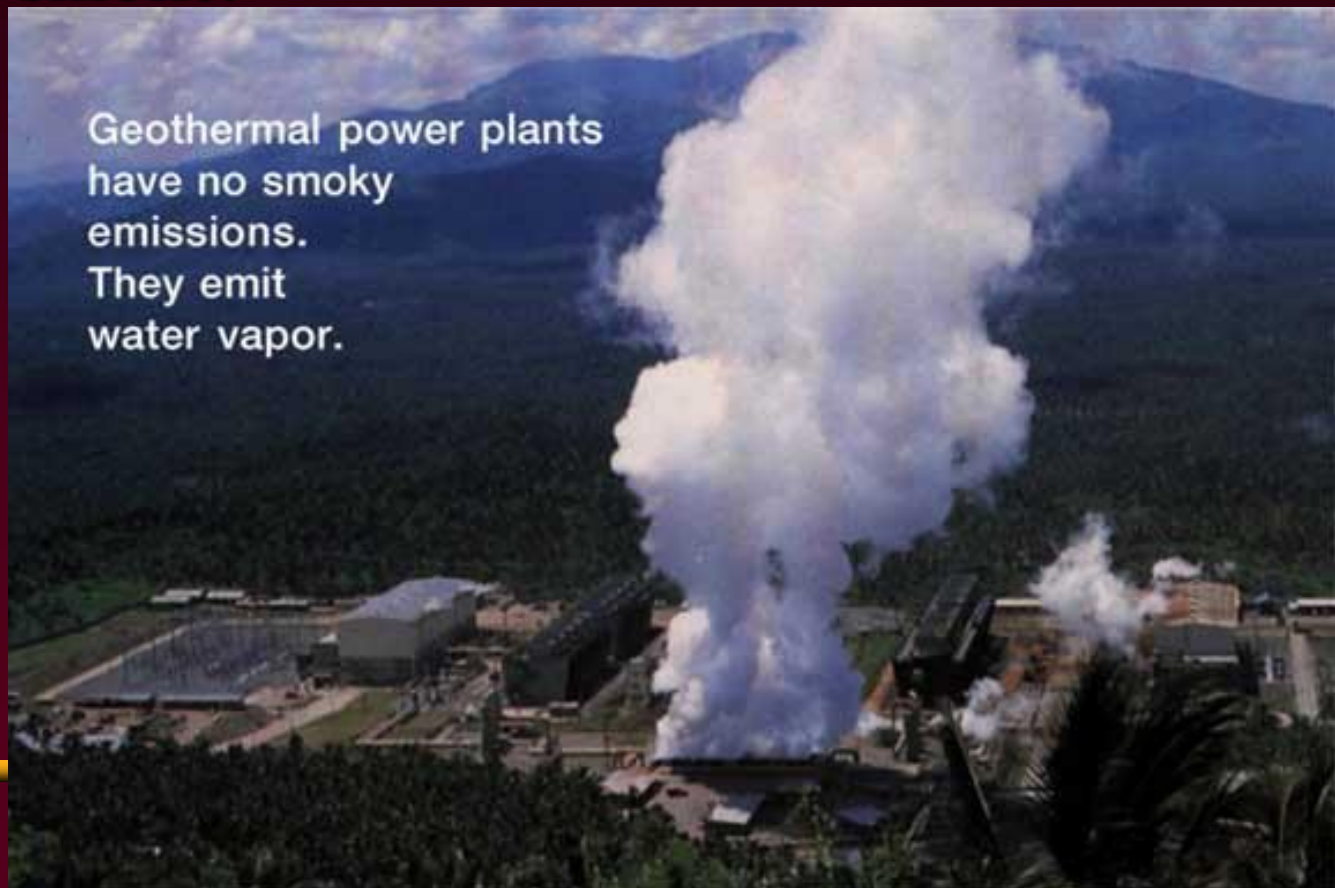


Power Station

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

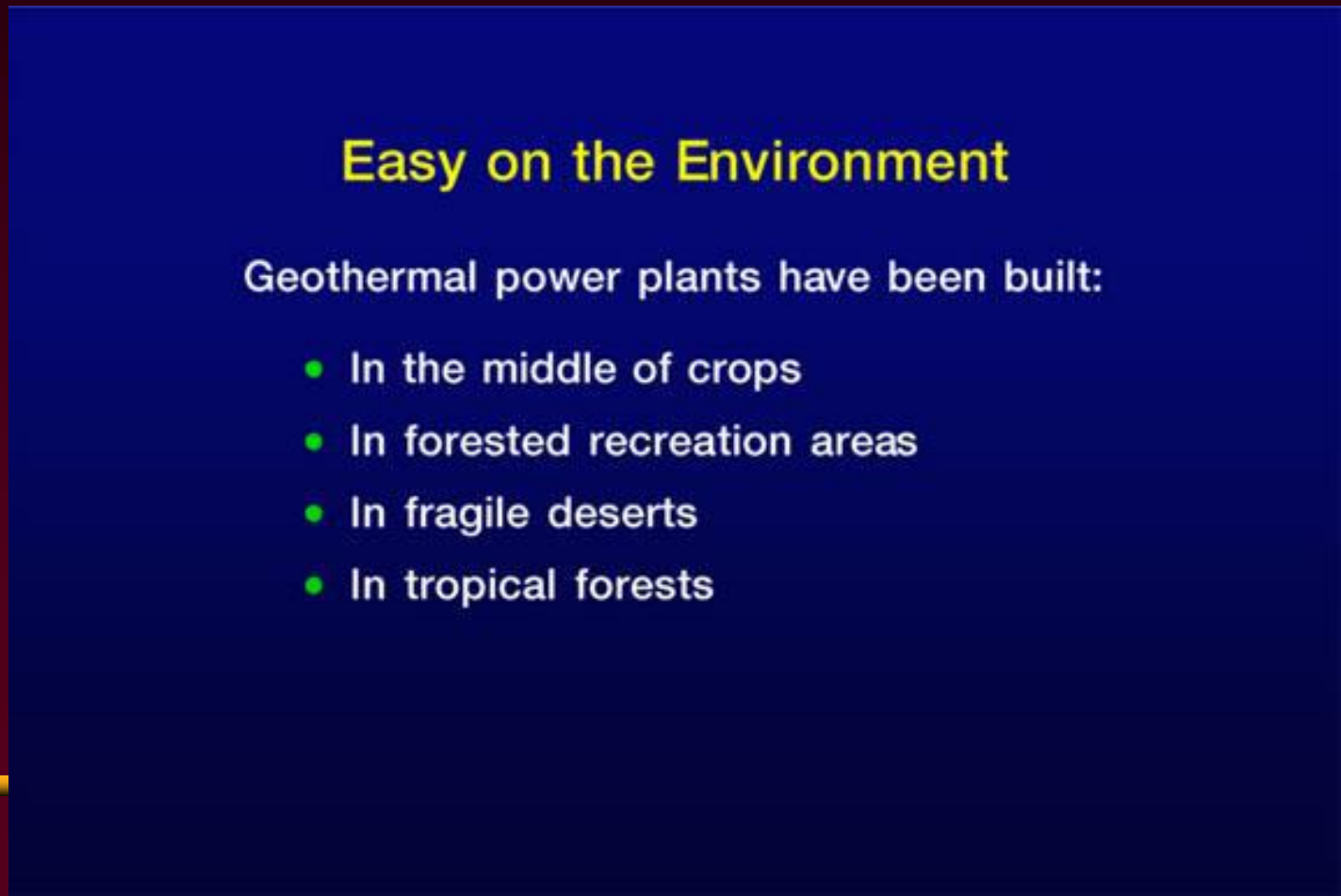
No Pollution

- Those white plumes you see at geothermal power plants are steam (water vapor). Geothermal plants do not burn fuel or produce smoke.



Environmental Friendly

- Geothermal power plants are clean and are operating successfully in sensitive environments.



More Friendlier

- 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

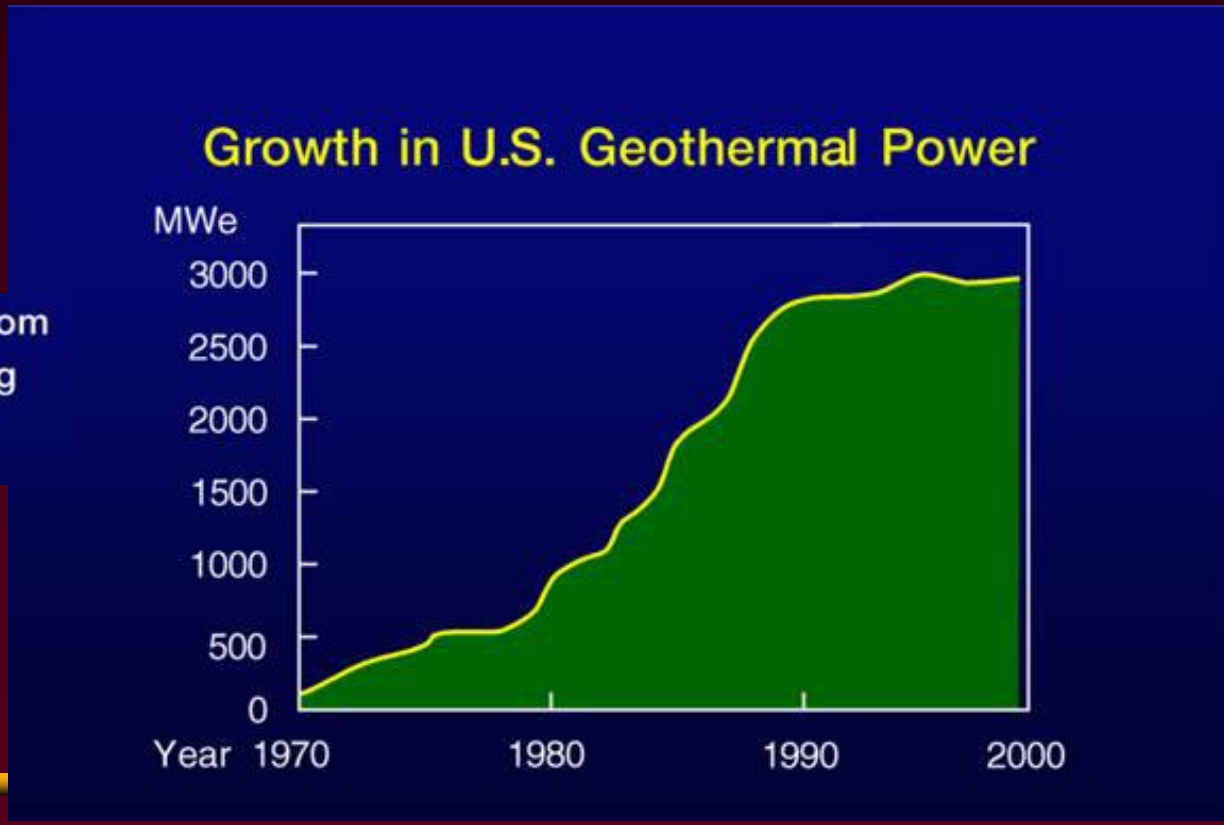
Largest Plant

- The first geothermal power plants in the U.S. were built in 1962 at The Geysers dry steam field, in northern California. It is still the largest producing geothermal field in the world.

Growth in USA

- **The fastest growth in US geothermal capacity was from 1980 to 1990, following enactment of federal laws that compelled utilities to purchase electricity from independent power producers**

Over 2,800 megawatts of electricity from geothermal power plants are supplying about 4 million people in the U.S.



Worldwide Geothermal

- People who live in these areas are receiving electricity from geothermal power plants

Worldwide

- **Geothermal power could serve 100% of the electrical needs of 39 countries (over 620,000,000 people) in Africa, Central/ South America and the Pacific. See: www.geotherm.org/PotentialReport.htm**

Countries Generating Electricity with Geothermal Resources

Australia	Indonesia	Portugal (Azores)
China	Italy	Russia (Kamchatka)
Costa Rica	Japan	Taiwan
El Salvador	Kenya	Thailand
Ethiopia	Mexico	Tibet
France (Guadeloupe)	New Zealand	Turkey
Guatemala	Nicaragua	United States
Iceland	Philippines	Zambia

...and geothermal power plants are planned in several other countries

History

- This historical drawing depicts Native Americans using hot springs at what is now Calistoga, California. Some tribes considered hot springs to be neutral territory where no wars were allowed.

Modern World

- Modern day Beppu, Japan uses geothermal water and heat in buildings and factories and has 4,000 hot springs and bathing facilities that attract 12 million tourists a year.

Geothermal Station in Iceland

In Food Industry

- Geothermal water is also used for industrial uses, like drying lumber or food products. This plant in Brady, Nevada, provides dried onions to Burger King.

Direct Heating too!

- The first geothermal district heating system in the US was built in Boise, Idaho. Today, Boise's capital and city buildings are heated with a geothermal district heating system

Greenhouses

- Peppers, tomatoes, and flowers are commonly grown in geothermally heated greenhouses

Cleaning Up our Air

Each year 22 million tons of carbon dioxide,
200 thousand tons of nitrogen oxides
and 110 thousand tons of particulate matter
are not emitted to the atmosphere because
we used electricity from geothermal resource
rather than burning fossil fuels.

RENEWABLE ENERGY TECH
OCEAN ENERGY

Types of ocean energy

Ocean Thermal Energy Conversion

Tidal Power

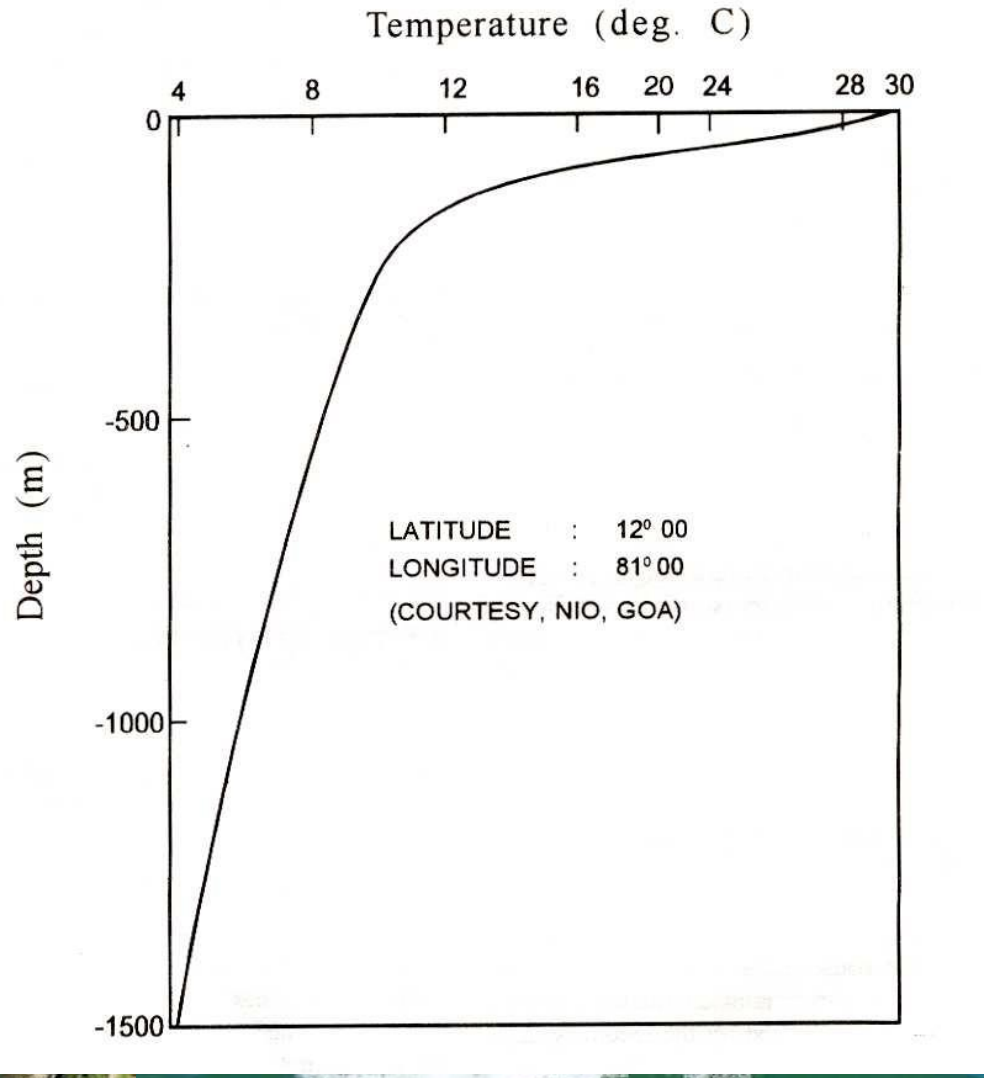
Wave Power

OCEAN Thermal Energy Conversion (OTEC)

- OTEC uses the heat energy stored in the Earth's oceans to generate electricity.
- OTEC works best when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is about 20 °C (36°F).
- These conditions exist in tropical coastal areas.
- To bring the cold water to the surface, OTEC plants require an expensive, large diameter intake pipe, which is submerged a mile or more into the ocean's depths.
- Some energy experts believe that if it could become cost-competitive with conventional power technologies, OTEC could produce billions of watts of electrical power.

Temperature Profile of Ocean

- UNLIKE OTHER RENEWABLE ENERGY SOURCES, OTEC COULD SERVE WELL AS A BASE-POWER.



ARIZONA STATE UNIVERSITY

OTEC Video

- http://www.oceanenergycouncil.com/

http://www.oceanenergycouncil.com/ocean-energy/otec-energy/

OTEC Technologies

Closed-Cycle

- These systems use fluid with a low-boiling point, such as ammonia, to rotate a turbine to generate electricity.
- Warm surface seawater is pumped through a heat exchanger where the low-boiling-point fluid is vaporized.
- The expanding vapor turns the turbo-generator.
- Cold deep-seawater pumped through a second heat exchanger condenses the vapor back into a liquid, which is then recycled through the system.

Closed-Cycle OTEC

- In 1979, the Natural Energy Laboratory and several private-sector partners developed the mini OTEC experiment, which achieved the first successful at-sea production of net electrical power from closed-cycle OTEC.
- The mini OTEC vessel was moored 1.5 miles (2.4 km) off the Hawaiian coast and produced enough net electricity to illuminate the ship's light bulbs and run its computers and televisions.
- In 1999, the Natural Energy Laboratory tested a 250-kW pilot OTEC closed-cycle plant (the largest plant).

OTEC Technologies

Open-Cycle

- When tropical ocean's warm surface seawater is placed in a low-pressure container, it boils.
- The expanding steam drives a low-pressure turbine attached to an electrical generator.
- The steam, which has left its salt behind in the low-pressure container, is almost pure fresh water.
- It is condensed back into a liquid by exposure to cold temperatures from deep-ocean water.