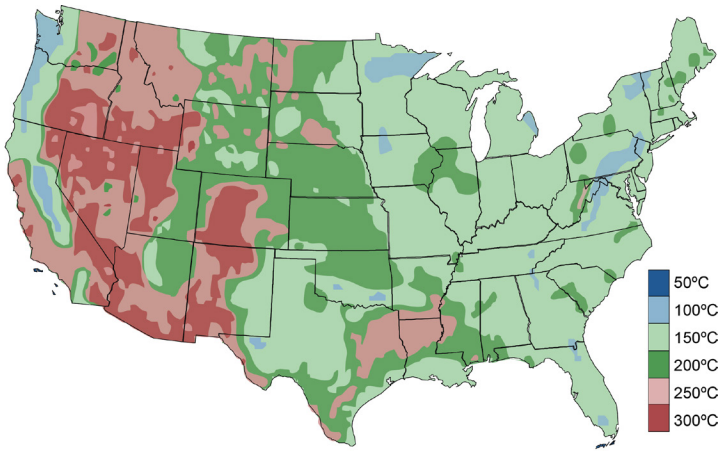
Geothermal Energy

Geothermal Resource and Potential

U.S. Geothermal Resources[3]
at 10 km depth

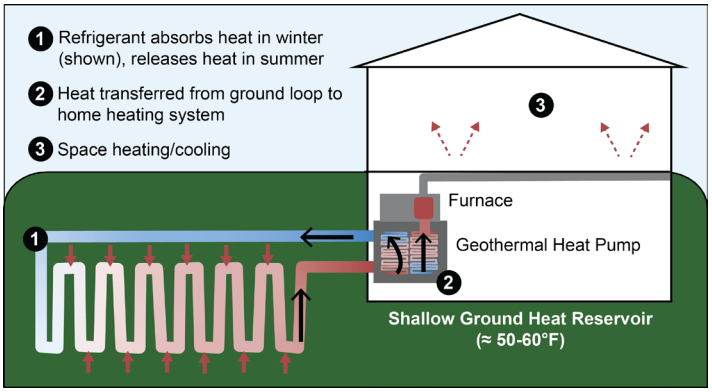


- Geothermal energy is derived from the natural heat of the earth.[1] It exists in both high enthalpy (volcanoes, geysers) and low enthalpy forms (heat stored in rocks in the Earth's crust). Nearly all heating and cooling applications utilize low enthalpy heat, called ground source heat.[2]
- Geothermal 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 3,567 MW of geothermal power plants in operation in the United States—the most of any country—and 1,270 MW of projects are in development.[6]
- Electricity generated from geothermal power plants is projected to increase from 16.7 billion kWh in 2015 to 69.6 billion kWh in 2040.[7,8] California, Nevada, Utah, Alaska, and Hawaii are the states with the most installed geothermal energy capacity.[6]
- The U.S., the Philippines, Indonesia, Mexico, New Zealand, Italy, Iceland, and Turkey have 84% of the world's total geothermal electricity generating capacity.[6]

Geothermal Technology and Impacts

Direct Use and Heating/Cooling

Geothermal Heat Pump in a Residential Heating Application[9]



- Geothermal (or ground source) heat pumps (GHPs) are the primary method for direct use of geothermal energy. GHPs use the shallow ground as an energy reservoir because it maintains a nearly constant temperature between 50°-60°F (10°–16°C).[10]
- GHPs 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.[11]

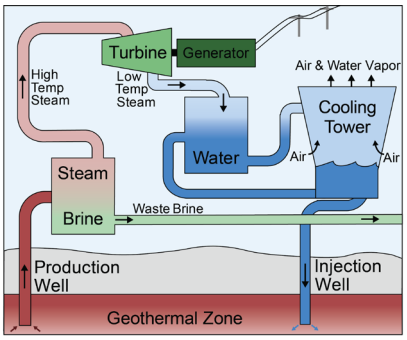
Electricity Generation

- 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.[12]
- Dry steam power plants use steam from a geothermal reservoir and route it directly through turbines, which drive generators to produce electricity.[12]
- 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.[12]
- 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.[12]
- An Enhanced Geothermal System (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 to generate electricity.[13]
- 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.[13]

Installation, Manufacturing, and Cost

- The main stages of geothermal power development are resource exploration, drilling, reservoir/plant development, and power generation.[15]
- Capital costs for conventional geothermal power plants in the U.S. are approximately $2,500 per installed kilowatt of capacity.[16]
- Although the development of geothermal power requires a large capital investment, geothermal has 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 4.2-6.9¢ per kilowatt-hour (kWh), depending on the type of technology. Without tax incentives, costs are 7.8-11.6¢ per kWh.[15]

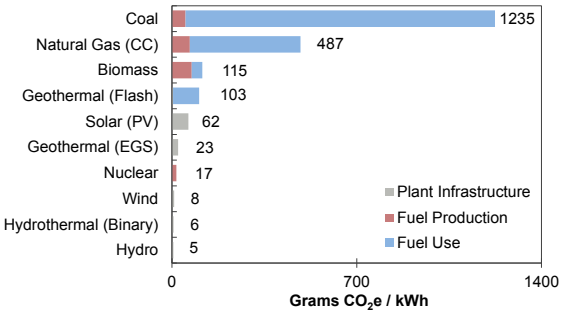
Flash Steam Geothermal Power Plant[14]



Energy Performance and Environmental Impacts

- Depending on the method of electricity generation, a geothermal power plant emits roughly 12 times less carbon dioxide (CO_2) 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 19 gallons of water per kWh used by thermoelectric plants in 2010).[18,19]
- Each year, U.S. geothermal electricity offsets the emission of 22 million metric tons of CO_2, 200 thousand tons of sulfur dioxide, and 110 thousand tons of particulate matter from coal-powered plants.[20]
- Current research suggests storing CO_2 in geothermal reservoirs may be possible, although the seismic risks of long-term and high-volume geologic carbon sequestration are uncertain.[21,22]
- Some geothermal facilities produce solid waste that must be disposed of in approved sites, though some by-products can be recovered and recycled.[23]

GHG Emissions from Power Generation[31]
by Life Cycle Stage



Solutions and Sustainable Actions

Funding Opportunities

- In 2016, there were 216 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 baseload supply in the electricity market.[16]
- The growth of geothermal deployment has been aided by state Renewable Energy Portfolio Standards (RPS) that require a certain percentage of electricity be derived from renewable sources.[21,26]
- 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 system costs with no upper limits.[28]

Steamboat Hills Geothermal Power Plant[32]
Steamboat Springs, Nevada

- Across the U.S., nearly 850 utilities offer "green pricing" programs that provide consumers with the option to purchase renewably generated electricity at a small premium.[29]
- Many companies purchase renewable energy as part of their environmental programs. Intel, Microsoft, Kohl's, Cisco and Google are the top five users of renewable energy as of April 2016.[30]

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