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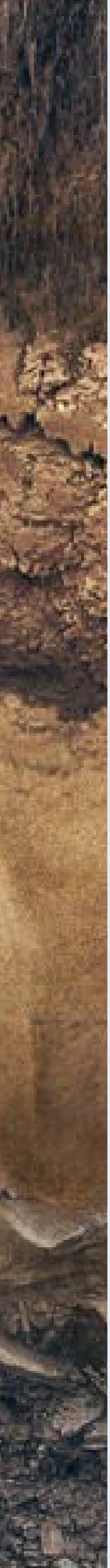
Geothermal Power: Overview and Considerations for State Policy, Planning, and Market Advancement



Geothermal Power: Overview and Considerations for State Policy, Planning, and Market Advancement

Contents

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Aerial view of a Geothermal power plant in the desert landscape of Nevada near Reno.

Introduction

Geothermal energy: it is old and it is new. People have long made use of the Earth's heat, including, since the early 20th century, for generating electricity. However, past technologies only enabled power production from relatively few geographic areas where sufficiently hot rock is adequately infused with water to produce useful steam. Today, new technologies allow vast expansion in the potential for geothermal energy to meet growing demand for dependable 24/7 clean power across diverse regions of the United States and the world. Many of the relevant technologies, along with expertise and supply chain capabilities, derive from the oil and gas industry where the United States has been a leader.[1] This report outlines these emerging opportunities and their potential with a focus on State and Territory Energy Offices[2]. State Energy Offices, through their policy, planning, and program interests and roles, can help advance new geothermal power generation to support state economic development, energy affordability and reliability, and environmental stewardship objectives.

What is Geothermal Power and Energy? Applications, Technologies, and Resources

Geothermal energy is, simply, heat from the earth.

This report focuses on geothermal energy for electric power generation. This is in contrast to direct use of geothermal energy for water heating and space conditioning in buildings and for some industrial processes, as well as use of ground-source heat pumps for heating and cooling. There are other geothermal energy applications, including innovative ideas for energy storage, and there is intriguing opportunity for tapping potentially large geologic hydrogen resources. (See Box 1. Direct Use, Ground-source Heat Pumps, and Other Geothermal Approaches and Box 2. Geologic Hydrogen and Complementarities with Geothermal Power.) Also, there can be opportunities for co-production of critical minerals and materials, such as lithium.[3]

Conventional, or hydrothermal*,* geothermal power generation has been commercial since 1904 when a generating plant opened in Italy. Hydrothermal power depends on the presence of underground hot water (above about 90° C or 194° F) that can be tapped to make steam or vaporize a secondary fluid to run a turbine.[4, 5] The United States began hydrothermal power generation in 1960 at The Geysers field in northern California, which is the world's largest geothermal power complex. Today, the United States is the world's largest hydrothermal power generator with 93 power plants rated at almost 3.7 gigawatts (GW) of nameplate installed capacity in California, Hawaii, Idaho, Nevada, New Mexico,

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1 U.S. Congress, Congressional Research Service, *Oil and Gas Technology and Geothermal Energy Development* (January 31, 2023), R47405 https://www.congress.gov/crs-product/R47405.

2 Henceforth, the term State Energy Office includes the Territory and District of Columbia Energy Offices.

3 For example, significant work is under way to develop ways to extract lithium from geothermal brines, including from California's Salton Sea. See U.S. Department of Energy, Can Geothermal Energy Solve the Lithium Shortfall? https://www.energy.gov/eere/geothermal/articles/can-geothermal-energy-solve-lithium-shortfall.

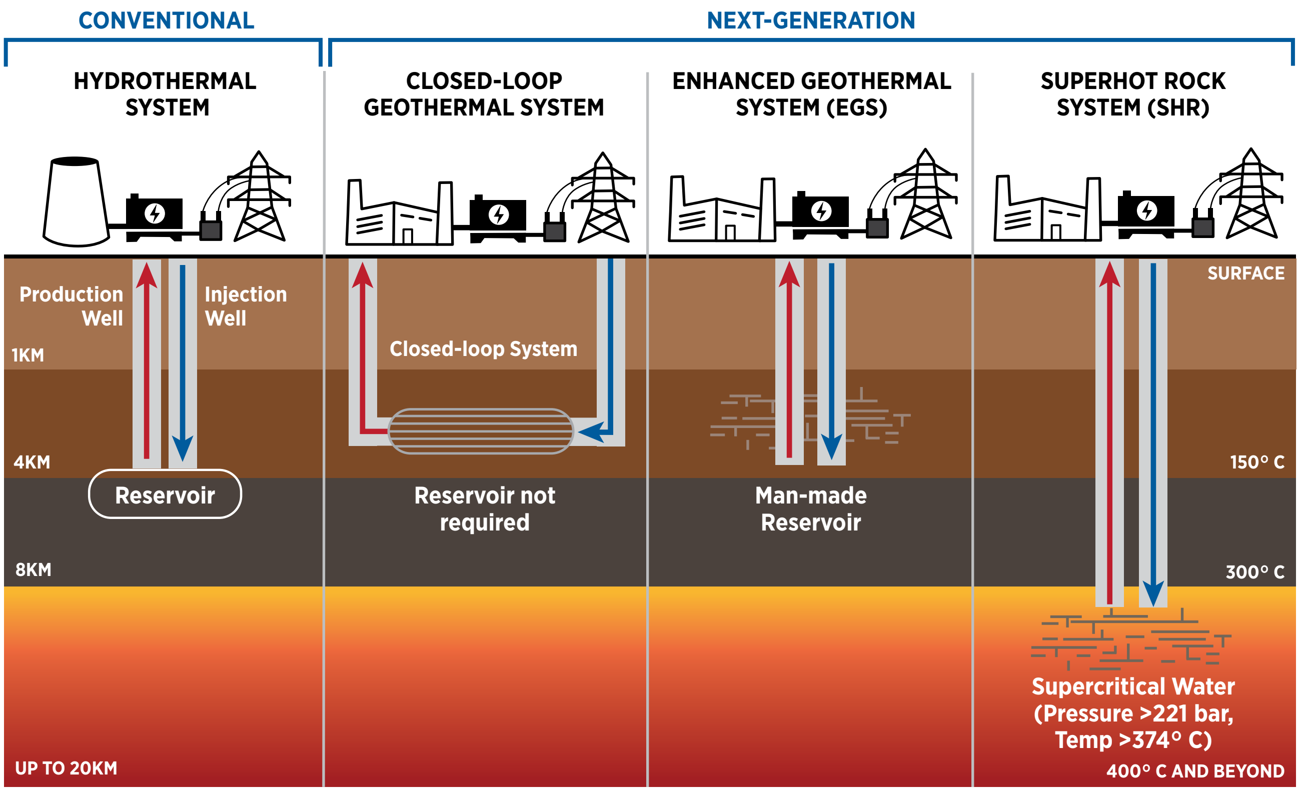
4 Dry steam plants use steam from the earth directly to drive a generator turbine. Flash steam plants collect high-pressure hot water, which is converted to steam to run a turbine, then condensate is reinjected into the earth. Binary-cycle plants used for both conventional and next-generation geothermal energy transfer heat from the collected hot water to boil another fluid in a separate loop whose vapor is used to drive a turbine. The secondary fluid may be organic with a boiling point lower than water, allowing more effective recovery of power from lower to medium temperature geothermal heat. Such plants are said to employ the organic Rankine cycle.

5 U.S. Department of Energy, Geothermal Technologies Office (GTO), Electricity Generation https://www.energy.gov/eere/geothermal/electricity-generation.

Oregon, and Utah.[6] The identified potential of hydrothermal power in the United States is approximately 9 GW, with about 23 GW of estimated undiscovered resources.[7]

The U.S. Department of Energy (DOE) identifies two major categories of emerging next-generation geothermal technologies while some also add a third category (see Figure 1).[8, 9] DOE estimates that next-generation geothermal technologies expand U.S. geothermal power generation potential over 100-fold to more than 7,000 GW, still mostly in the West but with hundreds of gigawatts possible in the Eastern United States.[10] However, based on techno-economic factors, DOE estimates that hydrothermal plus next geothermal energy systems may be able to provide 38.3 GW to the U.S. grid by 2035 and 90.5 GW 2050.[11]

Figure 1. Major categories of geothermal power generation



Source: Derived and modified from D'avack, F. and M. Omar, "Infographic: Next Generation Technologies Set the Scene for Accelerated Geothermal Growth," *S&P Global Commodity Insights* (2024), https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/011124-infographic-next-generation-technologies-set-the-scene-for-accelerated-geothermal-growth-energy-transition

6 Robins, J., at al. (National Renewable Energy Laboratory), *2021 U.S. Geothermal Power Production and District Heating Market Report* (2021) https://www.osti.gov/biblio/1879171.

7 Augustine, C., S. Fisher, J. Ho, I. Warren, and E. Witter (National Renewable Energy Laboratory), *Enhanced Geothermal Shot Analysis for the Geothermal Technologies Office* (2023), NREL/TP-5700-84822. https://www.nrel.gov/docs/fy23osti/84822.pdf, p.11.

8 As an emerging, innovative area, categories and nomenclature of geothermal technologies and approaches vary. For example, categories cited here differ somewhat from those found in University of Texas at Austin Energy Institute, *The Future of Geothermal in Texas*, https://energy.utexas.edu/research/geothermal-texas.

9 McBride, M., et al., *Unlocking Global Geothermal Energy: Pathways to Scaling International Deployment of Next Generation Geothermal* (July 2025), Carnegie Endowment for International Peace https://www.google.com/url?sa=t&source=web&rct=j&opi=89978449&url=https://carnegie-production-assets.s3.amazonaws.com/static/files/McBride%2520et%2520al_Geothermal%2520Energy_final-3.pdf&ved=2ahUKEwi3rKrok7WOAxWaLFkFH-dtwE6kQFnoECBoQAQ&usg=AOvVaw1dCbwYGHiBe5BC1vO7Qing.

10 Augustine, et al., op cit., p. 11.

11 Ibid. p. 16. Table 4.

Enhanced geothermal systems (EGS), sometimes called engineered geothermal systems, employ hydraulic fracturing (fracking) and horizontal drilling techniques developed for the oil and gas sector to fracture impermeable hot rock. Water is injected through one well, absorbing heat as it permeates through the fractured hot rock, then is collected by a second well, with heat recovered to make steam or vaporize a secondary fluid to drive a turbine. The water is then reinjected into the first well, creating a loop. The depth of EGS wells vary but would typically be in the 4,500 to 12,000-foot (1,370 to 3,660 meters) range. EGS research, development, and demonstration (RD&D) goes back to the 1970s and, again, draws on oil and gas sector expertise. DOE supports, with industry and academic partners, the Frontier Observatory for Research in Geothermal Energy (FORGE) in Milford, Utah as a dedicated field laboratory to research and advance EGS commercialization.[12] One industry EGS project example is Fervo Energy's 3.5-megawatt (MW) pilot plant in northern Nevada completed in 2023. The company is building a second plant near the Utah FORGE site, with an expected 10 MW, to open in 2026 and a full build-out capacity of 400 MW planned.[13]

The second next-generation geothermal approach is closed-loop geothermal systems, which some call advanced geothermal systems (AGS) (confusingly, as EGS is also an "advanced" approach). Here the heat transfer fluid is confined to pipes and is not injected into the open underground environment. There are multiple closed loop configurations. One is a coaxial system with single boreholes used for both injecting and recovering fluid — a pipe within a pipe. This is XGS Energy's approach for a planned project in New Mexico in partnership with Meta.[14] Another is a U-tube approach where fluid is injected through one borehole, flows confined within tubes, then is recovered as hot fluid through a second borehole. The bottom of the "U" may actually consist of multiple branches to increase the surface area available for fluid to absorb heat from surrounding rock. The closed loop approach may require drilling deeper to hotter rock than required for EGS because of limited heat transfer surface. Eavor Technologies has a demonstration site in Alberta (Canada) and tested deep drilling in New Mexico. The company is developing a commercial demonstration in Geretsreid, Germany that will drill to a depth of about 4,500 meters (about 2.8 miles) and will be designed to generate 8.2 MW of electricity and provide 64 MW of thermal output for district heating of 20,000 homes by 2027.[15]

Considered by some a third category, but essentially being more difficult applications of EGS and closed-loop geothermal systems, is superhot rock (SHR) or supercritical geothermal. Still at an early stage of research and development (R&D), SHR geothermal draws heat from rock above 375° C (707° F) where the combination of temperature and pressure puts water into a supercritical state. Much larger amounts of energy can be extracted from a given volume or mass of supercritical water than at lower, subcritical temperatures.

There are some places where SHR is at relatively shallow depths, comparable to other geothermal and sometimes oil and gas wells. For example, with DOE support, Mazama Energy is piloting SHR EGS at the Newberry Volcano in Oregon, where 320° C (608° F) can be reached at 3000 m depth and higher than 400° C (752° F) may be accessed at less

[12] Utah FORGE, https://utahforge.com/.

[13] Penrod, E., "Cape Station may be world's most productive geothermal system to date: Fervo," *Utility Dive* (Sept. 12, 2024), https://www.utilitydive.com/news/cape-station-enhanced-geothermal-utah-fervo-blm-lease/726796/.

[14] Office of the Governor (New Mexico), "Governor announces XGS Energy, Meta geothermal partnership – Nation-leading 150 MW geothermal project on its way to New Mexico" (June 12, 2025), https://www.governor.state.nm.us/2025/06/12/governor-announces-xgs-energy-meta-geothermal-partnership-nation-leading-150-mw-geothermal-project-on-its-way-to-new-mexico.

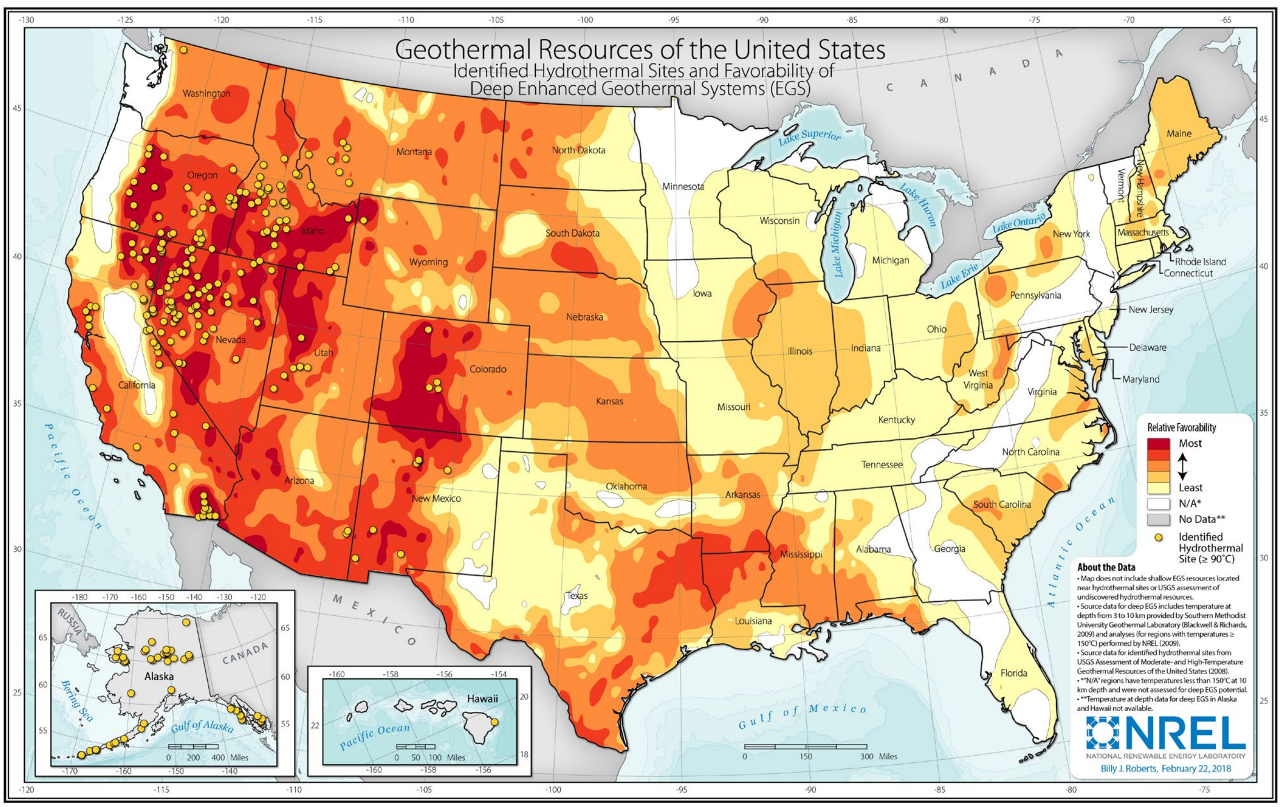
[15] Carlaga, C., "Eavor targets geothermal power production at Gerestried site by 1H 2025," *Think Geoenergy* (Jan. 7, 2025), https://www.thinkgeoenergy.com/eavor-targets-geothermal-power-production-at-gerestried-site-by-1h-2025/.

than 5000 m depth.[16] However, generally SHR is found in very deep rock (often 10 km or more deep), beyond the range of conventional drilling and also requiring new approaches to keep boreholes open and operating. At least two firms, Quaise Energy and GA Drilling, are working on ultra-deep boring approaches involving directed energy to bore and even melt and vaporize rock.[17]

As discussed later, all forms of next-generation geothermal energy extraction would benefit from improved technologies and techniques for site characterization; understanding heat reservoirs and flows; drilling (including speed and material durability and performance); and casings and cements, among other things, though each form of next-generation geothermal system also has its own particular challenges.

Figure 2 is a map of the U.S. geothermal resources indicating known hydrothermal sites (resources greater than 90° C) and relative regional favorability for EGS at 3 to 10 km depths. However, resource estimates are not well developed for much of the Eastern and Central states, Alaska, and Hawaii.

Figure 2. Geothermal Resources of the United States



Source: National Renewable Energy Laboratory, https://openei.org/w/images/a/a1/GeothermalPotential.jpg.

New and renewed attention to geologic energy resources has also opened growing interest and attention to potentially very large, but uncertain, opportunities for recovering hydrogen directly from underground as geologic hydrogen. (See Box 2.)

[16] Mazama Energy, Newberry, https://mazamaenergy.com/newberry/.
[17] Quaise Energy, https://www.quaise.com/, and GA Drilling, https://www.gadrilling.com/.

Box 1. Direct Use, Ground-source Heat Pumps, and Other Geothermal Approaches

Direct use geothermal energy sometimes draws heat from hot springs and can include deeper resources.[a, b] Also distinct from geothermal power generation is geothermal heating and cooling of buildings (including homes), campuses, and communities through the use of heat pumps to transfer heat to and from relatively shallow ground (a few to hundreds of feet or meters in depth) and distribute it via thermal energy networks. The ground can also be used as a thermal (including cooling) storage medium for buildings and other facilities, such as for data centers and some industrial processes.[c] While these geothermal energy applications do not generate electricity, their efficiency, energy storage capability, and demand flexibility characteristics can moderate total and peak power demand and shift the timing of demand, making them important to meet growing power needs affordably, reliably, and cleanly. Also, it is possible to have geothermal combined heat and power (CHP, also called cogeneration), where electric power is generated and heat is used directly by buildings, communities, or industry.

There are other innovative geothermal technologies and applications, such as energy storage as pressurized water underground, that can also support electricity system needs but are not covered here.[d] However, this report touches on nascent, intriguing possibilities for applying new geothermal technologies to tap potentially very large geologic hydrogen resources (see Box 2).

[a] For example, starting with two wells drilled in the 1890s, Boise, Idaho now hosts the nation's and one of the world's largest system of geothermal district heating, encompassing an estimated 7.4 million square feet of buildings. (Mink, L.L., *The Nation's Oldest and Largest Geothermal District Heating System*, GRC Transactions, Vol. 41 (2017), https://publications.mygeoenergynow.org/grc/1033718.pdf

[b] For example, see Cornell University, Deep Geothermal Heat Research, https://deepgeothermalheat.engineering.cornell.edu/

[c] U.S. Department of Energy, Reservoir Thermal Energy Storage, https://www.energy.gov/eere/geothermal/reservoir-thermal-energy-storage

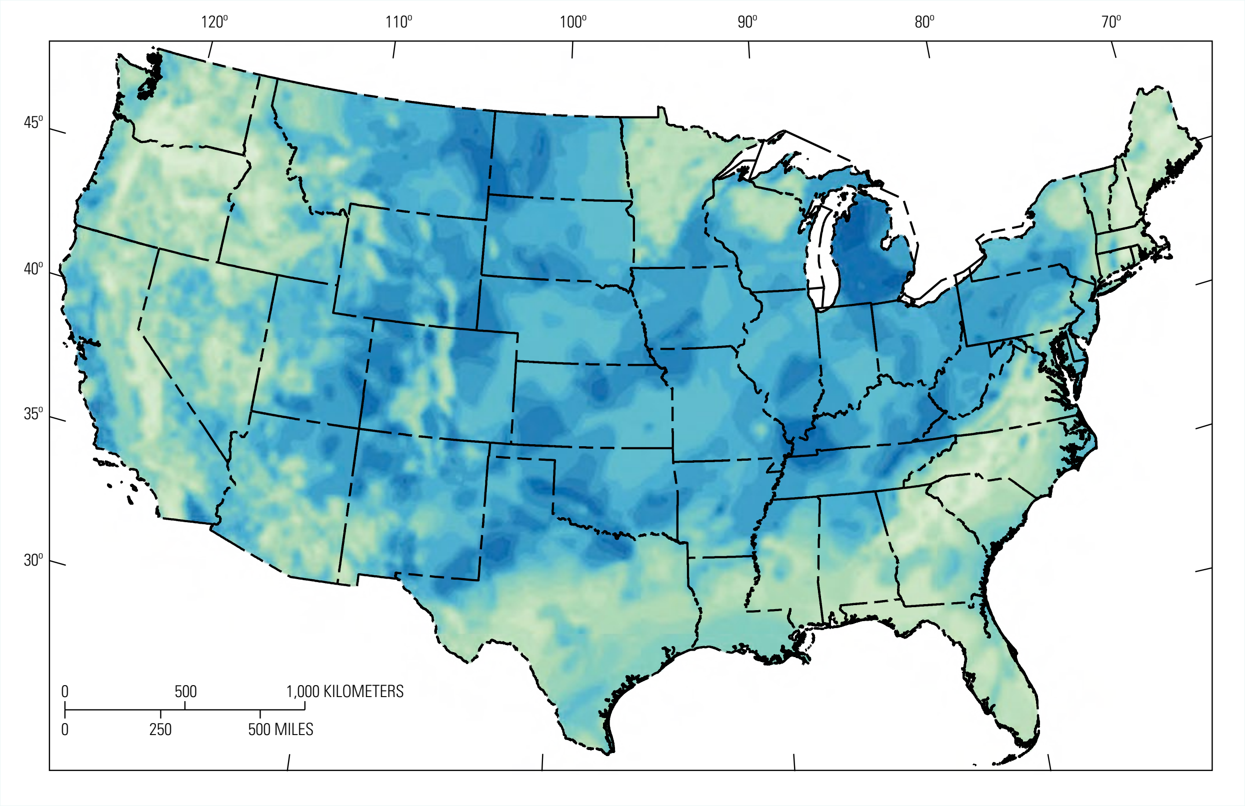
[d] Karaim, R, "Tech Insights: Geothermal Storage," *Rural Electric Magazine* (January 9, 2025) https://www.cooperative.com/remagazine/articles/Pages/Tech-Insights-Geothermal-Storage.aspx - this article discusses an agreement between San Miguel Electric Cooperative (Texas) and Sage Geosystems to develop a three megawatt Earthstore system that will store excess renewable generation as pressurized water underground.

Box 2. Geologic Hydrogen and Complementarities with Geothermal Power[a]

In the 1980s, a water drilling operation in the African nation of Mali instead hit a hydrogen-rich gas deposit that was later tapped to run a small generator to provide clean electricity locally. The nearly pure hydrogen found at the site was generated underground through natural geochemical processes, raising hope that there may be other such accessible deposits, perhaps abundantly so, awaiting exploitation as clean energy sources.

Billions or even trillions of tons of hydrogen gas may be present in the Earth's crust, but mostly in accumulations and concentrations infeasible to tap.[b] In principle, if even a small percentage of the total is feasibly recoverable, the amount could meet the world's annual energy and industrial hydrogen demands many times over. Great uncertainty is accompanied by even larger potential for such geologic hydrogen — both the recovery of naturally produced hydrogen and the possibility of stimulating hydrogen production by injecting water into suitable formations of certain iron-rich rock. Although imprecise, initial geologic mapping suggest promising conditions in multiple regions of the United States for hydrogen prospecting, which some companies are actively pursuing.

Figure 3. Prospectivity Map of Geologic Hydrogen in the Contiguous United States



Source: U.S. Geological Survey in Gelman, S.E., J.S. Hearon, and G.S. Ellis, 2025, *Prospectivity mapping for geologic hydrogen* (ver. 1.2, January 22, 2025): U.S. Geological Survey (USGS) Professional Paper 1900, https://doi.org/10.3133/pp1900. See also USGS Geologic Hydrogen page https://www.usgs.gov/centers/central-energy-resources-science-center/science/geologic-hydrogen. Prospectivity refers to the degree to which all major components necessary for a hydrogen accumulation are likely present. Darker blue shades denote greater prospectivity.

Some project the cost of natural hydrogen recovery at $0.40 to $0.80 per kilogram (kg) and stimulated geologic hydrogen at $0.80 to $1.50 per kg.[c] These costs compare favorably with the $1 to $2 per kg cost of hydrogen conventionally produced from natural gas via steam methane reformation (SMR) and are much cheaper than “blue” hydrogen (SMR with carbon capture and storage) or any form of electrolytic hydrogen (including “green” and “pink” from renewable and nuclear power, respectively). Beyond energy uses, abundant hydrogen could advance the performance and competitiveness of multiple industries, such as nitrogen fertilizer and iron and steel production.

What does this have to do with geothermal power generation? Both draw on world-class U.S. geoscience capabilities from government, academia, and private sector oil and gas and mining sectors. Both build on leading American oil and gas industry technical expertise, including for hydraulic fracturing, underground fluid management, and directional drilling. Both benefit from strong, capable oil and gas-related workforces and supply chains. And there can even be opportunities for developing co-located EGS and geologic hydrogen projects.

While next-generation geothermal and geologic hydrogen development face some differing hurdles, they also face some related challenges. These include concerns about possible groundwater and seismic impacts; rights and liabilities for subsurface resources that do not fit traditional categories (water, minerals, or oil and gas); and permitting and siting processes that may not necessarily be well-suited to new technologies and resource types.

State Energy Offices, governors, legislators, and other relevant state policy, planning, and regulatory actors encounter similar and related opportunities, challenges, and considerations in approaching these new possibilities to advance state economic development, energy reliability and affordability, and environmental objectives.

[a] This section draws extensively from EFI Foundation, *Exploring the Future of Geologic Hydrogen: Defining the Path Ahead* (June 2025), https://efifoundation.org/foundation-reports/analysis/exploring-the-future-of-geologic-hydrogen-2/. See also U.S. Geological Survey Geologic Hydrogen page https://www.usgs.gov/centers/central-energy-resources-science-center/science/geologic-hydrogen

[b] Bettenhausen, C., “Trillions of tons of hydrogen may be waiting under our feet,” *Chemical & Engineering News* 103, no. 7 (March 14, 2025), https://cen.acs.org/energy/hydrogenpower/Trillions-tons-hydrogen-waiting-under/103/i7.

[c] EFI Foundation, op. cit., p. 6.

Next-Generation Geothermal Power Characteristics

The nature of next-generation geothermal resources; state of technologies and scientific understanding; market characteristics; and legal, policy, and regulatory environments interact to offer very large potential benefits along with significant technical, financial, business model, and regulatory challenges. This section discusses such major factors and is followed by a section focusing on potential state approaches and State Energy Office opportunities to advance geothermal power.

The characteristics and factors that follow interact in multiple and sometimes complex ways that can advance or impede geothermal energy development. For example, up-front costs are a large impediment to developing next-generation geothermal projects. Scientific and engineering advances can improve prospecting, reduce the number of exploratory wells needed, and speed up drilling to reduce costs and financial risks. At the same time, state definitions of geothermal resources, ownership rights law, and permitting and siting processes have significant impacts on costs and financial risk. Improved science can inform development of legal and regulatory frameworks better suited for new geothermal approaches while being protective of the public and natural resources.

Conversely, conducive legal frameworks and streamlined regulation can encourage more resource exploration leading to technological advances and economies of learning that drive down project development costs and investment risk. Then add in the varied and complex contexts of electricity markets and regulation that affect the ability of geothermal power generators to sell electricity to contracted customers or utilities, which affects investor assessment of project risks. State Energy Offices can facilitate policies to address such factors and their interactions to advance geothermal energy to meet state objectives.

Next-generation geothermal resources are far more widely distributed with much larger production potential than conventional hydrothermal resources, but better mapping and characterization are needed. In principle, next-generation geothermal resources are available anywhere if one bores deep enough. In practice, areas with hot rock at relatively moderate depths will be more attractive and cost-effective targets for geothermal power development. As noted previously, in the United States most such areas are in the West but there are regions in the East that offer significant potential and are relatively close to large and growing power demand. As technologies advance and experience is gained, cost decreases will likely expand the map of feasible areas.

Existing resource maps are rough and the data are limited. More detailed assessments of potential resources and advances in modeling and analytics, including use of machine learning, to understand geologic characteristics, heat transfer rates, and other factors can improve prospecting success and reduce exploration costs. In some instances, data from oil and gas exploration and existing wells may be helpful to determine geothermal development viability.

Next-generation geothermal power plants offer firm, dispatchable, and flexible 24/7 operations with no or very low emissions, in contrast to variable weather-dependent solar and wind generation. These characteristics provide economic, operational, and reliability benefits for the electricity grid while entailing minimal or no emissions of greenhouse gas or criteria air pollutants. Flexibility and energy storage that can be incorporated into next-generation geothermal development provides additional value, allowing grid operators to better orchestrate generation, transmission, and distribution-level assets to enhance grid reliability and economics.

At some locations, such systems can provide local energy resilience. For example, the U.S. Department of Defense (DoD) through its Defense Innovation Unit is working with six companies to explore geothermal opportunities to enhance energy resilience at multiple military installations.[18] At times, co-location of geothermal generation with data centers, industrial facilities, communities or complexes (perhaps as CHP and district energy operations), and other large energy users can offer particular operational, economic, reliability, and resilience benefits.

Today's relatively high costs for next-generation geothermal power development will likely decrease with technological improvements and experience. However, much project development cost occurs up front, imposing significant financial risks. Project developers need to drill exploratory wells before being assured of economically sufficient resources to proceed. Then they need to drill production wells, create reservoirs (EGS) or loops (closed-loop systems), and build generation plants plus associated equipment and structures. As with any large power generation technology, there may be need for construction of transmission lines, making locations at or near existing transmission lines more attractive (such as at existing or retired generation plants, mines, and industrial sites).

The National Renewable Energy Laboratory (NREL) reports that recent publicly announced geothermal power purchase agreements (PPA) for conventional hydrothermal projects garner between $67.50 and $99 per megawatt-hour (MWh).[19] Field demonstration advances are reducing EGS project development costs through improvements in drilling, reservoir engineering, and resource exploration. DOE analysis indicates that continued improvements could achieve an average levelized cost of electricity for EGS projects of $45 per MWh by 2035, though individual projects will vary and Eastern U.S. projects will tend to have higher costs than some projects in the West.[20] As with many other fields, R&D, demonstration and validation, and economies of learning and experience that come from pilot and commercial implementation will likely together lead to significant cost reductions and performance improvements.

Still, even as cost reductions are anticipated, mechanisms to mitigate up-front costs and associated financial risks, especially for first-of-a-kind and early projects, may be important. Cost-sharing and insurance approaches may help with resource exploration and early project stages.

Also, there is need to bridge the gap between developers needing to show investors sufficiently certain offtake agreements (such as through PPAs or utility procurement assurances and conducive tariffs) and customers having confidence that projects will deliver on their agreements and expectations. The Center for Public Enterprise is among the organizations that has examined this issue and offers suggestions, including establishment of a publicly-supported PPA "warehousing facility" as a centralized off-taker backed by a clean firm energy tariff or portfolio requirement."[21]

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[18] Tucker, P., "Geothermal energy easing US military's logistics challenges," *Defense One* (April 16, 2024) https://www.defenseone.com/technology/2024/04/dod-doubles-investment-cutting-edge-geothermal-energy/395772/ and U.S. Department of Defense, Defense Innovation Unit, "Three Additional Next Generation Geothermal Technology Companies Advancing DoD Energy Resilience" (April 10, 2024). https://www.diu.mil/latest/three-additional-next-generation-geothermal-technology-companies-advancing.

[19] National Renewable Energy Laboratory, Annual Technology Baseline, Geothermal, https://atb.nrel.gov/electricity/2024/geothermal.

[20] Augustine, C., S. Fisher, J. Ho, I. Warren, and E. Witter (National Renewable Energy Laboratory), *Enhanced Geothermal Shot Analysis for the Geothermal Technologies Office* (2023), NREL/TP-5700-84822. https://www.nrel.gov/docs/fy23osti/84822.pdf.

[21] Feygin, Y. and C. Lala (Center for Public Enterprise), *The Dealer Always Wins: Stimulating Enhanced Geothermal Offtake* (2025), https://publicenterprise.org/report/the-dealer-always-wins/.

Geothermal energy development can build on strong U.S. oil and gas industry capabilities and experience. Some technologies critical to next-generation geothermal energy derive from directional drilling, hydraulic fracturing, exploratory and analytic methods, and other technologies developed and used by the domestic oil and gas industry. The United States possesses well-developed oil and gas expertise, workforce, and supply chains that can be brought to bear for geothermal energy development from the scientific frontiers to well operations.

That said, development of a next-generation geothermal industry will not be simply an extension of the shale oil and gas industry. Determining and accessing proven reserves, business and financing models, market structures, and some legal and financial features (like tax and accounting provisions) differ markedly between the two sectors.[22]

Shale oil and gas resource developers and their investors now have significant experience in estimating risks of exploration and production. The nature of land values, the commodity produced, exploration, and scale of production for oil and gas is amenable to speculative wildcat operations as well as to lower risk ventures.[23] Oil and gas producers sell into liquid (literally in the case of oil) national and global commodity markets.

This differs from next-generation geothermal projects in which developers and their investors bear high up-front costs with less certainty of the resource they may find and if and by how much it may degrade over time.[24] Projects include construction of generating plants and power infrastructure that generally depend on relatively stable, long-term cash flows, in contrast to oil and gas development for volatile commodity markets. Also, the product — electricity — is generally sold into fragmented and often regulated markets, whether to corporate off-takers via long-term PPAs, to utilities under contract, or into organized Independent System Operator/Regional Transmission Organization (ISO/RTO) wholesale markets. Electricity and hydrocarbons are very different businesses.

Definitions, rights, and ownership of geothermal resources may be complex or unclear. A state's system of property rights as it relates to subsurface resources may or may not be well-suited to exploiting geothermal heat as a resource. State definitions and legal frameworks affect geothermal resource rights and liabilities, interact with other rights, and can affect regulatory treatment for leasing, siting, and permitting of exploration and production projects.

Some states and the federal government subsume geothermal resources under mineral rights. Others may specify geothermal resources as separate. There can be interactions with water rights. Whether as a separate right or considered as mineral or something else, geothermal resources may be defined as fluids or as heat with or without a particular temperature threshold. These details can have important impacts on next-generation geothermal power development and the search for geologic hydrogen.

[22] Arun, A. and Y. Feygin (Center for Public Enterprise), *Committing to the Drill Bit: Derisking Enhanced Geothermal's Unique Market Structure* (2025), https://publicenterprise.org/report/committing-to-the-drill-bit/.
[23] Ibid.
[24] Geothermal resources can degrade if heat is extracted faster than it can be replenished from surrounding hot rock. Also, there can be physical changes that impede fluid flow, reducing the rate at which heat can be extracted.

A 2023 NREL study, [*Topics and Considerations for Developing State Geothermal Regulations*](https://www.nrel.gov/docs/fy23osti/86985.pdf), is a good starting point for considering legal and regulatory matters. The report draws on reviews of existing state geothermal regulations, best practices from geothermal and other extractive industries, and input from a Geothermal Regulatory Stakeholder Working Group to identify major state legal and regulatory considerations, provide state examples and cases, and offer advice on addressing such considerations.[25] The report addresses five major topics:

- Geothermal resource ownership and definition;
- Leasing processes;
- Exploration approval processes;
- Drilling/wellfield development processes; and
- Underground injection control (UIC) regulation.

The report also discusses federal definitions, regulations, and leasing processes and some of their interactions with states. For example, in multiple states, especially in the West, much land is federally owned. For such lands federal leasing procedures for geothermal exploration and production facilities apply (most often under Bureau of Land Management [BLM] authority). This can also be the case for lands, such as those allotted under the Stock-Raising Homestead Act of 1916, where there is a split estate, with private rights to the surface but federal government retention of mineral rights, which are federally defined to include geothermal resources.

Split estates that sever surface from subsurface rights are not uncommon. There can be interactions and potential conflicts and ambiguities across water, mineral, hydrocarbon (oil and gas), and geothermal rights. How geothermal resources and rights are defined or legally construed — as mineral or fluid or heat, which may or may not have a temperature threshold, and may or may not include other attributes (e.g., energy stored as geopressurized fluids) — can be important factors in determining the attractiveness of geothermal opportunities to developers and investors. Rights and ownership clarification is also important if projects may include co-products such as minerals that may be recovered from fluids, natural or stimulated hydrogen, or hydrocarbons and helium that may be collected. Such definitions and their implications for rights and liabilities may affect siting, permitting, and other regulatory processes.

Siting and permitting processes can be lengthy and costly, and can impose uncertainty that may dissuade investment but are needed to assure protection of the environment, health, and safety. Existing processes may or may not be apt for new next-generation geothermal development technologies. Permitting processes vary by state, including roles and authorities of local jurisdictions. There are state-federal interactions, such as for development on federal lands or where there is a split estate with federal retention of mineral rights, or with respect to shared environmental regulatory authorities. Tribal sovereignty and authority must be respected for Native American lands and communities.

[25] Levine, A., F. Martinez Smith, and H. Buchanan (National Renewable Energy Laboratory), *Topics and Considerations for Developing State Geothermal Regulations*, (September 2023), NREL/TP-6A20-86985, https://www.nrel.gov/docs/fy23osti/86985.pdf.

There are environmental and safety concerns that attend to geothermal resource development, including potential induced seismicity from underground fluid injection, adequacy of water supply and impacts on other water users and right-holders, potential impacts on groundwater quality from both geothermal reservoir creation and ongoing operations, and possible effluents, emissions, and wastes. Injection into the ground of water or other fluids may be subject to UIC regulation under the federal Safe Drinking Water Act (SDWA) and state law.[26]

These are in addition to land-use concerns that accompany energy and other project development generally, including potential impacts on agriculture, environmentally sensitive areas, historic and cultural sites, and local community character and quality of life.

On federal lands, environmental reviews may be required under the National Environmental Policy Act (NEPA). However, BLM finalized a "categorical exclusion" for certain geothermal resource confirmatory activities and proposed one for certain exploratory activities that can obviate the need for lengthy environmental assessments and environmental impact statements.[27] As a BLM announcement states:

> Until now, geothermal developers had to conduct two separate environmental reviews: one for initial exploration drilling and another to fully test the geothermal resource, even if the initial exploration drilling would cause negligible or minimal environmental effects. The categorical exclusion applies only to geothermal resource confirmation operations on public lands and split estates. Subsequent geothermal development would still require additional environmental analysis. Based on DOE analysis, this categorial exclusion could take up to a year off the timelines for certain types of geothermal exploration permitting and reduce overall capital costs for geothermal deployment.[28]

For projects on federal lands, categorical exclusions and other siting procedural streamlining can cut substantial time and expense from what had been estimated to be 7-to-10 year project development timelines.[29]

Uncertain and possibly lengthy siting and permitting processes raise financial risk and cost. States, tribes, and localities may wish to consider the adequacy of and potential gaps in their environmental permitting, siting, and land-use processes; options for coordinating and streamlining processes, including, as applicable, coordination with federal processes; and community engagement and education.

[26] Additionally, under the SDWA UIC program, states can take "primacy" for regulating different classes of underground injection wells. In some states a next-generation geothermal developer may apply to the state for a UIC permit while in others it will apply to the federal Environmental Protection Agency.

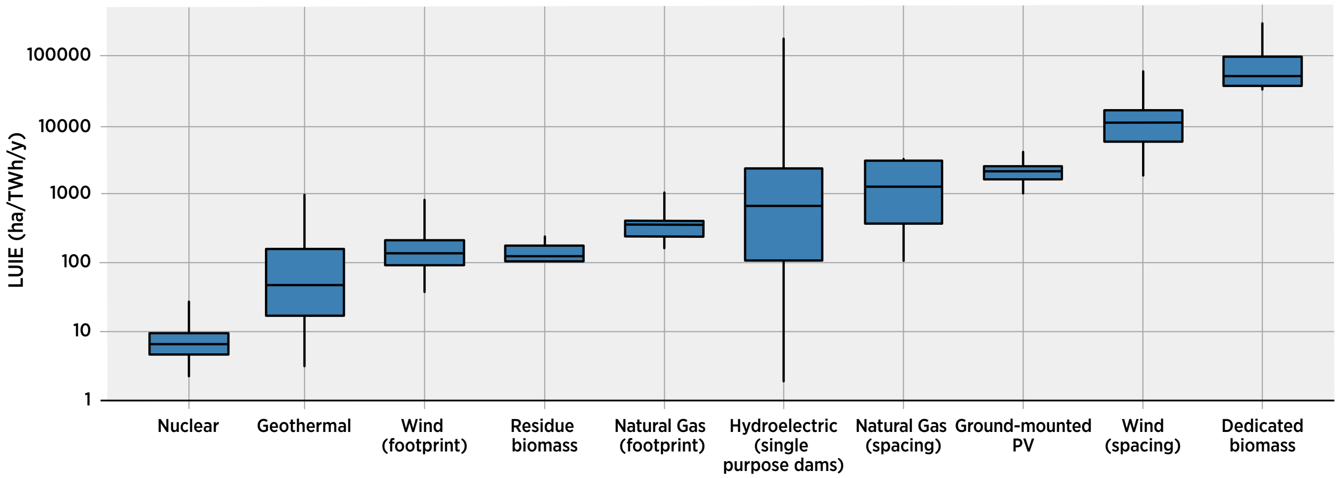
[27] U.S. Bureau of Land Management, *BLM takes Steps to Accelerate Geothermal Energy Development* (January 16, 2025), https://www.blm.gov/announcement/blm-takes-steps-accelerate-geothermal-energy-development.

[28] Ibid.

[29] U.S. Department of Energy, Permitting for Geothermal Power Development Projects, https://www.energy.gov/eere/geothermal/permitting-geothermal-power-development-projects

Geothermal power (both hydrothermal and next-generation) requires less land per unit of generation capacity (land-use intensity of electricity) than other renewable power sources (see Figure 4). This characteristic may lower leasing or acquisition costs. It may reduce potential environmental and social impact concerns regarding natural habitat, culturally sensitive sites, and competing agricultural and other land uses relative to other types of energy development. These factors can affect local community acceptance and the timing and costs or even the granting of permits and zoning or land-use approvals.

Figure 4. Land-use Intensities of Electricity Generation Systems



Notes: LIUE is land-use intensity of electricity. Horizontal line in each box denotes the median. For wind and natural gas, footprint area represents land directly covered by infrastructure while spacing area is the entire area within the perimeter of a production site. Geothermal includes power plant infrastructure and injection wells. Source: Adapted from Lovering, J., et al., "Land-use intensity of electricity production and tomorrow's energy landscape," *PLoS ONE* 17(7): e0270155 (2022), https://doi.org/10.1371/journal.pone.0270155.

There is need for greater awareness and education about next-generation geothermal power generation — its characteristics, impacts, risks, and benefits — to enable policymakers, communities, and the public to make reasoned decisions on potential applications and proposed projects. Energy technology projects, particularly those involving nascent approaches such as next-generation geothermal, engender both great enthusiasm and fears. Policymakers, community leaders, and the public often lack good understanding of new technologies and their potential impacts. Information provided by technology and project proponents and opponents may be biased or unreliable. State Energy Offices can support dialogues, analyses, and outreach to surface facts and advance understanding.

State Planning and Policy Considerations

Geothermal power development offers multiple potential benefits for states. Among the questions states can consider are:

- How might geothermal power help meet a state's electricity and broader energy needs? How can geothermal power help states to achieve their energy affordability, reliability, and environmental stewardship objectives? Consider both in-state and regional geothermal generation opportunities and impacts.
- What is the potential to develop geothermal resources in-state? What are economic development opportunities as well as concerns and impediments? How can existing in-state private and public sector capabilities, assets, and resources contribute to and benefit from geothermal development, including those from oil and gas, mining, and related sectors?
- Are state policies, regulations, and planning processes aligned to support geothermal development, or ought they be modified?

Achieving geothermal power's potential and benefits depends not only on relevant technological progress but also on states providing supportive policy and regulatory environments that encourage investment in resource exploration and development.

The following are among areas where State Energy Offices can work with their governors, legislatures, and other state agencies as well as with tribes, localities, private industry, academia, and non-governmental organizations (NGOs) to advance opportunities for next-generation geothermal energy development. Table 1 briefly summarizes potential state, including State Energy Office, roles.

Table 1. Roles States Can Play to Support Geothermal Energy Development

State Planning and Strategy Development	• Develop state geothermal plans, strategies, and road maps. • Include geothermal energy opportunities in state energy plans. • Include geothermal energy in other relevant plans, strategies, and road maps, such as electricity plans and economic development plans.
Geothermal Resource Mapping and Confirmation	• Convene relevant state and federal agencies, universities and national laboratories, tribes, the private sector (including mining, oil and gas), and others to collect available geologic resource maps and data; identify information/data gaps; make recommendations to fill gaps. • Hold regional multistate-federal convenings on resources. • Support public-private cost-shared resource exploration (drilling, confirmation), perhaps conditioned on publication of resulting data. Consider revolving forgivable loan, insurance, or other mechanisms. • Add to geologic resource maps other features important for resource development, permitting, and environmental reviews, such as water resources, transmission and transportation infrastructure, sensitive lands, and land-use and zoning status.

Policy, Law, and Regulation ▶ Definitions, rights, and ownership ▶ Permitting and siting	• Convene relevant public, private, and academic sector experts to determine definitions, ownership, rights, and liabilities concerning geothermal resources: ♦ Include interactions with water, mineral, oil and gas, and other rights; determine possible gaps and shortcomings. ♦ Consider legal, statutory, and regulatory options or recommendations. • Consider regional multistate-federal convenings on legal treatment of geothermal resources and development. • Convene relevant state, federal, and tribal agencies and local government representatives to clarify (or determine need to clarify) permitting and siting authorities, processes, and requirements: ♦ With industry and other stakeholder input, consider shortcomings and identify improvement options. ♦ Consider review and permitting streamlining options that are protective of environmental and community interests, e.g., one-stop shops, model or template ordinances, and technical assistance for localities. • Recommend executive and legislative policy enhancements and, if enacted, implement them.
Financing, Taxes, and Fiscal Incentives	• Provide and administer state grants, rebates, loan funds, credit enhancements, tax incentives, etc. • Identify, inform, and support applications for federal grants, loans, credit enhancements, tax incentives, etc. • Support or facilitate partnerships to apply for financial resources. • Implement, adapt, or develop new mechanisms to mitigate up-front costs and risks that attend to geothermal development (e.g., cost-sharing and insurance for exploration and early development).
Procurement and Utility Processes	• Recognize and value the combined firmness, dispatchability and flexibility, and low/no emissions nature of next-generation geothermal in utility planning and procurement and in renewable portfolio standards. • Consider "clean firm tariffs," allowances for "behind-the-meter" and co-located power sales to large loads, public procurement processes, PPA warehousing, and other approaches.
RD&D	• Provide direct funding of RD&D, including testbeds. • Provide tax incentives for RD&D, including testbeds. • Provide direct and indirect incentive support of technology incubators and commercialization assistance. • Consider supporting regional laboratories and field demonstration facilities, analogous to Utah FORGE. • (Also see "Geothermal Resource Mapping and Confirmation" above.)
Workforce and Supply Chains	• Assess potential workforce needs and skill requirements, considering opportunities to draw from oil and gas and other industries' workforce skills and experience. • Support development and delivery of training and education, from equipment operators and technicians to scientists and engineers, be they new, existing, or transitioning workers. • Assess supply chain needs and availability (equipment, materials and supplies, services), potential gaps, and options to address gaps.
Awareness and Education	• Support dialogues, convenings, analyses, and outreach to provide credible information on geothermal energy characteristics and potential risks and benefits to educate policymakers, community leaders, and the public. • Boost awareness and education to support policymaking as well as siting, permitting, and regulatory processes.

State Planning and Strategy Development

States may wish to consider developing or commissioning state-level reports that bring together the various geologic, economic, market, technical, legal, policy, and regulatory facets affecting geothermal energy resources in their states (including factors discussed below). Such reports can focus on next-generation geothermal or cover a wider scope that may include direct heat uses, thermal energy networks, and related approaches. States may wish to commission reports directly, via universities, or in collaboration with other well-regarded organizations. For example, Project InnerSpace collaborated with state, university, and other experts and organizations to develop the following reports:

- *The Future of Geothermal in New Mexico: A Land of Geothermal Enchantment*
- *The Future of Geothermal Energy in Pennsylvania: Leveraging the Commonwealth's Legacy of Energy Leadership*
- *The Future of Geothermal in Texas*

State Energy Offices, which have energy planning and policy responsibilities and typically are well-positioned to host convenings, can facilitate or oversee such efforts. **State Energy offices can also include geothermal energy in state energy plans and support geothermal inclusion in economic development, electricity, and other state planning activities.**

With or without published state-level geothermal reports, plans, and road maps, State Energy Offices can advise and support their governors, legislatures, and other agencies on geothermal energy (as they do on other energy types) as well as help develop pertinent policies.

State Energy Offices are also positioned to coordinate across relevant agencies and organizations, as discussed among items below. One notable example is Utah's Operation Gigawatt where, under the Department of Natural Resources, the Office of Energy Development (the State Energy Office) coordinates with the Utah Geological Survey, Division of Water Rights, and Division of Oil, Gas, and Mining.[30] Under Executive Order 2025-13, Arizona's Governor's Office of Resiliency (the State Energy Office) administers the Arizona Energy Promise Taskforce to work across agencies and various stakeholders to develop policy frameworks and energy strategy plans.[31] The task force includes a Geothermal Working Group.

30 Utah Office of Energy Development, *Fact Sheet: Geothermal in Utah*, https://energy.utah.gov/wp-content/uploads/Geothermal-In-Utah.pdf.

31 (Arizona) Office of the Governor, *Governor Katie Hobbs Acts to Cut Red Tape, Unleash Arizona Energy, and Lower Energy Costs* (September 15, 2025), https://azgovernor.gov/office-arizona-governor/news/2025/09/governor-katie-hobbs-acts-cut-red-tape-unleash-arizona-energy.

Geothermal Resource Identification and Confirmation

States may start by taking stock of their geothermal energy potential. They may focus on geothermal power generation potential, and could also include geothermal energy direct use and heating and cooling options and even geologic hydrogen possibilities.

State Energy Offices can work with their state geological survey[32] (or similar office); the U.S. Geological Survey; DOE; university geologists; and their mining, oil and gas, and related industries to compile maps and data and identify information gaps that need to be addressed. Operating and abandoned oil and gas wells, for example, can be important data sources and potential sites for geothermal energy development, perhaps for power generation but also for innovative energy storage. Convenings and collaborations can be done regionally among states.

States and, if available, federal agencies can offer public-private cost-shared support for exploratory drilling and site confirmation. Insurance, revolving forgivable loans, and other mechanisms can be considered. States may condition public support on publication of resulting data to support knowledge diffusion and stimulate more developer and investor interest. Cost-share mechanisms can be structured so that successful projects repay public funds, acting similarly to revolving loan funds. In 1978, DOE initiated the Industry-Coupled Case Studies Program to offset high initial development costs and mitigate financial risks of exploration and reservoir confirmation for hydrothermal resources. A successor DOE-supported Geothermal Resource Exploration and Definition Program ran from 2000 to 2007 that, likewise, provided public-private cost-shared support for (1) geophysical selections and test well site selection; (2) drilling of test wells and reservoir characterization; and (3) evaluation of test wells and assessments of site potential.[33] Japan's cost-shared drilling program (40 percent government cost-share for exploratory wells and 20 percent for production and injection wells) hastened development of that nation's conventional geothermal industry.[34] Australia provides federal and state cost-shared exploratory drilling support focused on EGS.[35] Such approaches can be applied to next-generation geothermal resource exploration, characterization and confirmation, and development to aid understanding of resource potential and mitigate up-front costs and financial risks of geothermal development.

State Energy Offices may engage natural resource and water agencies, state environmental agencies, economic development authorities, tribes, utilities, local governments, and others to map complementary and interacting features and characteristics that can affect geothermal project development. Geographical information systems (GIS) offer a way to consolidate information on water resources, electrical transmission availability, transportation access, proximity to potential users of co-produced heat, protected and environmentally sensitive lands, land-use and zoning categorization, and other features layered on geological characteristics to help developers and investors identify attractive sites as well as inform officials and the public.

These maps and data can be bases for developing geothermal energy strategies, road maps, and action plans. They also may contribute to broader state energy, electricity, and economic development plans and strategies.

32 Association of American State Geologists, State Geological Surveys, https://www.stategeologists.org/surveys.

33 U.S. Department of Energy, *Exploration 1976-2006: A History of Geothermal Energy Research and Development in the United States*, https://www1.eere.energy.gov/geothermal/pdfs/geothermal_history_1_exploration.pdf.

34 Sanyal, S., et al. (World Bank Group), *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey* (2016), ESMAP Knowledge Series 024/16, http://hdl.handle.net/10986/24277.

35 Ibid.

Policy, Law, and Regulation

Just as states can take stock of their geologic resources and relevant physical and geographic features, they can consider examining their legal, policy, and regulatory structures as they relate to geothermal energy development. Upon such reviews, they can consider options for addressing possible deficiencies, including developing or clarifying laws and policies to better support next-generation geothermal development in line with broader state objectives.

A state's system of property rights as it relates to subsurface resources may or may not be favorable to exploiting heat as a resource. Similarly, potential liabilities may attach to seeking, developing, and using such resources. Next-generation geothermal development may stretch and challenge existing environmental regulatory processes and raise concerns — well-founded or otherwise — among stakeholder groups and the general public concerning permitting and siting.

State Energy Offices could convene other state agencies and pertinent experts and stakeholders to identify relevant laws, policies, and regulations and identify agency responsibilities and authorities. Tribal governments should be included with respect to tribal lands and Native communities. Academic and private sector legal scholars and experts and local governments may also be included. This activity can be undertaken along two or more interacting tracks or working groups, which may include addressing geothermal resource definitions, ownership, and rights; and addressing permitting and siting regulations and procedures. These can include federal and state public lands and subsurface right leasing processes, too.

Such convenings can lead to recommendations to enhance and clarify as well as to streamline and coordinate policies, authorities, regulations, and procedures in light of new technologies and geologic understanding as well as current and prospective state energy, economic, and environmental priorities and objectives. Streamlined application processes, concurrent (versus sequential) reviews, "one-stop shops," technical assistance, and model or template ordinances for localities are among measures to consider.

Various regulatory and procedural topics may warrant specific attention. For example, should states differentiate between exploration and production well drilling in their reviews and permitting? States may wish to have a focus on UIC under the Safe Drinking Water Act and state law, including whether to obtain state primacy from the U.S. Environmental Protection Agency for Class V wells, interactions with other well classes (Class II for oil and gas related fluids, which may or may not apply to geologic hydrogen stimulation or extraction), and how they might coordinate drilling and injection authorizations and permitting. Should there be, as in New Mexico, provisions for temporary injection permits for exploratory wells? Coordination of state and, as applicable, federal environmental reviews can also be a focus.[36]

Colorado offers an example of updating geothermal regulatory structures. HB25-1165 "Geologic Storage Enterprise & Geothermal Resources" was enacted in 2025 to, among other things, clarify ownership of hot dry rock resources and geothermal resources "associated with nontributary groundwater," streamline permitting steps and authorities while removing certain overlapping requirements, and create well drilling notice requirements to protect existing geothermal operations.[37]

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[36] This paragraph draws from ideas in Levine, A., F. Martinez Smith, and H. Buchanan (National Renewable Energy Laboratory), *Topics and Considerations for Developing State Geothermal Regulations* (September 2023), NREL/TP-6A20-86985, https://www.nrel.gov/docs/fy23osti/86985.pdf.

[37] The bill also addresses carbon capture and sequestration (CCS) and shallow, direct use geothermal resources. Colorado General Assembly, Geologic Storage Enterprise & Geothermal Resources, https://leg.colorado.gov/bills/hb25-1165; bill text at https://leg.colorado.gov/sites/default/files/2025a_1165_signed.pdf.

States may wish to undertake these activities with other states regionally to share insights and lessons and, perhaps, to encourage consistency and even harmonization across states of definitions and, as warranted, rules and procedures. Consistent, compatible processes among states can stimulate and streamline geothermal development and reduce uncertainties and costs as resource developers move across state lines. While states may seek geothermal project development within their states, they can benefit from regional increases in firm, clean, reliable power produced in other states.

As noted previously, the 2023 National Renewable Energy Laboratory *Topics and Considerations for Developing State Geothermal Regulations* report is a good starting point for considering legal and regulatory matters.

Financing, Taxes, and Fiscal Incentives

Federal and state governments can offer financial incentives, such as grants, loans, loan guarantees and other credit enhancements, and tax concessions (credits, deductions, exemptions) as well as additional mechanisms (feed-in-tariffs or other market support) to advance geothermal development across the spectrum from RD&D through site exploration and confirmation to project development and operations.

At the federal level, geothermal project development can be eligible for the 48E Clean Electricity Tax Credit and geothermally-generated power can receive the 45Y Clean Electricity Production Credit, although a project or facility must choose between the two and cannot obtain both credits. Credit transferability and "direct pay" (for non-taxable entities) may be applicable. Also, companies may be eligible for other general (non-energy-specific) business tax provisions, such as bonus depreciation (full deduction of certain capital expenditures in the year put in service) and R&D tax deductions and, as applicable, credits.

States, likewise, can offer various tax incentives, such as income tax credits and deductions, waivers and discounts on sales and use taxes, and property tax concessions.

As discussed previously under Geothermal Resource Mapping and Confirmation, **cost-shared drilling and exploration incentives can support geothermal development**. These in the past have hastened hydrothermal geothermal development in the United States and Japan, and can be applied to next-generation geothermal exploration and development, such as Australia's federal and state cost-shared EGS drilling incentives.[38]

State Energy Offices can administer dedicated geothermal grant and loan programs, whether for geothermal power or also including direct use. For example, the California Energy Commission operates a Geothermal Grant and Loan Program, and the Colorado Energy Office administers a Geothermal Energy Grant program.[39]

Various states have infrastructure banks, green banks, or other financing authorities that may be able to support geothermal projects. For example, the Wyoming Energy Authority (the State Energy Office) operates an Energy Matching Fund program to leverage private and federal funding for research, demonstration, pilot, and commercial deployment related to the state's energy needs.[40]

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[38] Sanyal, S., et al. (World Bank Group), *Comparative Analysis of Approaches to Geothermal Resource Risk Mitigation: A Global Survey* (2016), ESMAP Knowledge Series 024/16, http://hdl.handle.net/10986/24277

[39] California Energy Commission, Geothermal Grant and Loan Program, https://www.energy.ca.gov/programs-and-topics/programs/geothermal-grant-and-loan-program and Colorado Energy Office, Geothermal Energy Grant Program, https://energyoffice.colorado.gov/geothermal-energy-grant.

[40] Wyoming Energy Authority, Energy Matching Funds, https://wyoenergy.org/energy-matching-funds/.

Procurement and Utility Regulation

Firm 24/7 availability combined with flexibility potential and low/no-emission characteristics should make next-generation geothermal highly appealing for utilities and other grid operators and for large electricity users. But the technologies and their applications are new, prospecting and site confirmation entail significant up-front costs accompanied by technical and financial risk, and electricity markets and regulations can be complex and discouraging.

State policy and regulatory bodies (including State Energy Offices and Public Utility Commissions), electric utilities (including consumer-owned public power and cooperative utilities), other grid operators (e.g., ISO/RTOs), large energy users, and others could place particular value on geothermal energy's combination of desirable characteristics: firmness, reliability, and flexibility; low/no-emissions; and no exposure to fuel supply constraints or price volatility.

One example of policy and regulation recognizing the value of these attributes is the 2021 California Public Utilities Commission mid-term reliability (MTR) mandate, which specifies that utilities procure "at least 1,000 MW from clean firm resources such as geothermal" to enhance grid reliability.[41] The MTR mandate catalyzed two Southern California Edison 15-year PPAs to purchase 320 MW from Fervo Energy's Cape Station EGS project under construction in Utah.[42]

Some data center developers, particularly hyperscalers, as well as some other large energy users recognize these characteristics and are seeking new ways to obtain requisite power relatively quickly — and may be willing to pay a premium to do so. **States can consider and develop new, innovative PPA, utility procurement, and tariff approaches that support the needs of growing large-load power demands while protecting utility ratepayers from higher costs and risks.** Some of these approaches are under development or being implemented now.[43, 44]

Fervo Energy provides a geothermal energy example of such approaches. The company, in partnership with Google and the utility NV Energy, proposed and the Nevada Public Utility Commission approved a "clean transition tariff" (sometimes called a "clean firm tariff"). The new tariff enables Google to enter a long-term agreement to procure power for its data centers from Fervo Energy's 115-MW Cormac Station EGS plant in Nevada. The mechanism is structured so Google pays a premium for the power that helps fund the EGS pilot and associated grid upgrades without passing those costs on to the utility's broader base of ratepayers.[45]

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[41] California Public Utilities Commission, *Fact Sheet: Decision Requiring Clean Energy Procurement for Mid-Term Reliability*, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/d2106035-mtr-decision-factsheet--07-01-2021.pdf.

[42] Fervo Energy, *Fervo Energy Announces 320 MW Power Purchase Agreements with Southern California Edison* (June 24, 2024)**,** https://fervoenergy.com/fervo-energy-announces-320-mw-power-purchase-agreements-with-southern-california-edison/.

[43] Collier, A. and J. Lindemann (Smart Electric Power Alliance), *Innovative Utility Tariffs Pave the Way for Flexible, Carbon-Free Data Centers* (February 25, 2025*),* https://sepapower.org/knowledge/innovative-utility-tariffs-pave-the-way-for-flexible-carbon-free-data-centers/.

[44] Smart Electric Power Alliance and North Carolina Clean Energy Technology Center, *Database of Emerging Large-Load Tariffs (DELTa)*, https://sepapower.org/large-load-tariffs-database/.

[45] Jenkins, L. M., "The 'clean transition tariff' won approval in Nevada. What's next for Fervo?", *Latitude Media* (May 15, 2025), https://www.latitudemedia.com/news/the-clean-transition-tariff-won-approval-in-nevada-whats-next-for-fervo/.

As noted previously, in light of high up-front uncertainties, there is a gap between developers needing to show investors adequate offtake commitments and sufficient customers willing to make such commitments. This can stymie project investment. Among the Center for Public Enterprise's suggestions for addressing this hurdle is establishment of a publicly supported PPA "warehousing facility as a centralized offtaker backed by a clean firm energy tariff or portfolio requirement."[46]

Research, Development, and Demonstration

There are numerous scientific and technical needs to advance geothermal energy. As discussed previously, the field needs better geological science understanding and improved ways of identifying and characterizing sites. The field will also benefit from new and better materials and techniques for drilling, for well casings and cements, for fracturing rock and managing fluids, for managing corrosion and scale, for potential recovery of co-products (such as minerals), for mitigating seismic and environmental hazards, for improving operational efficiencies, and for other things.

Advances will come from computer models and analyses, laboratory research, and field work. This work includes formal experiments, demonstration projects, and accumulated learning-by-doing experience in commercial operations. Test bed facilities can be particularly useful.

Federal and state governments can support relevant RD&D directly through funding and encourage private funding, including via tax incentives. States can directly support and encourage private, university, and philanthropic backing of technology incubators, accelerators, and related technical and business assistance**.** State economic development programs, including those targeting "clean tech," can support relevant technology development, commercialization, and deployment.[47]

States, with the federal government, and in collaboration with industry, academe, federal laboratories, and NGOs, may wish to consider options for replicating at least in part the Utah FORGE model by establishing field laboratories in other regions of the United States in their own geologic contexts.

[46] Feygin, Y. and C. Lala (Center for Public Enterprise), *The Dealer Always Wins: Stimulating Enhanced Geothermal Offtake* (2025), https://publicenterprise.org/report/the-dealer-always-wins/.

[47] NASEO Energy Technology Innovation, https://naseo.org/issues/technology-innovation.

Workforce and Supply Chain

States can assess potential workforce needs and skill requirements for developing geothermal resources. In conjunction with industry and educational and training institutions, states can consider opportunities to leverage skills, expertise, and experience of the oil and gas industry and its workforce as well as related industries. There are needs for skilled workers ranging from equipment operators and technicians to engineers and research scientists.

As is the case with other industries, **states can support development and delivery of training and education at vocational institutions, community colleges, colleges and universities, and at workplaces.** State officials may wish to review expertise present in their state's colleges and universities, oil and gas and other industries, federal laboratories, and non-governmental organizations for education and training resources as well as RD&D and innovation and commercialization possibilities.

Similar to assessing workforce needs, **states can work with industry and academia to assess supply chain needs and availability (equipment, materials and supplies, and services), identify potential gaps, and develop options to address gaps.**

Awareness and Education

States, with State Energy Offices well-suited, can support next-generation geothermal awareness-raising and education. States can support convenings, dialogues, analyses, and outreach to raise understanding of next-generation geothermal energy technology and project characteristics, opportunities, risks, and benefits to advance well-informed policymaking, discourse, and decision-making on programs and projects.

Conclusion

New technologies, many derived from oil and gas industry advances, are enabling vast expansion in the drive for geothermal energy to meet fast-growing demands for firm, dispatchable, flexible, and clean power across diverse parts of the United States.

No longer confined to a few specific sites, next-generation geothermal power has the potential to produce thousands of gigawatts of electricity in the United States, mostly in the West but with significant possibilities in the East, too. Based on techno-economic criteria, 90 GW of U.S. next-generation geothermal capacity is possible by 2050. The techniques making next-generation geothermal energy possible may also help tap potentially large but still uncertain geologic hydrogen resources.

These emerging opportunities face significant challenges: scientific and technical; legal, policy, and regulatory; and business and financial. The issues range from defining geothermal resource ownership to mitigating high up-front costs and risks to permitting timelines and electricity market complexities.

State Energy Offices, in conjunction with other state agencies and working with federal, tribal, private sector, academic, and other non-governmental partners, can play important roles to overcome the challenges and advance geothermal power to meet state energy reliability and affordability, economic development, and environmental stewardship objectives.

Resources

Arun, A. and Y. Feygin (Center for Public Enterprise), *Committing to the Drill Bit: Derisking Enhanced Geothermal's Unique Market Structure* (2025), https://publicenterprise.org/report/committing-to-the-drill-bit/.

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Augustine, C., S. Fisher, J. Ho, I. Warren, and E. Witter (National Renewable Energy Laboratory), *Enhanced Geothermal Shot Analysis for the Geothermal Technologies Office* (2023), NREL/TP-5700-84822, https://www.nrel.gov/docs/fy23osti/84822.pdf.

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GeoBridge, https://openei.org/wiki/GeoBridge – provides geothermal basics and "101," educational resources, organization, events, and career resources.

Geothermal Data Repository, https://gdr.openei.org/ – provides free access to data generated from efforts funded by the Geothermal Technologies Office of the U.S. Department of Energy and supporting projects and partnerships.

GeoVision Scenario Viewer, https://apps.openei.org/geovision/.

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State-level Resources

The following is a non-comprehensive list of links to state government and academic resources, plus selected recent state-oriented reports, pertinent to geothermal power. State web resources oriented to geothermal direct use (including heating and cooling and thermal energy networks) are not included.

Alaska Department of Natural Resources, Geological and Geophysical Surveys, Geothermal Energy, https://dggs.alaska.gov/energy/geothermal.html.

Arizona Geological Survey (University of Arizona), Geothermal in Arizona, https://azgs.arizona.edu/energy/geothermal-arizona.

California

California Energy Commission, Geothermal Grant and Loan Program, https://www.energy.ca.gov/programs-and-topics/programs/geothermal-grant-and-loan-program.

Department of Conservation, Geological Energy Management Division, https://www.conservation.ca.gov/CalGEM.

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Colorado

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Hawaii State Energy Office, Geothermal Factsheet, https://energy.hawaii.gov/wp-content/uploads/2025/07/HSEO-Geothermal-Fact-Sheet.pdf.

Idaho

Governor's Office of Energy and Mineral Resources, Geothermal, https://oemr.idaho.gov/sources/re/geothermal/.

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Ohio Department of Natural Resources, Geothermal Energy Resources, https://ohiodnr.gov/discover-and-learn/safety-conservation/about-odnr/geologic-survey/energy-resources/geothermal-energy.

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Texas Railroad Commission, Geothermal, https://www.rrc.texas.gov/oil-and-gas/applications-and-permits/injection-storage-permits/geothermal/.

Utah

Utah Office of Energy Development, Advanced Geothermal, https://energy.utah.gov/homepage/technology/advanced-geothermal-2/.

Utah Office of Energy Development, Operation Gigawatt, https://energy.utah.gov/homepage/about/operation-gigawatt/; Geothermal in Utah, https://energy.utah.gov/wp-content/uploads/Geothermal-In-Utah.pdf.

Virginia Department of Energy, Geothermal, https://energy.virginia.gov/geology/Geothermal.shtml.

Washington State Department of Natural Resources, Washington Geological Survey, Geothermal Resources, https://dnr.wa.gov/washington-geological-survey/energy-mining-and-minerals/geothermal-resources.

West Virginia Geological and Economic Survey, Geothermal Energy Research in West Virginia, https://www.wvgs.wvnet.edu/www/geothermal/index.html.

Wyoming State Geological Survey, Geothermal Resources, https://main.wsgs.wyo.gov/energy/geothermal.

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