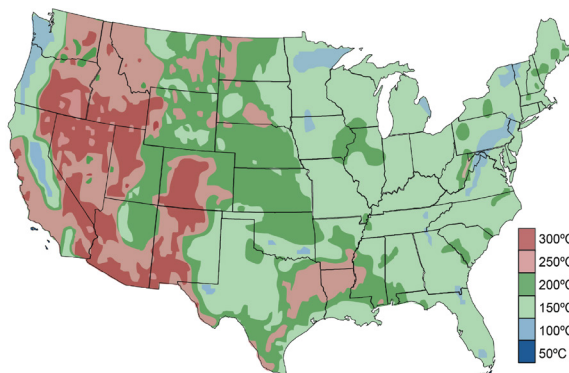


Geothermal Energy

Geothermal Resource and Potential

- Geothermal energy is derived from Earth's natural heat.¹ It exists in 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) use 75% less energy than traditional heating and cooling systems.³
- The U.S. has tapped less than 1% of its geothermal electricity resources; the majority is accessible through Enhanced Geothermal System (EGS) technology.^{4,5}
- Improving exploration and management technology could reduce development costs and risks, potentially increasing geothermal power generation 26-fold to 90 GW of always-on, flexible electricity generation capacity by 2050.^{6,7}
- The U.S., Indonesia, Turkey, Philippines, and New Zealand accounted for over 67% of global installed geothermal capacity in 2023.⁸ The U.S. leads with 4 GW of installed capacity. 95% of U.S. capacity is in California and Nevada.⁹
- Geothermal electricity generation is projected to increase from 15.7 TWh in 2025 to 56 TWh by 2050.^{10,11}

U.S. Geothermal Resources at 10 km Depth¹²

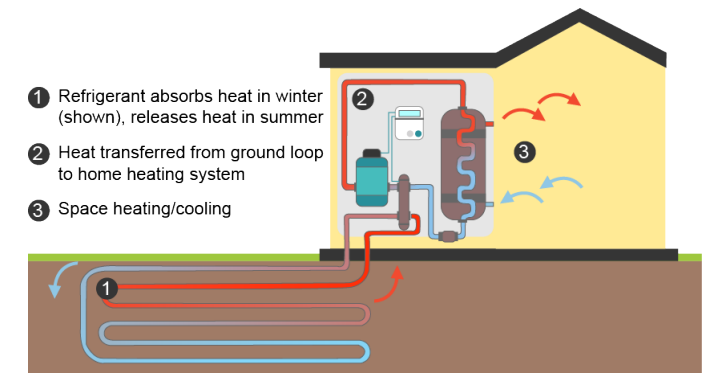


Geothermal Technology and Use

Direct Use and Heating/Cooling

- GSHPs are the primary method for direct geothermal use, utilizing shallow ground as an energy reservoir that maintains nearly constant temperature.¹³
- GSHPs transfer heat from buildings to the ground during cooling season and from the ground to buildings during heating season.¹³
- The U.S. installed capacity of geothermal heating and cooling represents less than 10% of market potential.⁶

Geothermal Heat Pump for Residential Heating^{14,15}

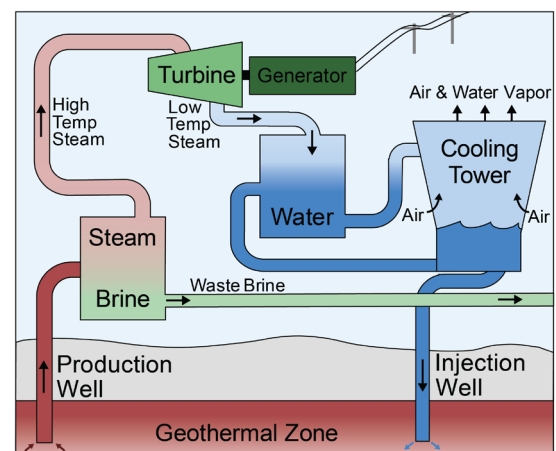


- Direct-use applications include space and district heating, greenhouses, and commercial and industrial processes.¹⁶

Electricity Generation

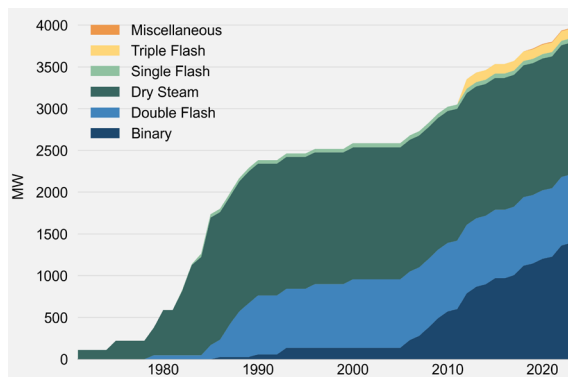
- In 2025, the U.S. had the most installed geothermal capacity in the world, representing 0.4% of U.S. electricity generation.¹⁰
- Hydrothermal energy from underground water reservoirs is the main thermal source for electricity generation. Water is pumped as steam to the surface to spin electricity-generating turbines.¹⁷
- Dry steam plants route steam directly from geothermal reservoirs through turbines to drive generators.¹⁷
- Flash steam plants pump high-pressure hot water into low-pressure surface tanks, causing rapid "flashing" to steam that spins turbine generators. These are the most common type of geothermal plants.¹⁷

Flash Steam Geothermal Power Plant²⁰



- Binary cycle plants use separate closed-loop systems for geothermal water and working fluid. Heat exchangers transfer heat to the working fluid, causing it to flash to steam to power turbine generators.¹⁷
- EGS technology under development could expand geothermal use to new geographic areas. EGS creates subsurface fracture systems to increase rock permeability, allowing injection of heat transfer fluid (typically water) that is heated by the rock and returned to the surface for electricity generation.¹⁸

Expansion of U.S. Geothermal Capacity⁵

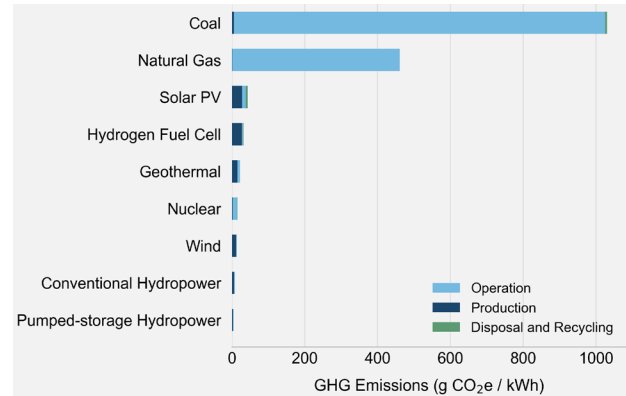


- The technical potential of new geothermal systems is second only to solar PV among renewable technologies and sufficient to meet global electricity demand 140 times over.¹⁹
- The U.S. DOE estimates 90 GW of potential geothermal electric capacity in the continental U.S.⁵
- Nascent technologies such as superhot geothermal could increase the potential of geothermal in the U.S. by making deeper and hotter resources available for development.⁵

Installation, Manufacturing, and Cost

- The main stages of geothermal power development are resource exploration, drilling, reservoir/plant development, and power generation.²⁰
- Geothermal power projects have higher capital costs (average \$7,000/kW for flash plants and \$9,200 for binary plants) than onshore wind (average \$1,700/kW) or utility-scale solar (average \$1,600/kW).⁶ However, geothermal offers low operating costs and high capacity factors (ratio of actual power production to production potential): 65.9% in 2025 compared to 34.2% for wind and 24.4% for solar.^{10,20,21} Capacity factor is not 100% due to local resource degradation,²² seasonal efficiency changes,²³ scale formation on piping surfaces,²⁴ and intentional load following.²⁵
- In 2025, geothermal electricity cost \$88/MWh, nearly half the price of coal or gas but about \$10-\$20 more than onshore wind and solar.²⁶
- The cost of EGS has dropped by over 50% since 2021, but capital costs remain higher than conventional systems: \$9,140/kW for near-field EGS binaries versus \$6,349/kW for conventional binaries.⁵
- Geothermal plants qualified for the federal Production Tax Credit (PTC) as of 2020. The 2023 Inflation Reduction Act renewed and expanded the PTC, providing up to 2.75¢/kWh for geothermal electricity generation.¹⁹ Geothermal plants still qualify for PTC despite recent legislation, which will provide credits through 2033.²⁸
- If deep cost reductions for next-generation geothermal can be achieved, total global investment could reach \$1T by 2035 and \$2.5T by 2050.¹⁹

Life Cycle GHG Emissions by Power Generation³⁵



Environmental Impacts

- Geothermal power plants do not burn fuel but release small amounts of SO₂ and CO₂. They emit 97% less acid rain-causing sulfur compounds and 99% less CO₂ than similarly sized fossil fuel plants.³⁰
- Most geothermal plants inject used geothermal steam and water back into the earth, helping renew the resource and reduce emissions.³⁰
- Binary cycle plants consume 0.24-4.21 gal of water/kWh while flash plants use 1.59-2.84 gal/kWh, compared to 15 gal/kWh for average thermoelectric plants in 2015.^{31,32}
- Each year, U.S. geothermal electricity avoids emissions of 22 Mt of CO₂, 0.2 Mt of nitrogen oxides, and 0.11 Mt of particulate matter from coal plants.⁶
- Some geothermal facilities produce solid waste due to entrained solids, such as silica and sulfur, that can be recovered and recycled.³³ Some of this waste (≈15%) is hazardous material.³⁴

Solutions and Sustainable Actions

- With high capacity factors, geothermal electricity generation could offset coal, natural gas, or nuclear power as baseload electricity supply.³⁶
- The IRA provided tax credits covering up to 30% of qualifying residential GSHP system costs, which were ended by recent legislation.^{37,38}
- Renewable Portfolio Standards (RPS) require electricity providers to obtain a minimum fraction of energy from renewable resources.³⁹
- 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.⁴⁰
- Around 850 utilities in the U.S. offer customers the option to purchase renewable energy, or “green power.”⁴¹