RACHEL CARSON COUNCIL

Fact Sheet

Turning Up the Heat:
An Introduction to Geothermal Energy

WHAT IS GEOTHERMAL ENERGY?

A geothermal resource refers to heat beneath the earth that can be harnessed either for thermal energy or for electricity production. Many geothermal resources are also hydrothermal resources, or existing reservoirs of geothermal fluid (usually superheated water or steam).

Drilling beneath the surface of the earth can tap this heat, allowing it to be used for heating and cooling either through direct use of hot water/steam, or by using the ground as a heat pump system (**Figure 1**). In these systems, excess heat above ground can be absorbed by the reservoirs when temperatures are warmer, and resources can be used as a source of heat when temperatures are cooler.

Geothermal resources generate electricity by heating steam that spins a turbine connected to a generator – analogous to how coal-fired power plants generate electricity.

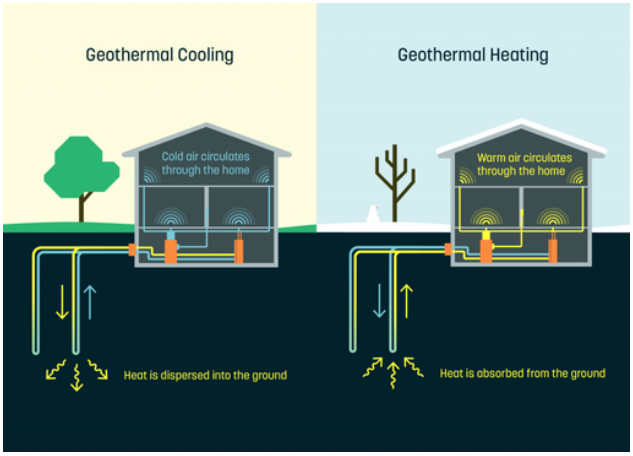

FIGURE 1: How geothermal energy can be used for heating and cooling. *Source: Dandelion Energy, 2024*

While the average capacity of a geothermal power plant is smaller than a gas or coal plant, geothermal plants have higher capacity factors than both fossil fuel plants and other types of renewables, meaning that they run on full output more consistently.[1,2] Geothermal also has one of the lowest lifecycle emission factors of any baseload power source, meaning it is a reliable form of power that emits extremely low amounts of CO2 per MWh generated.[3]

TYPES OF GEOTHERMAL POWER SYSTEMS

Conventional Geothermal Systems (CGS)

- Naturally occurring underground hydrothermal resource is brought to the surface.
- The thermal energy of the resource is used to power turbines for electricity.

Sometimes, significant thermal energy can exist underground, but there is no reservoir of geothermal fluid and/or the surrounding rock is impermeable (liquid cannot pass through easily). In these cases, **enhanced geothermal systems** can be engineered to harness this heat through artificial geothermal fluid/reservoirs.

Enhanced geothermal systems

- Artificial reservoirs are created by fracturing rock, which creates more surface area for fluid to flow and gain heat.
- Like a CGS, the hot water/steam produced by heating the fluid is then used to generate electricity.

The use of conventional geothermal has typically been limited to areas with natural hydrothermal resources and rock that liquids and gases can easily pass through.[4] Enhanced geothermal, on the other hand, can be used in a much wider variety of regions.

Conventional and enhanced systems can also be categorized as **binary** or **flash (Figure 2)**.

- In a **flash (open-loop) cycle**, the geothermal fluid is vaporized and turned into steam, which drives a turbine that generates electricity.
- In a **binary (closed-loop) cycle**, the geothermal fluid is used to heat a secondary fluid, instead of being vaporized directly. Since the secondary fluid has a lower boiling point, the geothermal resource does not have to be as hot to be able to turn it into steam. This secondary fluid then vaporizes and is used to drive the generator turbine.
- In both binary and flash systems, the remaining fluid is reinjected into the ground after use.

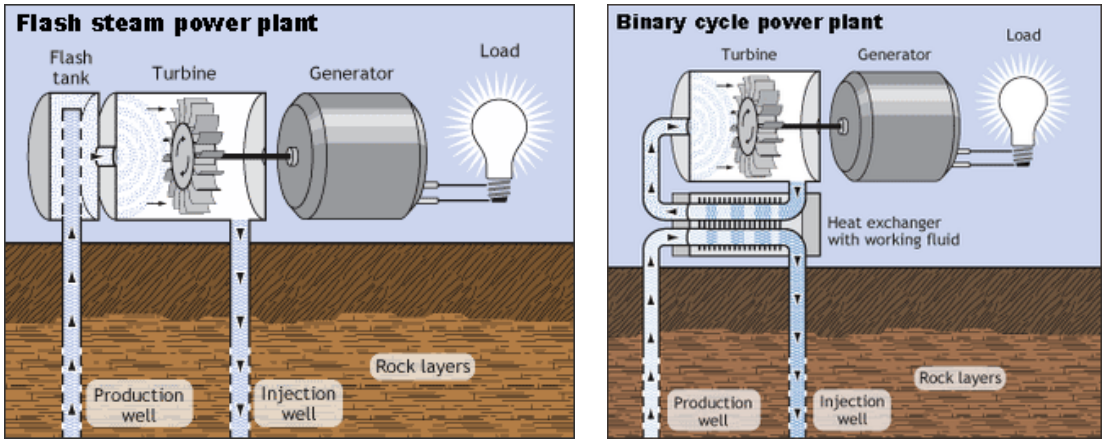

FIGURE 2: Binary vs. flash geothermal systems. *Source: U.S. Department of Energy*

THE FUTURE OF GEOTHERMAL ENERGY

Because it is powered by the heat of the earth, and does not involve the burning of fossil fuels, geothermal power production is considered both clean and renewable.

- Geothermal power plants, on average, emit 99% less carbon dioxide and 97% less sulfur than traditional fossil fuel power plants.[5]
- Geothermal power production still produces small amounts of greenhouse gas emissions, mainly due to the natural presence of carbon compounds in geothermal fluids and surrounding rock that are released during vaporization.[6]
- Systems with closed-loop/binary cycles emit much less greenhouse gases than those with open loop cycles, since the geothermal fluid itself is not vaporized.
- As of 2025, the United States has almost 4,000 MW of installed geothermal electricity capacity, with around 1,000 MW currently in development.[7] This represents approximately 0.3% of total capacity.[8]
- Geothermal as a whole makes up just 1% of global energy demand.[9]
- **Experts from the International Energy Agency predict that geothermal could account for up to 15% of global energy demand by 2050.**

Geothermal energy has the advantage of being “always-on”, since the heat of the earth is continuously flowing. With the development of EGS and other new-generation technologies, we are significantly expanding the geographical availability and scale of this fully renewable and reliable power source.

Americans show relatively low familiarity with geothermal technologies, highlighting the importance of educating the public on its benefits for energy affordability and the environment.[10] Those familiar with geothermal support it overall, but have concerns over risks to communities and landscape disruption. Currently, geothermal expansion faces some barriers to expansion in the form of necessary multi-stage permitting reviews under the National Environmental Policy Act of 1969, as well as overall long development times, as new projects can take up to 10 years to complete.[11]

With continued innovation and expansion, geothermal power production has the potential to become a cornerstone of the United States' baseload power grid, considerably reducing our emissions and accelerating us toward a clean energy future.

ENDNOTES

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