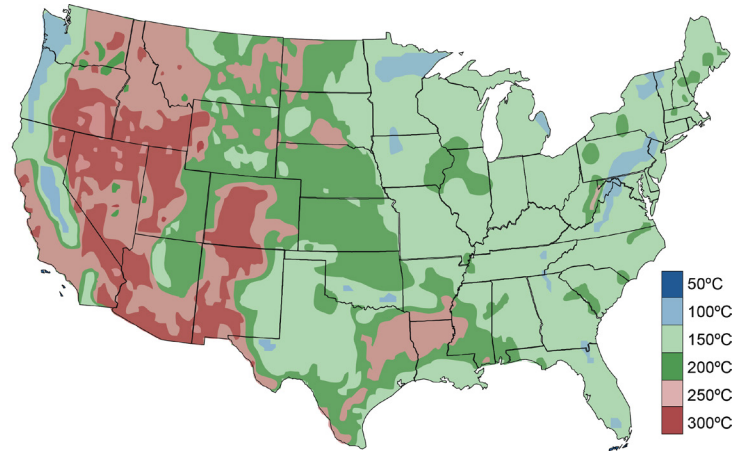


Geothermal Energy

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). Nearly all 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 for heating and cooling use 75% less energy than traditional heating and cooling systems.⁴
- The U.S. has tapped less than 0.7% of geothermal electricity resources; the majority can become available with Enhanced Geothermal System technology.^{5,6}
- In 2016, there were 3,812 MW of geothermal electricity plants in operation in the U.S.—the most of any country—and development has been growing at a rate of 2% per year.⁶
- Electricity generated from geothermal plants is projected to increase from 16 billion kWh in 2021 to 47.4 billion kWh in 2050.^{7,8} In 2016, California, Nevada, Utah, and Hawaii were the states with the most installed geothermal energy capacity.⁶
- The U.S., Indonesia, Philippines, Turkey, New Zealand, and Mexico had 75% of global installed geothermal power capacity in 2021.⁹

U.S. Geothermal Resources³
at 10 km depth



Geothermal Technology and Impacts

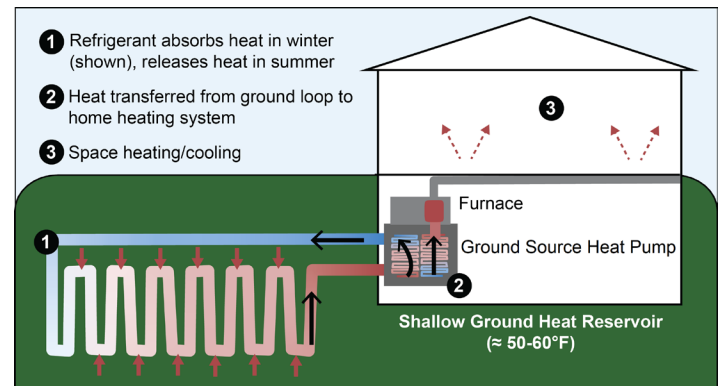
Direct Use and Heating/Cooling

- Geothermal (or ground source) heat pumps (GSHPs) are the primary method for direct use of geothermal energy. GSHPs use the shallow ground as an energy reservoir because it maintains a nearly constant temperature between 50–60°F (10–16°C).¹¹
- GSHPs transfer heat from a building to the ground during the cooling season, and from the ground into a building during the heating season.¹¹
- Direct-use applications include space and district heating, greenhouses, aquaculture, and commercial and industrial processes.¹²

Electricity Generation

- Geothermal energy currently accounts for 0.4% of net electricity generation in the United States.⁷
- In 2019, the U.S. generated the most geothermal electricity in the world: more than 18,300 GWh.⁹
- 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.¹³
- Dry steam power plants use steam from a geothermal reservoir and route it directly through turbines, which drive generators to produce electricity.¹³
- 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.¹³
- 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.¹³
- 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.¹⁴
- According to the U.S. Department of Energy, 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.¹⁴

Ground Source Heat Pump in a Residential Heating Application¹⁰



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 kilowatt of 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).^{6,16}
- In 2016, geothermal electricity cost between 7.8-22.5¢ per kWh.⁶
- Geothermal plants that began construction before January 1, 2021 are eligible for the Renewable Electricity Production Tax Credit (PTC) at 2.5¢ per kWh.¹⁸

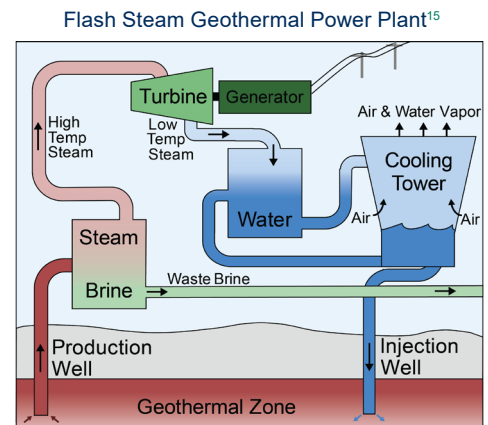
Energy Performance and Environmental Impacts

- An average U.S. coal power plant emits roughly 35 times more carbon dioxide (CO₂) per kWh electricity generated than a geothermal power plant.¹⁹
- Binary cycle power plants and flash power plants consume around 0.24-4.21 gallons and 1.59-2.84 gallons of water per kWh, respectively (compared to 15 gallons of water per kWh used by thermoelectric plants in 2015).^{20,21}
- Each year, U.S. geothermal electricity offsets the emission of 4.1 million tons of CO₂, 80 thousand tons of nitrogen oxides, and 110 thousand tons of particulate matter from coal-powered plants.¹⁹
- 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.^{22,23}
- Some geothermal facilities produce solid waste that must be disposed of in approved sites, though some by-products can be recovered and recycled.²⁴

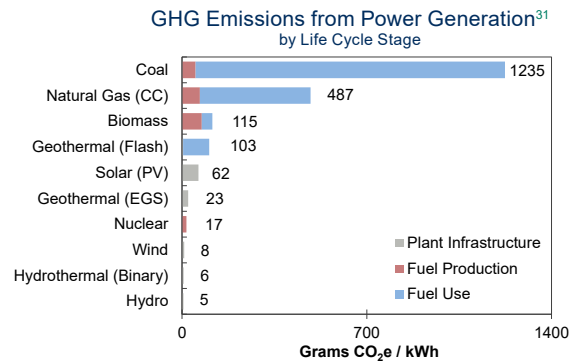
Solutions and Sustainable Actions

Funding Opportunities

- In 2019, there were 16 national laboratories and research institutions in the U.S. conducting research into geothermal energy technologies.²⁵
- 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
- Renewable Portfolio Standards (RPS) require electricity providers to obtain a minimum fraction of energy from renewable resources.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 covers 26% of qualifying ground source heat pump system costs from 2020 through 2022, stepping down to 22% in 2023.²⁸
- Around 850 utilities in the U.S. offer consumers the option to purchase renewable energy, or “green power.”²⁹
- Many companies purchase renewable energy as part of their environmental programs. Microsoft, Google, T-Mobile, Intel, and The Proctor & Gamble Company were the top five users of renewable energy as of April 2022.³⁰



Flash Steam Geothermal Power Plant¹⁵



Steamboat Hills Geothermal Power Plant³²
Steamboat Springs, Nevada



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