

Geothermal Energy

Geothermal Resource and Potential

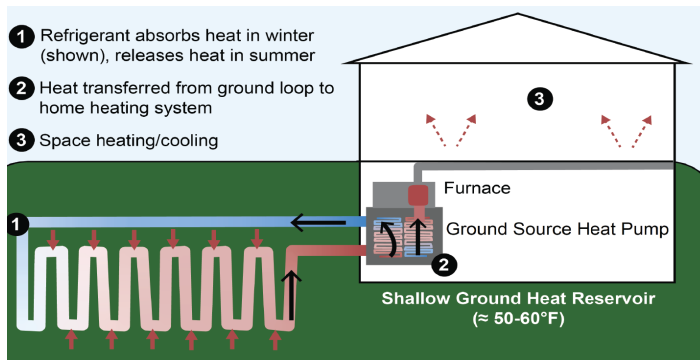
- Geothermal energy is derived from the natural heat of the earth.¹ It exists in both high enthalpy (volcanoes, geysers) and low enthalpy forms (heat stored in rocks in the Earth’s crust). Most heating and cooling applications utilize low enthalpy heat.²
- Geothermal energy has two primary applications: heating/cooling and electricity generation.¹ Ground source heat pumps (GSHPs) for heating and cooling use 75% less energy than traditional heating and cooling systems.³
- The U.S. has tapped less than 0.7% of geothermal electricity resources; the majority can become available with Enhanced Geothermal System technology.^{4,5}
- The U.S., Indonesia, Turkey, Philippines, and New Zealand accounted for over two-thirds of global installed geothermal power capacity in 2022.⁶
- In 2022, there were 3,965 MW of geothermal electricity plants in operation in the U.S.—the most of any country—and generation has been growing at 3% per year.⁷ Electricity generated from geothermal plants is projected to increase from 16.5B kWh in 2023 to 37.2B kWh in 2050.^{8,9}
- In 2021, California and Nevada had 95% of U.S installed geothermal capacity.⁷

Geothermal Technology and Impacts

Direct Use and Heating/Cooling

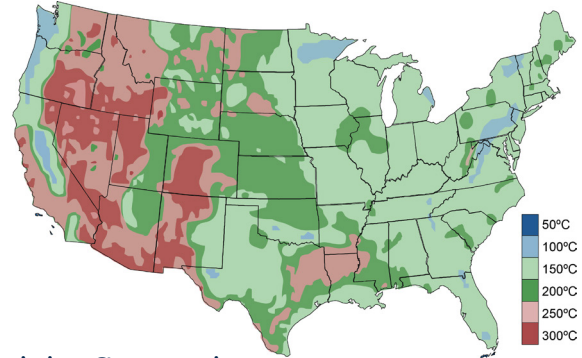
- GSHPs are the primary method for direct use of geothermal energy. GSHPs use the shallow ground as an energy reservoir that maintains a nearly constant temperature.¹⁰

Geothermal Heat Pump for Residential Heating¹¹



- GSHPs transfer heat from a building to the ground during the cooling season, and from the ground into a building during the heating season.¹⁰
- Direct-use applications include space and district heating, greenhouses, aquaculture, and commercial and industrial processes.¹²

U.S. Geothermal Resources at 10 km Depth¹³



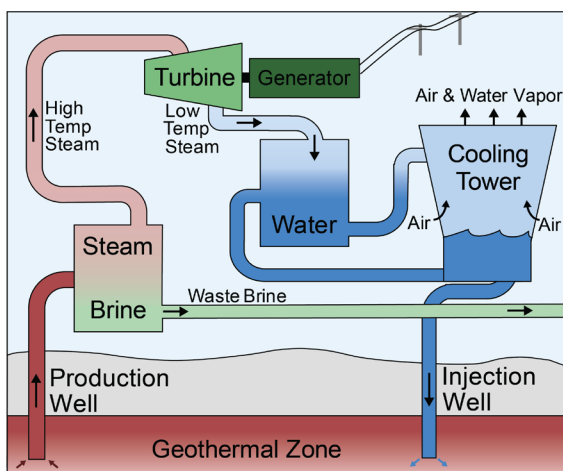
Electricity Generation

- In 2022, the U.S. generated the most geothermal electricity in the world at 19,142 GWh, 0.4% of all electricity generation.^{8,6}
- Hydrothermal energy, typically supplied by underground water reservoirs, is a main source of thermal energy used in electricity generation. The water is often pumped as steam to the earth’s surface to spin turbines that generate electricity.¹⁴
- Dry steam power plants use steam from a geothermal reservoir and route it directly through turbines, which drive generators to produce electricity.¹⁴
- 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 a turbine/generator to produce electricity. Flash steam plants are the most common type of geothermal power plants.¹⁴
- 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.¹⁴
- Enhanced Geothermal System (EGS) is a technology under development that could expand the use of geothermal resources to new geographic areas. EGS creates 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 to generate electricity.¹⁵
- According to the U.S. DOE, there may be over 100 GW of geothermal electric capacity in the continental U.S., which would account for nearly 10% of current U.S. electricity capacity and be 40 times the current installed geothermal capacity.¹⁵

Installation, Manufacturing, and Cost

- The main stages of geothermal power development are resource exploration, drilling, reservoir/plant development, and power generation.¹⁶
- Capital costs for conventional geothermal power plants in the U.S. are approximately \$2,500 per installed kW capacity.¹⁷
- Although the development of geothermal power requires a large capital investment, geothermal has low operating costs and a capacity factor of >90% (ratio of actual power production to production potential).^{16,18}
- In 2016, geothermal electricity cost between 7.8-22.5¢ per kWh. As of May 2020, geothermal plants qualified for the federal Production Tax Credit (PTC).¹⁸
- In 2023, the Inflation Reduction Act (IRA) renewed and expanded the PTC, which provides up to 2.75¢ per kWh for electricity generated from geothermal resources.¹⁹

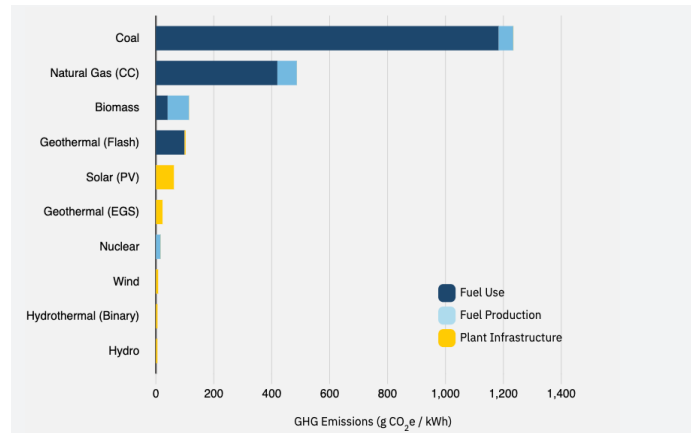
Flash Steam Geothermal Power Plant²⁰



Environmental Impacts

- An average U.S. coal power plant emits roughly 35 times more carbon dioxide (CO₂) per kWh of electricity generated than a geothermal power plant.²¹
- Binary cycle power plants and flash power plants consume around 0.24-4.21 gal and 1.59-2.84 gal of water per kWh, respectively (compared to 15 gal of water per kWh used by thermoelectric plants in 2015).^{22,23}
- Each year, U.S. geothermal electricity offsets the emission of 22 Mt of CO₂, 200,000 Mt of nitrogen oxides, and 110,000 t of particulate matter from coal-powered plants.¹⁸
- The U.S. DOE is actively funding research into combining carbon capture and storage with geothermal energy production, although the risks of long-term and high-volume geologic carbon sequestration are uncertain.^{24,25}
- Some geothermal facilities produce solid waste that must be disposed of in approved sites, though some by-products can be recovered and recycled.²⁶

Life Cycle GHG Emissions by Power Generation²⁷



Solutions and Sustainable Actions

Funding Opportunities

- With a capacity factor of over 90%, geothermal electricity generation could offset coal, natural gas, or nuclear power as baseload supply in the electricity market.¹⁷
- A federal tax credit for homeowners from the IRA can cover up to 30% of qualifying GHSP system costs (depending on construction date) from 2006 through 2034.³⁰
- Renewable Portfolio Standards (RPS) require electricity providers to obtain a minimum fraction of energy from renewable resources.²⁸
- Renewable Energy Certificates (RECs) are sold by renewable energy producers in addition to the electricity they produce; for a few cents per kWh, consumers can purchase RECs to “offset” their usage and help renewable energy become more competitive.²⁹
- Around 850 utilities in the U.S. offer customers the option to purchase renewable energy, or “green power.”³¹
- Many companies purchase renewable energy as part of their environmental programs. Microsoft, Google, T-Mobile, Walmart, and AT&T were the top five users of renewable energy as of July 2024.³²

Steamboat Hills Geothermal Power Plant, Nevada³³

