CLEAN AIR TASK FORCE

Water Use and Next-Generation Geothermal

Why next-generation geothermal?

Next-generation geothermal technologies, including Superhot Rock (SHR) geothermal, are poised to play a transformative role in the global energy mix. This technology, in particular, stands out for its potential to deliver cost-competitive, continuous clean power at a scale capable of meeting rising global electricity demand. Next-generation geothermal offers the promise of low-emission, firm electricity that reinforces grid reliability and reduces long-term energy costs. Like any emerging energy technology, next-generation geothermal must address potential challenges—one of which is water requirements.

While water is an essential part of creating some forms of next-generation geothermal energy, there are many innovations in place that help minimize water use. This fact sheet provides clear answers to common questions on water use in next-generation geothermal technologies.

Key Takeaways

- Geothermal systems are designed to recirculate, rather than consume, water.
- The U.S. Department of Energy's (DOE's) GeoVision study found that ~90% of next-generation geothermal energy can be developed using non-freshwater sources (e.g., brackish groundwater or municipal wastewater). For example, the Geysers geothermal field uses recycled wastewater from nearby cities to replace the water lost during operations and maintain the pressure in the reservoir, and none of Fervo's operations require freshwater.
- When using similar equipment on the surface, geothermal systems at higher temperatures consume less water per MWh produced, due to the higher energy density of the geofluid, which allows more energy to be generated with fewer wells and less water.
- According to the U.S. DOE's 2024 Pathways to Commercial Liftoff report on Next-Generation Geothermal Power, next-generation geothermal, which includes enhanced geothermal systems (EGS) and closed-loop geothermal systems (CLGS) (see Fig. 1), could satisfy nearly one tenth of the nation's electricity needs while withdrawing only ~1% of the water that the power sector typically uses.

How does next-generation geothermal work?

Next-generation geothermal works like an underground radiator. Water or another type of fluid (e.g., CO_2) is injected deep into the earth's subsurface, where it absorbs the earth's heat and is returned to the surface to produce clean electricity and heat for existing and novel industrial applications ranging from metal processing to desalination.

Where is water used in next-generation geothermal systems?

There are two types of water use in next-generation geothermal systems:

1. **Water withdrawal**, which includes water that is taken from another source. An example of this is water that is used to fill a swimming pool.
2. **Water consumption**, which is water that cannot be returned to its original source. An example of this is water that evaporates off a swimming pool.

Developers of next-generation geothermal projects have a strong incentive to keep water consumption low, because they pay for what they consume, and any water that goes to waste results in higher costs and less energy created.

Water consumption in next-generation geothermal projects can vary depending on the ease in which the water flows through the surrounding rocks, the geofluid temperature, and the type of power plant and cooling technology used. Most of the water that is initially used to fill the reservoir comes back to the surface and is then reused in a continuous loop, reducing water consumption.

Water use for next-generation geothermal systems can be divided into 3 categories:

3. **Startup – drilling, reservoir stimulation, and circulation testing:** This includes the filling of the system with water and is expected to have a relatively small impact on the total water consumed over the life of the system for EGS (<3%). For example, The Utah Frontier Observatory for Research in Geothermal Energy (FORGE) site successfully completed stimulation and circulation tests in 2024, which used just over 11M gallons (similar to how much water a medium-sized golf course uses in ~1 month) of non-potable water. More than 90% of the fluid was returned in the most recent round of circulation test.
4. **Operational – underground:** In air-cooled binary systems (Figure 1 below), over 90% of water consumption occurs underground in EGS. CLGS purport to reduce belowground water loss to nearly zero.
5. **Operational – aboveground:** The choice of power generation system (i.e., binary versus steam generation) and the cooling technology used (i.e., wet-cooled versus air-cooled) has a large impact on the amount of water consumed. Although binary systems consume less water than steam generation systems, the choice of cooling technology has the largest impact, with a wet-cooled system consuming ~20x the water of an air-cooled system. Air-cooling is more common in binary systems, since air-cooling has a smaller impact on the economics of a binary facility. On the other hand, steam generation systems tend to lean more heavily on water cooling for improved economic efficiency. Most of the water consumed is from the processes on the surface (>90%) when using a wet-cooled steam generation system (Figure 1 below). In contrast, an air-cooled binary system can reduce water consumption by over 1,500 gal/MWh, lowering surface-level water consumption to less than half.

Tradeoffs in water consumption and efficiency

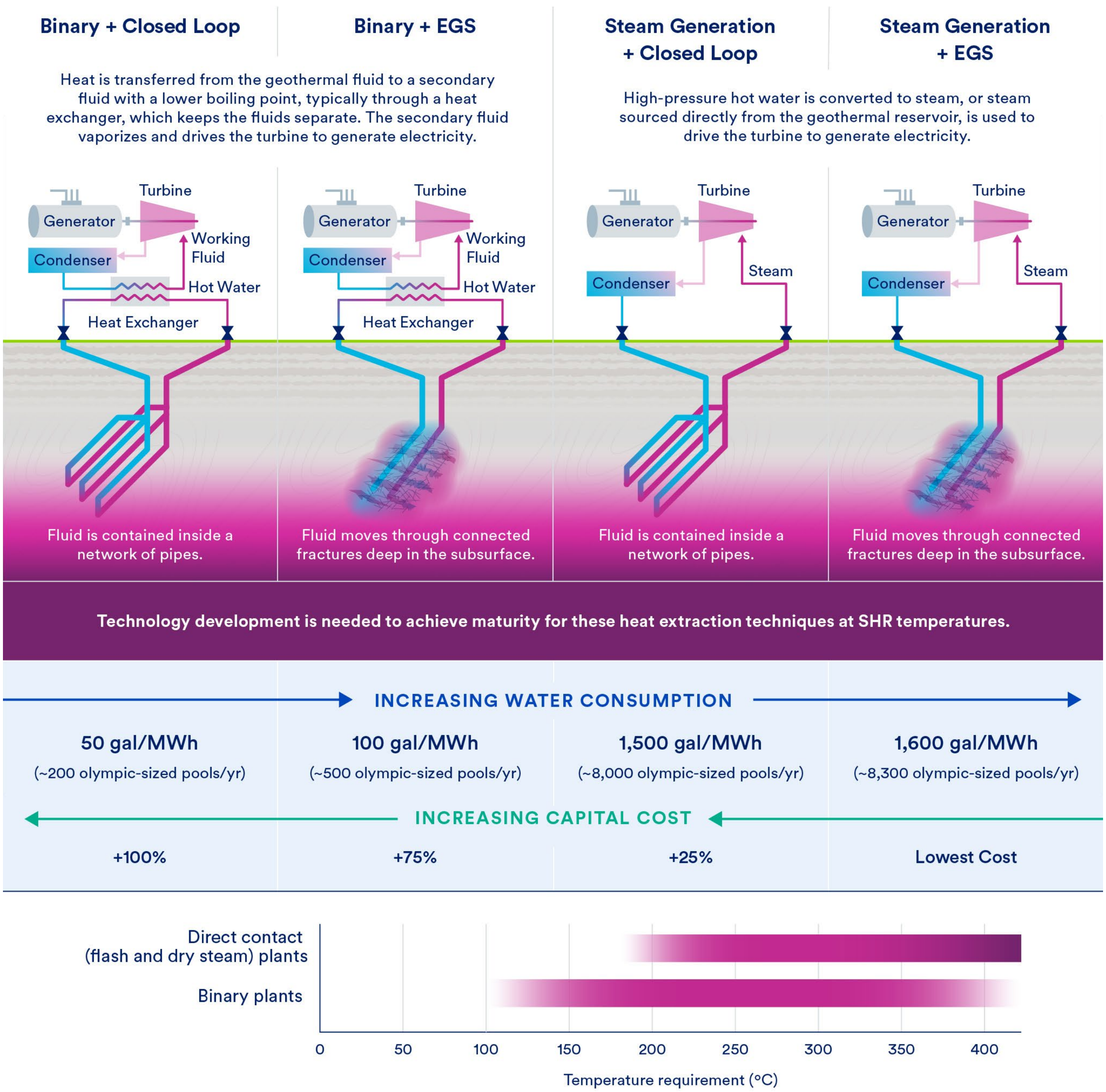
Systems that use air-cooled binary cycle technologies tend to have minimal water consumption – comparable to wind and solar – but are more capital-intensive to build and operate. In contrast, systems that use wet-cooled steam generation typically consume more water due to higher water losses from the surface equipment but offer lower cost per megawatt hour due to their higher thermal efficiency.

The lowest water-consumption systems are air-cooled binary CLGS configurations, while the highest are wet-cooled steam generation EGS, which consume slightly more water than other sources of baseload power.

This trade-off reflects a broader tension: the most water-efficient systems also tend to be the costliest, both to construct and operate – whereas the most water-intensive configurations offer lower costs but raise sustainability considerations in water-constrained regions.

Figure 1: Graphic showing tradeoffs between cost of different next-generation geothermal systems relative to water consumption.

More information about the assumptions and calculations used to create this graphic can be found in Seligman (2025) from the GRC Transactions, which is stored in the Geothermal Library.



How can freshwater requirements be reduced?

Recommendations to Minimize Water Consumption

- Reduce the use of freshwater by providing convenient and low-cost access to alternative water sources such as wastewater, brackish groundwater, and impaired surface waters that aren't clean enough for drinking. The leading next-generation geothermal projects in the U.S., Cape Station and Project Red, use water that is not safe to drink or use for agriculture, so that families and communities still have the fresh drinking water they need.
- Consider deploying CLGS and air-cooled binary technology, which consumes very little water.
- Research and develop cooling technologies to improve performance of geothermal and other baseload energy generation facilities while reducing water consumption.
- Fund next generation projects and laboratory testing to better understand the potential for belowground water loss in different types of rock.
- Increase transparency and reporting on surface equipment, bedrock type, and water usage both above and belowground to better understand next-generation geothermal water requirements.

Harder bedrock with fewer cracks is expected to consume less water. As temperature and pressure increase, the structure of rocks changes, allowing less water to pass through. This means that SHR systems will likely retain more water.

As Nth of a kind (NOAK) next-generation geothermal projects, such as SHR, develop and more learnings are shared, site selection can include regions that require deeper drilling to access geothermal resources, allowing deployment in regions with greater water availability.

For more information, please contact:

Angela Seligman at aseligman@catf.us