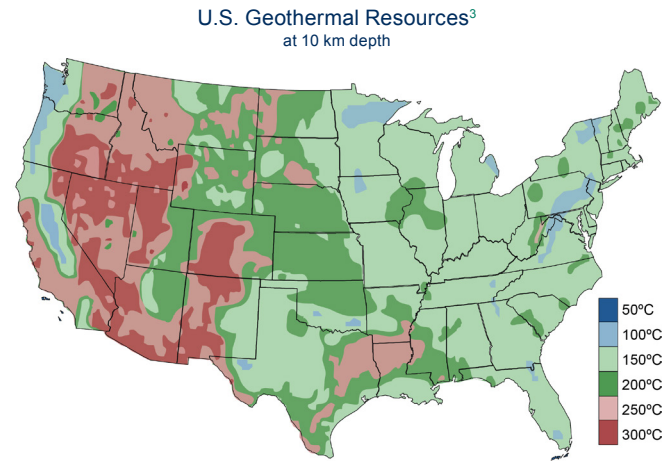


Geothermal Energy

Geothermal Resource and Potential

- Geothermal energy is derived from the natural heat of the earth.¹ It exists in both high enthalpy (volcanoes, geysers) and low enthalpy forms (heat stored in rocks in the Earth’s crust).² Nearly all heating and cooling applications utilize low enthalpy heat, called ground source heat.
- Geothermal energy has two primary applications: heating/cooling and electricity generation.¹
- Ground source heat pumps for heating and cooling use 30-60% less energy than traditional heating and cooling systems and could potentially reduce U.S. residential energy use by 3 Quadrillion Btu (~3 % of total U.S. energy use).⁴
- The U.S. has tapped less than 0.6% of geothermal electricity resources; the majority can become available with Enhanced Geothermal System technology.⁵
- There are presently 3,442 MW of geothermal power plants in operation in the United States—the most of any country—and more than 4,000 MW are in development.⁶
- Electricity generated from geothermal power plants is projected to increase from 16.5 billion kWh in 2013 to 67.3 billion kWh in 2040.^{7,9} California, Nevada, Utah, Oregon, and Hawaii, all in the Western U.S., are among the top geothermal energy producing states.⁶
- The U.S., the Philippines, Indonesia, Mexico, Italy, New Zealand, Iceland, and Japan generate 89% of the world’s total geothermal electricity.⁶



Geothermal Technology and Impacts

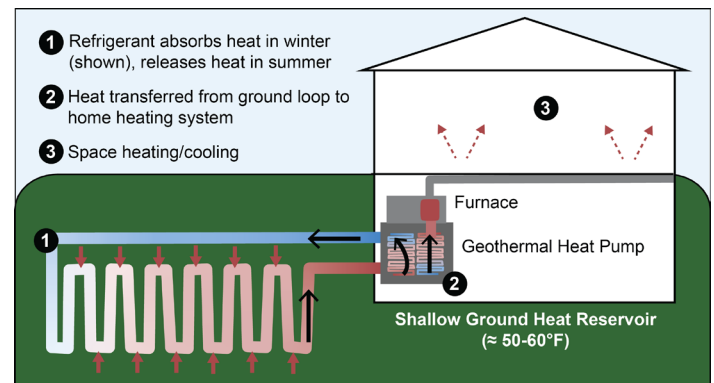
Direct Use and Heating/Cooling

- Geothermal heat pumps (GHPs) are the primary method for direct use. GHPs use the shallow ground as an energy storage medium, because it maintains a nearly constant temperature between 50° and 60°F (10°–16°C).⁹
- GHPs transfer heat from a building to the ground during the cooling season, and from the ground into a building during the heating season.⁹
- Direct-use applications include space and district heating, greenhouses, aquaculture, and commercial and industrial processes.¹¹⁰

Electricity Generation

- Geothermal energy currently accounts for 0.4% of net electricity generation in the United States.⁷
- Hydrothermal energy, typically supplied by underground water reservoirs, is the main source of geothermal electricity. The water is often pumped as steam to the earth’s surface to spin turbines that generate electricity.¹²¹
- Dry steam power plants use steam from a geothermal reservoir and route it directly through turbines, which drive generators to produce electricity.¹²¹
- Flash steam power plants pump hot water under high pressure into a surface tank at much lower pressure. This pressure change causes the water to rapidly “flash” into steam, which is then used to spin the turbine and power the generator to produce electricity. Flash steam plants are the most common type of geothermal power plants.¹²¹
- Binary cycle power plants feature geothermal water and a working fluid that are confined to separate circulating systems, or “closed loops.” A heat exchanger transfers heat from the water to the working fluid, causing it to “flash” to steam, which then powers the turbine/generator to produce electricity.¹²¹
- An Enhanced Geothermal Systems (EGS) is a technology under development that could expand the use of geothermal resources to new geographic areas. The EGS concept is to create a subsurface fracture system to increase the permeability of rock and allow for the injection of a heat transfer fluid (typically water). Injected fluid is heated by the rock and returned to the surface for use in electricity generation.¹³²

Geothermal Heat Pump in a Residential Heating Application⁸



Installation, Manufacturing, and Cost

- The main stages of geothermal power development are resource exploration, drilling, reservoir and plant development, and power generation.¹⁵
- Capital costs for conventional geothermal power plants in the U.S. are approximately \$2,500 per installed kilowatt.¹⁶
- Although the development of geothermal power requires a large capital investment, the power generation itself has relatively low operating costs and a high capacity factor (ratio of actual power production to production potential).¹⁵
- With tax incentives, geothermal electricity costs an estimated \$0.042-\$0.069 per kilowatt-hour (kWh), depending on the type of technology. Without tax incentives, costs can rise to \$0.078-\$0.116 per kWh.¹⁵

Energy Performance and Environmental Impacts

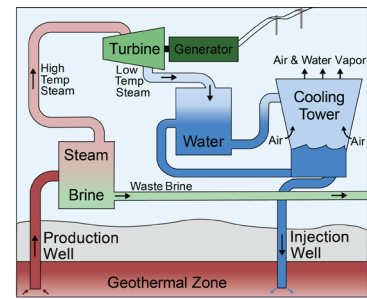
- Depending on the method of electricity generation, a geothermal power plant emits roughly 12 times less carbon dioxide (CO₂) per unit of electricity than the average U.S. coal power plant.¹⁷
- Binary cycle power plants and flash power plants consume around 0.27 gallons and 0.01 gallons of water per kWh, respectively (compared to 23 gallons of water per kWh used by thermoelectric plants in 2005).^{18,19}
- Each year, U.S. geothermal power offsets the emission of 22 million metric tons of CO₂, 200,000 tons of sulfur dioxide, and 110,000 tons of particulate matter from coal-powered plants.²⁰
- Current research suggests storing CO₂ in geothermal reservoirs may be possible, although the seismic risks of long-term and high-volume geologic carbon sequestration are uncertain.^{19,22}
- Some geothermal facilities produce solid waste that must be disposed of in approved sites. However, some by-products can be recovered and recycled.²³

Solutions and Sustainable Actions

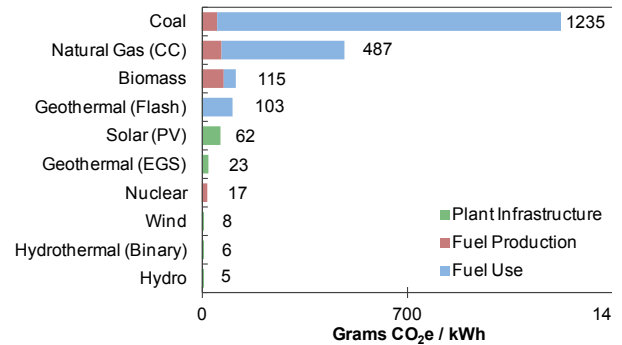
Funding Opportunities

- In 2014, there were 244 different federally-funded geothermal research projects in the U.S.²⁴
- The American Recovery and Reinvestment Act of 2009 provided up to \$364 million in new funding for geothermal research, development, demonstration, and deployment activities.²⁵
- With a capacity factor of over 90%, geothermal electricity generation could offset coal, natural gas, or nuclear power as a baseload supply in the electrical energy market.¹⁶
- The growth of geothermal deployment has been aided by state Renewable Energy Portfolio Standards (RPS) that require a certain percentage of electricity to be derived from renewable sources.^{19,26}
- Renewable Energy Certificates (RECs) are sold by renewable energy producers in addition to the electricity they produce; for a few cents per kilowatt hour, consumers can purchase RECs to “offset” their usage and help renewable energy become more competitive.²⁷
- A federal tax credit for homeowners available through 2016 covers 30% of qualifying geothermal costs with no upper limits.²⁸
- Across the U.S., many utilities offer “green pricing” programs, which provide consumers with the option to purchase renewably generated electricity at a small premium.²⁷
- Many companies purchase renewable energy as part of their environmental programs. Intel, Microsoft, Kohl’s, Whole Foods, Google, Walmart, and Staples are among the top 10 users of renewable energy.²⁹

Flash Steam Geothermal Power Plant¹⁴



GHG Emissions from Power Generation³⁰
by Life Cycle Stage



Steamboat Hills Geothermal Power Plant³¹
Steamboat Springs, Nevada



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31. Photo courtesy of National Renewable Energy Laboratory.