

Geologist

Task

Create a presentation that tells the story of the Yellowstone Hotspot. You will share your presentation with your classmates in small groups. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Geologist

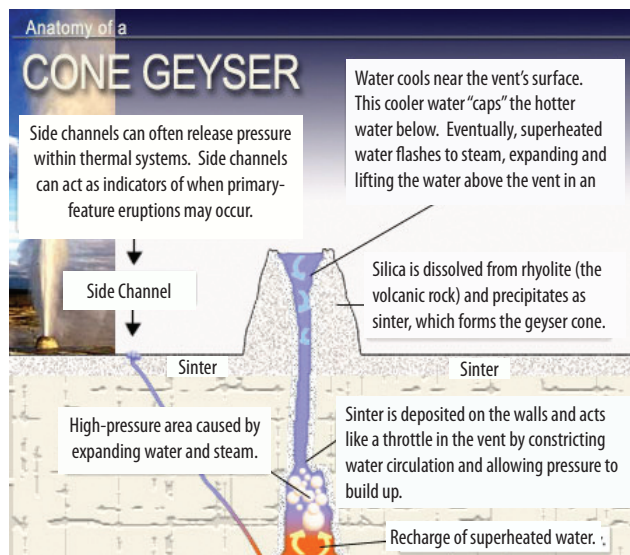
- How do the major geothermal features in Yellowstone work?
- What is the historic path of the Yellowstone Hotspot?

Information

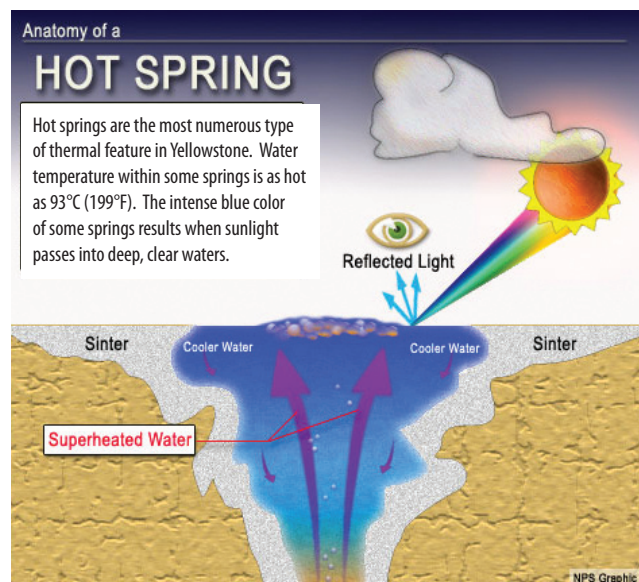
Yellowstone National Park is known for its diverse hydrothermal features. How do they work? These diagrams explain how **geysers** build pressure to erupt and why **hot springs** are so blue.

The brilliant colors in hot springs come from archaeobacteria. Aptly called extremophiles for their ability to survive in extreme environments, these colorful organisms can live in extremely high temperatures. Scientists study these creatures to understand how their cells and proteins are capable of surviving and functioning in environmental conditions far beyond the tolerance of most life.

Mud pots are drier than hot springs. Sulfuric acid dissolves the surrounding sediments into the muddy pots. **Fumaroles**, or steam vents, are hot springs with a lot of heat but so little water that the water boils away before reaching the surface.



Artistic representation of a hot spring shows the colors that are created from the presence of archaeobacteria.



Mud pot.



Volcanic fumarole steam mud pot spring.

Geologists not only study the current active features in Yellowstone, but they also ask questions about ancient active areas and the patterns in the landscape. Satellite images have allowed geologists to view a pattern of ancient calderas through the Snake River Plain that become progressively older to the southwest of Yellowstone.

The islands of Hawaii also offer a nice model of how a series of volcanoes can form when a plate moves over a heat source.

Events

16-8 mya: North American Plate moves southwest by 6.1 cm/year.

12-10 mya: Bruneau-Jarvis eruption in the Snake River Plain expels 250 km³ of ash, creating ash-fall fossil beds in NE, 1,600 km toward the east.

8 mya: North American Plate slows to move southwest 3.3 cm/year.

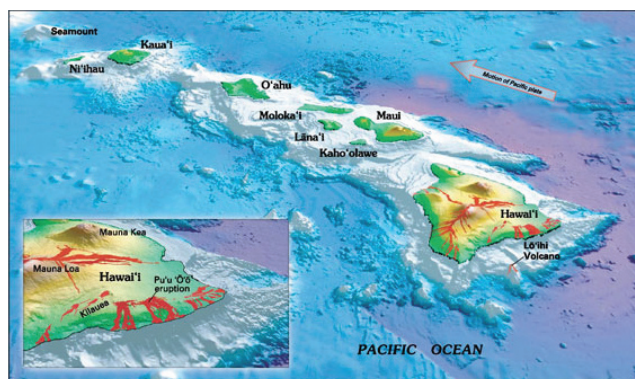
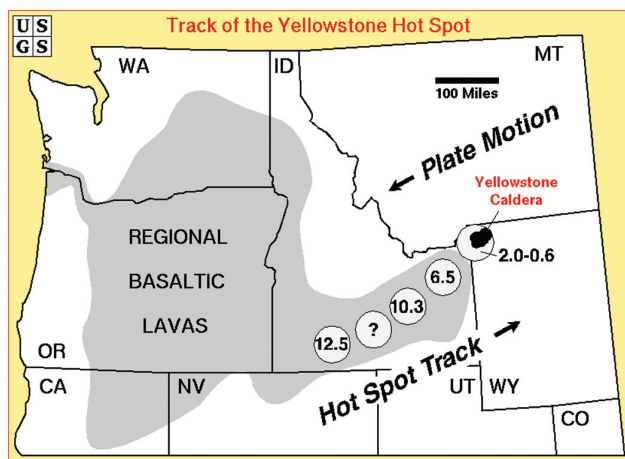
6.6 mya: Blacktail Tuff forms from eruption in Snake River Plain that expels 1,500 km³ of ash.

4.5 mya: Kilgore Tuff forms from eruption in Snake River Plain that expels 1,800 km³ of ash.

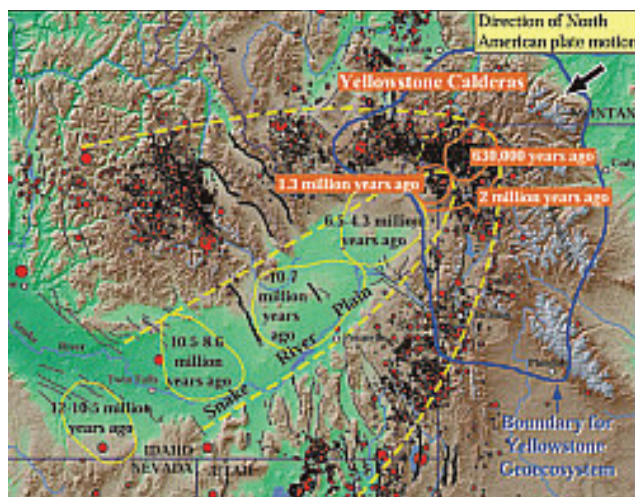
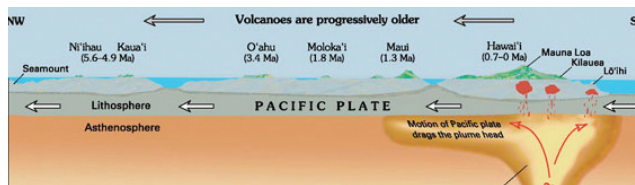
1872: Yellowstone is designated as the first National Park in the United States.

1972: Jason Morgan uses caldera ages to calculate the southwest motion of the North American plate, at 1-2 cm/year.

1994: Geologists at the University of Utah recalculate plate movements to current rates found in this time line.



The above image shows the Hawaiian Islands (with the youngest (Hawaii) closest) and the direction of the Pacific Plate. Now look at the cross section (below) for another view of the evolution of the Hawaiian Island chain.



Similar to the Hawaiian Hotspot and the Pacific Plate, the North American Plate has been moving over the Yellowstone Hotspot, melting a path through the Rocky Mountains. The red dots indicate earthquakes, and the yellow and orange circles show the ancient calderas.

Vocabulary

fumaroles steam vents

geysers hot springs with underground spaces that trap steam pressure that create periodic eruptions

hot springs naturally occurring warm bodies of water

hydrothermal features features created from underground superheated water

mud pots drier, more acidic hot springs that dissolve rock to create hot, muddy, bubbling pots

Seismologist

Task

Create a presentation that tells the story of the Yellowstone Hotspot. You will share your presentation with your classmates in small groups. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

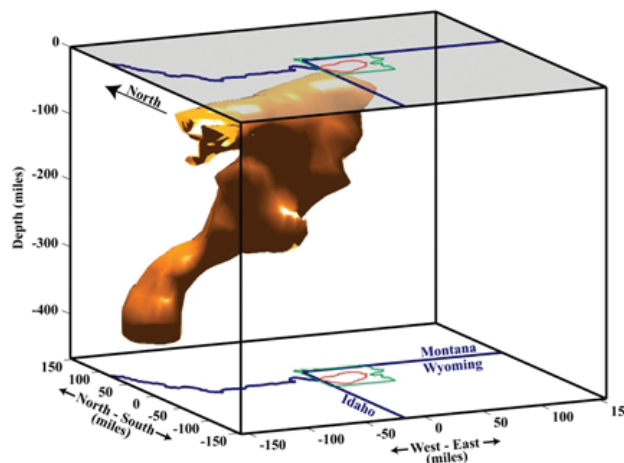
Questions for the Seismologist

- What is a hotspot?
- Where in the world are the major hotspots?

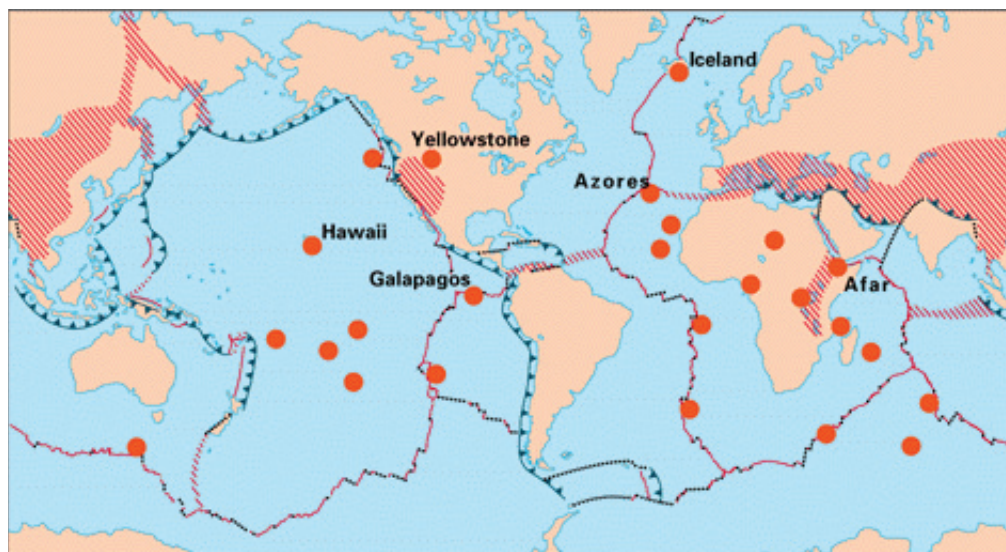
Information

In 1963, John Tuzo Wilson came up with a theory to explain volcanic activity in the middle of continental plates or the more-than-normal activity along faults. Wilson described stationary magma chambers, or hotspots, beneath the plate's crust that could cause volcanic activity far from any boundary zone.

Since then, scientists have been able to create images of the Yellowstone Hotspot using seismic technology. Scientists at the University of Utah constructed this illustration (right) of the Yellowstone Hotspot plume beneath Yellowstone National Park. Researchers believe that blobs of hot rock float off the top of the plume, then rise to recharge the magma chamber located 3.7–10 miles beneath the surface. The illustration also shows a region of warm rock extending southwest from near the top of the plume. It represents the eastern Snake River Plain where the Yellowstone Hotspot triggered numerous caldera supereruptions before the plume began feeding Yellowstone, about 2 million years ago.



The park boundaries are outlined in green at the surface, or top, of the illustration. The Yellowstone caldera, or giant volcanic crater, is outlined in red. State boundaries are shown in black. The park, caldera, and state boundaries are also projected on the bottom of the illustration to better show the plume's tilt. This image was created by seismologists at the University of Utah and the U.S. Geological Survey (USGS).

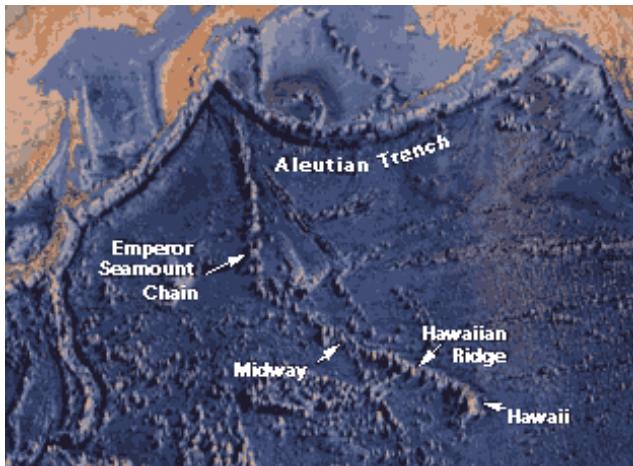


In this U.S. Geological Survey (USGS) map, you can notice some of the most established hotspots in the world.

Other Major Hotspots

Hawaiian Islands

The Hawaiian Hotspot is one of the best-known and most studied hotspots. It was the premise for Wilson's understanding of how plates move over magma plumes. Ancient fisherman first noticed that the islands got sequentially older as you moved toward the northwest. Notice the abrupt change in direction from the north-south oriented Emperor Seamount Chain to the southeastern progression of the chain of the Hawaiian Islands. Scientists continue to debate whether this is because of an abrupt change in plate movement or a shifting hotspot.



Iceland

The island of Iceland was created by a hotspot beneath the Mid-Atlantic Ridge. The abundant geothermal reservoir, provided by the Iceland Hotspot, combined with hydropower from many rivers and waterfalls, supply all of Iceland's electricity. This accounts for about 80% of the nation's total energy. Iceland plans to be independent from oil by the year 2050.



Galapagos Islands

Located in the eastern Pacific Ocean near the equator, the geology of the Galapagos Islands is as complicated and mysterious as its ecology. The Galapagos Hotspot rests beneath the Nazca Plate, and, like Iceland, it is near a divergent boundary

with the Cocos Plate. Yet unlike Iceland and the Mid-Atlantic Ridge, four major reservoirs feed this hotspot, causing changes in volcanic activity. Thus, landforms formed on both sides of the divergent boundary over the past 20 million years.



Azores

The Azores Hotspot lies beneath the junction of three of the world's largest tectonic plates (the North American Plate, the Eurasian Plate and the African Plate), creating islands on all three plates. The Azores were uninhabited when Portuguese navigators arrived in the early 15th century. Since these young, remote islands were settled over two centuries, culture, dialect, and traditions vary from island to island. The main source of income for all the islands is farming, fishing, and tourism.



Events

1946: A model of the Hawaiian Islands by ages is created, based on dating of surface rocks.

1963: John Tuzo Wilson develops hotspot theory.

Vocabulary

caldera a cauldron-like feature formed when the center of a volcano collapses after a major eruption

hotspot volcanic regions that are fed by superheated areas in the underlying mantle. These can be found near or far from plate boundaries.

mantle plume a thermal dome of hot rock that rises through Earth's mantle and creates a hotspot

Volcanologist

Task

Create a presentation that tells the story of the Yellowstone Hotspot. You will share your presentation with your classmates in small groups. Take advantage of all the information in the geoscenario to successfully present your story and the supporting evidence. You will be responsible for presenting information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Volcanologist

- How have major eruptions in the past impacted Earth?
- When did the supervolcano erupt? When could it erupt again?

Information

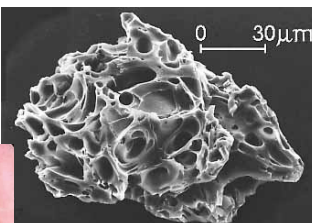
Volcanic eruptions can have a remarkable global impacts—from burying forests to causing climate cooling to possible involvement in three of the world's greatest mass extinctions. More recent, smaller eruptions have helped scientists observe atmospheric effects, shedding light on how ancient eruptions impacted the planet.

Effusive eruptions are a more gentle and steady outpouring of lava. **Explosive eruptions** usually involve thicker felsic magma that becomes volatile as it approaches Earth's surface. Explosive eruptions are measured by the size of the caldera and the amount of volcanic ash released into the atmosphere that eventually settles out and creates layers of rock called tuff.

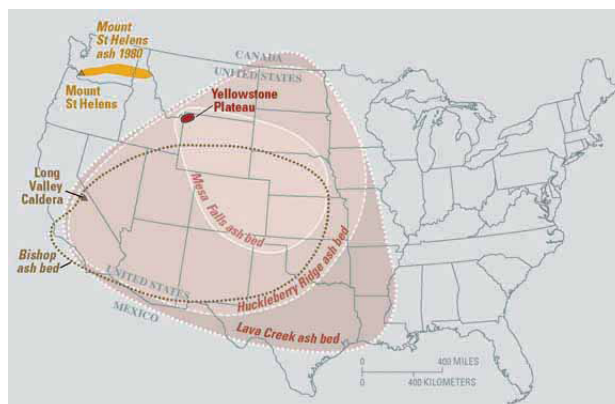
Some influential effects of eruptions are:

- **Ash Fall:** Even a light dusting of volcanic ash can cause respiratory health problems and damage crops, electronics, and machinery. When ash mixes with rain, it creates heavy cement-like substances that can collapse buildings.
- **Haze Effect:** Particles such as dust and ash can block Earth's sunlight, thus reducing solar radiation and lowering global temperatures. The amount of sulfur-rich gases released seems to be more important than the general size of the eruption. It can take years for these particles to settle out of the atmosphere.
- **Ozone Depletion:** Chemicals released in eruptions can interact with human-made chlorofluorocarbons to further deteriorate the ozone layer, which would increase solar radiation. Luckily, these particles settle out of the stratosphere in just a few years. While eruptions can enhance global warming by adding CO₂ into the atmosphere, human activities far outweigh any effects from any eruption in human history.

Ash particle (magnified 200 times) showing the jagged abrasive and sticking nature of the particles.



Volcanic ash from the 1980 Mt. St. Helens eruption.



Eruptions at Yellowstone in the past have spread ash over much of the U.S. The biggest eruption formed the Huckleberry Ridge ash bed.



Close view of Mesa Falls ash-flow tuff and underlying fallout ash exposed in a quarry near Ashton, Idaho.

For example, while the Eyjafjallajökull eruption in Iceland in April 2010 released approximately 0.15 million tons of CO₂ each day, the reduction of air travel over Europe caused by the ash cloud saved an estimated 1.3–2.8 million tons of CO₂ during that time.

If there were a major yellowstone eruption today,

- the park and surrounding areas would be obliterated.
- heavy ash rains would bury large areas of the United States, collapsing buildings and devastating livestock, wildlife, croplands, and forests.
- all communication and transportation systems would be useless until the ash cleared.
- ash would create a volcanic winter that could last for years and influence the climate, causing massive extinctions, human famine, and disease.

Scientists at Yellowstone Volcano Observatory (YVO) are constantly monitoring hydrothermal systems, earthquakes, and even the shape of the magma chamber. This allows YVO to warn the public of potential hazards in advance. While evidence shows that there will be future volcanic activity in Yellowstone, the probability of a large caldera-forming eruption within the next few thousand years is exceedingly low.

Events

66 mya: Deccan Flood Basalts in Western India releases 20.8 million km³ of gases, possibly contributing to the extinction of dinosaurs after the meteorite hit.

2.1 mya: Huckleberry Ridge eruption in Yellowstone, expelling 2,500 km³ of ash, is considered greater than 100,000 atomic bombs.

1.3 mya: Mesa Falls Tuff formation from the eruption in Yellowstone expels 280 km³ of ash.

640 tya: Lava Creek tuff formation from the eruption in Yellowstone expels 1,000 km³ of ash.

70-150 tya: Rhyolitic lava flows occur all over Yellowstone.

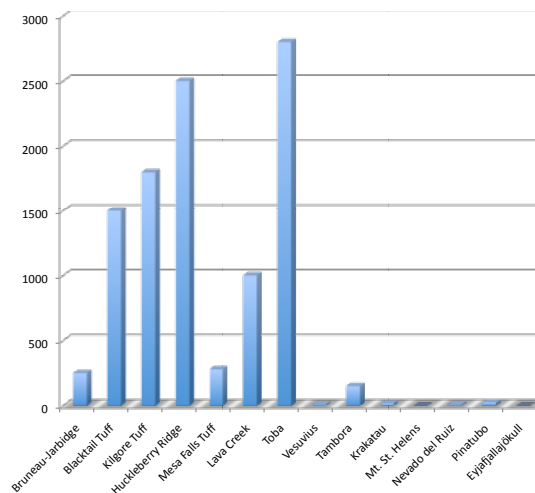
74 tya: Toba eruption in Indonesia expels 2,800 km³ of ash that blocks up to 90% of sunlight and causes temperatures to drop 2-6°F. Some scientists believe this started the last Ice Age, and other evidence suggests that our human ancestors were almost wiped out.

15-2 tya: Formation of Craters of the Moon, the largest lava field of the Snake River Plain.

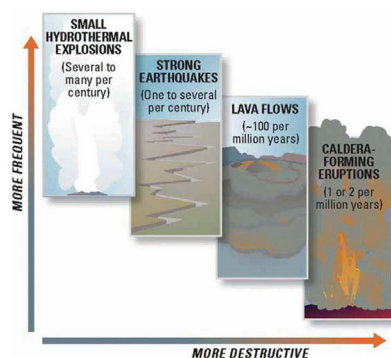
1815: Tambora eruption in Indonesia creates a caldera 4 miles wide. Global temperatures drop 5°F, creating “the year without summer.” 117,000 people die due to starvation from lost croplands.

1980: Mt. St. Helens’ blast kills 57 people and causes \$3 billion in damage.

1991: Pinatubo eruption in the Philippines expels 20-25 km³ of ash. Scientists are able to closely study the atmospheric effects. Over one-half million people are safely evacuated, due to an increased understanding of volcanic behavior.



Yellowstone has produced two of the world's most cataclysmic explosive eruptions in the last 2 million years. The table above shows some of the most significant eruptions in Earth's history, in order of the volume of ash released.



Scientists evaluate natural-hazard levels by combining their knowledge of the frequency and severity of hazardous events. In the Yellowstone region, damaging hydrothermal explosions and earthquakes can occur several times a century. Lava flows and small volcanic eruptions occur only rarely—none in the past 70,000 years. Massive caldera-forming eruptions, though the most potentially devastating of Yellowstone's hazards, are extremely rare. Only three have occurred in the past several million years.

Vocabulary

ash fall ash layers created from an eruption

effusive eruptions gentle, continuous outpouring of lava

explosive eruptions caldera-forming eruptions that cause immediate destruction

supereruption eruptions greater than 1,000 cubic km

tuff type of rock made from volcanic ash

Renewable Energy Consultant

Task

Create a presentation that tells the story of the Yellowstone Hotspot. You will share your presentation with your classmates in small groups. Take advantage of all the information in the geoscientific scenario to successfully present your story and the supporting evidence. You will be responsible for displaying information that answers the focus questions in the box below (and on the Team Questions notebook sheet) for your team's final product.

Questions for the Renewable Energy Consultant

- How does geothermal energy compare to other natural resources?
- What are the pros and cons of tapping into geothermal energy in Yellowstone National Park?

Information

The large magma chamber beneath Yellowstone National Park causes the surrounding rock and underground water reservoirs to be super heated. The U.S. Geological Survey (USGS) estimates the average heat flow from Earth's interior at Yellowstone to be 30 times greater than the typical heat flow for the surrounding areas. At Norris Geyser Basin, water temperatures were recorded as hot as 238°C (460°F) at just 330 meters deep.

Geothermal energy uses Earth's internal heat to derive usable energy to generate hot water, heat buildings, stabilize building temperatures, and create electricity.

Geothermal energy is considered a renewable energy source because it is continuously replenished by Earth's core heating system. Naturally occurring areas for exploitation are called geothermal reservoirs. Most geothermal reservoirs in the United States are located in the western states and Hawaii. California currently offers the most opportunities to produce electricity from geothermal energy in the United States.

Three Main Uses of Geothermal Energy

- **Direct use:** Hot water from springs or reservoirs near the surface is used to heat buildings, water systems, sidewalks, or greenhouses.
- **Electricity-generated power plants:** Geothermal reservoirs super heat water, which creates steam that is run through turbines to convert the thermal energy into electricity. Geothermal plants emit 97% less acid rain-causing pollutants than coal and natural gas power plants and a fraction of the CO₂

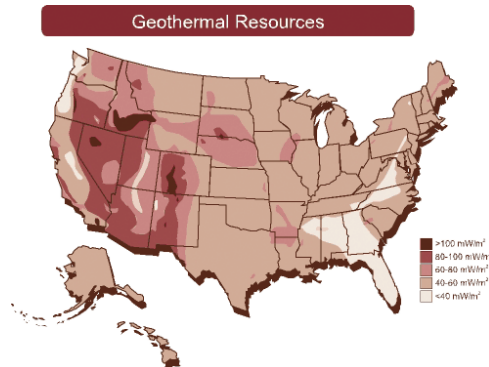
emissions. Much of the steam and water are injected back into reservoirs for efficiency and further emission reduction.

- **Geothermal heat pumps:** These do not require reservoirs and, thus, can be used almost everywhere in the world. The pumps use the stable temperature of 10–16°C (50–60°F) found most places 10 feet beneath Earth's surface to control building temperatures above ground. Geothermal heat pumps reduce electricity by using 30–60% less compared with traditional heating and cooling systems. This is because the electricity that powers the system is used only to move heat, not to produce it.



Steam vents from a geothermal power plant.

A map of the United States showing geothermal resource potential, based on current technology, for seeking viable geothermal reservoirs.



PROS AND CONS OF BUILDING A GEOTHERMAL POWER PLANT

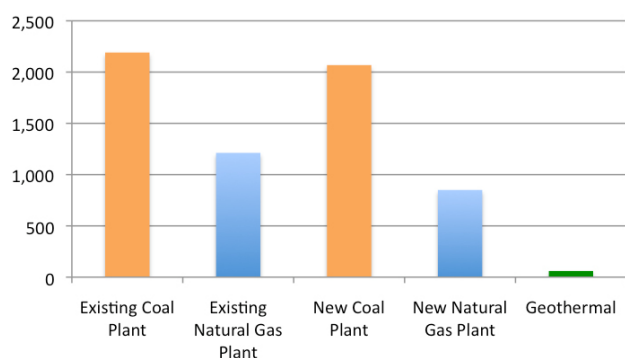
Pros

- Renewable energy source with minimal pollution.
- Most stable renewable resource (compared to wind and solar) and much less destructive than building dams for hydropower.
- Good against our foreign dependence on oil and for lowering CO₂ emissions.
- Reduce acid rain-producing pollutants by 97% compared to fossil fuel-burning power plants.
- Much more efficient systems for producing heat and electricity than converting fossil fuels.
- Geothermal heat pumps can be incorporated almost anywhere. Can reduce energy for electrically controlling building temperature by 30–60%.

Cons

- Can deplete flow of nearby geysers and hot springs.
- Many of our nation's geothermal resources are located in wild or protected areas. Yellowstone National Park is the largest intact, pristine ecosystem in the lower 48 states.
- Mineral-rich discharge water as waste. However, most systems pump back into reservoirs to solve this issue.
- Some geothermal plants produce some solid materials, or sludges, that require disposal in approved sites.
- Substantial costs are required to build the power plants, and it can take years for investors to see returns.
- Geothermal power plants often require large areas of space, making it difficult to access some potential reservoirs.

Average CO₂ emission for U.S. Power Plants
(pounds per Megawatt-hour)



Events

40-9 kya: Hot springs are used for bathing during the Paleolithic era.

300 BC: The oldest known spa is a stone pool on China's Lisan Mountain.

1300s: The world's oldest geothermal district heating system starts in Chaudes-Aigues, France (and is still successful).

1892: America's first district heating system in Boise, Idaho, is powered directly by geothermal energy.

1904: The first use of geothermal energy for electric power is in Italy.

Late 1940s: The first direct-exchange, ground-source heat pump is created.

1960: Pacific Gas and Electric begins operation of the first successful geothermal electric power plant in the United States at The Geysers in California.

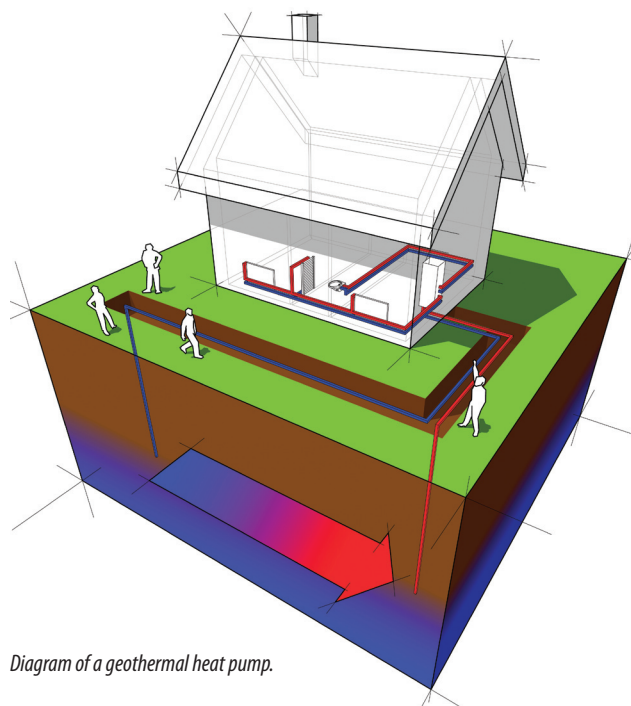


Diagram of a geothermal heat pump.

Vocabulary

geothermal thermal energy generated and stored in the Earth

heat flow the natural transfer of heat (thermal energy) from hotter to cooler mass

renewable energy energy from natural resources (such as sunlight, wind, rain, tides, and geothermal heat) that is naturally replenished