Build Here: How Targeted State Investment in Geothermal Can Fill California's Clean Firm Gap

Authors: Wilson Ricks and Ann Garth

May 2026

CLEAN AIR
TASK FORCE

Executive Summary

California is a global leader in climate and energy policy. The linchpin to reaching the state's climate targets – and doing so affordably – will be securing a vast new supply of clean firm generation: renewable and low-carbon resources that can provide dependable electricity whenever it is needed and strengthen the reliability of an increasingly electrified grid.

In recent years, a revolution in geothermal technologies has given rise to next-generation geothermal, one of the most promising sources of clean firm power in the world. Next-generation geothermal technologies enable geothermal power generation at a much greater scale than is possible with conventional geothermal resources. These technologies could contribute many gigawatts of clean, firm generation toward California's electricity needs. And if those gigawatts are developed in-state, they could provide significant benefits to California ratepayers, workers, and communities compared to other available alternatives. More importantly, abundant, low-cost firm electricity at this scale could help reshape California's long-term economic trajectory—supporting new advanced manufacturing, energy-intensive industries, and forms of economic activity that become possible when reliable electricity is both widely available and affordable.

California can advance in-state next-generation geothermal by funding a program to explore and map the subsurface around the state, which could help to directly catalyze gigawatts of local development – just as the Frontier Observatory for Research in Geothermal Energy (FORGE) program did in Utah. A program of this type is just one of multiple steps needed to fully derisk next-generation geothermal development in California[1] – but it is an important step, and could meaningfully contribute to enabling development in high-potential geologic regions, crowding in private investment, and helping California deploy next-generation geothermal at scale.

This report examines the electricity system and cost impacts if California is successful in overcoming development barriers and establishing an in-state next-generation geothermal industry for its clean energy targets. It presents new electricity system modeling that examines the benefits of enabling large-scale development of next-generation geothermal technologies in California. Key findings of this modeling include:

- Commercially mature and widely available enhanced geothermal systems (EGS) deployable at average costs ranging from \$2,700/kW to \$7,700/kW[2] could reduce annual electricity supply costs in California in 2045 by \$10-44 billion (or 23-52%) compared with scenarios where EGS power and other clean firm generation technologies are unavailable due to development barriers.
- Availability of in-state EGS leads to annual electricity supply cost savings of \$3.5-5.5 billion compared to scenarios where it is only available out-of-state, while also producing in-state economic development and employment benefits.

---

[1] For more detail about other policy actions necessary to unlock geothermal in California, see Rogers, T., Garth, A., & Arax, A. (2025). Unlocking California's Geothermal Potential: A Strategic Opportunity for Clean, Firm Power. Clean Air Task Force. https://cdn.catf.us/wp-content/uploads/2025/06/23162128/california-geothermal-report.pdf

[2] \$2,700/kW is the average cost of EGS resources deployed in the scenario where they are least expensive, while \$7,700/kW is the average cost of EGS resources deployed in the scenario where they are most expensive.

- EGS availability (especially in-state EGS) reduces the marginal cost of greenhouse gas abatement in California's electricity system by 50-100%, suggesting that EGS deployment can ease the path to emission reductions beyond the 2045 target.
- Availability of enhanced geothermal power would reduce the infrastructure buildout required to achieve California's 2045 clean energy targets – for example, deploying 30 GW of EGS would allow California to maintain its current pace of solar installation at around 3 GW/year, rather than requiring a three-fold increase in the buildout of solar to almost 10 GW/year, along with the associated transmission.[3]
- The need for interregional transmission expansion, which can be particularly challenging, is reduced by 28-53% in scenarios where EGS can be built in California.

Achieving these benefits will require widespread deployment of next-generation geothermal. California enjoys some of the best geologic conditions for next-generation geothermal in the nation, and private capital is ready to develop these resources – but only if development risks are lowered. Lack of understanding of the subsurface across many regions of California is one such development risk, and it is a major impediment to project deployment.

This barrier is already being overcome outside of California, through the U.S. Department of Energy's (DOE) Utah Frontier Observatory for Research in Geothermal Energy (FORGE) project. The FORGE testbed identified a targeted location and drilled exploration wells in rural, southwest Utah and then released the resulting subsurface data publicly, reducing subsurface uncertainty and unlocking development in the surrounding region. As a direct result of FORGE, billions of dollars in private capital flowed into nearby geothermal projects, including the world's first commercial-scale enhanced geothermal systems facility – bringing jobs and tax revenue to the surrounding community.[4] California has the opportunity to replicate this success.

And given California's scale and its role as an anchor customer for early next-generation geothermal projects, these efforts could play a meaningful role in determining whether the technology achieves commercial success more broadly.

---

[3] California Energy Commission. (n.d.) Electric Generation Capacity and Energy. Energy Almanac. Retrieved March 16, 2026. https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

[4] Jeffreys, F. (N.d.). Fervo Energy's Cape Station: A landmark next generation geothermal development. Seequent. https://www.seequent.com/fervo-energys-cape-station-a-landmark-next-generation-geothermal-development/.

The Clean Firm Challenge

California law requires that 90% of retail electricity sales come from renewable or carbon-free sources by 2035, and 100% by 2045.[5] For reference, the most recent data shows that 67% of the state's electricity comes from such sources.[6] Additionally, state law requires a drastic reduction in the effective carbon dioxide (CO2) content of California's physical electricity supply over that time period. Achieving these targets will require a massive transformation of the state's electric sector as well as many other parts of the economy. Achievement of these ambitious goals is further complicated by growing electricity demand to support California's growing economy, building electrification, electric vehicles, data centers, and other uses; the California Energy Commission (CEC) estimated that the state's peak electricity demand will rise by about half by 2045.[7]

To date, California's climate policies have proven very successful at driving the development of new solar and wind power, as well as batteries. However, system studies consistently show that the state also needs clean firm generation[8] to achieve decarbonization targets affordably, reduce the infrastructure buildout necessary, and reduce the state's reliance on gas power. Although clean firm generation generally costs more per unit of energy produced,[9] its ability to generate clean baseload power yields system-wide cost savings that outweigh this cost.[10]

The California Public Utilities Commission has repeatedly recognized the need for clean firm generation across multiple regulatory actions and planning processes, including:

- A 2021 procurement order, which directed utilities to procure new clean firm capacity;[11]
- The 2026 Integrated Resource Plan (IRP) modeling, which showed an economic need for 5-10 gigawatts (GW) of new clean firm generating capacity;[12] and
- The California Public Utilities Commission's (CPUC) 2026-2027 Transmission Planning Process analysis, conducted to support the IRP portfolio, which called for at least 5.1 GW of new clean firm generating capacity by 2036.[13]

---

[5] S.B. 100, 2017–2018 Leg., Reg. Sess. (Cal. 2018).

[6] Governor Gavin Newsom. (2025, July 14). In historic first, California powered by two-thirds clean energy, becoming largest economy in the world to achieve milestone [Press release]. https://www.gov.ca.gov/2025/07/14/in-historic-first-california-powered-by-two-thirds-clean-energy-becoming-largest-economy-in-the-world-to-achieve-milestone/

[7] Baustin, N. (2026, January 22). EVs, data centers to drive 50% rise in California electricity demand, state predicts. Politico E&E News. https://www.eenews.net/articles/evs-data-centers-to-drive-50-rise-in-california-electricity-demand-state-predicts/

[8] Clean firm generation technologies are those that can generate low- or zero-carbon power on demand, for as long as needed, regardless of the weather.

[9] See, e.g., Moraski, J., Qvist, M., & Spokas, K. (2025). Beyond LCOE: A Systems-Oriented Perspective for Evaluating Electricity Decarbonization Pathways. Clean Air Task Force. https://cdn.catf.us/wp-content/uploads/2025/06/30100806/CATF_BeyondLCOEReport_P_roof_09.30.25.pdf

[10] A summary of relevant literature can be found in Spokas, K. & Ricks, W. (2026). Clean Firm Electricity Technologies: What, Why, How. Clean Air Task Force. https://www.catf.us/resource/clean-firm-electricity-technologies-why-what-how/

[11] Public Utilities Commission of the State of California. (n.d.). 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

[12] Public Utilities Commission of the State of California. (2026). Rulemaking 25-06-019. (p.60). https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M601/K777/601777006.PDF

[13] Public Utilities Commission of the State of California. (2026). Proposed Decision of ALJ Fitch. (p.60). https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M600/K398/600398976.PDF

Taken together, these actions illustrate the strong need that has already been identified for clean firm power in California.

But while California has signaled that clean firm generation will play a critical role in achieving its climate and reliability objectives, no clean firm technologies are currently being deployed at the scale the state's planning processes anticipate. Several promising clean firm technologies are candidates to fill this role, but each faces distinct technical, economic, and regulatory barriers, and it is not yet clear which will be viable options for commercial deployment in California in the coming decades. State policies that support and enable the local commercial availability of at least one – and ideally more than one – clean firm technology will therefore be key to achieving California's clean electricity targets cost-effectively. Supporting multiple clean firm technology options in parallel will maximize the chances of success.

Why Next-Generation Geothermal Matters to California

While there are multiple candidate technologies that could meet California's clean firm generation needs (including advanced nuclear power, natural gas paired with carbon capture and storage, and fusion), this report focuses on next-generation geothermal power as a particularly promising opportunity for the state.

By enabling geothermal energy generation across a much wider geographic range than is possible with conventional technologies, next-generation geothermal holds the potential to revolutionize California's – and the world's – energy mix (see Figure 1). CATF's modeling indicates that just 1% of the highest-temperature geothermal resources available in California at currently accessible depths could produce 35 GW of power, translating to nearly 300,000 gigawatt-hours of power annually – about the same amount as the entire state consumed in 2023.[14] By contrast, conventional geothermal power currently produces less than 3 GW of power in California.[15]

Continued technology advancements are bringing down costs for next-generation geothermal (see Figure 2), making this resource increasingly practical to deploy at scale with minimal impact on ratepayers. More than 1 GW of next-generation geothermal capacity is already under commercial contract in the U.S., with a majority of this capacity planning to sell its power to customers in California. But despite California's excellent geothermal resource base and key role as an anchor customer for early next-generation geothermal projects, nearly all of these projects are being developed in other states. This relative lack of in-state project activity suggests the existence of real or perceived barriers to next-generation geothermal development in California.

Beyond the success or failure of basic technology development efforts, two questions will largely determine the extent to which next-generation geothermal contributes to California's electricity decarbonization: whether the technology reaches commercial maturity and broad availability by 2045, and whether it can be developed at scale within California itself. Notably, these questions are not fully independent. Given California's scale and its role as an anchor customer for early next-generation geothermal projects, the state's own procurement and development choices may help determine whether the technology achieves commercial maturity.

To assess the importance of these issues, CATF has performed new high-fidelity electricity system modeling that replicates the structure of California's most recent SB100 Joint Agency Report[16] and compares the achievability of the state's clean energy goals in scenarios where only currently commercialized electricity technologies are available for deployment with ones where next-generation geothermal (specifically enhanced geothermal systems, or EGS) is also available. The modeling also compares scenarios that allow enhanced geothermal development locally in California with scenarios that do not, highlighting the additional potential long-term reliability and cost benefits of policies that enable in-state development. The Appendix to this report provides detailed information on modeling methods and assumptions.

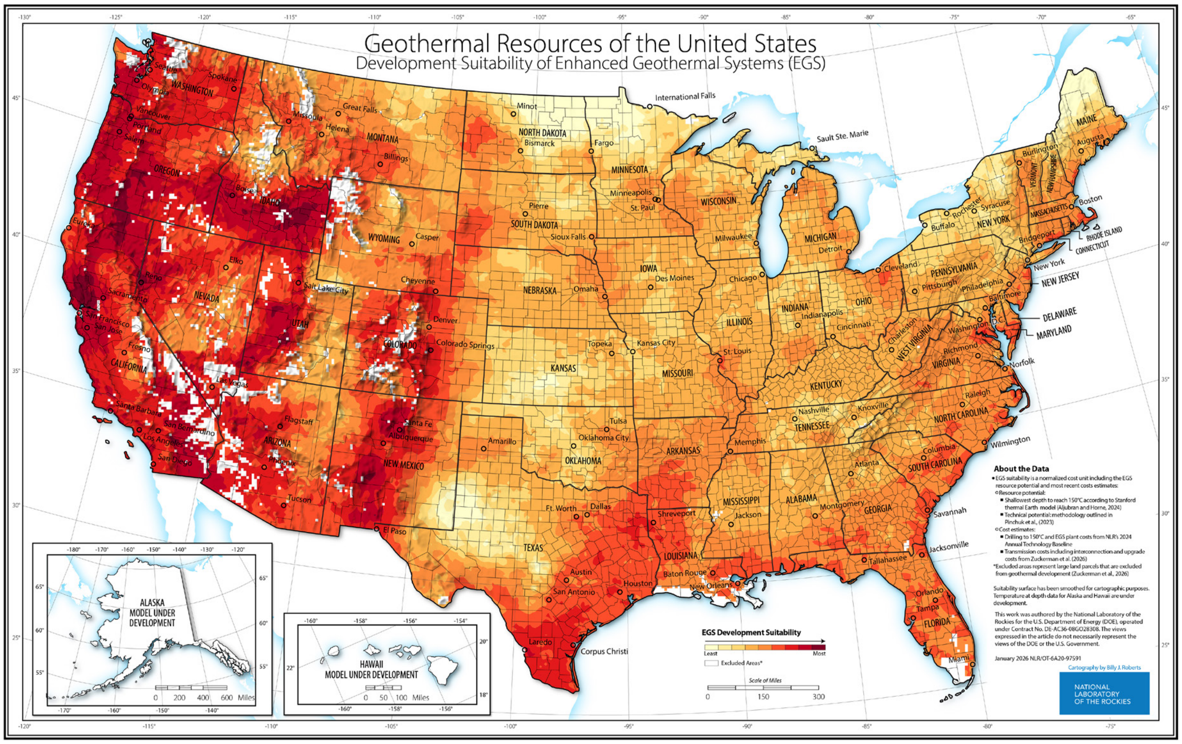
---

[14] This estimate is for superhot rock geothermal, the highest-temperature and highest-energy-density form of geothermal.

[15] Akindipe, D. et al. (2025). 2025 U.S. Geothermal Market Report. National Lab of the Rockies. https://www.nlr.gov/geothermal/2025-us-geothermal-market-report

[16] California Energy Commission. (2024). Presentation for SB100 Inputs and Assumptions Workshop. https://www.energy.ca.gov/event/workshop/2024-02/senate-bill-100-modeling-inputs-and-assumptions-staff-workshop

Figure 1. Estimated locational suitability for next-generation geothermal development across the U.S.[17]



About the Data

- EGS suitability is a normalized cost unit including the EGS resource potential and most recent costs estimates:
  - Resource potential:
    - Shallowest depth to reach 150°C according to Stanford thermal Earth model (Aljubran and Horne, 2024)
    - Technical potential: methodology outlined in Pinchuk et al., (2023)
  - Cost estimates:
    - Drilling to 150°C and EGS plant costs from NLR's 2024 Annual Technology Baseline
    - Transmission costs including interconnection and upgrade costs from Zuckerman et al. (2026)

*Excluded areas represent large land parcels that are excluded from geothermal development (Zuckerman et al., 2026)

Suitability surface has been smoothed for cartographic purposes. Temperature at depth data for Alaska and Hawaii are under development.

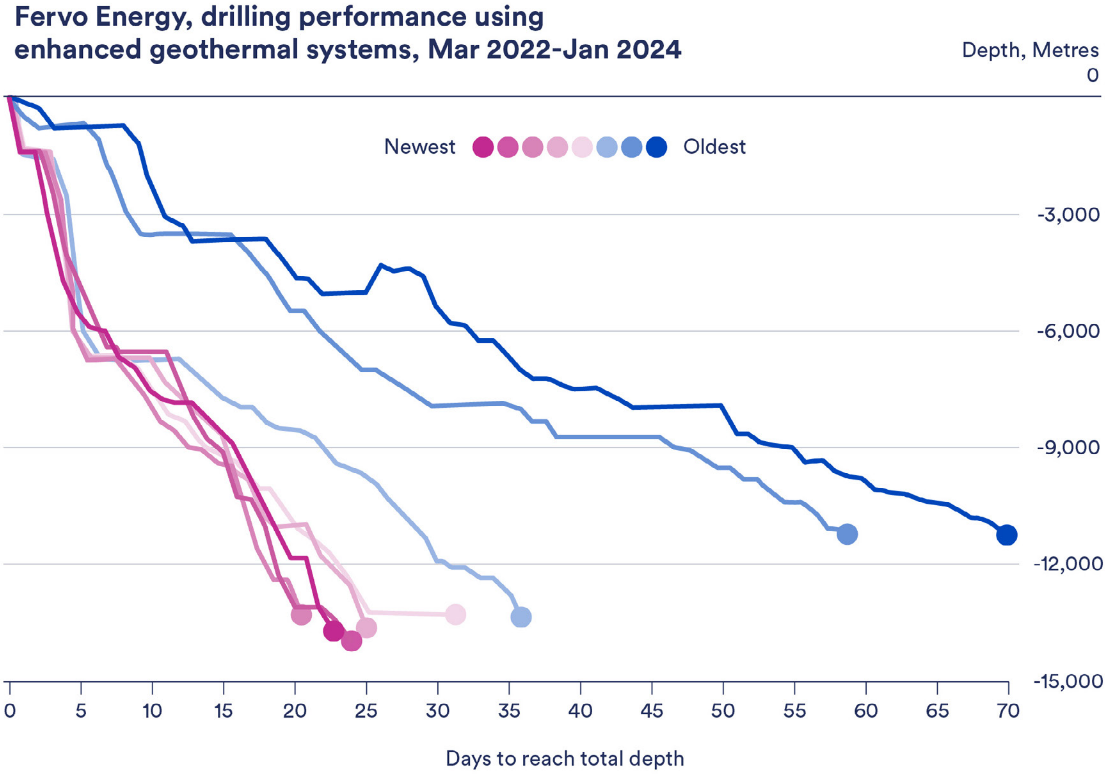
This work was authored by the National Laboratory of the Rockies for the U.S. Department of Energy (DOE), operated under Contract No. DE-AC36-08GO28308. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

January 2026 NLR/OT-6A20-97591

Cartography by Billy J. Roberts

NATIONAL LABORATORY OF THE ROCKIES

Figure 2. Drilling performance over time for a leading next-generation geothermal developer[18]



---

17 National Lab of the Rockies. (2026). Geothermal Resources of the United States. https://docs.nrel.gov/docs/gen/fy26/97591.jpg

18 The Economist. (2025, November 18). Geothermal's time has finally come. https://www.economist.com/interactive/science-and-technology/2025/11/18/geothermal-time-has-finally-come

How It Works

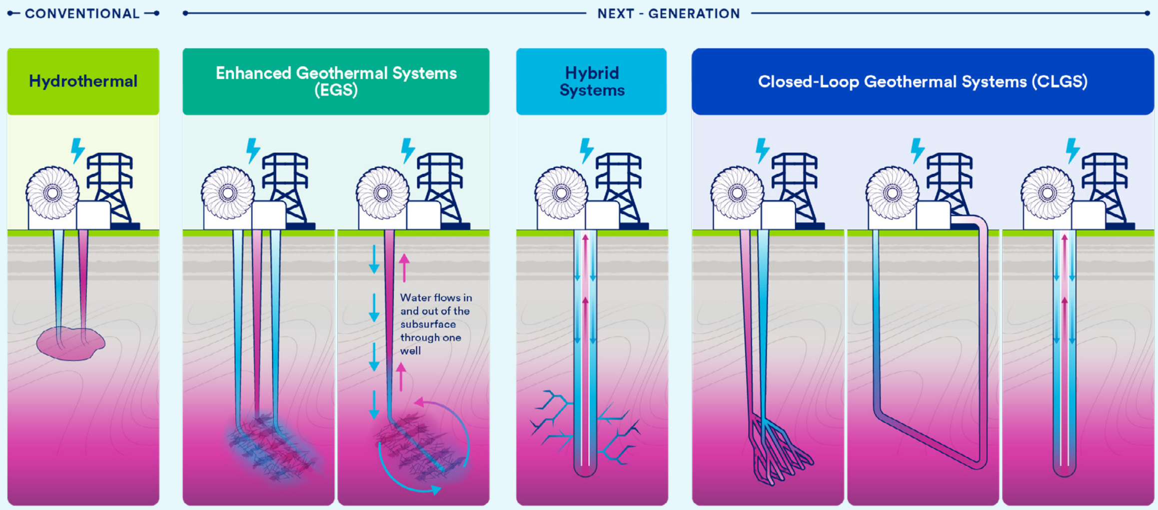
For decades, geothermal energy generation was limited to reservoirs of hot subsurface water. These conventional geothermal systems feature three components, all occurring naturally: hot subsurface rocks, subsurface fluid to transfer the rocks' heat, and permeability (small, interconnected pathways in the rock) so the fluid can travel through the rock and collect the heat. Though conventional geothermal power is a critical part of California's electricity mix, it is also geographically limited.

A sea change in geothermal potential occurred with the recent development of next-generation geothermal systems. Rather than requiring heat, fluid, and permeability to all occur naturally, next-generation geothermal relies only on naturally occurring heat; the other two elements are introduced by the developer. This dramatically expands the resource potential and the locations where next-generation geothermal could be developed.

There are multiple types of next-generation geothermal (see Figure 3):

- closed-loop geothermal systems drill enclosed pathways through rock,
- enhanced geothermal systems use engineered reservoir stimulation to create an underground reservoir,[19] and
- hybrid systems blend some elements of both.

Figure 3. Geothermal systems



Fluids circulate openly through naturally occurring fractures

Fluids circulate openly between wells connected by engineered/ stimulated fractures

Blends elements of EGS and CLGS

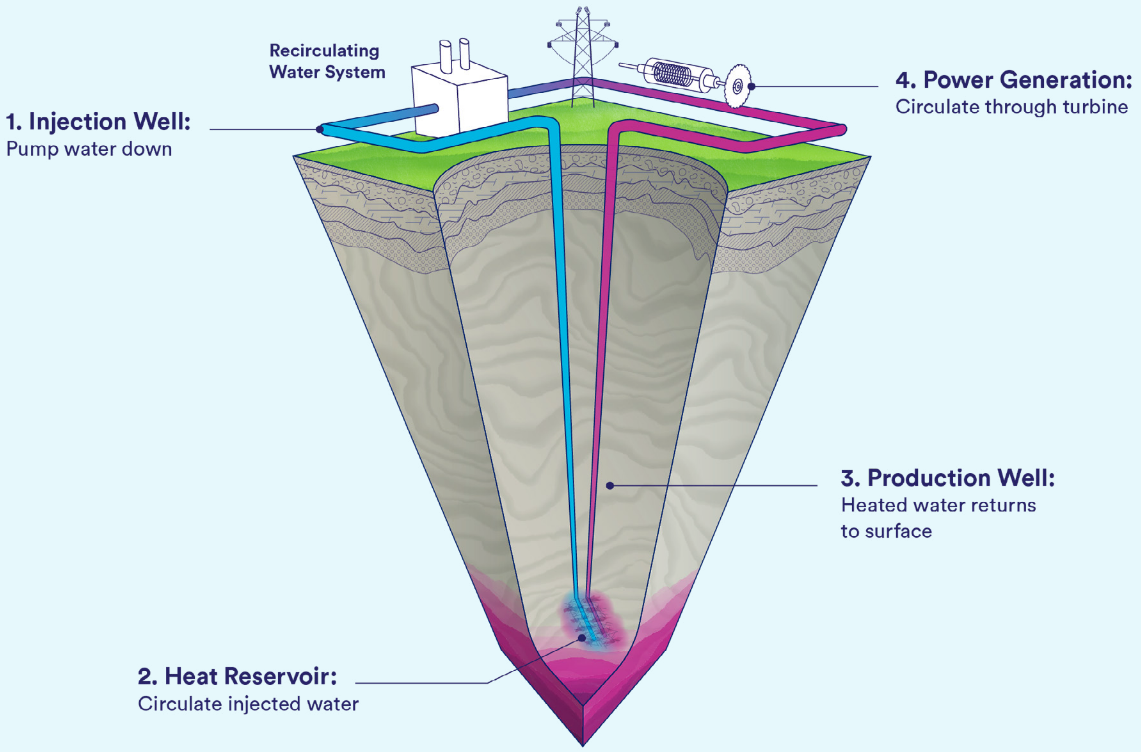
Fluids circulate through closed wellbore loop(s)

Regardless of approach, the goal is to create a subsurface loop through which water can flow, be heated by the surrounding rock, be brought back to the surface, generate electricity, and then be recirculated back through the system (see Figure 4).

---

[19] Engineered reservoir stimulation is also known as hydraulic fracturing or "fracking." Hydraulic fracturing for geothermal energy is different from – and significantly less risky than – fracking for oil and gas, but still carries some risk. Safety protocols developed by leading independent scientists have been used for years to help ensure that geothermal projects which use fracking can be developed and operated safely.

Figure 4. Schematic of next-generation geothermal production[20]



The cost assumptions used for commercially mature EGS in this report are based on a recent peer-reviewed analysis by Ricks & Jenkins (2025), which used published data from recent pilot projects to build a bottom-up cost model for early commercial EGS.[21] Pessimistic 2045 capital cost assumptions for commercially mature EGS are based on near-term cost projections from that paper (i.e., assuming limited long-term cost reductions), while optimistic cost assumptions are based on estimated costs for commercially mature superhot rock geothermal resources from Pezzino (2026).[22] Full input supply curves for in-state and out-of-state EGS resources are shown in Figure 5.

As a point of comparison, the 2045 EGS capital cost assumptions for the pessimistic scenario are approximately equivalent to the announced costs of Fervo Energy's Cape Station EGS pilot project in Utah.[23] To further assess the robustness of EGS's impact and understand the sensitivity to system costs, CATF modeled two sets of future resource cost assumptions, "Low Resource Cost" and "High Resource Cost", where the costs of variable renewables, energy storage, and natural gas power plants and fuel are all either significantly lower than or higher than baseline projections used in the most recent SB100 Joint Agency Report, respectively. While this modeling does not consider the potential deployment of other clean firm technologies, it is plausible that these technologies could fill a role similar to the one identified for next-generation geothermal here.

---

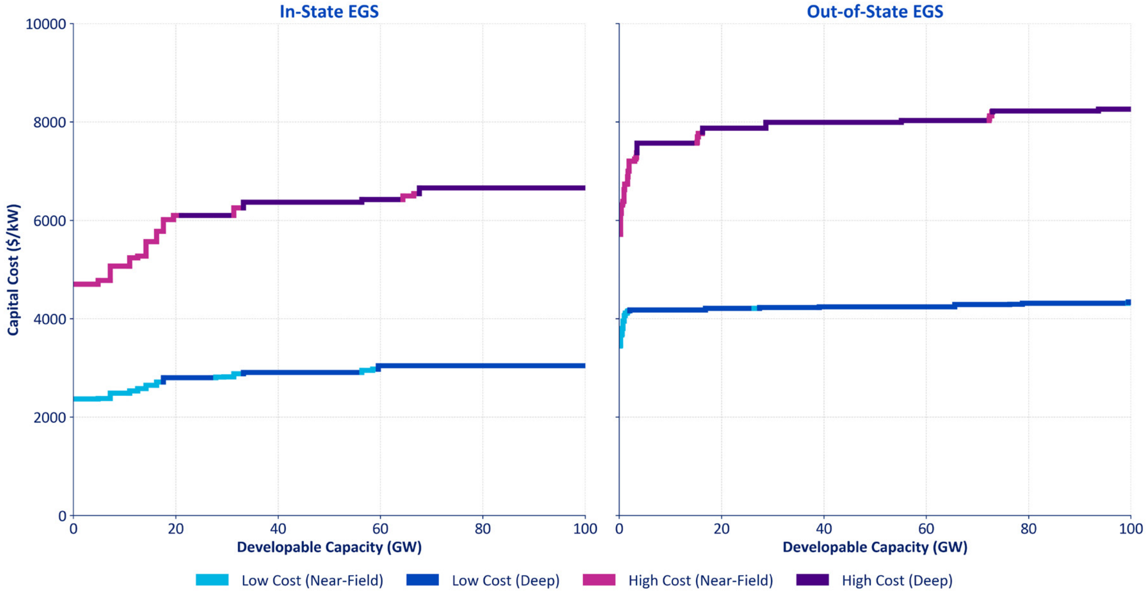
[20] Note: Not to scale. Underground flow conduits for water may involve fracture networks (pictured) or subsurface piping.

[21] Ricks, W. & Jenkins, J.D. (2025). Pathways to national-scale adoption of enhanced geothermal power through experience-driven cost reductions. Joule. https://www.cell.com/joule/abstract/S2542-4351(25)00152-7

[22] Pezzino, J. (2026). Techno-Economic Viability of Next Generation Geothermal Resources Across the Temperature Spectrum: A Comparative Analysis with Superhot Rock. Proceedings of the 51st Workshop on Geothermal Reservoir Engineering. https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2026/Pezzino2.pdf

[23] See the Appendix for details.

Figure 5. Enhanced geothermal supply curves used as model inputs for planning year 2045



Note: Near-field resources located close to conventional geothermal sites are shown in lighter colors. Capital costs for out-of-state resources include costs and losses associated with necessary interregional transmission expansion.

Figure 6 displays the modeled impact of EGS availability on cost-optimal 2045 electricity supply portfolios in California. The first (leftmost) bar represents a scenario where only technologies that are currently experiencing large-scale commercial deployment[24] are available. The rest of the bars represent scenarios where enhanced geothermal power is also available as a commercially mature electricity supply option under optimistic or pessimistic cost assumptions, either anywhere in the western U.S. (including California) or only in regions outside of California.

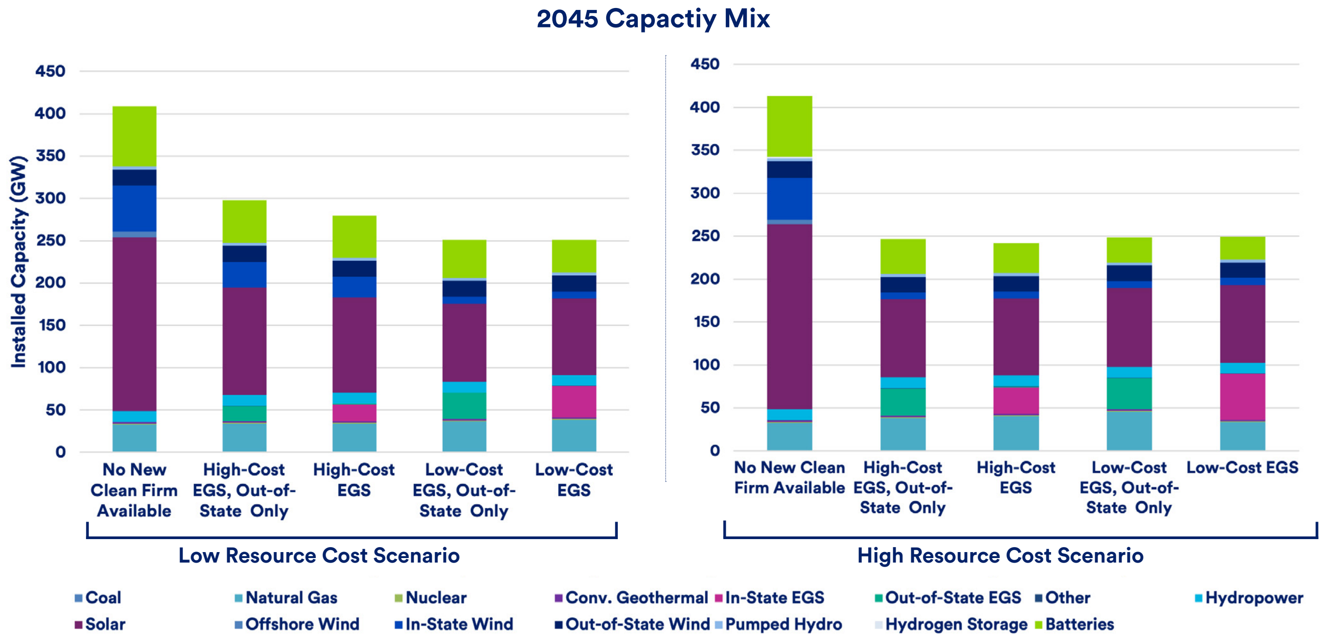
The results shown in Figure 6 indicate that deployment of EGS would drastically reduce the amount of new generating capacity necessary to achieve California's 2045 clean energy targets. Most notably, installation of 30 GW of EGS would provide flexibility for the required pace of solar installation to ease from almost 10 GW/yr to as little as 3 GW/yr, which is closer to California's current pace of solar deployment and likely to be more feasible.3 It would simultaneously reduce the required pace of wind deployment from 3 GW/yr to 1 GW/yr. Due to its relatively lower surface footprint, next-generation geothermal could also serve as an important solution in cases where land use limitations restrict clean infrastructure buildout.[25]

---

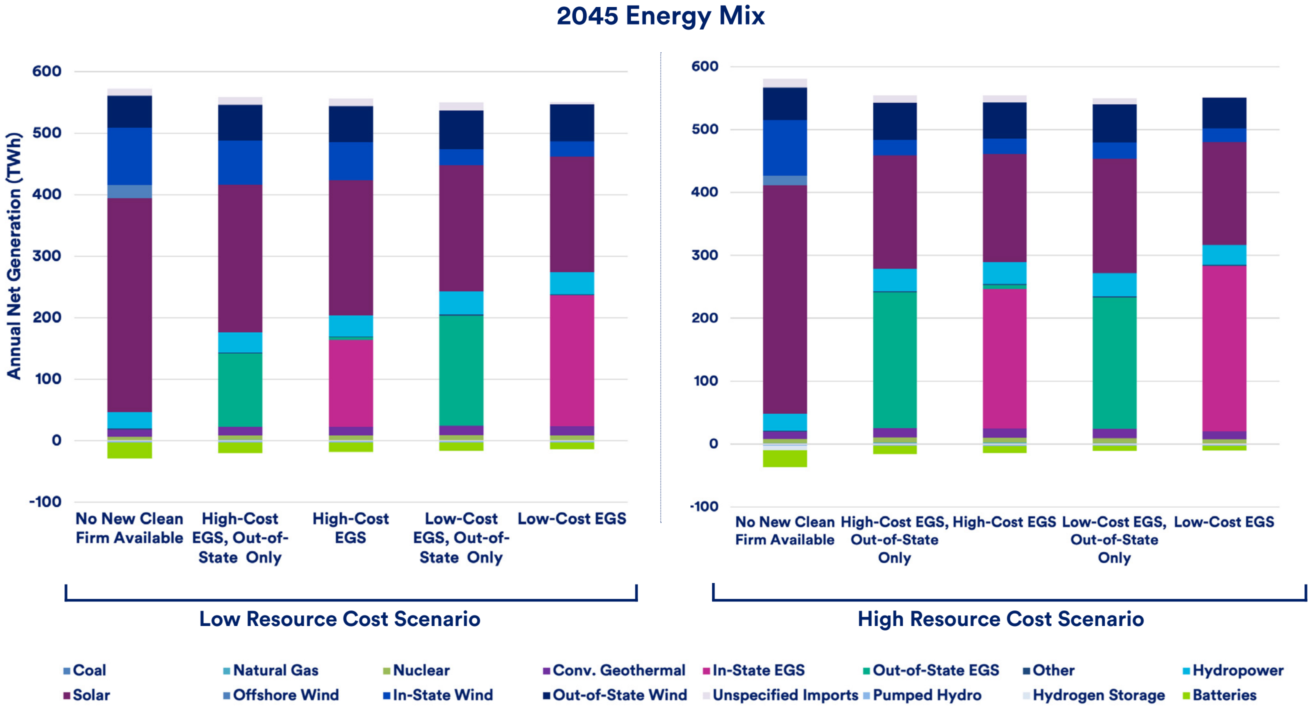
[24] These technologies include: solar photovoltaics, onshore and offshore wind, lithium-ion battery storage, hydrogen storage, and unabated natural gas. New nuclear is not available to the model because of CA's moratorium on new nuclear plants.

[25] Natural gas capacity increases in some scenarios alongside EGS, but these plants operate purely as a reliability backstop and do not contribute additional generation.

Figure 6. Optimized capacity (top) and energy (bottom) mixes for California's 2045 electricity supply portfolio under different resource cost and availability scenarios



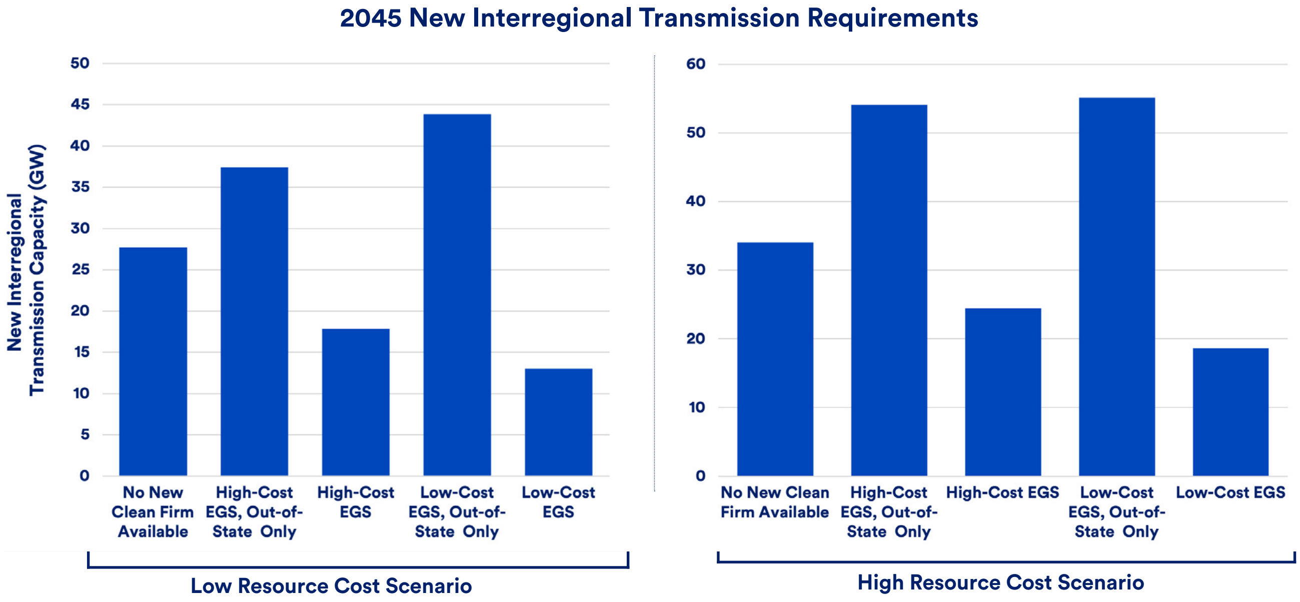
2045 Capactiy Mix



2045 Energy Mix

While the results show similar generating capacity needs across scenarios where enhanced geothermal is only available out-of-state and ones where it can be built in-state, the interregional electricity transmission needs of these scenarios differ significantly. As shown in Figure 7, required interregional transmission expansion between California and other regions is substantially higher (35-62%) in scenarios where enhanced geothermal is only available out-of-state than in the no-geothermal baseline. By contrast, interregional transmission needs are substantially lower (28-53%) compared to the baseline in scenarios where enhanced geothermal can be built in California. Given ongoing challenges with large-scale, long-distance electricity transmission buildout in the U.S., the significant reduction in interregional transmission needs is a major advantage of in-state enhanced geothermal availability.

Figure 7. New-build interregional transmission requirements for the same scenarios shown in Figure 6



The ability to deploy enhanced geothermal power, whether in-state or out-of-state, provides clean firm power that dramatically reduces the cost of achieving California's clean energy targets.

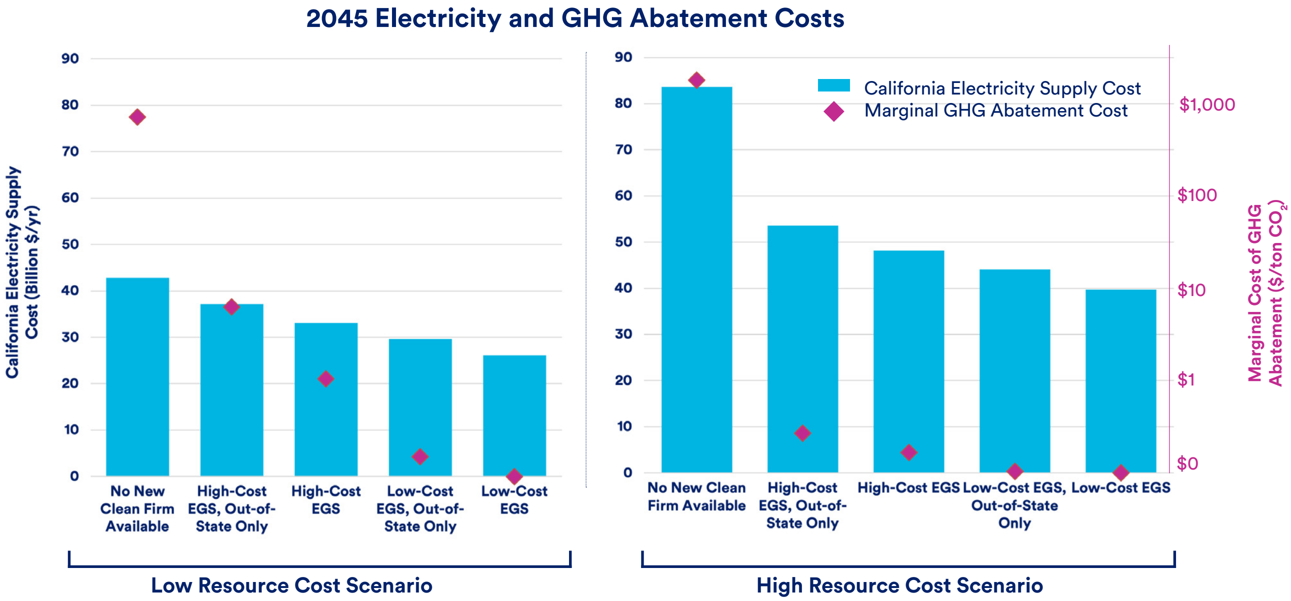
> As shown in Figure 8, deployment of enhanced geothermal power reduces annual electricity supply costs in California in 2045 by $10-44 billion (or 23-52%) by reducing the need to deploy much larger amounts of other resources to achieve the same clean energy and system reliability targets. Furthermore, availability of in-state enhanced geothermal leads to annual cost savings of $3.5-5.5 billion compared to scenarios where it is only available out-of-state.

In-state development creates savings by both enabling utilization of California's own higher-quality geothermal resources and avoiding the need for additional interregional transmission capacity. The marginal cost of greenhouse gas abatement in California's electricity system[26] also falls substantially (by 50-100%) when enhanced geothermal is available, particularly when in-state deployment is possible, suggesting that further emission reductions beyond the 2045 target would be much more achievable when EGS can be developed within California. Importantly, these results hold even when the costs of other technologies fall more than expected (the Low Resource Cost scenario), and the costs of enhanced geothermal are assumed to be relatively high. For reference, the average capital cost of EGS resources deployed in the scenario where they are most expensive (high cost, out-of-state only) is $7,700/kW, while the average capital cost for EGS resources in the scenario where they are least expensive (low cost, deployable anywhere) is $2,700/kW.

---

[26] This is the effective cost of removing the next ton of CO2 from California's electricity supply, and is equivalent to the cost of a carbon allowance.

Figure 8. The total annual cost of California's electricity supply in 2045 under different scenarios, alongside the estimated marginal cost of carbon abatement for each scenario



The above results demonstrate that California has an interest in both ensuring the commercial availability of next-generation geothermal power as an option for procurement, and specifically in ensuring and incentivizing its deployment in-state. While it may be possible for California utilities to initially source next-generation geothermal power from neighboring states where projects are currently more advanced, the combination of cost advantages and lack of dependence on interregional transmission expansion makes in-state development a clear long-term priority.

Though this report focuses on opportunities around next-generation geothermal power, it is possible that other clean firm technologies could fill the same niche identified for EGS in the above modeling if they can be deployed at commercial scale in California. The success of any one of these technologies is not guaranteed, however, and each faces a distinct set of barriers.[27] California policymakers should therefore make parallel efforts to support the local commercialization of as many clean firm technology options as possible.

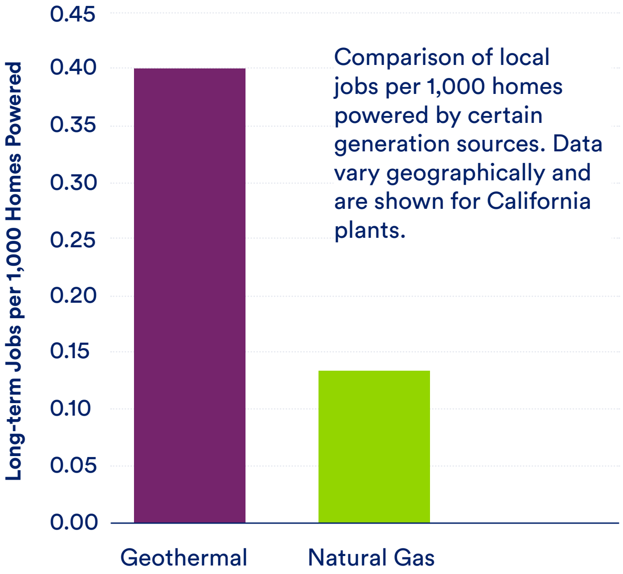
---

[27] For example, the effective moratorium on new nuclear power deployment in California.

Next-generation geothermal also holds a number of additional co-benefits which make it well-suited for deployment in California:

- **Environmental and Community Benefits:** Next-generation geothermal is a low-emissions renewable energy resource that supports climate and public health goals. Because most of the project infrastructure is underground, geothermal development has a small surface footprint, reducing land use impacts.
- **Workforce Development:** Geothermal energy creates stable, long-term jobs for local workers (see Figure 9). Many of the technical capabilities required for next-generation geothermal development—especially drilling, subsurface characterization, reservoir engineering, and well construction—closely match those used in the oil and gas sector. This alignment offers a major opportunity to leverage existing workforce expertise while supporting a practical transition toward clean firm energy deployment.[28] One leading next-generation geothermal developer has stated that it takes only two days to retrain an oil and gas worker to work on an enhanced geothermal system rig.[29]
- **Community Economic Benefits:** Geothermal projects provide significant economic benefits to the local communities in which they take place, most of which are rural and often underinvested in.[30] Even after the initial exploration and construction phases, geothermal power plants create long-term and sustainable sources of tax revenue. Calpine, a company that operates a conventional geothermal project in northern California, is the largest taxpayer in both Lake and Sonoma Counties.[31]

Figure 9: Comparison of long-term jobs per 1,000 homes powered by energy-generation technology[32]



Comparison of local jobs per 1,000 homes powered by certain generation sources. Data vary geographically and are shown for California plants.

---

[28] International Energy Agency. (2025). The Future of Geothermal Energy. https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf; U.S. Department of Energy. (2024). Pathways to Commercial Liftoff: Next-Generation Geothermal Power. https://cdn.catf.us/wp-content/uploads/2025/06/09154348/doe-liftoff-nextgen-geothermal.pdf

[29] House Natural Resources Committee Democrats. (2025, December 16). Energy and Mineral Resources Legislative Hearing | December 16, 2025 [Video]. YouTube. https://democrats-naturalresources.house.gov/news/videos/watch/energy-and-mineral-resources-legislative-hearing_december-16-2025

[30] Clean Air Task Force. (2025, October 15). Advancing the Next-Generation Geothermal Economy in Utah [Video]. YouTube. https://www.youtube.com/watch?v=mLd3o4bRyzc

[31] The Geysers Calpine. (n.d.). The Water Story. https://geysers.com/the-water-story/

[32] U.S. Department of Energy. (2019). Geovision: Harnessing the heat beneath our feet. https://www.energy.gov/sites/prod/files/2019/06/f63/GeoVision-full-report-opt.pdf

A Critical Intervention: An In-State Testbed Program

The need for clean power to serve California's ambitious climate goals is almost single-handedly creating the market for geothermal projects and driving development in western states today.[33] If these projects are built in California, they will positively impact local workers and generate in-state revenue; if they are built exclusively out-of-state, they will lead to a permanent export of wealth from California ratepayers and a very significant missed opportunity to invest in local communities.

The Investment Barrier: Financing Exploration

Next-generation geothermal projects are planned or underway in Utah, Nevada, Oregon, New Mexico, and Texas,[34] but relatively few projects have been announced in California despite the state's rich subsurface heat endowment. This is due to various hurdles that make the development environment riskier and more uncertain in California than it is in other states. Some of these hurdles to development relate to regulations and agency processes,[35] but insufficient understanding of large portions of California's geology is also a significant hurdle, which creates financing challenges and limits geothermal development.

Companies and investors need a good understanding of the subsurface geology at a geothermal project site before commencing large-scale development. During the exploration phase of a next-generation geothermal project, developers collect information about subsurface conditions (e.g., variations in rock type, geochemistry, temperature, and stress regime). This data allows the developer to plan their approach and equipment selection for a full-scale project: improving drilling speed, decreasing costs, and lowering the risk of unsuccessful wells.[36] Exploration wells are a critical step for project viability. However, drilling wells is expensive – wells at recent next-generation geothermal projects cost between $5 million and $13 million,[37] and costs could rise as high as $20 million depending on the length of the well and the geologic settings[38] – and a geothermal

---

[33] For instance, California's 2021 procurement mandate for 1 GW of clean firm power was immediately followed by a surge in geothermal PPAs from 2022-2023. Seventy percent of those PPAs were with California utilities (Zhou, Y., personal communication, February 4, 2026).

[34] Terrell, M. (2023, November 28). A first-of-its-kind geothermal project is now operational. The Keyword. https://blog.google/company-news/outreach-and-initiatives/sustainability/google-fervo-geothermal-energy-partnership/; Cariaga, C. (2025, October 29). Mazama Energy develops 331 °C enhanced geothermal system at Newberry, Oregon. ThinkGeoEnergy. https://www.thinkgeoenergy.com/mazama-energy-develops-331-c-enhanced-geothermal-system-at-newberry-oregon/; Office of the Governor Michelle Lujan Grisham. (2025, June 12). Governor announces XGS Energy, Meta geothermal partnership – Nation-leading 150 MW geothermal project on its way to New Mexico [Press release]. 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/; Patel, S. C. (2025, September 2). Geothermal breakthrough in South Texas signals new era for ERCOT. POWER. https://www.powermag.com/geothermal-breakthrough-in-south-texas-signals-new-era-for-ercot/

[35] Rogers, T., Garth, A., & Arax, A. (2025). Unlocking California's Geothermal Potential: A Strategic Opportunity for Clean, Firm Power. Clean Air Task Force. https://cdn.catf.us/wp-content/uploads/2025/06/23162128/california-geothermal-report.pdf

[36] For example, "Drilling speeds at the Department of Energy (DOE)'s EGS Demonstration Site 'FORGE' improved by over 500 percent in 3 years, and well development costs decreased from $13 million to under $5 million per well between the first two large-scale commercial EGS pilots in the United States." See U.S. Department of Energy. (2024). Pathways to Commercial Liftoff: Next-Generation Geothermal Power. (p. 3). https://cdn.catf.us/wp-content/uploads/2025/06/09154348/doe-liftoff-nextgen-geothermal.pdf

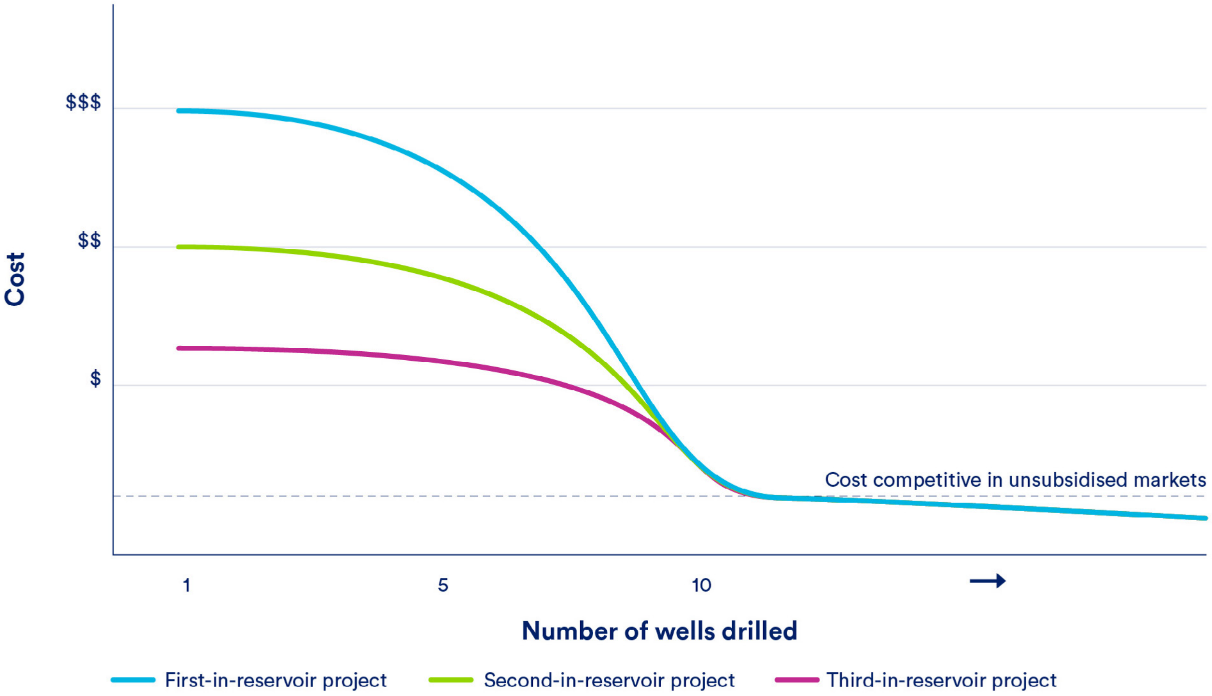
[37] U.S. Department of Energy. (2024). Pathways to Commercial Liftoff: Next-Generation Geothermal Power. (p. 3). https://cdn.catf.us/wp-content/uploads/2025/06/09154348/doe-liftoff-nextgen-geothermal.pdf

[38] The average drilling cost of wells at an early next-generation geothermal project (Project Red), applied to a 6 km well, would be approximately $20 million. See Akindipe, D. & Witter, E. (2025). 2025 Geothermal Drilling Cost Curves Update. National Lab of the Rockies. (p. 3). https://docs.nrel.gov/docs/fy25osti/92793.pdf

project in the exploration phase does not produce revenue and will not for several more years. This creates a structural mismatch between the types of risks present during early-stage geothermal development and the types of investors typically positioned to finance large infrastructure assets. Exploration wells involve subsurface uncertainty and emerging technology risk that traditional infrastructure investors are generally not structured to absorb, while investors more comfortable supporting early technical risk often require shorter return timelines than geothermal development can provide. The result is what's often described as the "missing middle": a gap in available capital for early deployment of large infrastructure projects using emerging energy technologies.[39]

In the case of geothermal energy, this missing middle phenomenon partially repeats in each new geological region (see Figure 10). Due to the lack of historical commercial-scale next-generation geothermal in large swaths of California, the local geology is not as thoroughly characterized for geothermal purposes as it is in some other western states. This means that next generation geothermal projects in California will face significantly higher technical uncertainty than follow-on projects in other, better understood regions with ongoing geothermal development. Given the high expected quality of California's geothermal resources - and the scale achievable with next-generation geothermal technologies - targeted exploration at a single site holds the potential to catalyze many gigawatts of development.

Figure 10: Illustration of the cost of geothermal development over time. Learnings from early wells will dramatically reduce costs and risk for future projects in the same geologic region, but will only partially derisk wells in different regions.



State Action Can Kickstart Development

Improving subsurface knowledge can crowd in significant private investment, but most geothermal companies are startups with limited capital and cannot fund state-wide subsurface mapping programs on their own balance sheets. The best-positioned actor to acquire and distribute subsurface knowledge is the public sector.

A paradigmatic example is the Department of Energy (DOE)'s Frontier Observatory for Research in Geothermal Energy (Utah FORGE) project. This project funded the drilling of geothermal wells in a geologically promising region of southwest Utah and

---

[39] Spokas, K., Ulama, D., Greig, C., Waltzer, K, & Hobart, S. (2025). Systemic bankability is the key to unlocking energy transition speed and scale. Clean Air Task Force. https://www.catf.us/resource/systemic-bankability-is-the-key-to-unlocking-energy-transition-speed-and-scale/

then publicly released the resulting subsurface data, de-risking future development in that region. The result was an influx of billions of dollars of private investment into that area, including developer Fervo Energy's multi-gigawatt Cape Station project, which is directly adjacent to the Utah FORGE site.[40]

This public investment into Utah FORGE directly enabled commercial-scale projects in Utah from which California load-serving entities are now contracted to purchase nearly 500 megawatts of power.[41] But without similar support for the exploration phase of next-generation geothermal power development, California is exporting ratepayer money to develop those workforce and economic benefits to other states.

An in-state testbed effort could address early-stage exploration risk and position California as a leader in next-generation geothermal power, unlocking local development at the scale necessary to meet its clean firm generation needs. California's geothermal resources are also expected to be higher-temperature than the resources in many nearby states, and developing these superhot geothermal systems could lower costs even further compared to current prices.

State investment could support a coordinated program of exploration wells in one, or various, geological regions. Integrating a cost-share from geothermal developers would reduce the cost of a California testbed relative to the original Utah FORGE model while also accelerating private-sector investment in commercial-scale deployment. Information gained through these wells would reduce subsurface uncertainty and could incentivize new geothermal development, crowd in private capital, and initiate a virtuous cycle of development. As a result of the scale achievable with next-generation geothermal technologies, efforts that successfully de-risk a single area could directly catalyze multiple gigawatts of local development. Ultimately, a testbed program could meaningfully contribute to the deployment of next-generation geothermal resources across much of California. Given California's importance as an offtaker of next-generation geothermal power, the ability to develop next-generation geothermal in-state and avoid potential interregional transmission constraints could help the technology scale up and achieve commercial maturity more rapidly than would otherwise be possible.

With the state's electricity decarbonization deadlines fast approaching and limited clean firm technology options available for in-state deployment, now is the time for state action to advance geothermal energy. A testbed initiative could also take advantage of federal funding opportunities that require a cost-share. An example from spring 2026 is the U.S. Department of Energy's (DOE) Notice of Funding Opportunity for up to $71.5 million to fund a geothermal exploration program.[42]

California has a strong track record in helping promising clean energy technologies reach commercial scale through targeted early-stage support, including the Million Solar Roofs initiative that helped bring down the cost of solar photovoltaics,[43] financial and policy support that enabled today's electric vehicle and lithium-ion battery revolution,[44] and the Electric Program Investment Charge (EPIC) program.[45] Thoughtful effort can do the same for next-generation geothermal.

> While a testbed program is just one of multiple steps needed to derisk next-generation geothermal development in California, it is an important step. State investment could meaningfully contribute to derisking the subsurface in high-potential geologic regions, crowding in private investment, and helping California deploy next-generation geothermal at scale.

---

[40] Fervo Energy. (2025). Fervo energy drills 15,000-ft, 500°F geothermal well pushing the envelope For EGS deployment [Press release]. https://fervoenergy.com/fervo-energy-pushes-envelope/

[41] Fervo Energy. (2026, March 19). Fervo Energy Secures $421 Million in Non-Recourse Project Financing for Cape Station [Press release]. https://fervoenergy.com/fervo-energy-secures-421-million-in-non-recourse-project-financing-for-cape-station/

[42] See Department of Energy. (n.d.). Funding Notice: Next-Generation Geothermal Field Tests and Geothermal Resource Characterization and Confirmation. U.S. Department of Energy. https://www.energy.gov/hgeo/geothermal/funding-notice-next-generation-geothermal-field-tests-and-geothermal-resource. New Mexico is planning to reserve some of its Geothermal Projects Development Fund to serve as potential cost-share for DOE-funded projects in New Mexico.

[43] Hallock, L. & Kinman, M. (2015). California's Solar Success Story: How the Million Solar Roofs Initiative Transformed the State's Solar Energy Landscape. Environment California Research & Policy Center and Frontier Group. https://environmentamerica.org/california/wp-content/uploads/2015/07/CA_Solar_Success_scrn_FINAL_7-7-2015.pdf

[44] UC Davis India ZEV Research Centre. (N.d.). A brief history of California ZEV Policy. https://indiazev.ucdavis.edu/brief-history-california-zev-policy

[45] California Energy Commission. (2023, May 3). California's Clean Energy Research and Development Program Delivers 10x Return on Investment [Press release]. https://www.energy.ca.gov/news/2023-05/californias-clean-energy-research-and-development-program-delivers-10x-return

Conclusion

Next-generation geothermal holds the potential to revolutionize California's energy mix. CATF's modeling shows that access to next-generation geothermal power, even if developed outside the state, reduces overall system costs. In-state deployment further lowers ratepayer costs, reduces reliance on large-scale transmission expansion, and eases the pace of solar and storage buildout required to meet 2045 targets. Developing these resources within California would also support local economic activity and workforce opportunities. Together, these results suggest that ensuring the commercial availability of enhanced geothermal power would strengthen both the affordability and the deliverability of California's long-term clean energy strategy.

State action is needed to kickstart the development of this important new energy source and realize its benefits for Californians. Targeted intervention is needed in multiple places in the geothermal project lifecycle – including at the exploration stage, when risks are highest and private capital is unwilling to step in. Thoughtful public support for geothermal exploration could help kickstart a cycle of development, deployment, and growth in next-generation geothermal in California. If California wants to bring geothermal in-state, rather than continuing to export ratepayer wealth to out-of-state development, the time to act is now.

Appendix: Modeling Methods

The modeling results presented in this report were produced using GenX,[46] a state-of-the-art open-source electricity sector capacity expansion model developed at MIT and Princeton University. The model optimized electricity system expansion across a 34-zone representation of the Western Interconnection (see Figure A1) for planning years 2030, 2035, and 2045, minimizing system costs in each planning year while meeting physical and policy constraints. The representation of California's electricity supply portfolio and electricity sector climate policies was designed to replicate the electricity system modeling featured in the most recent SB100 Joint Agency Report as closely as possible, including constraints on out-of-state resources, limits on GHG emissions, and the SB100 policy itself.[16] For example, the model implements an 8 MMTCO2/yr limit on emissions from California's electricity supply in 2045, including emissions from both in-state generation and specified plus unspecified imports. The model furthermore assumes that California's current moratorium on new nuclear development remains in place, and that the Diablo Canyon nuclear plant retires by 2030, as required under current statute.

GenX inputs, including existing resource capacities, were compiled using PowerGenome.[47] This analysis uses future electricity demand projections from the National Lab of the Rockies' (NLR) ReEDS electricity system model default inputs,[48] and future technology cost projections from NLR's 2024 Annual Technology Baseline (ATB).[49] Low Resource Cost and High Resource Cost scenarios shown in this analysis increase capital costs for renewables, storage, and natural gas power plants by 50% or reduce them by 33% compared to the ATB baseline, respectively. The High Resource Cost scenario also uses "Low Oil and Gas Resource" natural gas price projections from the EIA's 2025 Annual Energy Outlook (AEO),[50] while the Low Resource Cost scenario uses "High Oil and Gas Resource" projections. Because natural gas prices are highly volatile and, with increasing liquefied natural gas exports, can be sensitive to geopolitical market shocks, future gas price projections vary more significantly than the capital costs of electricity technologies. See Figure A2 for a comparison of cost assumptions in these modeled scenarios to the SB100 report baseline.

For enhanced geothermal, the high-cost scenario adopts near-term cost projections from Ricks & Jenkins (2025) while assuming baseload operations, and the low-cost scenario uses estimates of commercially mature superhot rock geothermal costs from Pezzino (2026), while also assuming flexible operations.[51] Supply curves for in-state and out-of-state enhanced geothermal resources are shown in Figure 5 of the main text, and are based on temperature-at-depth datasets from the Stanford Thermal Earth Model.[52]

---

[46] Jenkins, J.D. et al. (n.d.). GenX: A configurable electricity resource capacity expansion model [Computer software]. Github. https://github.com/GenXProject/GenX.jl

[47] Schivley, G. et al. (n.d.). Powergenome: Power system optimization model inputs [Computer software]. Github. https://github.com/PowerGenome/PowerGenome

[48] National Laboratory of the Rockies. (n.d.). ReEDS 2.0: Regional energy deployment system model [Computer software]. GitHub. https://github.com/NatLabRockies/ReEDS-2.0

[49] National Laboratory of the Rockies. (2024). 2024 Annual technology baseline: Electricity. https://atb.nrel.gov/electricity/2024/data

[50] U.S. Energy Information Administration (2025). Annual energy outlook 2025. https://www.eia.gov/outlooks/aeo/

[51] Flexible operations allow wellfield capacity (and therefore cost) to be reduced by 23% while retaining the same maximum flow rate and electric generating capacity. Maximum allowable annual heat extraction is also reduced by the same proportion to maintain thermal decline rates.

[52] Aljubran, M. and Horne, R. (2024). Thermal Earth model for the conterminous United States using an interpolative physics-informed graph neural network. Geothermal Energy. https://link.springer.com/article/10.1186/s40517-024-00304-7

Figure A1: Visualization of the 34-zone Western Electricity Coordinating Council (WECC) system model used in the GenX modeling presented here, including existing interregional transmission

WECC 34-Zone System Topology: Model Regions and Transmission Network

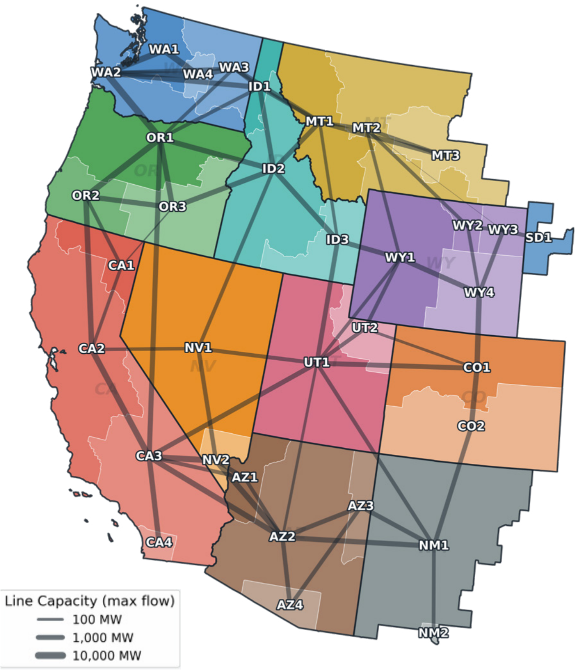
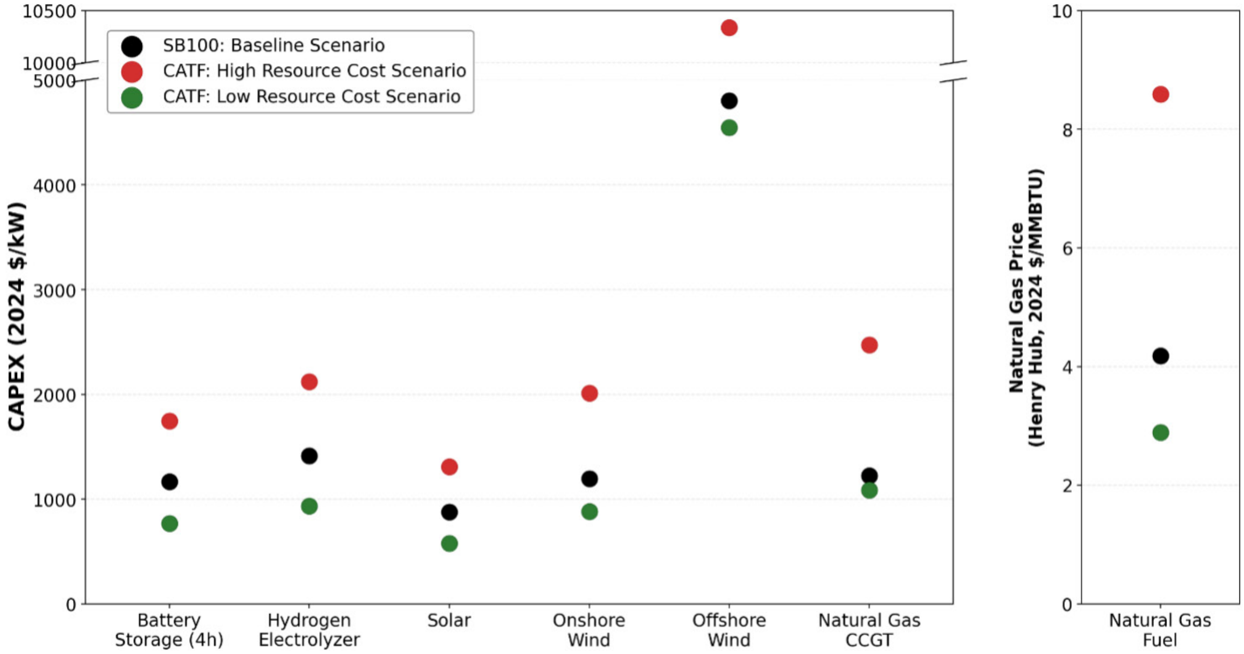


Figure A2: Technology cost input assumptions from the most recent SB100 Joint Agency Report and the CATF modeling presented in this report

2036-2045 Resource Cost Input Assumptions

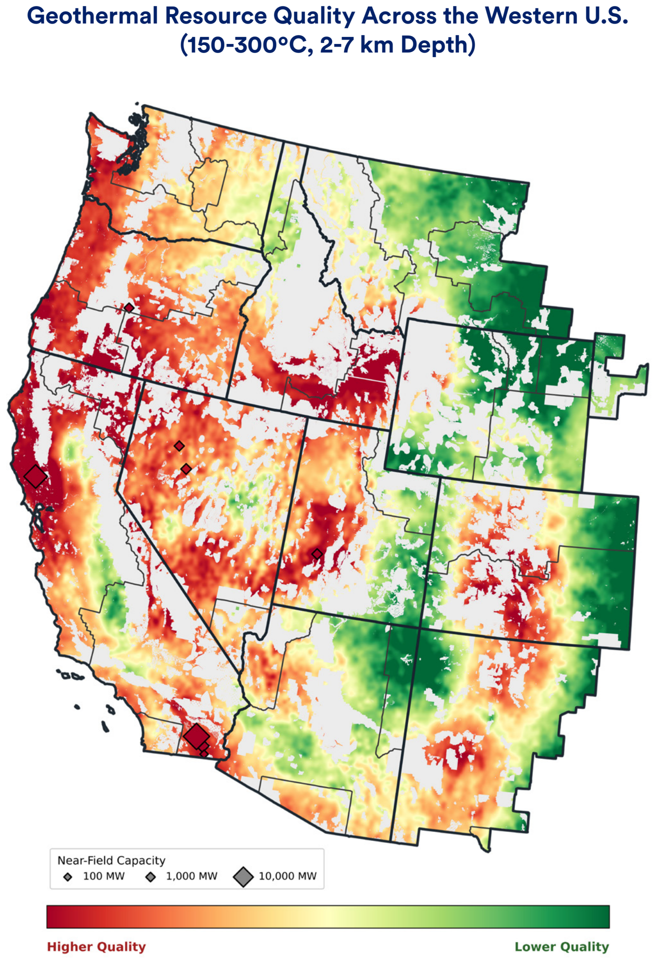


Note: CAPEX values compare average input capital costs over the 2036-2045 buildout period, while natural gas prices are for the year 2045. SB100 report inputs come from the 2023 NLR ATB and EIA AEO, while CATF inputs come from the 2024 ATB and 2025 AEO.

For reference, developer Fervo Energy estimates the capital cost of the first 100 MW of its Cape Station EGS pilot project at approximately $7,000/kW, and the capital cost of the next 400 MW phase at approximately $5,500/kW. The latter value is effectively equivalent to the cost estimated by the Ricks & Jenkins (2025) model for an early-commercial EGS project operating at the same depth, resource temperature, and ambient air temperature (approximately $5,400/kW).[53] Policymakers should note that upfront capital costs will not necessarily reflect the full cost of electricity from an EGS project, and that additional operational data from early projects will be needed to project future commercial-scale EGS cost and performance with high confidence.

A map of developable near-field and deep enhanced geothermal resources – those without surface land use restrictions – illustrating relative resource quality by location is shown in 3. Following the practice used in the SB100 Joint Agency Report, out-of-state geothermal and wind resources are modeled as in-state, with costs and losses associated with any interregional transmission expansion necessary to deliver these resources' energy and capacity factored in. Finally, this report assumes that EGS power plants are designed as air-cooled binary systems to minimize water usage, meaning enhanced geothermal power output is reduced when ambient air temperature is high and increased when air temperature is low. Hourly enhanced geothermal capacity factors used in the modeling are based on historical weather data for the same weather years used to produce wind, solar, and demand variability profiles.

Figure A3: Map of deep and near-field EGS resource potential across the western U.S. based on temperature-at-depth data from the Stanford Thermal Earth Model



Note: Areas with current surface development barriers are excluded.

---

[53] Fervo Energy Company. (2026, April 17). Form S-1 registration statement under the Securities Act of 1933 (Registration No. 333-[number]). U.S. Securities and Exchange Commission. https://www.sec.gov/Archives/edgar/data/1853868/000162828026025821/fervoenergy-sx1.htm