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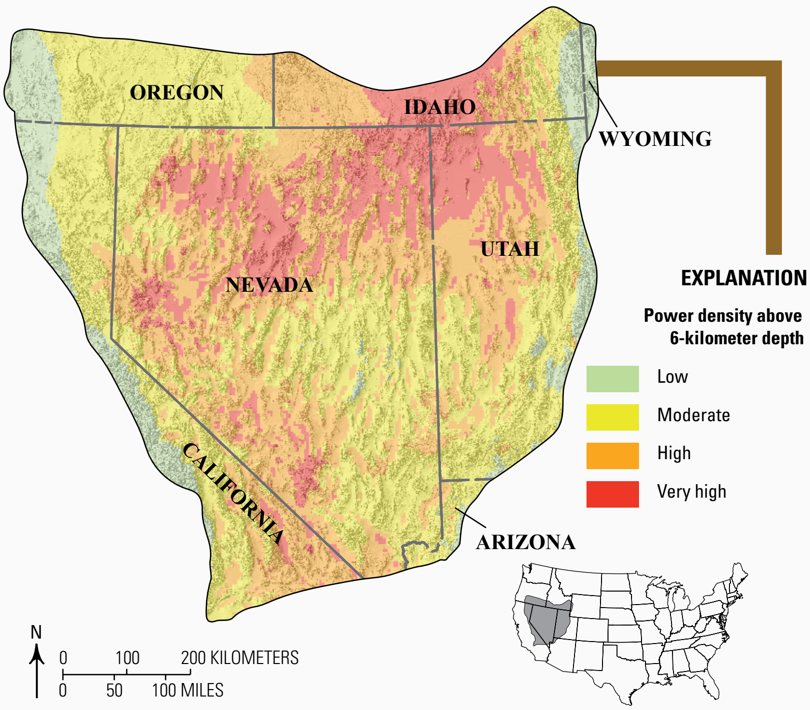
Enhanced Geothermal Systems Electric-Resource Assessment for the Great Basin, Southwestern United States

Abstract

The U.S. Geological Survey recently (2025) completed a provisional assessment of the geothermal-electric resources associated with high-temperature, low-permeability rock formations of the Great Basin, Southwestern United States. If sufficient technological advances to commercialize enhanced geothermal systems occur, then a current best provisional estimate for electric-power generation capacity of 135 gigawatts electric are available from the upper 6 kilometers of the Earth's crust. This estimate is a potential substantial increase of the installed geothermal electricity-generating capacity from <1 to 10 percent of current total U.S. power production capacity.

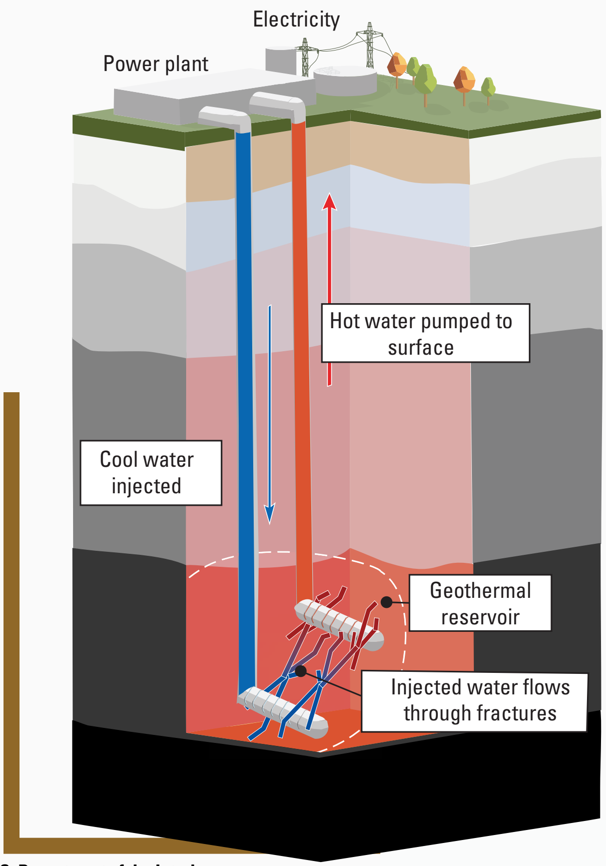


Shaded relief from National Atlas of the United States, 2012.
https://purl.stanford.edu/zz186ss2071
Numeric values for best estimate power density above 6 km from https://doi.org/10.5066/P14LU7WD

Estimated power density map showing how a best-estimated 135 gigawatts electric are distributed across the Great Basin.

Introduction

Enhanced geothermal systems (EGS) are geothermal resources that require some form of engineering to develop the permeability (typically by creating open connected fractures) necessary for the circulation of water through hot crust, which allows extraction of heat for electrical power generation. Although EGS are still relatively few in number and the subject of research, the past several decades have seen an increase in exploration and development. Almost all present-day geothermal-electric production comes from conventional systems that host active, natural hydrothermal circulation. However, such systems are rare and localized compared to the larger volume of hot rock with low permeability, and these low-permeability EGS resources have been estimated to be capable of producing 10 times more electricity than conventional hydrothermal resources. Because the Great Basin of the southwestern United States has high heat flow, the corresponding presence of elevated temperatures at depths where EGS reservoirs might reliably be created is a dominant factor controlling the quality of the resource.



Enhanced geothermal systems extract heat from hot, low-permeability rock by circulating water through engineered fractures. Refer to U.S. Department of Energy Fact Sheet DOE/EE-0785 for more information about enhanced geothermal systems.

U.S. Department of the Interior
U.S. Geological Survey

Fact Sheet 2025–3027
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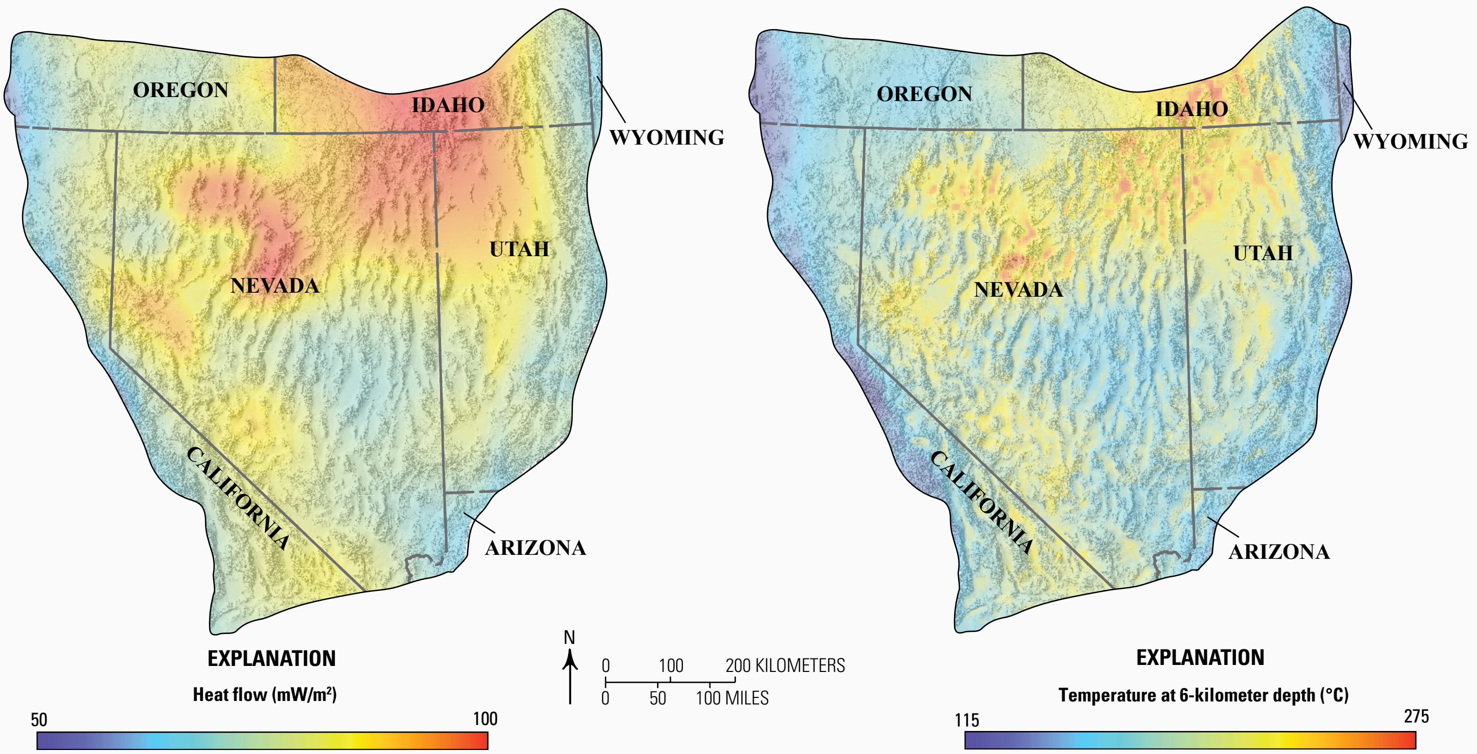


Heat flow map from https://doi.org/10.5066/P9BZPVUC

Shaded relief from National Atlas of the United States, 2012. https://purl.stanford.edu/zz186ss2071

Temperatures at 6 km from https://doi.org/10.5066/P149FR54

A heat flow map (left) of the Great Basin illustrates where heat conduction, in milliwatts per square meter (mW/m²), from the Earth's interior to its surface is the highest. A temperature map (right) shows estimated temperatures, in degrees Celsius (°C), at a 6-kilometer (km) depth above which enhanced reservoirs might reliably be created.

The U.S. Geological Survey (USGS) last assessed the electric power generation potential of high-temperature (>150 ºC) EGS resources in the western conterminous United States in 2008 (refer to USGS Fact Sheet 2008–3082). Updates of geothermal energy assessments by the USGS occur when warranted by new technologies or sufficient additional or refined data and scientific understanding. The Energy Act of 2020 directed the USGS to complete new or updated assessments for geothermal resources (including EGS) for the conterminous U.S., Alaska, Hawaii, and Puerto Rico.

Since the 2008 assessment, the Great Basin has been the focus of many conventional geothermal and EGS studies at a wide range of scales. In addition to research to enhance subsurface permeability and increase fluid flow, the USGS and its partners created the following necessary components to update the 2008 EGS assessment for the region:

- updated heat flow maps,
- updated underground temperature maps, and
- new methods to estimate
  - energy extraction efficiency for different fracture geometries and
  - conversion of thermal energy to electricity.

In contrast to the previous EGS assessment, electric power production potential is provisionally estimated herein for all electric-grade temperatures greater than 90 °C.

Why is the EGS Resource Assessment Provisional?

USGS conventional geothermal-resource assessments quantify the likely energy production, which is a best estimate of the expected quantity (including uncertainty) of conventional resources that have a history of widespread development and have been proven to be both technically and commercially recoverable. Conversely, the technology in use for EGS is still being developed and has not been widely (geographically) adopted enough that records of production can be used to estimate energy production and associated uncertainty. Research continues to identify the range of geologic conditions and engineering strategies that could result in economically viable EGS power plants. A provisional assessment assumes that technologies will evolve and perform as anticipated or projected.

The provisional assessment of EGS resources defines the term "accessible electric-grade resource base" as the thickness of rock shallower than 6 kilometers (km) with temperatures high enough to produce electricity. The term "useful resources" refers to accessible resources that will be economically competitive with other sources of electricity, and the term "residual" is the remainder of the accessible electric-grade resource base. To provide regional estimates of EGS electric-power resources, this provisional geothermal resource assessment uses industry operational knowledge of converting geothermal heat to electricity, an understanding of anticipated geology-dependent fracture-length and fracture-spacing, and three-dimensional temperature maps representing Great Basin recoverable heat.

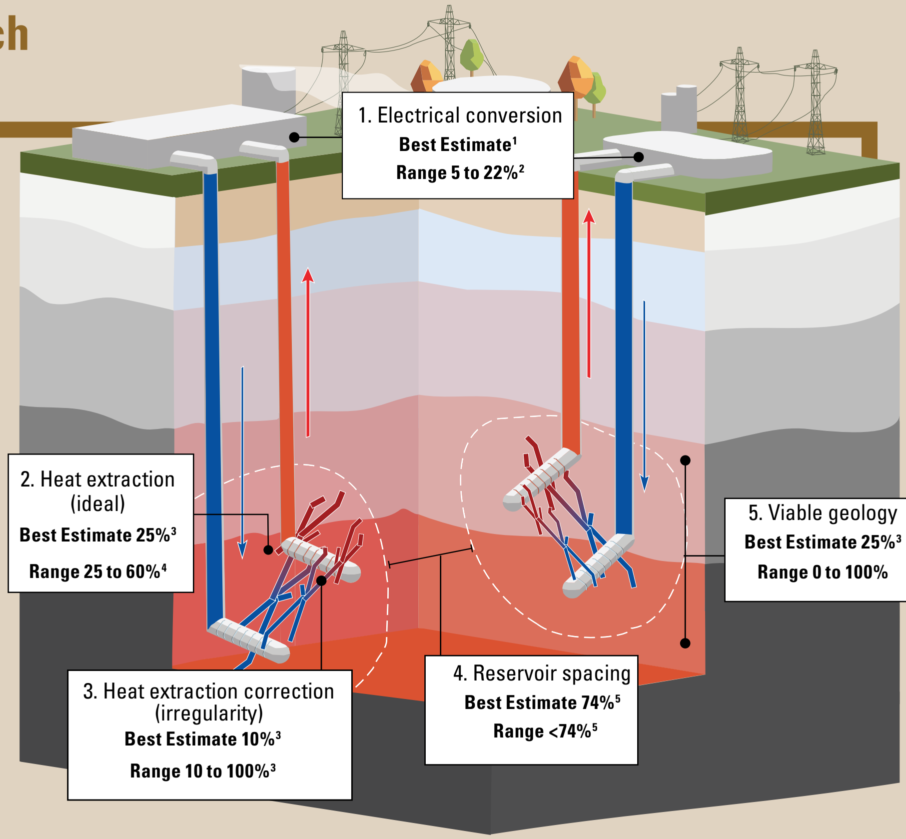
Resource Estimates

If EGS technology research is successful at achieving the best estimates of efficiencies, then cumulative EGS power production resource estimates are a function of depth, and most of the resource occurs in deeper and hotter rocks. Because depths greater than 6 km may require additional technological advances, the current best provisional estimate for total EGS power production capacity of the Great Basin (an area of 633,072 square kilometers) is 135 gigawatts electric (GWe), or 0.5 percent of the accessible electric-grade resource base (that is, the useful resource), which leaves 99.5 percent of the thermal energy as residual. Thermal resources from elevated-temperature rock near active hydrothermal systems comprise less than 1 percent of the total rock volume and are not included in this estimate. The new estimate of EGS resource potential is consistent with the 518 GWe previously estimated in the 2008 geothermal assessment for the upper 6 km of the larger western United States assessment area (~3 million square kilometers), in which 150 GWe was estimated in Nevada and Utah alone.

Continued technological improvements may greatly increase the possible power production by EGS and may yield more than ten times the current best estimate, which corresponds to a 5 percent useful resource. Although extreme values of production efficiencies are unlikely, they provide upper and lower limits of the resource and range from near zero (if a vanishingly small fraction of the geology is appropriate for EGS) to 44 percent of the resource base being useful. The upper limit corresponds to power production of 13 terawatts-electric (approximately ten times the current U.S. power generation capacity). Power production could also be increased by improving the electric plant conversion efficiencies, but such improvements are not considered here.

Factors That Affect How Much of the Resource is Useful

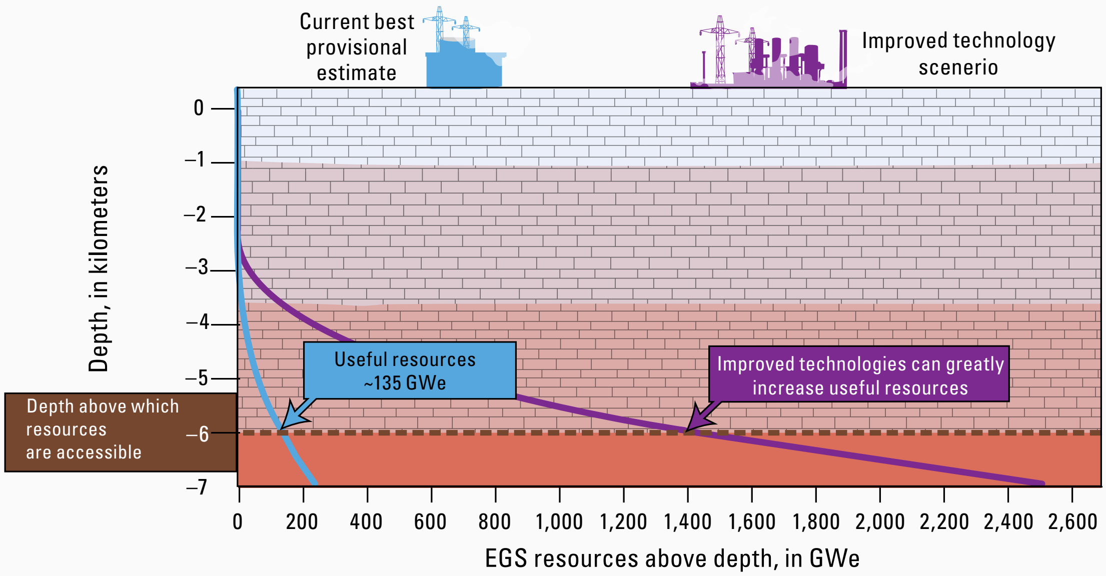
Electricity can be produced from hot rock with sufficient heat to boil water or other power-plant fluids. The total amount of energy that can be extracted from hot rock and converted into electricity can be quantified as a series of efficiencies (represented by percentages) that can be multiplied together to get the net electricity produced. For example, if 50 percent of thermal energy within the rock can be extracted to boil a working fluid (that is, the useful resource), and 20 percent of that extracted thermal energy can be converted from thermal to electrical energy, then electricity produced (in units of megawatt-electric) can be estimated as 10 percent (that is 50 percent times 20 percent) of the available electric-grade thermal energy in the rock. The provisional estimates of EGS electrical power producing resource consider the following efficiencies, which have a range of uncertainties and best estimates:



Efficiencies and factors are multiplied together to estimate the net efficiency of electric power production from geothermal heat in place.

[1]Model fit to data in tables 4–6 of https://doi.org/10.1016/j.geothermics.2013.11.001
[2]Range estimated from data in tables 4–6 of https://doi.org/10.1016/j.geothermics.2013.11.001
[3]Estimate from https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2025/Burns.pdf
[4]Range estimate for range of well- and fracture-spacing from https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2025/Burns.pdf
[5]Closest spacing without thermal interaction from https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2025/Burns.pdf

1. **Electrical conversion**—Ratio of electric power generated to heat extracted from the working fluid.
2. **Heat extraction (ideal)**—Ratio of heat extracted from a fractured reservoir to total electric-grade heat in the rock in ideal conditions.
3. **Heat extraction correction (irregularity)**—Factor that lowers ideal heat extraction efficiency to account for irregularities of fractures and heterogeneity of rock.
4. **Reservoir spacing**—Percentage of a given geologic unit that can be used as a geothermal reservoir. The closest spacing where reservoirs do not thermally interact is 74 percent but could be higher if thermal interference is allowed.
5. **Viable geology**—Percentage of all geologic units that can be engineered for enhanced geothermal systems. Although few sites in the Great Basin have successful created EGS reservoirs, the actual percentage is likely greater than zero, but this factor is the most uncertain.



The current best provisional estimate for total enhanced geothermal systems (EGS) power production capacity is 135 gigawatts electric (GWe) above 6 kilometers depth (blue); however, a scenario in which technological advances continue (purple) to increase efficiencies of viable geology from 25 to 50 percent, increase reservoir size and fracture density so that ideal heat extraction improves from 25 to 65 percent, and heat extraction correction from 10 to 20 percent yields more than 10 times the current best estimate.

Estimation of uncertainty allows understanding of how low or high the true value might be relative to the best estimate. In the 2008 assessment, EGS power-production uncertainty was split into two parts: the uncertainty related to the underlying models of temperature and other physical parameters, and the uncertainty related to how much of the geology could be successfully developed with EGS technologies. In 2008, uncertainty related to temperature and other physical parameters was ~45 percent, and current underlying model uncertainty is similar. In contrast, uncertainty related to how much of the geology could be successfully developed could easily exceed 1,000 percent. Given current limitations on the understanding of EGS resources, uncertainty is dominated by factors of heat extraction efficiency and viable geology. In practical terms, these factors correspond to reliably predicting EGS reservoir properties that are likely to result from a suite of engineering strategies, and the ability to predict locations in the subsurface where favorable geologic units exist under favorable stress conditions. As technologies are demonstrated and understanding of three-dimensional geology is improved, uncertainty will decline. If technologies continue to improve, then viable EGS resource estimates will increase because more heat is accessible for the generation of electricity.

Acknowledgments

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Additional Resources

Additional resources support the factual statements made herein.

Energy Act of 2020—https://www.directives.doe.gov/ipt_members_area/doe-o-436-1-departmental-sustainability-ipt/background-documents/energy-act-of-2020

What are enhanced geothermal systems?

U.S. Department of Energy Fact Sheet DOE/EE-0785—https://www.energy.gov/sites/prod/files/2016/05/f31/EGS%20Fact%20Sheet%20May%202016.pdf

U.S. Geological Survey 2008 geothermal resource assessment of the United States:

U.S. Geological Survey Fact Sheet 2008–3082—http://pubs.usgs.gov/fs/2008/3082/

Underground temperature and heat flow maps:

Updated three-dimensional temperature maps for the Great Basin, USA—https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2024/Burns.pdf

Three-dimensional temperature model of the Great Basin, USA—https://doi.org/10.5066/P149FR54

Heat flow maps and supporting data for the Great Basin, USA—https://doi.org/10.5066/P9BZPVUC

Maps of conductive heat flow in the Great Basin, USA; separating conductive and convective influences—https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2023/Deangelo.pdf?t=1674862190

Methods for assessing geothermal resources:

Data for the enhanced geothermal systems (EGS) electric-resource assessment for the Great Basin, USA—https://doi.org/10.5066/P14LU7WD

Update of the 2008 provisional enhanced geothermal systems assessment for the Great Basin, USA—https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2025/Burns.pdf

Methods for regional assessment of geothermal resources—https://digital.library.unt.edu/ark:/67531/metadc1208202/

Developing improved methods for the assessment of enhanced geothermal systems—https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2015/Williams.pdf

Review of the state of EGS technologies (2025):

Enhanced geothermal systems for clean firm energy generation—https://doi.org/10.1038/s44359-024-00019-9

Operating power plant efficiencies:

Efficiency of geothermal power plants; a worldwide review—http://doi.org/10.1016/j.geothermics.2013.11.001

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