Geothermal Water-Energy Nexus

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The Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) projects that geothermal energy generation in the United States will more than triple by 2040. This increase, which translates to more than 5 GW of generation capacity, is anticipated because of technological advances and an increase in available sources through the continued development of enhanced geothermal systems (EGSs) and low-temperature resources. Studies have shown that geothermal electricity generation results in fewer impacts from air emissions, water consumption, and land use than from traditional fossil fuel-based electricity generation. Nevertheless, the long-term sustainability of geothermal power plants can be affected by insufficient replacement of aboveground or belowground operational fluid that was lost as a result of normal operations. Thus, access to water is critical for the increased deployment of geothermal technologies. To date, most active development of geothermal projects in the United States has occurred in the Western part of the country, within states and regions that have traditionally experienced water scarcity issues. Thus, the availability of water has the potential to significantly impact the long-term success of geothermal development. Therefore, understanding the interaction between geothermal energy production and water resources is critical.

How Much Water Does Geothermal Production Consume and How?

	Drilling and Construction	Stimulation	Circulation Testing	Belowground Operational Loss	Cooling-Related Operational Loss	Non-Cooling-Related Operational Loss	**TOTALS**
EGS Binary – Air Cooled	0.79 – 9.0 gal/MWh	1.9 – 32 gal/MWh	1.8 – 29 gal/MWh	190 – 4,100 gal/MWh	0 gal/MWh	40 gal/MWh	235-4100 (44 – 110) gal/MWh
EGS Flash – Wet Cooled	0.40 – 2.0 gal/MWh	0.8 – 4.7 gal/MWh	0.0 – 4.2 gal/MWh	49 – 490 gal/MWh	1,500 – 2,300 gal/MWh	40 gal/MWh	1590 – 2841 (41-51) gal/MWh
Hydrothermal Binary – Air Cooled	0.49 – 2.0 gal/MWh	0 gal/MWh	0 gal/MWh	0 gal/MWh	0 gal/MWh	40 gal/MWh	41 – 42 (41 – 42) gal/MWh
Hydrothermal Flash– Wet Cooled	0.64 – 1.0 gal/MWh	0 gal/MWh	0 gal/MWh	0 gal/MWh	2,500-3,600 gal/MWh	40 gal/MWh	2,500-3,600 (41) gal/MWh

No Water Consumption, Fresh Water Required, Low Quality Water Can Be Used, Geofluid Loss, Total Fluid

Geothermal Life Cycle Stages

Drilling and Construction – Drilling fluid for wells and cement for wells and pipelines.

Stimulation – Water for stimulation of EGS wells

Circulation Testing – Water for testing the connectivity of the enhanced reservoir

Belowground Operational Loss – Water lost to the formation surrounding an artificially created EGS reservoir requiring additional water injection to maintain sufficient production well flow.

Cooling-Related Operational Loss – Cooling water consumed for wet or hybrid cooled systems.

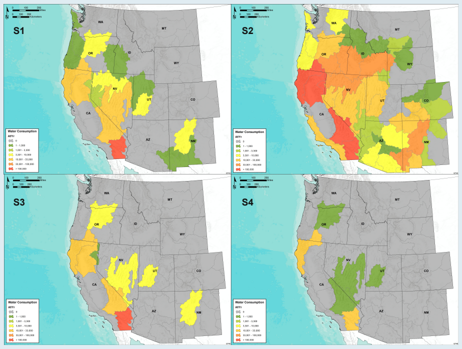
Non-Cooling Related Operational Loss – Water required for regular power plant operations such as dust suppression, maintenance, and domestic needs.

- There is a strong relationship between resource temperature and water consumption for EGS, with higher resource temperatures resulting in lower water consumption due to greater plant efficiency.
- The vast majority of water consumption for both hydrothermal systems and EGS is loss of geothermal fluid either belowground, due to reservoir loss, or aboveground for cooling.
- Although total fluid consumption for most EGS scenarios is quite high relative to most energy systems, with a low of 235 gal/MWh and a high of 4,200 gal/MWh, the consumption of fluid that would typically have to be freshwater for most of the scenarios is approximately 40 to 50 gal/MWh, which is significantly less than most generation technologies and on par with other renewables such as solar and wind.

Where Will Water Stress from Geothermal Be Felt the Most?

Argonne's regional water resource assessment builds upon previous work that explores the geospatial distribution of water demand for future geothermal power production. It combines previous Life Cycle Analysis (LCA) results with a detailed supply curve for geothermal resources developed by the National Renewable Energy Laboratory (NREL), which uses the Geothermal Electricity Technology Evaluation Model (GETEM) to model electricity generation capacity (MWe) and estimate the levelized cost of energy (LCOE) ($/kWh) of geothermal resources.

Scenario	Basis	LCA Scenarios	New Generation (MWe)
1	Resources <$0.10/KWh	Reference	30,000
2	Resources <$0.15/KWh	Reference	58,000
3	NEMS-GPRA 2030	Reference	12,000
4	EIA 2035	Reference	3,900



The general conclusion that can be drawn from this analysis is that over the next 20 to 30 years, the incremental water demand from geothermal is likely to be manageable in most basins.

However, if geothermal technology, especially EGS, continues to improve and become less expensive and the resource base becomes more fully exploited, water conflicts are likely to grow significantly. These conflicts could also be exacerbated if climate change results in reduced water availability in the region in the future.

These potential conflicts, however, may be at least partially mitigated if technological improvements also lead to lower life cycle water consumption or through the use of lower quality, alternative water sources.

Can Alternative Water Sources Be Used To Mitigate Freshwater Consumption?

Estimating the cost of different sources of water in the areas surrounding existing EGS projects in the western United States is important in helping the industry better understand the impacts water availability and the type of water utilized can have on the cost of geothermal projects. Water costs were evaluated at five existing EGS test sites—Brady Hot Springs, Desert Peak 2, the Geysers, Newberry Volcano, and Raft River, using the Argonne Water Cost Model (AWCM). This Microsoft Excel®– based water cost model was designed for easy integration with the GETEM. State regulations regarding the use of alternative water sources were also evaluated.

Water Source	Depth (ft.)	Distance (mi.)	Cost A ($)	Cost B ($)	Cost C ($)
Brady Hot Springs, NV					
Fresh Groundwater	NA	NA	-	-	-
Surface Water	NA	NA	-	-	-
Brackish Groundwater	500	1	358	192	148
Newberry Volcano, OR					
Fresh Groundwater	800	1	451	271	225
Surface Water	0	5	808	384	241
Brackish Groundwater	3,000	1	812	539	473
The Geysers, CA					
Fresh Groundwater	1,000	30	4,540	2,160	1,390
Surface Water	NA	-	-	-	-
Brackish Groundwater	3,000	1	812	539	473
WWTP, Nearest	0	34	4,630	2,060	1,200
WWTP, Furthest	0	74	10,200	4,530	2,650
Raft River, ID					
Fresh Groundwater	NA	-	-	-	-
Surface Water	0	2	382	181	113
Brackish Groundwater	500	1	358	192	148
WWTP, Nearest	0	40	5,350	2,470	1,440
WWTP, Furthest	0	88	10,900	4,840	2,830

- For all locations and plant sizes there appear to be water sources available with costs below the default value of $2000/ac-ft used in GETEM.
- Lower cost water sources vary across the locations and include surface water, groundwater, and brackish groundwater. The use of these lower values would result in slightly lower estimates of LCOE for most power plants.
- Estimated costs for Wastewater Treatment Plant (WWTP) effluent ranged below and above the GETEM default depending upon the scenario, which was driven by the distance from the field to the WWTP and the economies of scale of pipeline transport.
- Given the large impact of economies of scale, costs could potentially be reduced further, especially with respect to transportation from WWTPs, if multiple power plants are built in close proximity to these facilities within the same geothermal area.

Summary of Alternative Water Regulations and Regulatory Agencies in States with Active EGS Development

State	*Types of Alternative Waters Regulated*	*Regulatory Agencies Involved*
California	Treated Wastewater Effluent	California Department of Public Health (CDPH); California State Water Resources Control Board (SWRCB); Regional Water Quality Control Boards (RWQCBs); California Department of Water Resources (CDWR)
Idaho	Treated Wastewater Effluent	Idaho Department of Environmental Quality (IDEQ); Idaho Department of Water Resources (IDWR)
Nevada	Treated Wastewater Effluent; Saline Groundwater (proposed)	Nevada Department of Environmental Protection (NDEP); Nevada Division of Water Resources (NDWR)
Oregon	Treated Wastewater Effluent	Oregon Department of Environmental Quality (ODEQ)

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