How Does Geothermal Energy Work?

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Summary

Geothermal energy is a powerful renewable resource. According to a 2023 U.S. Department of Energy report, geothermal energy will power an estimated 65 million U.S. homes by 2050. [DOE2] But how does geothermal energy work?

Chapter 1: What Is Geothermal Energy?

Geothermal energy is a renewable energy mostly used for generating electricity and heating and cooling buildings that is extracted from the heat under the earth's surface. [EIA]

Types of Geothermal Energy Use [DOE]

- **Geothermal electricity:** Fluid heated by the earth's magma rises naturally or is brought to the surface, where it is turned into steam. This steam is used to drive turbines that produce electricity.
- **Geothermal heat pumps:** Heat pumps heat and cool structures using the constant temperature underground by extracting and delivering heat during cold times and absorbing excess heat during hot times.
- **Geothermal direct use:** Wells pull hot water from below ground to the surface to use in heating, industrial operations, or other processes that require hot water.

The History of Geothermal Energy

- Humans have used geothermal energy for thousands of years. Indigenous North Americans used hot springs to cook 10,000 years ago. [Alberta]
- Ancient Romans bathed in natural hot springs and used the water to heat their homes. [Alberta]
- The first geothermal power plant dates to 1904 and used a natural steam vent to generate energy in Tuscany, Italy. [EIA]

Global Geothermal Energy Fast Facts [EIA3]

- Twenty-four countries generated electricity from geothermal energy in 2022.
- Indonesia produced the most geothermal energy: 17 billion kWh (kilowatt-hours) out of a global total of 92 billion kWh.
- Kenya produced the highest percentage of its electricity from geothermal energy, with geothermal electricity making up 45 percent of the country's total electricity usage.
- Geothermal energy heats about 85 percent of homes in Iceland. [Iceland]

U.S. Geothermal Energy Fast Facts [EIA3]

- Seven states have geothermal power plants: California, Nevada, Utah, Hawaii, Oregon, Idaho, and New Mexico.
- Two-thirds of the 17 billion kWh of geothermal electricity generated in the U.S. come from California.
- Nevada produces more than 10 percent of the state's electricity from geothermal energy.
- California's Geysers dry steam reservoir is the largest geothermal power plant in the world and has generated electricity continuously since 1960.

Types of Geothermal Power Plants [EIA4] [CA]

- Flash steam plants cycle water through geothermal fissures to heat it, then convert it to steam to drive a turbine that generates energy. This is the most common type of geothermal power plant and requires sources at temperatures of 360 degrees or higher.
- Dry steam plants use naturally emerging steam to create electricity without converting water into steam.
- Binary-cycle power plants transfer heat from water to another liquid with a lower boiling point to create steam. These plants can use moderate-temperature sources at temperatures of 400 degrees or lower.

Chapter 2: 5 Steps in the Geothermal Energy Process

How does geothermal energy work? The process starts with identifying underground geothermal reservoirs. Modern technology has made this process easier, boosting the rate at which these reservoirs are accurately located from 25 percent to 80 percent. [BBC]

Step 1: Identify a Geothermal Source

Geothermal energy can only be extracted from active geothermal regions, including near volcanoes, hot springs, or geysers. Identifying suitable resources is a critical first step. [KnowHow]

- Geothermal power plants require the temperature of geothermal sources to be 300 degrees to 700 degrees. [EIA4]

Step 2: Drill a Well

In some locations, underground pathways carry heated fluids to the surface naturally. Geothermal power plants speed up the process by drilling a well to access an underground geothermal reservoir. Many also pump in cold water that the magma heats. [KnowHow] [BBC]

- Geothermal wells can be up to 2 miles deep. [EIA4]

Step 3: Harness Steam Power

After tapping a geothermal reservoir, the geothermal power plant pumps the hot water to the surface to transfer it into steam. In a binary-cycle plant, the water boils a second liquid, usually butane, to create the steam. [BBC] This steam is then used to power a turbine. [KnowHow]

Step 4: Transfer the Energy

As the steam turns the turbine, a generator captures its energy in the form of electricity. Then the cooled water is returned to the geothermal well where it is reheated. [KnowHow] [BBC]

- The consistency of the earth’s underground temperature means that geothermal power plants can run day and night without interruption. [DOE]

Step 5: Deliver Electricity

The electricity generated at the geothermal power plant travels through power lines to provide power to communities. [KnowHow]

- Geothermal energy is inexpensive, with operation and maintenance costs of 1 cent to 3 cents per kWh. [WBGD]

Chapter 3: Geothermal Energy Pros and Cons

What are the pros and cons of geothermal energy? While this renewable energy source can generate a lot of power, finding sources and funding power plant construction pose barriers.

Geothermal Energy Pros

- **Low emissions:** Geothermal power plants release 99 percent less carbon dioxide than fossil fuel power plants, making them a clean energy source. [EIA5]
- **Efficient process:** Because the fluids geothermal power plants use to create electricity cycle through the process in a loop, their emissions and resource use are low. [EIA5]
- **Consistent:** Unlike solar, wind, and hydroelectric power, geothermal power remains consistently available regardless of the weather, time of year, or other factors. [DOE] [IRENA]

Geothermal Energy Cons

- **Difficulty finding resources:** According to the U.S. Geological Survey, 70 percent to 80 percent of geothermal resources are hidden. That makes identifying them challenging. [WBGD]
- **High start-up costs:** While geothermal energy is cheap to produce, it is expensive to set up a power plant. Capital costs are around $2,500 per kWh. [WBGD]
- **High water needs:** Geothermal power requires a large amount of water, which can create problems in drought-prone regions. [FWS]

Conclusion

Geothermal energy is a renewable and consistently available type of energy because the temperature under the earth’s surface remains basically the same throughout the year. Harnessing the power of geothermal energy requires expertise in energy technology and the electric power market.

Sources

- Geothermal explained
- Where geothermal energy is found

- Use of geothermal energy
- Geothermal power plants
- Geothermal energy and the environment
- Geothermal Basics
- Electricity Generation
- Geothermal
- Geothermal Energy: An Underutilised Source of Renewable Energy
- Geothermal Electricity Production Basics
- How does geothermal energy work to produce electricity?
- Geothermal Electric Technology
- Geothermal Energy
- Geothermal Energy throughout the Ages
- Goverment of Iceland Ministry of the Environment, Energy and Climate: Energy
- Types of Geothermal Power Plants