

Next-Generation Geothermal at Scale: A Global Action Framework

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CLEAN AIR TASK FORCE

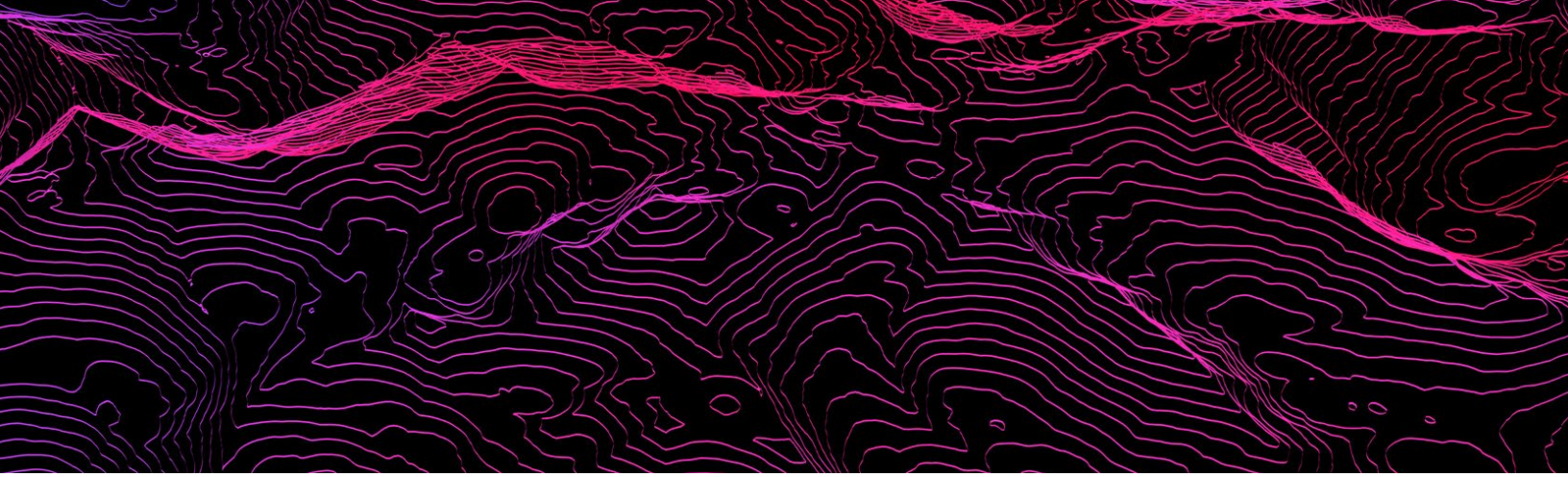
This report is part of a broader effort at Clean Air Task Force (CATF) to address technical and policy barriers to next-generation geothermal development.[1] CATF's Next-Generation Geothermal at Scale report series[2] maps the barriers that next-generation geothermal energy faces and the policy actions that governments across the globe can take to remove those barriers. This report provides policy recommendations suitable for policymakers at the level of national governments and regional institutions.

Acknowledgements

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[1] *See* Clean Air Task Force. (n.d.). Bridging the Gaps: A Survey of Methods, Challenges, and Pathways Forward for Superhot Rock Geothermal Energy. https://www.catf.us/superhot-rock/bridging-gaps/ *and* Clean Air Task Force. (n.d.). The Heat Beneath our Feet: Mapping the potential of superhot rock geothermal. https://www.catf.us/superhot-rock/heat-mapping/

[2] *See* Clean Air Task Force. (n.d.). *Next-Generation Geothermal at Scale.* https://www.catf.us/resource/next-generation-geothermal-at-scale/



Executive Summary

Recent innovations are unlocking geothermal energy in regions where it was once thought impossible. Instead of searching for subterranean pockets of hot water, "next-generation geothermal" can produce power wherever subsurface rocks are hot. It has the potential to generate vast amounts of clean firm energy across the world, which can support grid resilience, help meet projected growth in energy demand, and enable affordable decarbonization. However, this enormous potential has not yet translated into wide-scale deployment. Policy work is needed to meaningfully advance geothermal energy, and the first countries to complete that work will reap the benefits of this transformative new energy resource.

Next-generation geothermal technologies are poised to scale across the world, but countries can do more to help the industry overcome challenges associated with early-stage financing and deployment. Developing early projects comes with higher costs and greater uncertainty, necessitating large amounts of capital. At the same time, the suppliers of such capital have a low appetite for risk. Detailed subsurface data, critical for derisking project development, is lacking in many regions. Uncertainty about key project requirements – such as transmission access or permitting timelines – adds additional risk. With thoughtful and targeted policy, governments can address these barriers, helping geothermal projects deploy and generating learnings that will reduce costs and risk for the whole industry.

While innovation is crucial to expanding the geographic range of geothermal energy, there are many geothermal approaches that are already commercially viable and poised to scale today. Policy action is crucial to enable large-scale, near-term deployment of geothermal energy while simultaneously advancing innovation.

Realizing next-generation geothermal's full potential requires policy action across five deployment levers: key areas that collectively represent the full spectrum of barriers to deployment. Governments and multilateral institutions that take the initiative on targeted policy interventions in these areas will derisk development, attract private capital, and unlock geothermal energy in their jurisdictions.

1. Characterize: Mapping geothermal's subsurface resource potential is a crucial lever to lowering the cost and risk of projects in new regions. Collecting and sharing information about key subsurface characteristics – such as temperature at depth, the distribution and properties of rock formations, and the structure and connectivity of natural fracture networks – will derisk geothermal projects and crowd in private investment.

2. Govern: Establishing a regulatory system that works for industry and communities is necessary to ensure that geothermal can scale efficiently and safely. Countries can develop clear and predictable regulations for leasing and permitting all phases of a geothermal project. Also critical is coordination and communication among and between regulatory agencies.

3. Finance: Incentivizing exploration and demonstration through targeted funding programs will ensure that geothermal projects can deploy, thus attracting private investment and bringing costs down through iterative cycles of "learning-by-doing."

4. Connect: Developing supportive infrastructure is necessary for the geothermal industry to scale. Countries can improve access to transmission, facilitate the transition of oil and gas workers to the geothermal industry, ensure companies have access to robust supply chains for key materials, and educate the public about geothermal energy.

5. Innovate: Sustaining research and development (R&D) is necessary to help next-generation geothermal reach hotter temperatures and deeper depths, making it scalable and affordable in more locations. Targeted R&D and global coordination can advance superhot rock geothermal and ultra-deep drilling, helping create a world of terawatt-scale geothermal deployment.

Implementing these recommendations[3] will require information sharing and coordination among relevant stakeholders as well as funding for implementation by government agencies. Considering the energy and economic benefits of next-generation geothermal deployment, targeted policy can lead to outsized benefits.

Thoughtful implementation of the recommendations above can advance next-generation geothermal to its full potential – producing abundant clean firm energy, providing economic opportunities for workers and communities, and delivering affordable and reliable energy.

[3] For a list of all policy recommendations in this report, *see* Appendix A: Policy Recommendations.

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SECTION 1

Introduction

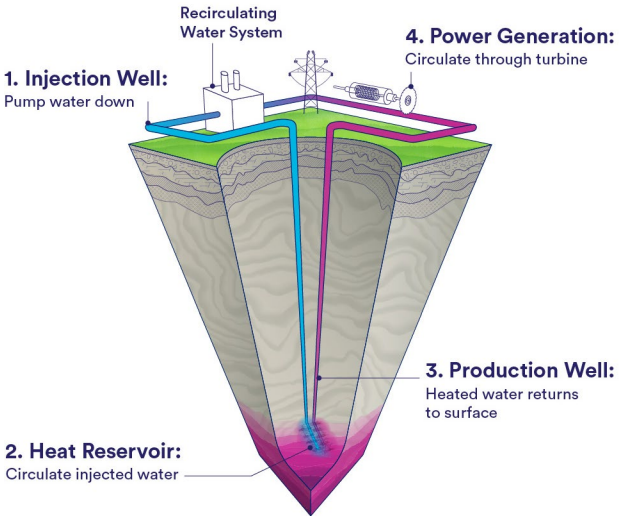
Geothermal can deliver clean firm power at unprecedented scale

Geothermal energy requires three components: hot subsurface rocks, fluid to transfer the rocks' heat, and permeability (small pathways in the rock) so the fluid can travel through the rock and collect the heat (see Figure 1). For many years, geothermal energy was limited to locations where all three of these factors occurred naturally – reservoirs of hot subsurface water known as conventional geothermal systems. Because these reservoirs are rare, geothermal deployment has been limited – global installed geothermal capacity is only 17 gigawatts (GW),[4] compared to 4,448 GW of global installed capacity for all renewables.[5]

Technological advancements over the last decade have enabled the development of game-changing next-generation geothermal systems.[6] Rather than requiring heat, fluid, and permeability to all occur naturally, next-generation geothermal relies on only naturally occurring heat; the other two elements are introduced by the developer.[7]

Figure 1: Schematic of next-generation geothermal production

For a representation of different types of next-generation geothermal systems, see Figure 2.[8]



4 Richter, A. (2026, January 12). *Global top 10 geothermal power countries at year-end 2025.* ThinkGeoEnergy. https://www.thinkgeoenergy.com/global-top-10-geothermal-power-countries-at-year-end-2025/

5 International Renewable Energy Agency. (2025, March 25). *Renewable capacity highlights.* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2025/Mar/IRENA_DAT_RE_Capacity_Highlights_2025.pdf

6 These advancements include faster drilling, the ability to access higher subsurface temperatures, and faster water flow through geothermal systems. Innovations in hydraulic fracturing and horizontal drilling from the oil and gas sector have also been modified to make geothermal possible in "dry rock" conditions. *See* Lipton, J., & Seligman, A. (2025). *Powering the future: What 50 years of enhanced geothermal teaches us today.* Clean Air Task Force. https://www.catf.us/wp-content/uploads/2025/08/CATF-EGS-Trend-Analysis-Report.pdf. Hydraulic fracturing is also known as "fracking"; it is used in some geothermal systems. Fracking 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 that use fracking can be developed and operated safely. *See* McLaughlin, K., Jaeger, J., Womble, J., Bird, L., Hausker, K. (2024). (p.16-17). *Next-generation geothermal: Considerations and opportunities for responsible development.* World Resources Institute. https://doi.org/10.46830/wriib.24.00015.

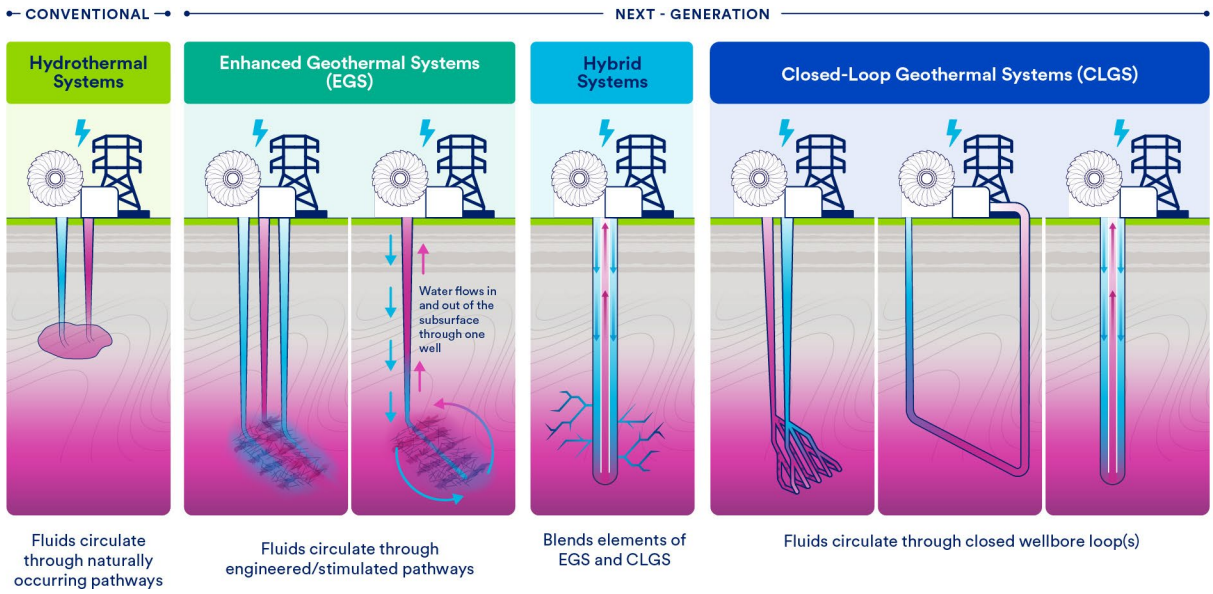
7 Projects often use brackish water or municipal wastewater rather than freshwater.

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

There are multiple types of next-generation geothermal (e.g., enhanced geothermal systems, closed-loop geothermal systems, and hybrid systems), which work in slightly different ways (see Figure 2). These systems can generate electricity and can also produce heat for industrial processes and district heating, either separately or as a cascading benefit from electricity generation.[9]

Figure 2: Types of geothermal systems

Each type can produce geothermal energy at varying temperatures, from low to superhot.



Next-generation geothermal has significant growth potential: **the International Energy Agency (IEA) estimates that global geothermal power generation could increase 60-fold by 2050,[10] ultimately providing as much as 8% of global electricity.[11]** And these estimates reflect geothermal resources accessible using current and near-commercial technologies; continued innovation in areas such as superhot rock geothermal could expand the resource base substantially.

9 For example, one next-generation geothermal project in Germany is expected to produce 8.2 MW of electricity and 64 MW of district heating; this model could be used in the U.S. as well. Geothermal energy can also be used as a source of heat for residential, commercial, and industrial sectors. *See* Gallucci, M. (2025, October 28). Eavor is about to bring its first-of-a-kind geothermal project online. Canary Media. https://www.canarymedia.com/articles/geothermal/eavor-is-about-to-bring-its-first-of-a-kind-geothermal-project-online

10 IEA estimates geothermal's potential at over 6,000 TWh of power, compared to 97 TWh produced from geothermal in 2022. *See* International Energy Agency. (2024). *The Future of Geothermal Energy.* https://www.iea.org/reports/the-future-of-geothermal-energy *and* International Renewable Energy Agency. (2024). *Renewable energy highlights* [Fact sheet]. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2024/Jul/Renewable_energy_highlights_FINAL_July_2024.pdf

11 International Energy Agency. (2024). *The Future of Geothermal Energy.* https://www.iea.org/reports/the-future-of-geothermal-energy

Superhot rock geothermal, at temperatures of 375°C and above, is the highest-temperature form of geothermal. It can be produced in any type of geothermal system (for an illustration of the types of geothermal systems, see Figure 2) and has the greatest potential of any geothermal approach, though innovation will be required to effectively produce power at superhot temperatures.[12] CATF's modeling finds that just 1% of the world's superhot rock geothermal resource could produce 63 terawatts of clean firm power, which could generate over 526,000 terawatt hours of electricity: the equivalent of 310 billion barrels of oil[13] or 8 times global electricity consumption.[14]

Beyond its abundant energy potential, next-generation geothermal also produces domestic energy without fuel, reducing exposure to fuel price volatility and increasing energy security. It has a much smaller land footprint than other energy sources. It is renewable power that supports community health by reducing air pollution. Because it requires drilling and subsurface expertise, it can also provide quality domestic jobs for workers from the fossil fuel industry. And it is a baseload resource that can deliver reliable, clean firm electricity whenever it is needed, reducing infrastructure requirements, lowering total system costs, and expanding viable decarbonization pathways.[15]

About this report

Next-generation geothermal energy has vast resource potential, but it still needs targeted policy support to scale.

This report identifies five deployment levers essential to unlocking geothermal's full potential:

Characterize	Govern	Finance	Connect	Innovate
Map geothermal's subsurface resource potential	Establish a regulatory system that works for industry and communities	Incentivize exploration and demonstration	Develop supportive infrastructure	Sustain R&D

[12] Most next-generation geothermal systems operate at temperatures of about 150-275°C (300-525°F), but superhot rock geothermal targets subsurface heat of around 375°C (707°F) and above. These temperatures create a step change in energy density, giving superhot rock geothermal the potential to produce the lowest-cost geothermal energy. *See* LucidCatalyst and Hotrock Research Organization. (2023). *A preliminary techno-economic model of superhot rock energy.* Clean Air Task Force. https://cdn.catf.us/wp-content/uploads/2022/12/26120004/shr-technoeconomic_2023report.pdf

[13] Using the formula 1 GWh of electrical generation = 588 barrels of oil equivalent

[14] Clean Air Task Force. (n.d.). The Heat Beneath our Feet: Mapping the potential of superhot rock geothermal. https://www.catf.us/superhot-rock/heat-mapping/

[15] 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/

These deployment levers are based on the systemic bankability framework, which describes systemic financing challenges and risks for emerging energy technologies and suggests policies that are calibrated to address those risks.[16] A description of the overlap between the systemic bankability framework and the deployment levers listed in this report can be found in Appendix C. In addition to content related to systemic bankability, this report also considers actions needed to enable technological progress for next-generation geothermal.

Each deployment lever in the report is followed by a list of supportive policy mechanisms. Not every policy mechanism will be possible in each region, and some may be more appropriate in some places than others. What matters is that action is taken for each of the five deployment levers in each jurisdiction that wants to scale next-generation geothermal.

The report focuses on utility-scale electricity generation from next-generation geothermal. Ground-source heat pumps, thermal energy networks, district heating, and conventional geothermal energy are out of scope for this report, though some of the recommendations may also enable their development.

To inform the recommendations in this report, CATF spoke with leading geothermal developers to understand the barriers to deployment that their projects face, and with academic and technical experts on geothermal from around the world. The clear conclusion from this research is that **government action to support next-generation geothermal can significantly impact the scale and scope of its deployment.**

[16] 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/

SECTION 2

Barriers to Geothermal Deployment

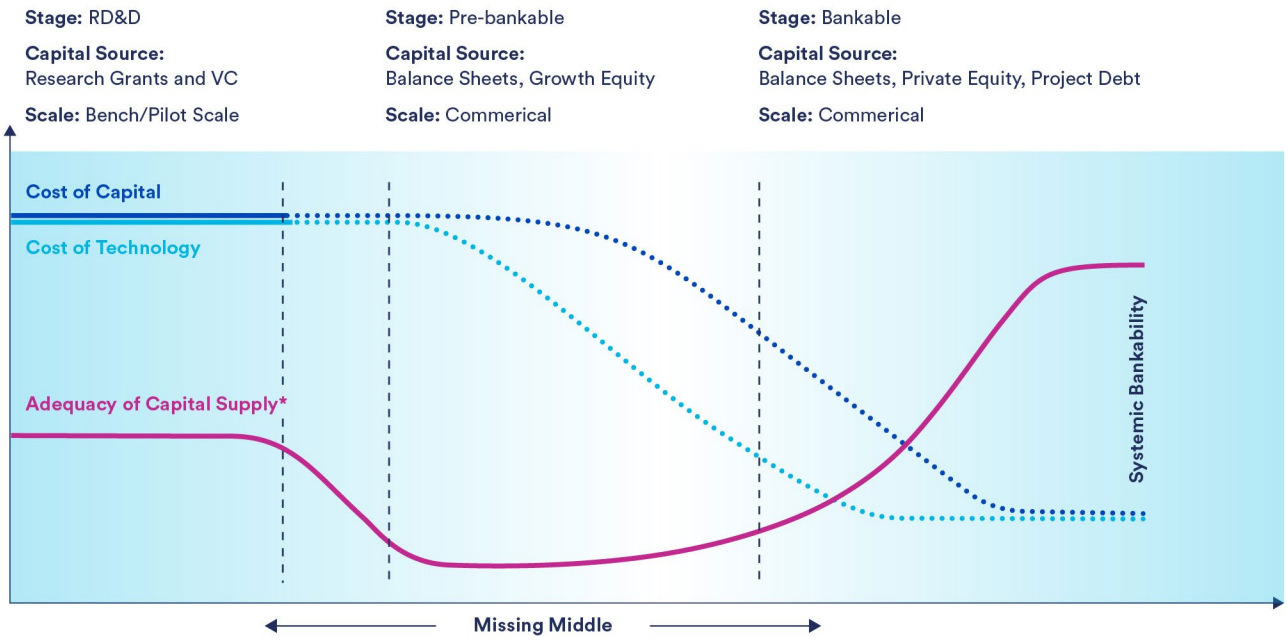
Next-generation geothermal is poised for global expansion, but its development has been limited – clustered in the places where shallow heat, well-characterized subsurface conditions, transmission access, and transparent regulatory frameworks already exist. Government action is critical to achieving commercial-scale deployment across broader geographies. While continued R&D will help bring costs down and improve long-term performance, **technology is no longer the primary barrier to deployment – economics and project development risk are.**

The root cause of economic barriers to deployment is the intersection between geothermal development risks and the preferences of the private capital market in many countries, which governments can alleviate with thoughtful and targeted policy action.

Next-generation geothermal faces a familiar financing gap commonly referred to as the "missing middle" (see Figure 3).[17] This refers to an intermediate stage of commercial development, after the pilot stage but before bankable replication. In this period, projects are perceived as too risky for late-stage infrastructure investors and too capital-intensive for most early-stage venture capital (VC) funds.

[17] 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/

Figure 3: Illustrative figure of cost of capital, cost of technology, and adequacy of capital from the early research, development and deployment (RD&D) stage to the pre-bankable and bankable stages[18]



In many emerging industries, the missing middle stems primarily from technical risk. For next-generation geothermal, this investment valley is attributable to a combination of technical as well as geological resource risks – both of which can be mitigated through policy action.

Early-stage project risks

Like any new technology, the first commercial-scale next-generation geothermal projects are expected to generate electricity at above-market prices in most regions, and they face elevated risks of cost overruns during early deployment. Over time, learning-by-doing brings costs down (see Figure 4). In the case of next-generation geothermal, learning-by-doing is enabling rapid cost declines, largely due to improvements in drilling speed and operational efficiencies that come from standardized practices and repeatable execution in the field (see Figure 5).[19] But it remains uncertain how first-of-a-kind (FOAK) commercial deployments will perform over their intended operational life, in part because the application of these technologies in geothermal settings at commercial scale is still relatively new.

Investors are eager to back geothermal projects once costs and uncertainty decrease further but hesitate to put in the capital necessary for early projects.

[18] 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/

[19] The FORGE testbed in the western U.S. has demonstrated a 500% improvement in drilling speeds since 2017, and recent modeling updates based on data from early commercial projects indicates that drilling costs could be up to 25% lower than previously expected. *See* Palmer, I. D. (2025, January 30). Third energy innovation signaling a golden age: Enhanced geothermal. Forbes. https://www.forbes.com/sites/ianpalmer/2025/01/30/third-energy-innovation-signaling-a-golden-age-enhanced-geothermal *and* Akindipe, D. & Witter, E. (2025). *2025 Geothermal Drilling Cost Curves Update.* National Lab of the Rockies. (p. 3). https://docs.nlr.gov/docs/fy25osti/92793.pdf

Figure 4: Illustration of a technology cost curve for next-generation geothermal energy

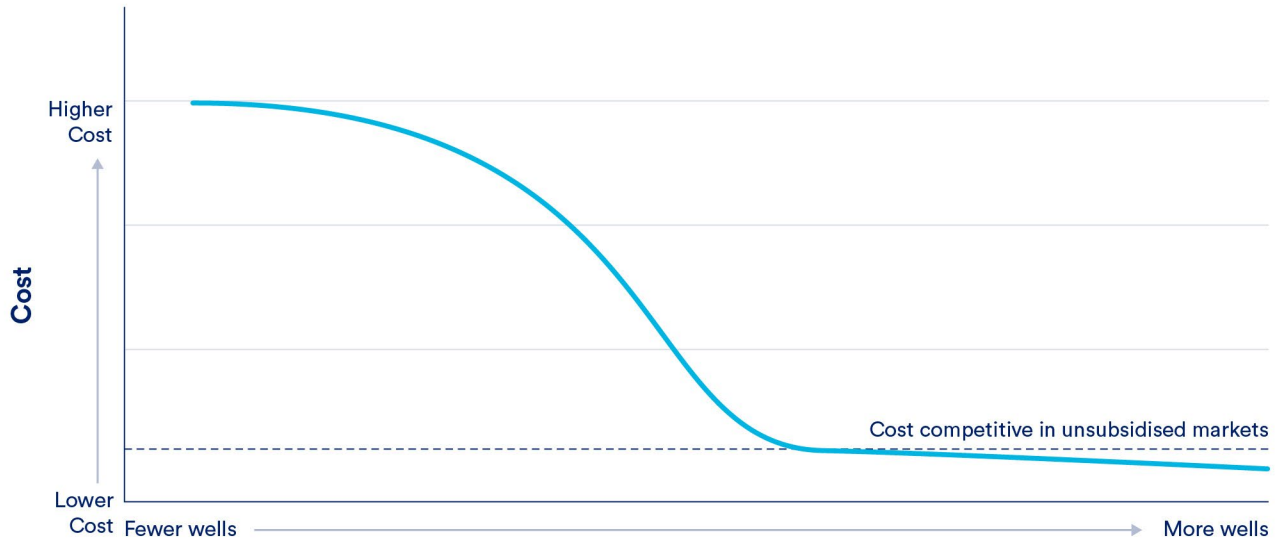
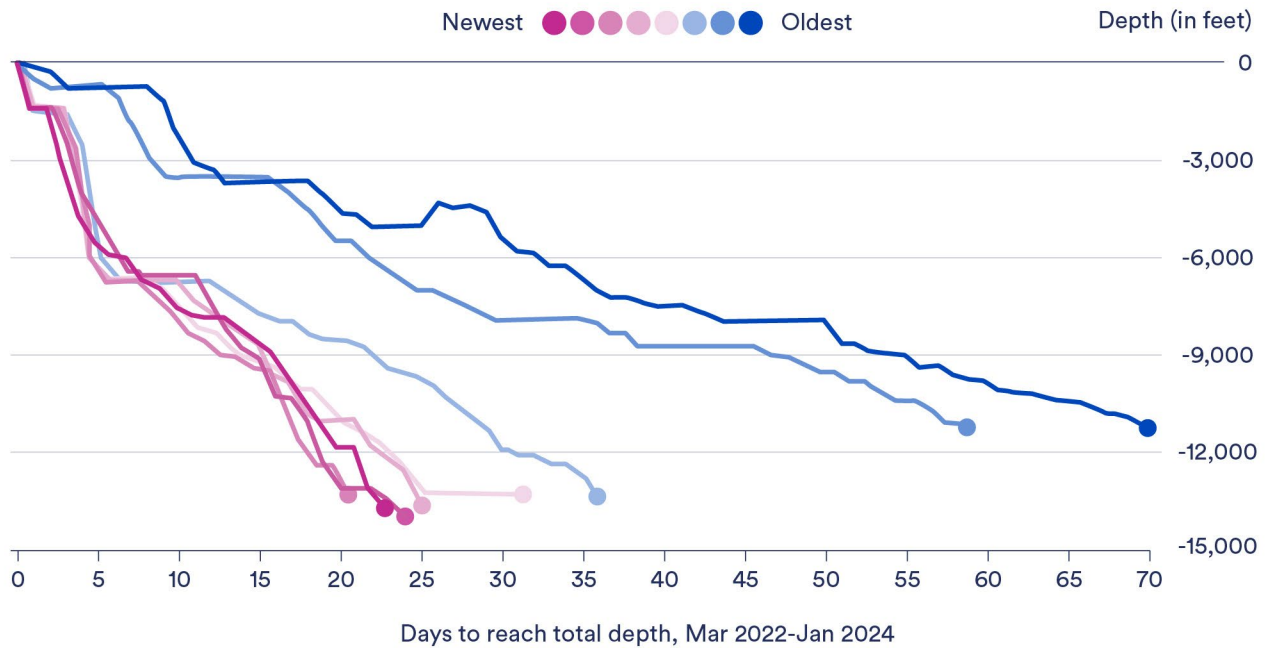


Figure 5: Drilling performance over time for a leading next-generation geothermal developer[20]

Source: Fervo Energy



[20] 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

The financing gap

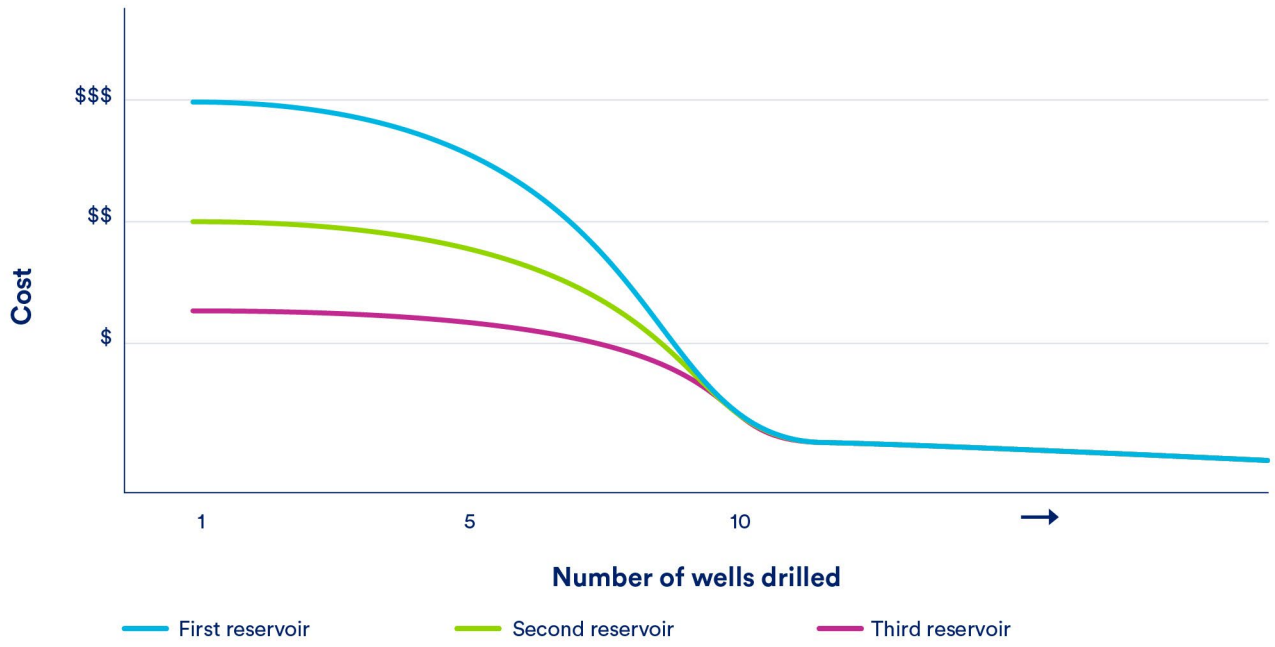
Constructing a commercial-scale next-generation geothermal project requires hundreds of millions of dollars (in USD) of upfront capital for exploration drilling, resource confirmation, and plant construction.[21] This often exceeds what venture capital investors provide; geothermal development requires large, infrastructure-scale investments. Additionally, although project costs must be paid upfront, revenues are realized slowly over the life of the project, typically 20 to 30 years. Startups cannot manage this timing mismatch using their own balance sheets the way mature industries can. The result is a persistent financing gap between the early-stage equity funding available to most startups and the large-scale project finance required for commercial deployment.

Subsurface uncertainty

The first commercial-scale next-generation geothermal projects succeeded because they drilled repeatedly in well-characterized regions, where learnings from early wells and projects allowed for optimization of subsequent wells and projects. By contrast, the first projects in new regions will be drilled and engineered conservatively, without the benefit that comes from a detailed understanding of the subsurface, creating the risk of unanticipated cost overruns. This uncertainty translates to increased costs of capital for projects in unexplored regions (see Figure 6).

Figure 6: Illustration of next-generation geothermal cost curves

Learnings from early projects drilled will dramatically reduce costs and risk for future projects in the same geologic region, but will only partially derisk wells in different regions.



[21] For example, next-generation geothermal projects in the western U.S. currently cost about $7 million USD per MW of installed capacity; this means that a 100 MW project would cost about $700 million USD.

Outdated risk perceptions

Many investors remain wary of geothermal based on assumptions drawn from conventional geothermal systems, where drilling in the wrong place could mean a "dry hole" and failed project.[22] Recent improvements in modeling reduce this risk for all types of geothermal,[23] and next-generation geothermal has a fundamentally different risk profile: underperformance typically reduces output rather than eliminating the project's ability to generate electricity.[24] However, next-generation technologies have advanced so rapidly in the last decade that many investors have not fully internalized their different risk profiles and remain cautious of geothermal investments.

Non-technical barriers

Though the industry has overcome many technical barriers in recent years, it also faces non-technical barriers; depending on the country, these may include lack of access to transmission, slow and uncertain permitting timelines, and more. If a developer spends years waiting for a non-technical barrier to be overcome and it is not, the money invested into their project site can become stranded; this risk disincentivizes private investment in geothermal and increases the cost of capital. Even when these barriers are eventually overcome, invested capital must often wait for years before the project can begin generating a return. While other energy industries face similar barriers, the high upfront cost of capital for geothermal projects makes these barriers more costly.

Policy action can unlock private capital

Once the geothermal industry reaches full commercial scale, many of these problems will be solved: large-scale deployment will bring costs down through learning-by-doing, regional deployment will improve subsurface knowledge, and new entrants will bring innovation and competition. Private capital is ready to flow into next-generation geothermal once more of these barriers are overcome through targeted policy.

In some locations, national governments have the fiscal and administrative capacity to implement the deployment levers below. In other cases, support from regional and multilateral institutions is necessary to derisk investments from private investors and national governments.

Policymakers can bring geothermal energy through the missing middle and kickstart large-scale deployment.

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22 Robertson-Tait, A., Henneberger, R., & Sanyal, S. (2008). Managing geothermal resource risk – Experience from the United States. *Workshop on Geological Risk Insurance, World Bank Geothermal Energy Development Program (GEOFUND).* https://pangea.stanford.edu/ERE/pdf/IGAstandard/GeoFund/Germany2008/Robertson-Tait.pdf

23 Kaufman, A. (2025, December 4). In a geothermal milestone, Zanskar claims major discovery in Nevada. *Canary Media.* https://www.canarymedia.com/articles/geothermal/zanskar-claims-geothermal-milestone-nevada

24 Feygin, Y., O'Connor, M., & Manero, L. (2026). *Misunderstood and manageable.* Mountain West Geothermal Consortium. https://www.mountainwestgeo.org/research/misunderstoodandmanageable

SECTION 3

Key Levers for Geothermal Deployment

Policy action to help next-generation geothermal scale is needed at all levels of government around the world,[25] though the specific policies needed most will vary by location.

Scaling geothermal energy requires access to subsurface heat at costs that are competitive with other energy options. In some areas of the world, these conditions have already been met and **next-generation geothermal is on the cusp of large-scale deployment.[26] In other areas, continued technological advancements (primarily in deep drilling and accessing next-generation geothermal at superhot temperatures) are needed to make next-generation geothermal viable** – but innovation is proceeding rapidly, steadily expanding the set of locations where geothermal can be economically deployed.

In jurisdictions where next-generation geothermal is currently cost-competitive, this report will indicate the actions that can help it deploy at commercial scale. In jurisdictions where next-generation geothermal is not yet viable, this report will lay out the conditions that will allow it to scale as soon as it becomes cost-competitive.

[25] For additional reports focusing on deploying next-generation geothermal from the perspective of specific countries and subnational jurisdictions, *see* Clean Air Task Force. (n.d.). *Next-Generation Geothermal at Scale.* https://www.catf.us/resource/next-generation-geothermal-at-scale/

[26] Commercial-scale next-generation geothermal projects have been developed or are under development in the western U.S. and Germany. *See* Fervo Energy. (2025, April 15). *Fervo Energy announces 31 MW power purchase agreement with Shell Energy* [Press release]. https://fervoenergy.com/fervo-energy-announces-31-mw-power-purchase-agreement-with-shell-energy/ *and* Gallucci, M. (2025, October 28). Eavor is about to bring its first-of-a-kind geothermal project online. Canary Media. https://www.canarymedia.com/articles/geothermal/eavor-is-about-to-bring-its-first-of-a-kind-geothermal-project-online

The Value of Testbeds

Public-private testbeds are a particularly impactful way to advance geothermal deployment.[27] Testbeds – locations where new materials and equipment can be tested in real-world conditions – simultaneously advance R&D (see Deployment Lever 5: Innovate) and improve understanding of the subsurface (see Deployment Lever 1: Characterize), derisking deployment in the surrounding area. Though they are crucial for advancing geothermal, the cost of developing a testbed remains prohibitively capital-intensive for many companies. Small amounts of public investment into testbeds can therefore unlock enormous private sector growth.

One example of this is the FORGE testbed in the United States, which has been active since 2017.[28] The site proved that EGS is possible at low enough prices to be commercial, provides an invaluable opportunity for developers and researchers to test new equipment and materials in real-world conditions,[29] and published detailed subsurface data that improved knowledge of the local geology. FORGE was essential in enabling the development of the world's first commercial-scale next-generation geothermal project, Fervo Energy's Cape Station, which is located directly adjacent to the FORGE site. Fervo is contracted to deliver 500 MW of clean firm power from Cape Station, which could generate over $418 million USD in annual gross revenue and reach $8.4 billion USD over the course of a 20-year power purchase agreement (PPA).[30] Utah FORGE has received approximately $330 million USD in DOE funding since its launch, so the multiplier effect of public funding is significant: the U.S. government's $330 million USD investment produced an estimated twenty-five times as much value (in the form of gross commercial revenue) as was initially invested. And largely on the basis of Cape Station's success, the company had the largest clean energy IPO of all time, raising $1.89 billion USD,[31] increasing the indirect impact of FORGE.

In addition to accelerating technology development, testbeds can also support workforce training, international research collaboration, and the development of shared datasets that benefit future geothermal projects.

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27 Clean Air Task Force (2025). *Gaps, Challenges, and Pathways Forward for Superhot Rock Geothermal Synthesis Report.* https://www.catf.us/wp-content/uploads/2025/09/CATF_SHRTechRoapMapReport_Digital_09.18.25.pdf

28 Ough, T. (2025, April 10). Why FORGE Works. IFP. https://ifp.org/why-forge-works/

29 For a list of tested products, see Utah FORGE. (n.d.). *Research and development funding opportunities.* https://utahforge.com/solicitations/

30 This assumes a PPA of $115 USD/MWh and 83% capacity factor, which are the estimates cited by Fervo in their S-1 filing. These numbers they do not necessarily reflect the specific terms of Fervo's contracts. *See* Fervo Energy Company. (17 April 2026). *Form S-1.* (p. 122). https://www.sec.gov/Archives/edgar/data/1853868/000162828026025821/fervoenergy-sx1.htm

31 Blum, J. (2026, May 14). *The earth beneath your feet just minted a $10 billion company to power America's AI boom.* Fortune. https://fortune.com/2026/05/14/fervo-clean-energy-biggest-ipo-10b-valuation-powered-earths-heat-ai-hunger/

Lever Zero: Strategic Planning for Geothermal

To support information sharing and coordination, especially in jurisdictions where next-generation geothermal is still scaling or has yet to arrive, governments should comprehensively landscape the state of play for next-generation geothermal in their region and set goals for its development. Most global energy policy stakeholders have not internalized the potential of next-generation geothermal. Decades of experience with conventional geothermal projects has often created perceptions that geothermal energy has a limited resource base, leading many to underestimate next-generation geothermal's ability to play a significant role in their region's future energy system. In addition, the system-level value of firm, always-available power is often underappreciated in energy planning discussions, particularly as many grids begin to incorporate higher proportions of variable renewable generation and reliability becomes increasingly valuable.[32] Even when stakeholders recognize geothermal's potential, many jurisdictions are not yet positioned to commercialize it at scale. To address this, governments should include geothermal in planning processes of all types, including government and utility resource planning processes; transmission planning processes; and energy policy frameworks that define goals, priorities, and metrics for geothermal at scale. Regulators, policymakers, utilities, and others involved in planning processes should receive education about next-generation geothermal, allowing them to properly consider its role in the energy system of tomorrow. Governments should also assess their jurisdiction's readiness against the five key deployment levers outlined in this report to identify gaps and prioritize the actions needed to support timely deployment.



1. Characterize: Map Geothermal's Subsurface Resource Potential

Why It Matters

High-quality subsurface mapping is one of the fastest and most cost-effective ways to reduce early exploration risk for next-generation geothermal. Mapping the subsurface is the first step in identifying geothermal project sites and successfully developing projects.

Subsurface features[33] determine how deep a developer must drill, at what drilling speed, what wear and tear on equipment to expect, and how to place wells so they align with the natural features of the rock – all of which affect project cost, risk of cost overruns, and safety.

We have only scratched the surface of understanding the full geothermal potential across the globe, and additional attention toward subsurface mapping is necessary for geothermal to reach full commercial scale.[34]

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[32] For an in-depth discussion of the role of clean firm power, see Abrahams, L. (2023, May 19). *We need clean firm electricity for a decarbonized energy system.* Clean Air Task Force. https://www.catf.us/2023/05/we-need-clean-firm-electricity-decarbonized-energy-system/

[33] The most important subsurface information includes geothermal gradient (how rock temperature changes with depth), exactly what types of rock are found at different depths, and the structure and connectivity of the rock's natural fracture network and stress regime.

[34] Mapping is also valuable for a wide range of industries and sectors, far beyond just geothermal. *See* Berg, R. C., & Faulds, J. E. (Eds.). (2025). *Economic analysis of the costs and benefits of geological mapping in the United States of America from 1994 to 2019.* American Geosciences Institute. https://doi.org/10.62322/wra5.gs9v *and* Bhagwat, & Ipe, V. C. (2000). *Economic benefits of detailed geological mapping to Kentucky.* Illinois State Geological Survey. https://library.isgs.illinois.edu/Pubs/pdfs/specialreports/sp-03.pdf

Where Things Stand

Collecting additional and new subsurface data will help geothermal scale, especially in regions with limited historical data. However, gathering subsurface data is costly. Some data can be gathered using surface surveying tools, but one of the most important types of data needed to derisk geothermal development – geothermal gradient – can only be gathered from real wells. Most developers can't afford the millions of dollars that would be required to drill enough wells to fully de-risk a region. And even if they could, they wouldn't share that data with others, limiting its reach. For geothermal energy as a whole to scale and grow, public (and publicly-funded) data is necessary.

Additionally, many governments have amassed decades of historical subsurface data from oil, gas, mining, carbon sequestration, conventional geothermal, and water wells. This data includes well logs (including geophysical logs) and physical samples of well cores and cuttings, and much of it could be relevant for next-generation geothermal.[35] Unfortunately, historic well logs are often stored in formats that cannot be used in digital analysis (such as paper copies or static images). Turning this historical data into useable digital files requires equipment as well as human capital.[36]

To maximize its impact, geothermal data must be easy to access, download, and interpret. Because geological boundaries do not always line up with political borders, sharing data across multiple jurisdictions and countries is important to enable better modeling.

What Governments Can Do

Policy Recommendations:

1A. Resource Mapping
Gather the foundational geoscience data needed to identify the most promising locations for geothermal projects. This requires gathering and publicly sharing data on subsurface heat, lithology, and strain profiles (see Case Study: Subsurface Monitoring, below).[37] Governments can do this work directly (e.g., through government-funded geological surveys) or can fund private or academic institutions (e.g., through exploration drilling rebates for private companies or funding for academic mapping). Regional and multilateral institutions can also fund and coordinate resource mapping efforts at a regional level. Resource mapping efforts should focus on geothermal resources of all types and temperatures, including superhot rock geothermal resources. (For more detail on monitoring and safety, see Deployment Lever 2: Govern.)

1B. Cross-Sector Data
Require and/or incentivize information sharing from other subsurface industries – such as oil, gas, mining, carbon sequestration, conventional geothermal, and water wells – that can provide valuable information for next-generation geothermal modeling and site characterization.

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[35] For example, well logs generally track temperatures at different depths, which can inform knowledge of geothermal gradients, while geophysical logs can provide information about rock permeability and porosity, subsurface fracture networks, and water quality. Well cores and cuttings can provide information about rock type at depth, rock porosity and permeability, and subsurface fracture networks. Additional analysis of thin sections of well cores can provide additional information (e.g., which types of minerals make up the rock, which informs a more detailed understanding of rock strength).

[36] The first step is to catalogue what records exist. Next, paper records are scanned to produce digital files (e.g., PDFs); this requires specialized well log scanners. Finally, the files are digitized so that the data can be inputted into geothermal modeling software; this requires access licenses for digitization software as well as time and effort to interpret the scanned data during the digitization process. Some (but not all) of this work can be completed by interns with supervision from professional staff.

[37] This includes things like measuring the rock's density at depth using gravimetry; determining a rock's magnetic susceptibility through satellite or airborne-mounted systems; determining the rock's electrical conductivity using magnetotellurics, controlled-source electromagnetics, and transient electromagnetics; conducting seismic wave propagation studies to better understand the local rock strength, fluid content, fracture destiny, orientation, and mapping of potentially active faults; utilizing remote sensing (e.g., satellites or aerial sensors) to determine surface deformation; drilling deep wells to gather information through cores or borehole tomography; and determining fluid geochemistry.

Case Study: Subsurface Monitoring

The federal government of Switzerland funds the Swiss Seismological Service to provide free baseline monitoring and seismological expertise to subnational jurisdictions, rather than relying on developers to conduct this subsurface mapping themselves.[38] This system improves subsurface characterization, reduces costs for developers, and improves safety by ensuring that appropriate monitoring is in place for projects (for more detail on monitoring and safety, see Deployment Lever 2: Govern).

1C. Data Infrastructure

Develop data sharing platforms to make it easy to upload, find, review, and synthesize data related to the subsurface and geothermal operations. Data should be uniform, allowing it to be analyzed across projects; viewable by map; and downloadable by common attributes, such as region. Data from different jurisdictions (e.g., states/provinces, countries, and regional organizations such as the EU) should be combined and shared as part of a single database. Where possible, common data formats and standards should be used to ensure that geothermal datasets can be integrated across jurisdictions and used in regional resource assessments. Regional and multilateral institutions can play a key role in funding and coordinating this work.

1D. Data Sharing

Ensure that subsurface information from projects (especially projects which receive government support) is shared to inform future geothermal work. Proprietary information about the performance of specific tools and materials should be kept confidential to enable companies to develop and innovate. However, companies should be required to disclose non-proprietary subsurface data (including temperature gradient, rock type at depth, groundwater depth and chemistry, local fracture networks, and fault sizes and structures).

[38] Ritz, V. A., Antunes, V., Bergamo, P., Kraft, T., Marti, M., Roth, P., Simon, V., Toledo, T., & Wiemer, S. (2026). Overview of the Swiss Seismological Service's Efforts to Monitor the July 2025 Test-Stimulation in Haute-Sorne, Switzerland. PROCEEDINGS, *51st Workshop on Geothermal Reservoir Engineering.* https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2026/Ritz.pdf

2. Govern: Establish a Regulatory System that Works for Industry and Communities

Why It Matters

Regulatory systems for next-generation geothermal energy should aim to enable safe, environmentally responsible production of as much geothermal energy as is needed and economically viable. Clear, consistent and predictable regulatory systems are essential to speed up deployment and crowd in private investment while maintaining appropriate safety and environmental protections. Consistent and frequent lease sales are necessary for developers to be able to access land and to plan projects knowing that land will be available for lease.

Where Things Stand

Next-generation geothermal is viable in many parts of the world where prior forms of geothermal were not, which means that many regions with geothermal potential have little or no regulatory framework for its development. And geothermal regulatory frameworks that do exist were usually developed for conventional hydrothermal systems, which differ in important ways from next-generation systems.[39] Permitting processes designed for older forms of geothermal may not reflect the actual risks and benefits of new approaches like next-generation geothermal.

Furthermore, reviewing geothermal permit applications requires staff with expertise in a wide range of topics, including the geosciences (geology, geophysics, geochemistry, hydrology, soil sciences, etc.), drilling and well construction, subsurface engineering, surface facility engineering, and geothermal energy. Especially in locations where geothermal is new, regulatory agencies may not have access to this staff expertise.

What Governments Can Do

Policy Recommendations:

2A. Regulatory Modernization

Create or update geothermal regulations to address the following topics in the context of next-generation geothermal (including next-generation geothermal at superhot temperatures): drilling; well design, casing, and construction; surface and groundwater protection; and induced seismicity.

- Governments and multilateral institutions should coordinate to support regulatory modernization. This might include sharing best practices, co-developing standards, and creating planning and regulatory capacity building programs.
- Governments should require induced seismicity mitigation protocols for geothermal projects, building on leading models such as those developed by the U.S. Department of Energy[40] (see Case Study: Induced Seismicity Mitigation, below) and the Swiss Seismological Service.[41]
- Governments should track and update regulations to account for the innovative new approaches, techniques, and materials that are being developed by the rapidly-growing geothermal industry.

2B. Government Capacity

Governments should ensure adequate staff capacity to manage geothermal permitting, leasing, and review processes. This includes staff with expertise in the geosciences (geology, geophysics, geochemistry, hydrology, soil sciences, etc.), drilling and well construction, subsurface engineering, surface facility engineering, and geothermal energy (including next-generation geothermal) who can properly evaluate projects and risks.

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39 Next-generation geothermal systems use new drilling and reservoir creation techniques, and are sited in dry rock rather than preexisting geothermal reservoirs.

40 Majer, E., Nelson, J., Robertson-Tait, A., Savy, J., & Wong, I. (2012). *Protocol for addressing induced seismicity associated with enhanced geothermal systems.* Geothermal Technologies Program, U.S. Department of Energy. https://www1.eere.energy.gov/geothermal/pdfs/geothermal_seismicity_protocol_012012.pdf

41 Kraft, T., Roth, P., Ritz, V., Antunes, V., Toledo, T., & Wiemer, S. (2025). *Good-practice guide for managing induced seismicity in deep geothermal energy projects in Switzerland.* Swiss Seismological Service (SED) at ETH Zurich. https://doi.org/https://doi.org/10.3929/ethz-b-000714220

Case Study: Induced Seismicity Mitigation

In 2012, the U.S. Department of Energy published a "Protocol for Addressing Induced Seismicity Associated with Enhanced Geothermal Systems."[42] The protocol was explicitly developed in response to public concerns about seismic activity associated with geothermal energy, and it brought together leading experts to develop a data-informed mitigation approach. The protocol's seven steps include preliminary screening, pre-project and real-time seismic monitoring, modeling and quantification of seismic hazards, and the development and implementation of a risk-based mitigation approach to guide operator actions during development. Adhering to the protocol is required as a condition of DOE funding for geothermal projects. Since its publication, no next-generation geothermal project in the U.S. has created felt induced seismicity.[43]

2C. Interagency Coordination
In many jurisdictions, geothermal projects require permits and reviews from multiple regulatory bodies due to the broad expertise required across the lifespan of a geothermal project. These groups should develop coordinated, streamlined processes to share information and synchronize permitting requirements and forms where possible. Governments should consider assigning one regulatory body as the lead regulator and point of contact on geothermal projects, and set clear delineations of roles and responsibilities between regulators to reduce duplication and project timelines.

2D. Process Tracking
Governments should develop systems to track and manage regulatory processes. These programs should streamline coordination across agencies and include external-facing capabilities so developers can monitor the status of their permits in real time.

2E. Integrated Review
Geothermal development unfolds in phases, including exploration, resource confirmation, well field development, construction of surface facilities, and operations (see Figure 7). Governments should develop holistic, integrated environmental review processes which allow for simultaneous consideration of multiple project phases while recognizing the unique characteristics and environmental risks associated with different phases.

2F. Permitting Roadmap
To facilitate standardization and increase certainty for all parties involved, governments should develop clear step-by-step guides that outline the permitting process in their jurisdiction and identify the entities with which developers must coordinate.

2G. Leasing Framework
Governments should develop leasing and land use frameworks that account for the full range of areas which might host geothermal resources (including areas which were not previously viable for development), protect ecologically and culturally sensitive areas, maximize public benefit from geothermal projects on public lands, incentivize exploration of new areas which might be suitable for geothermal development, and ensure that land is used promptly for projects.

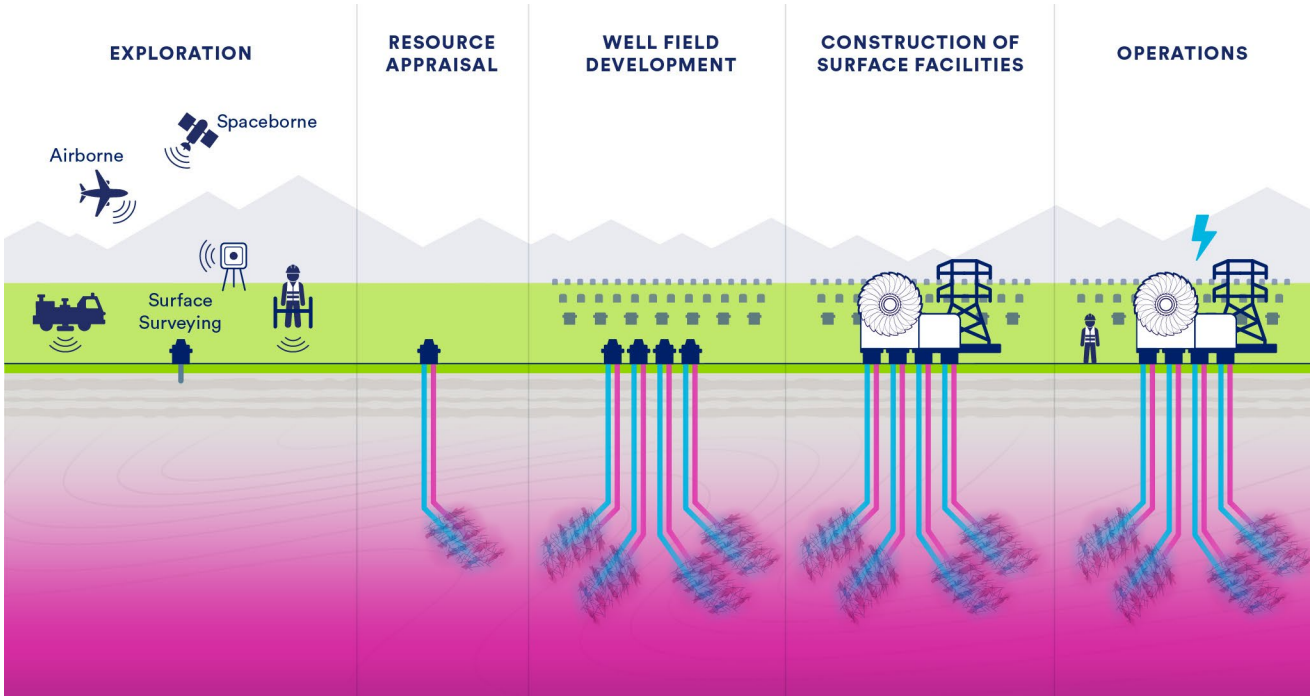
2H. Fair Leasing
Governments should facilitate fair leasing and compensation practices for those who own geothermal resources, giving special consideration to the rights of Indigenous communities.

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[42] Majer, E., Nelson, J., Robertson-Tait, A., Savy, J., & Wong, I. (2012). Protocol for addressing induced seismicity associated with enhanced geothermal systems. U.S. Department of Energy, Energy Efficiency & Renewable Energy, Geothermal Technologies Program. https://www1.eere.energy.gov/geothermal/pdfs/geothermal_seismicity_protocol_012012.pdf

[43] Seligman, A. (2026). *Induced seismicity and next-generation geothermal* [Fact sheet]. Clean Air Task Force. https://www.catf.us/resource/induced-seismicity-next-generation-geothermal/

Figure 7: Next-generation geothermal energy project development phases



3. Finance: Incentivize Exploration and Demonstration

Why It Matters

Government support is necessary to help any early-stage technology scale up and move through the missing middle, including next-generation geothermal.

Where Things Stand

Different policies will be suitable depending on the unique financing conditions for geothermal in different places and at different times in the project lifecycle. Geothermal projects face technology risks associated with early commercial deployment as well as geological risks associated with proving a resource in a new geologic region, where uncertainty regarding subsurface conditions remains a major barrier to investment. As a general principle, **the highest-impact geothermal financing policy for governments is to derisk early projects in new regions.** Ensuring that early projects are profitable enough to secure financing can trigger a virtuous cycle of learning-by-doing: deployment lowers costs, enabling further deployment, which brings costs down further. Government funding can also incentivize industry behaviors that reduce risk and lower costs, benefiting individual projects and the geothermal industry as a whole.

What Governments Can Do

Policy Recommendations:

3A. Energy Planning
Governments should assess their jurisdiction's future power needs – including capacity, reliability, security and grid services – and then evaluate the role geothermal can play in meeting these needs through its unique grid benefits (e.g., baseload source of power, spinning reserve, price stability due to lack of fuel volatility, etc.). Based on that assessment, governments should require inter-regional and long-term energy plans that incorporate the use of geothermal and other energy sources that meet these needs.

3B. Regional Derisking

Governments and multilateral institutions should help derisk early next-generation geothermal projects in unique geological regions, where uncertainty regarding subsurface conditions remains a major barrier to investment. There are several ways this can be accomplished – including directly funding and building those projects as well as incentivizing and mandating procurement and demand-side support – but the best option for any given jurisdiction will vary based on the unique circumstances of that region and market. Because learning curves for geothermal repeat in new regions, many of these incentives can be tiered, with the most generous support going to early projects in a new area and subsequent projects receiving less and eventually no support.

- When the major energy companies in a region are state-owned, they can develop entire geothermal projects directly. In some cases, governments may wish to develop the subsurface portion of a geothermal project and then sell the "de-risked" project to a private company.
- Governments can facilitate demand-side support for geothermal energy. These policies provide certainty that project economics will be sufficient over the life of the project, crowding in private investment. Existing models for this type of support include direct procurement requirements,[44] contracts for difference,[45] and tax credits for production of geothermal power or investment into geothermal energy development.
- Governments can provide direct funding to share and encourage the mitigation of some of the risk associated with early commercial projects (or for specific parts of a project, such as exploration drilling). Risk sharing can occur through grants, forgivable loans (see Case Study: Convertible Loans), and government-subsidized insurance.
- Regional and multilateral institutions can provide financial support in countries with limited fiscal capacity, advancing regional economic development goals (see Case Study: Convertible Loans).

Case Study: Convertible Loans

In December 2025, the Philippines launched a $170 million USD convertible loan program to fund geothermal exploration and drilling. Funds distributed through the program will be treated as a loan if the exploration activities indicate a strong geothermal resource, but will convert to a grant if the resource is unfavorable. The program was funded through a loan to the Philippines from the Asian Development Bank.[46]

3C. Data Transparency

Governments should require that non-proprietary subsurface data from government-funded projects is made public; more access to subsurface data is crucial to derisk future geothermal projects (see Deployment Lever 1: Characterize).

3D. Derisking Design

Governments should support engineering and design work for the first geothermal projects in new regions. Government support for these activities would incentivize developers to do more detailed planning, helping reduce costs for not just the projects directly funded but also for future projects which would benefit from the learnings. Such support could come in the form of grants or tax credits.

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[44] This has been a core component of the growth of next-generation geothermal industry: a 2021 procurement requirement for 1 GW of clean firm power in California, United States, spurred an enormous influx of investment into geothermal across the western U.S. *See* Zhou, Y. & Annex, M. (2023, May 10). *Next-generation geothermal technologies are heating up.* Bloomberg NEF. https://about.bnef.com/insights/clean-energy/next-generation-geothermal-technologies-are-heating-up/

[45] A contract for difference is "a subsidy model in which both positive and negative deviations from a fixed reference price are paid out to the contractual partner. This means that a minimum compensation is guaranteed, but revenues are capped." *See* Next Kraftwerke. (N.d.). *What is a contract for difference?* https://www.next-kraftwerke.com/knowledge/contract-for-difference

[46] Cariaga, C. (2025, December 16). *$170M geothermal de-risking facility in the Philippines officially launched.* ThinkGeoEnergy. https://www.thinkgeoenergy.com/170m-geothermal-de-risking-facility-in-the-philippines-officially-launched/

4. Connect: Develop Supportive Infrastructure

Why It Matters

Deploying next-generation geothermal requires more than just a heat resource and the technology to access it. Supportive infrastructure is also necessary, including access to transmission, a trained workforce to staff projects, supply chains for equipment, and social license from local communities.

Where Things Stand

In many jurisdictions, the supportive infrastructure that next-generation geothermal needs to scale is either unavailable or not sufficient to match the potential need. For example, oil and gas workers can transition or expand into geothermal with minimal training required, and the same rigs used to drill oil and gas wells are also used to drill geothermal wells. But this supportive infrastructure will be less available in countries with limited oil and gas development – and even in countries which do have a large oil and gas sector, it may not be available in sufficient quantities as geothermal scales up. Other types of equipment are less available and often rely on a small number of manufacturers, relying on global supply chains that are at risk of disruption.[47]

It is crucial to develop supportive infrastructure for geothermal in advance of, or concurrently with, early-stage geothermal development in any given region. Waiting until after geothermal has reached the cusp of deployment to develop supportive infrastructure will unnecessarily delay projects and may even close off the opportunity to develop geothermal energy in a region altogether.

What Governments Can Do

Policy Recommendations:

4A. Transmission Access
Ensure that geothermal projects have access to transmission. This is especially important for the first geothermal projects in a region; to reduce costs and risk, these early-stage projects will be sited in areas with shallow heat and a well-characterized subsurface. These areas are geographically limited, and ensuring that transmission can reach them is crucial. Efficient, clear, and speedy transmission buildout is necessary. Governments should also consider proactively planning and/or building transmission to areas of high geothermal resource potential, which will incentivize development in those regions.

4B. Workforce Needs Mapping
Landscape the needed workforce for geothermal development and existing workers who may be able to transition to geothermal. Geothermal energy development requires workers in a range of professions, including geoscientists, subsurface engineers, drillers, surface engineers, construction workers, power plant operators, and more.[48]

4C. Workforce Transition
In jurisdictions with an oil and gas workforce, facilitate the transition of those workers to geothermal by ensuring that technical/academic qualifications from oil and gas can be applied to geothermal projects as appropriate, by supporting retraining programs, and by reframing academic areas focused on oil and gas to focus on subsurface energy more broadly.

4D. Workforce Training
In jurisdictions where an additional workforce is needed for geothermal energy beyond what is available from other sectors, partner with educational institutions, industry associations, unions, and other relevant stakeholders to set up training and certification programs for those workers.

4E. Supply Chains
Analyze which parts of the next-generation geothermal supply chain are (or will become) bottlenecks to deployment at scale and support the production of equipment and materials to reduce such bottlenecks.[49]

4F. Community Trust
Support social acceptance of geothermal by developing a regulatory system that is appropriately protective of communities and the natural environment (see Deployment Lever 2: Govern), by supporting or requiring community engagement from project developers, and by helping educate the public about the benefits of geothermal and how it can be safely deployed.

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47 Clean Air Task Force. (2025, September 25). *Geothermal supply chain.* https://www.catf.us/2025/09/geothermal-supply-chain/; Feshbach, B., Garland, E., & Meisel, J. (2026). *The geothermal supply chain is America's to gain – or lose.* Rocky Mountain Institute. https://rmi.org/the-geothermal-supply-chain-is-americas-to-gain-or-lose/

48 U.S. Department of Energy. (2024). *Pathways to Commercial Liftoff: Next-Generation Geothermal Power.* (p. 17-18). https://cdn.catf.us/wp-content/uploads/2025/06/09154348/doe-liftoff-nextgen-geothermal.pdf

49 For example, turbines could be a significant bottleneck to geothermal development; *see* Clean Air Task Force. (2025, September 25). *Geothermal supply chain.* https://www.catf.us/2025/09/geothermal-supply-chain/ and Feshbach, B., Garland, E., & Meisel, J. (Forthcoming). *The United States should invest in next-generation geothermal supply chains.* Rocky Mountain Institute.

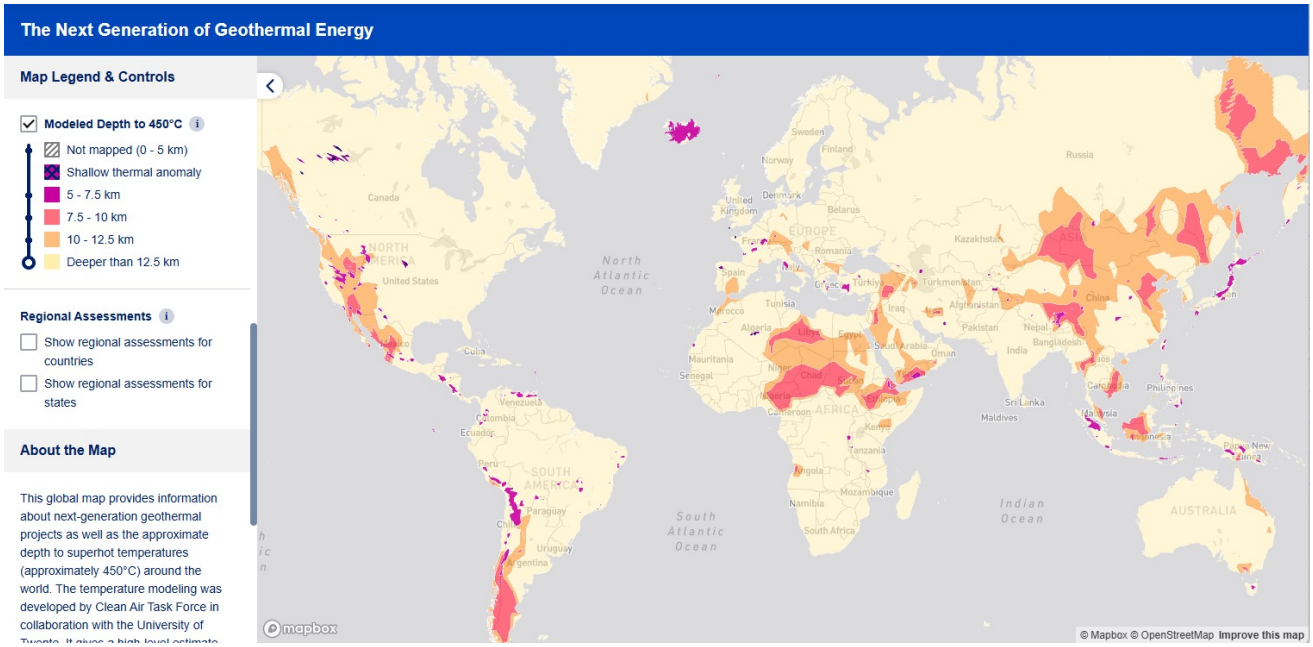
5. Innovate: Sustain R&D

Why It Matters

Next-generation geothermal energy is in the midst of a dramatic expansion in a few regions, most notably the western United States, and is ready to build and scale elsewhere using current technologies and approaches. But for geothermal to be a global energy solution, advancements are needed in deep drilling and drilling at hotter temperatures. Reaching depths below 12km expands the geographies where next-generation geothermal energy is possible (see Figure 8). Reaching superhot temperatures (375°C and above) dramatically increases the energy density per well, making the resource more affordable.

Figure 8: Estimate of US superhot rock geothermal potential at varying depths[50]

While deeper depths are not currently economically viable, progress in drilling innovation holds the potential to unlock resources in more areas.



50 Clean Air Task Force. (N.d.). *The Heat Beneath our Feet: Mapping the potential of superhot rock geothermal.* https://www.catf.us/superhot-rock/heat-mapping/

Beyond technical advances, widespread deployment will enable global standardization of equipment, materials, and well designs. This will drive manufacturing scale, faster execution, and steep cost declines over time. Continued innovations in site characterization, drilling, subsurface engineering, power conversion, and equipment standardization will further lower costs for all geothermal technologies available today.[51]

Where Things Stand

Geothermal R&D requires labs and field testing locations. Labs around the world have the equipment and materials to make progress on key R&D topics,[52] but moving new technologies from concept to deployment requires real-world testing which depends on dedicated testbeds. However, the cost of R&D – especially drilling and site development for a testbed – remains prohibitively capital-intensive for many companies. Government funding, support, and coordination is needed to make rapid R&D progress achievable.

Not every government is equally positioned to advance geothermal R&D. But all jurisdictions can contribute in some way, and can also track and integrate innovations from around the globe into the projects they fund and deploy.

What Governments Can Do

Policy Recommendations:

5A. Targeted R&D
Fund targeted R&D for next-generation and superhot rock geothermal. This might include funding for public institutions such as laboratories and universities as well as for research conducted by private industry and labs. To maximize the impact of government funding, these programs should be directed towards research areas not already being explored by commercial actors, such as domains lacking immediate commercial demand.[53]

5B. Public Testbeds
Create public geothermal testbeds and field testing sites that are open to researchers of all kinds – including public labs, universities, nonprofit consortia, private research groups, and for-profit companies – to test new approaches, products, and materials. These testbeds should focus on cutting-edge innovation, such as superhot rock geothermal and deep drilling, which will decrease costs and ultimately increase the scale of geothermal deployment (see Case Study: Superhot Testbed).

Case Study: Superhot Testbed

The government of Iceland and the European Union (through European Research Council) are helping to fund the Krafla Magma Testbed, an Icelandic test site which is pursuing groundbreaking research into geothermal energy at superhot temperatures.[54] The testbed will bring together experts from around the world, advancing global understanding of superhot rock geothermal energy.

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51 For an in-depth analysis of key R&D needs for superhot rock geothermal, *see* Clean Air Task Force. (N.d.). *Bridging the gaps: A survey of methods, challenges, and pathways forward for superhot rock geothermal energy.* https://www.catf.us/superhot-rock/bridging-gaps/

52 Forthcoming research from CATF finds that there are nearly 100 institutions spread around the world that have expertise in the five key areas needed to deploy next-generation geothermal anywhere it is needed: resource characterization and modeling, drilling and well design, monitoring and instrumentation, reservoir creation and management, and engineering and power generation.

53 For more details, including an evaluation of which areas of superhot rock geothermal R&D are unlikely to be funded privately and merit government support, see Hill, J. (2025). *A Technology Road Map for Next-Generation Geothermal: Unlocking Superhot Rock Innovation through Strategic Collaboration.* Page 45. Clean Air Task Force. https://www.catf.us/wp-content/uploads/2025/09/CATF_SHRTechRoapMapReport_Digital_09.18.25.pdf

54 Krafla Magma Testbed. (2024, September 27). *Krafla Magma Testbed secures key support to lead the future of super-hot geothermal* [Press release]. https://kmt.is/kmt-government-industry-support/; Lavallée, Y. (2025). Krafla Magma Testbed (KMT): Creation of the first international magma observatory for volcanology and geothermal innovation. *Proceedings of the 2025 GeoConvention.* https://geoconvention.com/wp-content/uploads/abstracts/2025/115729-krafla-magma-testbed-kmt-creation-of-t

5C. Global Coordination

Coordinate geothermal R&D across countries and ensure that learnings are shared widely. The more quickly learnings are integrated, the more quickly the entire field derisks, crowding in private capital and helping geothermal reach its full potential.

- There are a limited number of next-generation geothermal projects globally, and the projects that do exist are spread across countries. Next-generation geothermal research projects should leverage multilateral bodies to share information and learn from others doing similar work. Governments that wish to lead in next-generation geothermal should support participation in multilateral initiatives that coordinate research priorities, testbed activities, subsurface data standards, and knowledge sharing, including mechanisms such as the International Energy Agency's Technology Collaboration Programs.
- Multilateral collaboration is especially important in the case of R&D for cutting-edge geothermal technologies, such as superhot rock geothermal. The geothermal innovation ecosystem is not vertically integrated; rather, companies and labs tend to work on only one or two siloed technology areas in which they have specific technical expertise, creating a complex web of intellectual property and proprietary data. Advancing superhot rock geothermal to commercial scale will require bringing together innovations in numerous subfields, which will require incentives for collaboration and information sharing.

SECTION 4

Conclusion

Next-generation geothermal is an exciting new source of clean firm power that is ready to scale, but it needs support from policymakers to achieve its full potential. This report lays out key policy recommendations under five deployment levers, highlighting better subsurface characterization, appropriate regulatory structures, targeted funding mechanisms, access to supportive infrastructure, and programs to sustain further innovation. Implementing the recommendations under each lever will improve the conditions for next-generation geothermal to scale and grow in any state with a geothermal resource.

Fully implementing any of these policy recommendations will require *information sharing and coordination as well as targeted funding for implementation*.

Large-scale geothermal deployment requires information sharing and coordination among many entities: governments at all levels (including regional organizations such as the EU), multilateral institutions, national laboratories and research centers, universities, private research institutions, geothermal developers, service providers, nonprofits and think tanks, and the communities that host geothermal projects. Improved coordination and communication among these stakeholders will be necessary for full implementation of the deployment levers described above.

Action on the levers described above will also require targeted funding for relevant agencies to ensure that geothermal research and project deployment proceed smoothly and efficiently. This includes regulatory agencies, agencies that conduct subsurface mapping, and labs and research agencies. Next-generation geothermal can bring new economic benefits to host countries through royalties, tax revenues, investment in local communities, and local jobs. But targeted short-term investments are needed to unlock this potential.

Geothermal energy has the potential to revolutionize the global energy system by providing terawatts of affordable, secure, and clean firm energy. **Focused attention across the five key deployment levers laid out in this report can catalyze geothermal growth, creating a virtuous cycle of deployment and cost reduction that advances a future of abundant, affordable clean energy.**

APPENDIX A

Policy Recommendations

1. Characterize: Map Geothermal's Subsurface Resource Potential

1A. Resource Mapping

1B. Cross-Sector Data

1C. Data Infrastructure

1D. Data Sharing

2. Govern: Establish a Regulatory System that Works for Industry and Communities

2A. Regulatory Modernization

2B. Government Capacity

2C. Interagency Coordination

2D. Process Tracking

2E. Integrated Review

2F. Permitting Roadmap

2G. Leasing Framework

2H. Fair Leasing

3. Finance: Incentivize Exploration and Demonstration

3A. Energy Planning

3B. Regional Derisking

3C. Data Transparency

3D. Derisking Design

4. Connect: Develop Supportive Infrastructure

4A. Transmission Access

4B. Workforce Needs Mapping

4C. Workforce Transition

4D. Workforce Training

4E. Supply Chains

4F. Community Trust

5. Innovate: Sustain R&D

5A. Targeted R&D

5B. Public Testbeds

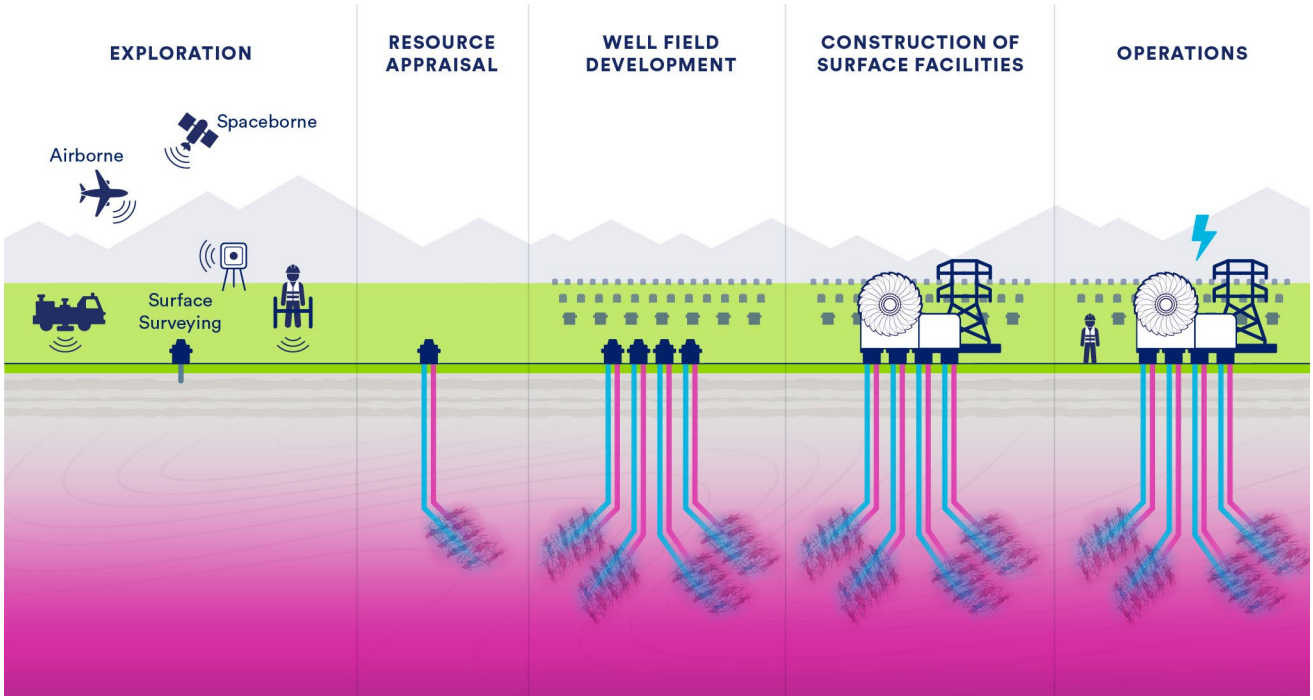
5C. Global Coordination

APPENDIX B

Geothermal Project Phases

Geothermal energy development unfolds in phases, including *exploration, resource appraisal, well field development, construction of surface facilities,* and *operations* (see Figure 9).

Figure 9: Next-generation geothermal energy project development phases



In the *exploration* phase, developers use subsurface mapping to identify promising location(s) for geothermal development. Subsurface mapping draws on existing subsurface data, surveys of multiple types,[55] and drilling small-diameter test wells. The cost of exploration varies widely depending on the location and what activities are included, but could range from around $2 million USD for limited surveying to as much as $50 million USD for more extensive surveying and drilling small-diameter wells.[56]

During *resource appraisal* (sometimes referred to as "resource confirmation"), developers drill full-size wells. The goal is to confirm the temperature at depth and ensure that water[57] can continuously and reliably circulate through the system, from subsurface to surface and back again. Enhanced geothermal systems (EGS) use at least two wells, an injection well and a production well. Water is pumped down the injection well, which is generally lined with cement and cased in steel (or an equivalent impermeable material) from the surface down to the target depth to keep the well stable and prevent water from escaping. At the bottom of the well, the casing ends, allowing water to exit the well and travel through a network of small cracks and pathways (known as "fractures") in the rock until it reaches the production well and flows back up to the surface. Closed-loop geothermal systems generally have some type of casing or barrier lining the entire well so that the water does not directly touch the rock. Some closed-loop systems use only one well, in which water flows both down and up, while others use two or more wells that are connected in the subsurface to form a loop. Hybrid projects blend elements from both EGS and closed-loop systems. Resource confirmation activities require permits, though the details of the permitting process will vary by jurisdiction. Costs vary by project; wells at recent next-generation geothermal projects in the U.S. have cost between $5 million USD and $13 million USD,[58] and costs could rise as high as $20 million USD depending on the length of the well and the geologic settings.[59]

The *well field development* phase replicates the resource confirmation stage at scale, often with lower costs per well. The exact number of wells drilled in a full-scale geothermal project varies, but can be as many as hundreds of wells. The permits required for well field development replicate the permits required for resource confirmation. Costs for well field development often decrease over time as project developers learn more about the subsurface and are able to improve their approach, bringing costs down a "learning curve," as well design is no longer bespoke (see "Barriers to Geothermal Deployment" section for a longer discussion of learning curves).

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55 Aerial surveys are conducted from airplanes or drones, while other surveys are conducted on the ground using special trucks and/or equipment carried by hand.

56 R. Pearce (personal communication, May 15, 2026).

57 Some next-generation geothermal systems use another type of fluid, such as CO_2, in place of water. Geothermal projects that do use water often use brackish water that is not suitable for agriculture or human consumption. For ease of readability, this section will use "water" throughout.

58 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

59 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 USD. *See* Akindipe, D. & Witter, E. (2025). *2025 Geothermal Drilling Cost Curves Update.* National Lab of the Rockies. (p. 3). https://docs.nlr.gov/docs/fy25osti/92793.pdf

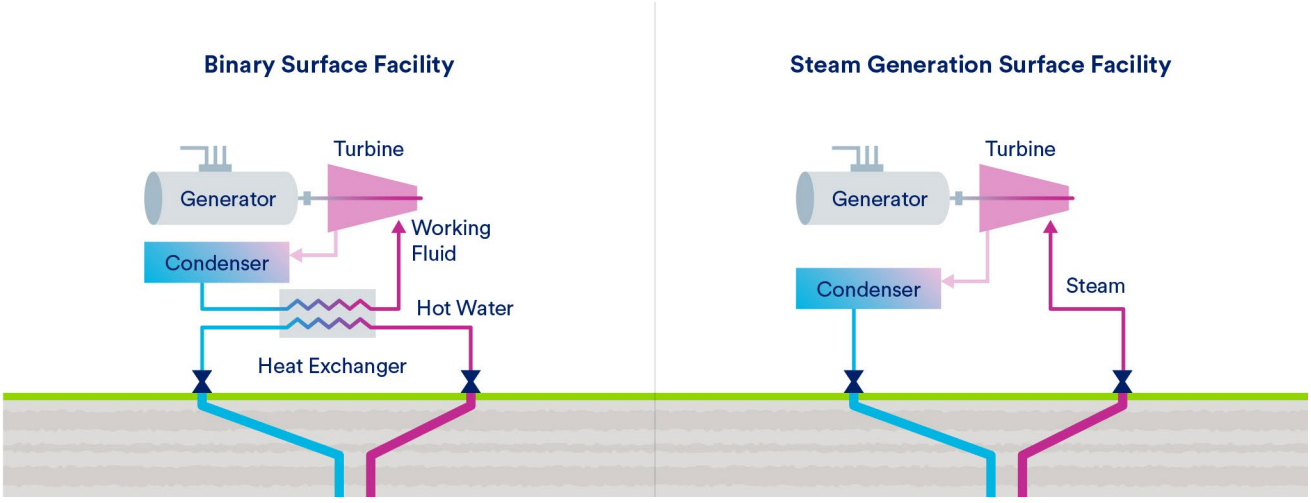
The *surface facility construction* phase requires building surface facilities to process heated water.[60] For electricity generation, there are two primary options for surface facilities: binary and steam generation (see Figure 10).[61] Both surface facilities require equipment such as turbines, generators, transformers, cooling equipment, and plant control systems (e.g., a control room) to turn heated fluid into electricity and enable the continuous operation and monitoring of the project. Surface facility construction requires additional permits beyond those required for prior phases of development.

The first phase of the first commercial-scale next-generation geothermal project in the U.S. cost about $7 million USD per MW of installed capacity.[62] Continued learning-by-doing is bringing costs down; the second phase of that project is expected to cost $5.5 million USD per MW, and the project developer is targeting $3 million USD per MW for later phases and projects.[63]

Once construction is completed and transmission and buyer(s) secured, the project enters the *operations* phase, generating electricity and revenue over years or decades.

Figure 10: Geothermal surface facilities

Air-cooled binary cycle equipment minimizes water consumption but is more costly to build and operate, whereas wet-cooled steam generation systems typically consume more water but have higher thermal efficiency and thus lower costs.[64]



60 Thus far, next-generation geothermal projects in the U.S. have generated electricity, but next-generation geothermal can also be used to produce heat for industrial processes and/or district heating. For example, one next-generation geothermal project in Germany produces 8.2 MW of electricity and 64 MW of district heating; this model could be used in the U.S. as well. Different end uses require different surface facilities to process the heat. *See* Gallucci, M. (2025, October 28). *Eavor is about to bring its first-of-a-kind geothermal project online.* Canary Media. https://www.canarymedia.com/articles/geothermal/eavor-is-about-to-bring-its-first-of-a-kind-geothermal-project-online

61 Seligman, A. (April 2026). *Water use and next-generation geothermal* [Fact sheet]. Clean Air Task Force. https://www.catf.us/wp-content/uploads/2026/04/water-use-fact-sheet.pdf

62 Fervo Energy Company. (17 April 2026). *Form S-1.* https://www.sec.gov/Archives/edgar/data/1853868/000162828026025821/fervoenergy-sx1.htm

63 Fervo Energy Company. (17 April 2026). *Form S-1.* https://www.sec.gov/Archives/edgar/data/1853868/000162828026025821/fervoenergy-sx1.htm

64 Seligman, A. (2026). *Water use and next-generation geothermal* [Fact sheet]. Clean Air Task Force. https://www.catf.us/resource/water-use-next-generation-geothermal/

APPENDIX C

Systemic Bankability for Geothermal

The deployment levers listed in this report are based on the systemic bankability framework, which describes systemic financing challenges and risks for emerging energy technologies and suggests policies that are calibrated to address those risks.[65] In addition to content related to systemic bankability, this report also considers actions needed to enable technological progress for next-generation geothermal.

Systemic Bankability Conditions:

Cost overrun risks
Addressed by Deployment Lever 1: Characterize and Deployment Lever 3: Finance

Technology performance risks
Addressed by Deployment Lever 1: Characterize and Deployment Lever 3: Finance

Revenue adequacy risks
Addressed by Deployment Lever 3: Finance

Regulatory certainty
Addressed by Deployment Lever 2: Govern

Access to enabling infrastructure
Addressed by Deployment Lever 1: Characterize and Deployment Lever 4: Connect

Social acceptance
Addressed by Deployment Lever 2: Govern and Deployment Lever 4: Connect

Robust supply chains
Addressed by Deployment Lever 4: Connect and Deployment Lever 5: Innovate

Access to commercial insurance
Addressed by Deployment Lever 3: Finance

Adequate delivery system
Addressed by Deployment Lever 4: Connect

[65] 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/