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Breaking Ground on Next-Generation Geothermal Energy

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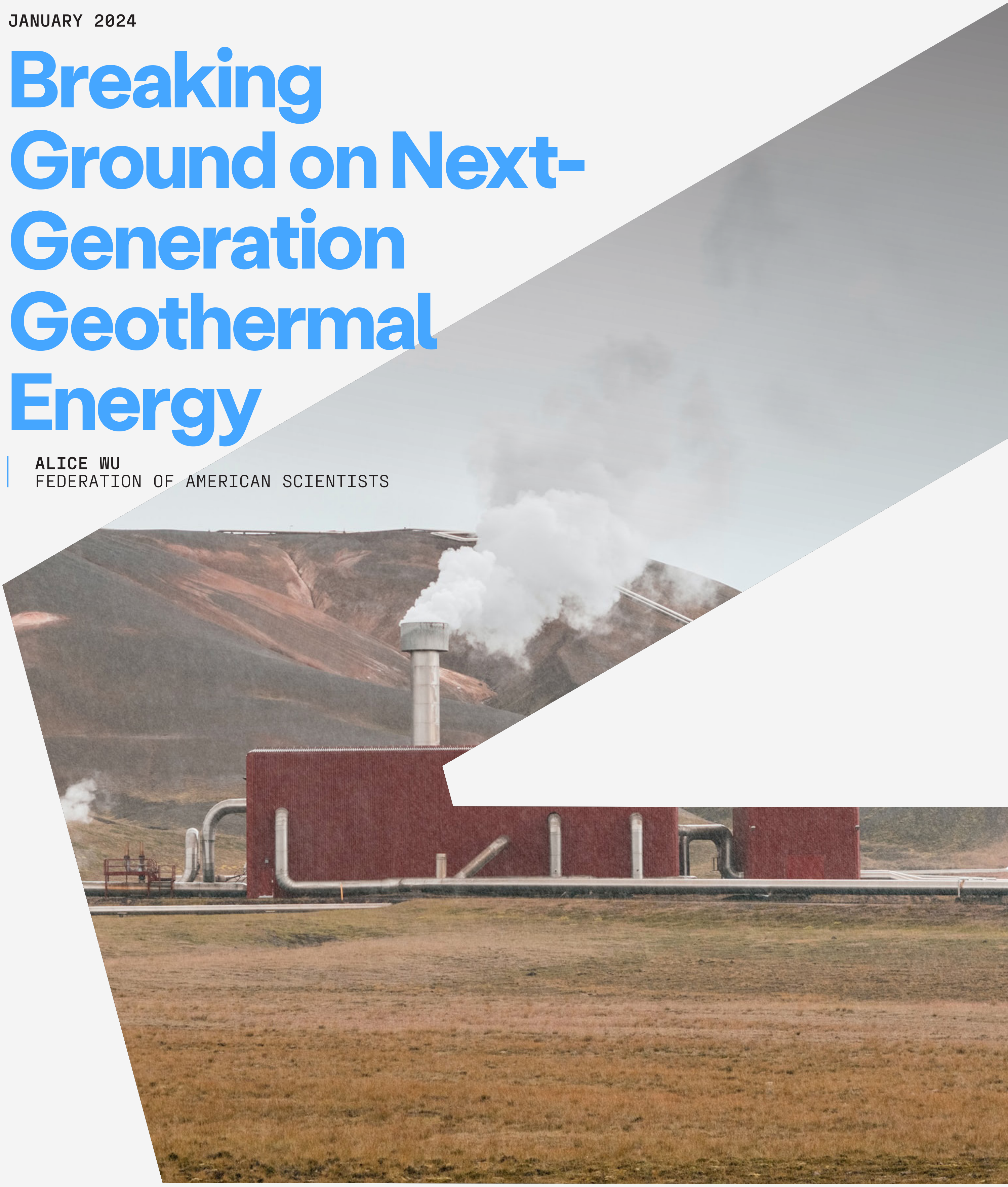

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COVER IMAGE: TOMMY KWAK, "GEOTHERMAL PLANT IN ICELAND," 2020.

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This report is part one of a series on underinvested clean energy technologies, the challenges they face, and how the Department of Energy can use its Other Transaction Authority to implement programs custom tailored to those challenges.

Executive Summary

The United States has been gifted with an abundance of clean, firm geothermal energy lying below our feet – tens of thousands of times more than the country has in untapped fossil fuels. Geothermal technology is entering a new era, with innovative approaches on their way to commercialization that will unlock access to more types of geothermal resources. However, the development of commercial-scale geothermal projects is an expensive affair, and the U.S. government has severely underinvested in this technology. The Inflation Reduction Act and the Bipartisan Infrastructure Law concentrated clean energy investments in solar and wind, which are great near-term solutions for decarbonization, but neglected to invest sufficiently in solutions like geothermal energy, which are necessary to reach full decarbonization in the long term. With new funding from Congress or potentially the creative (re)allocation of existing funding, the Department of Energy (DOE) could take a number of different approaches to accelerating progress in next-generation geothermal energy, from leasing agency land for project development to providing milestone payments for the costly drilling phases of development.

Introduction

As the United States power grid transitions towards clean energy, the increasing mix of intermittent renewable energy sources like solar and wind must be balanced by sources of clean firm power that are available around the clock in order to ensure grid reliability and reduce the need to overbuild solar, wind, and battery capacity. Geothermal power is a leading contender for addressing this issue.

Conventional geothermal (also known as hydrothermal) power plants tap into existing hot underground aquifers and circulate the hot water to the surface to generate electricity. Thanks to an abundance of geothermal resources close to the earth's surface in the western part of the country, the United States currently leads the world in geothermal power generation. Conventional geothermal power plants are typically located near geysers and steam vents, which indicate the presence of hydrothermal resources belowground. However, these hydrothermal sites represent just a small fraction of the total untapped geothermal potential beneath our feet — more than the potential of fossil fuel and nuclear fuel reserves combined.

Next-generation geothermal technologies, such as enhanced geothermal systems (EGS), closed-loop or advanced geothermal systems (AGS), and other novel designs, promise to allow access to a wider range of geothermal resources. Some designs can potentially also serve double duty as long-duration energy storage. Rather than tapping into existing hydrothermal reservoirs underground, these technologies drill into hot dry rock, engineer independent reservoirs using either hydraulic stimulation or extensive horizontal drilling, and then introduce new fluids to bring geothermal energy to the surface. These new technologies have benefited from advances in the oil and gas industry, resulting in lower drilling costs and higher success rates. Furthermore, some companies have been developing designs for retrofitting abandoned oil and gas wells to convert them into geothermal power plants. The commonalities between these two sectors present an opportunity not only to leverage the existing workforce, engineering expertise, and supply chain from the oil and gas industry to grow the geothermal industry but also to support a just transition such that current workers employed by the oil and gas industry have an opportunity to help build our clean energy future.

Over the past few years, a number of next-generation geothermal companies have had successful pilot demonstrations, and some are now developing commercial-scale projects. As a result of these successes and the growing demand for clean firm power, power purchase agreements (PPAs) for an unprecedented 1GW of geothermal power have been signed with utilities, community choice aggregators (CCAs), and commercial customers in the United States in 2022 and 2023 combined. In 2023, PPAs for next-generation geothermal projects surpassed those for conventional geothermal projects in terms of capacity. While this is promising, barriers remain to the development of commercial-scale geothermal projects. To meet its goal of net-zero emissions by 2050, the United States will need to invest in overcoming these barriers for next-generation geothermal energy now, lest the technology fail to scale to the level necessary for a fully decarbonized grid.

Meanwhile, conventional hydrothermal still has a role to play in the clean energy transition. The United States needs all the clean firm power that it can get, whether that comes from conventional or next-generation geothermal, in order to retire baseload coal and natural gas plants. The construction of conventional hydrothermal power plants is less expensive and cheaper to finance, since it's a tried and tested technology, and there are still plenty of untapped hydrothermal resources in the western part of the country.

Challenges Facing Geothermal Projects

Funding is the biggest barrier to commercial development of next-generation geothermal projects. There are two types of private financing: equity financing or debt financing. Equity financing is more risk tolerant and is typically the source of funding for start-ups as they move from the R&D to demonstration phases of their technology. But because equity financing has a dilutive effect on the company, when it comes to the construction of commercial-scale projects, debt financing is preferred. However, first-of-a-kind commercial projects are almost always precluded from accessing debt financing. It is commonly understood within industry that private lenders will not take on technology risk, meaning that technologies must be at a Technology Readiness Level (TRL) of 9, where they have been proven to operate at commercial scale, and government lenders like the DOE Loan Programs Office (LPO) generally will not take on any risk that private lenders won't. Manifestations of technology risk in next-generation geothermal include the possibility of underproduction, which would impact the plant's profitability, or that capacity will decline faster than expected, reducing the plant's operating lifetime. Moving next-generation technologies from the current TRL-7 level to TRL-9 will be key to establishing the reliability of these emerging technologies and unlocking debt financing for future commercial-scale projects.

Underproduction will likely remain a risk, though to a lesser extent, for next-generation projects even after technologies reach TRL-9. This is because uncertainty in the exploration and subsurface characterization process makes it possible for developers to overestimate the temperature gradient and thus the production capacity of a project. Hydrothermal projects also share this risk: the factors determining the production capacity for hydrothermal projects include not only the temperature gradient but also the flow rate and enthalpy of the natural reservoir. In the worst-case scenario, drilling can result in a dry hole that produces no hot fluids at all. This becomes a financial issue if the project is unable to generate as much revenue as expected due to underproduction or additional wells must be drilled to compensate, driving up the total project cost. Thus, underproduction is a risk shared by both next-generation and conventional geothermal projects. Research into improvements to the accuracy and cost of geothermal exploration and subsurface characterization can help mitigate this risk but may not eliminate it entirely, since there is a risk-cost trade-off in how much time is spent on exploration and subsurface characterization.

Another challenge for both next-generation and conventional geothermal projects is that they are more expensive to develop than solar or wind projects. Drilling requires significant upfront capital expenditures, making up about half of the total capital costs of developing a geothermal project, if not more. For example, in EGS projects, the first few wells can cost around $10 million each, while conventional hydrothermal wells, which are shallower, can cost around $3–7 million each. While conventional hydrothermal plants only consist of two to six wells on average, designs for commercial EGS projects can require several times that amount of wells. Luckily, EGS projects benefit from the fact that wells can be drilled identically, so projects expect to move down the learning curve as they drill more wells, resulting in faster and cheaper drilling. Initial data from commercial-scale projects currently being developed suggest that the learning curves may be even steeper than expected. Nevertheless, this will need to be proven at scale across different locations. Some companies have managed to forgo expensive drilling costs by focusing on developing technologies that can be installed within idle hydrothermal wells or abandoned oil and gas wells to convert them into productive geothermal wells.

Beyond funding, geothermal projects need to obtain land where there are suitable geothermal resources and permits for each stage of project development. The best geothermal resources in the United States are concentrated in the West, where the federal government owns most of the land. The Bureau of Land Management (BLM) manages a lot of that land, in addition to all subsurface resources on federal land. However, there is inconsistency in how the BLM leases its land, depending on the state. While Nevada BLM has been very consistent about holding regular lease sales each year, California BLM has not held a lease sale since 2016. Adding to the complexity is the fact that although BLM manages all subsurface resources on federal land, surface land may sometimes be managed by a different agency, in which case both agencies will need to be involved in the leasing and permitting process.

Last, next-generation geothermal companies face a green premium on electricity produced using their technology, though the green premium does not appear to be as significant of a challenge for next-generation geothermal as it is for other green technologies. In states with high renewables penetration, utilities and their regulators are beginning to recognize the extra value that clean firm power provides in terms of grid reliability. For example, the California Public Utility Commission has issued an order for utilities to procure 1 GW of clean, firm power by 2026, motivating a wave of new demand from utilities and community choice aggregators. As a result of this demand and California's high electricity prices in general, geothermal projects have successfully signed a flurry of PPAs over the past year. These have included projects located in Nevada and Utah that can transmit electricity to California customers. In most other western states, however, electricity prices are much lower, so utility companies can be reluctant to sign PPAs for next-generation geothermal projects if they aren't required to, due to the high cost and technology risk. As a result, next-generation geothermal projects in those states have turned to commercial customers, like those operating data centers, who are willing to pay more to meet their sustainability goals.

Federal Support

The federal government is beginning to recognize the important role of next-generation geothermal power for the clean energy transition. For the first time in 2023, geothermal energy became eligible for the renewable energy investment and production tax credits, thanks to technology-neutral language introduced in the Inflation Reduction Act (IRA). Within the DOE, the agency launched the Enhanced Geothermal Shot in 2022, led by the Geothermal Technologies Office (GTO), to reduce the cost of EGS by 90% to $45/MWh by 2035 and make geothermal widely available. In 2020, the Frontier Observatory for Research in Geothermal Energy (FORGE), a dedicated underground field laboratory for EGS research, drilling, and technology testing established by GTO in 2014, drilled their first well using new approaches and tools the lab had developed. This year, GTO announced funding for seven EGS pilot demonstrations from the Bipartisan Infrastructure Law (BIL), for which GTO is currently reviewing the first round of applications. GTO also awarded the Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE) grant to a consortium formed by Project Innerspace, the Society of Petroleum Engineering International, and Geothermal Rising, with over 100 partner entities, to transfer best practices from the oil and gas industry to geothermal, support demonstrations and deployments, identify barriers to growth in the industry, and encourage workforce adoption.

While these initiatives are a good start, significantly more funding from Congress is necessary to support the development of pilot demonstrations and commercial-scale projects and enable wider adoption of geothermal energy. The BIL notably expanded the DOE's mission area in supporting the deployment of clean energy technologies, including establishing the Office of Clean Energy Demonstrations (OCED) and funding demonstration programs from the Energy Division of BIL and the Energy Act of 2020. However, the $84 million in funding authorized for geothermal pilot demonstrations was only a fraction of the funding that other programs received from BIL and not commensurate to the actual cost of next-generation geothermal projects. Congress should be investing an order of magnitude more into next-generation geothermal projects, in order to maintain U.S. leadership in geothermal energy and reap the many benefits to the grid, the climate, and the economy.

Another key issue is that DOE has currently and in the past limited all of its funding for next-generation geothermal to EGS technologies only. As a result, companies pursuing closed-loop/AGS and other next-generation technologies cannot qualify, leading some projects to be moved abroad. Given GTO's historically limited budget, it's possible that this was the result of a strategic decision to focus their funding on one technology rather than diluting it across multiple technologies. However, given that none of these technologies have been successfully commercialized at a wide scale yet, DOE may be missing the opportunity to invest in the full range of viable approaches. DOE appears to be aware of this, as the agency currently has a working group on AGS. New funding from Congress would allow DOE to diversify its investments to support the demonstration and commercial application of other next-generation geothermal technologies.

Alternatively, there are a number of OCED programs with funding from BIL that have not yet been fully spent (Table 1). Congress could reallocate some of that funding towards a new program supporting next-generation geothermal projects within OCED. Though not ideal, this may be a more palatable near-term solution for the current Congress than appropriating new funding.

Table 1. OCED programs that have remaining unspent funding from BIL as of publication in Jan 2024.

OCED Program	Total Funding	Committed Funding	Unspent Funding
Carbon Capture Demonstration Projects	$2.537 billion	$1.889 billion	$658 million
Carbon Capture Large Scale Pilot Projects	$937 million	$820 million	$117 million
Energy Improvements in Rural and Remote Areas	$1 billion	$365 million	$635 million
Clean Energy Demonstration Program on Current and Former Mine Land	$500 million	$450 million	$50 million
Energy Storage Demonstration Projects and Pilot Grant Program	$355 million	$349 million	$6 million
Long-Duration Demonstration Program and Joint Initiative	$150 million	$30 million	$120 million

A third option is that DOE could use some of the funding for the Energy Improvements in Rural and Remote Areas program, of which $635 million remains unallocated, to support geothermal projects. Though the program's authorization does not explicitly mention geothermal energy, geothermal is a good candidate given the abundance of geothermal production potential in rural and remote areas in the West. Moreover, as a clean firm power source, geothermal has a comparative advantage over other renewable energy sources in improving energy reliability.

Other Transactions Authority

BIL and IRA gave DOE an expanded mandate to support innovative technologies from early stage research through commercialization. To do so, DOE will need to be just as innovative in its use of its available authorities and resources. Tackling the challenge of scaling technologies from pilot to commercialization will require DOE to look beyond traditional grant, loan, and procurement mechanisms. Previously, we identified the DOE's Other Transaction Authority (OTA) as an underleveraged tool for accelerating clean energy technologies.

OTA is defined in legislation as the authority to enter into any transaction that is not a government grant or contract. This negative definition provides DOE with significant freedom to design and implement flexible financial agreements that can be tailored to the unique challenges that different technologies face. OT agreements allow DOE to be more creative, and potentially more cost-effective, in how it supports the commercialization of new technologies, such as facilitating the development of new markets, mitigating risks and market failures, and providing innovative new types of demand-side "pull" funding and supply-side "push" funding. The DOE's new Guide to Other Transactions provides official guidance on how DOE personnel can use the flexibilities provided by OTA.

With additional funding from Congress, the DOE could use OT agreements to address the unique barriers that geothermal projects face in ways that may not be possible through other mechanisms. Below are four proposals for how the DOE can do so. We chose to focus on supporting next-generation geothermal projects, since the young industry currently requires more governmental support to grow, but we included ideas that would benefit conventional hydrothermal projects as well.

Program Proposals

Geothermal Development on Agency Land

This year, the Defense Innovation Unit issued its first funding opportunity specifically for geothermal energy. The four winning projects will aim to develop innovative geothermal power projects on Department of Defense (DoD) bases for both direct consumption by the base and sale to the local grid. OT agreements were used for this program to develop mutually beneficial custom terms. For project developers, DoD provided funding for surveying, design, and proposal development in addition to land for the actual project development. The agreement terms also gave companies permission to use the technology and information gained from the project for other commercial use. For DoD, these projects are an opportunity to improve the energy resilience and independence of its bases while also reducing emissions. By implementing the prototype agreement using OTA, DoD will have the option to enter into a follow-on OT agreement with project developers without further competition, expediting future processes.

DOE could implement a similar program for its 2.4 million acres of land. In particular, the DOE's land in Idaho and other western states has favorable geothermal resources, which the DOE has considered leasing. By providing some funding for surveying and proposal development like the DoD, the DOE can increase the odds of successful project development, compared to simply leasing the land without funding support. The DOE could also offer technical support to projects from its national labs.

With such a program, a lot of the value that the DOE would be providing is the land itself, which the DOE currently has more of than actual funding for geothermal energy. The funding needed for surveying and proposal development is much less than would be needed to support the actual construction of demonstration projects, so GTO could feasibly request funding for such a program through the annual appropriations process. Depending on the program outcomes and the resulting proposals, the DOE could then go back to Congress to request follow-on funding to support actual project construction.

Drilling Cost-Share Program

To help defray the high cost of drilling, the DOE could implement a milestone-based cost-share program. There is precedent for government cost-share programs for geothermal: in 1973, before the DOE was even established, Congress passed the Geothermal Loan Guarantee Program to provide "investment security to the public and private sectors to exploit geothermal resources" in the early days of the industry. Later, the DOE funded the Cascades I and II Cost Shared Programs. Then, from 2000 to 2007, the DOE ran the Geothermal Resource Exploration and Definitions (GRED) I, II, and III Cost-Share Programs. This year, the DOE launched its EGS Pilot Demonstrations program.

A milestone payment structure could be favorable for supporting expensive, next-generation geothermal projects because the government takes on less risk compared to providing all of the funding upfront. Initial funding could be provided for drilling the first few wells. Successful and on-time completion of drilling could then unlock additional funding to drill more wells, and so on. In the past, both the DoD and the National Aeronautics and Space Administration (NASA) have structured their OT agreements using milestone payments, most famously between NASA and SpaceX for the development of the Falcon9 space launch vehicle. The NASA and SpaceX agreement included not just technical but also financial milestones for the investment of additional private capital into the project. The DOE could do the same and include both technical and financial milestones in a geothermal cost-share program.

Risk Insurance Program

Longer term, the DOE could implement a risk insurance program for conventional hydrothermal and next-generation geothermal projects. Insuring against underproduction could make it easier and cheaper for projects to be financed, since the potential downside for investors would be capped. The DOE could initially offer insurance just for conventional hydrothermal, since there is already extensive data on past commercial projects that can inform how the insurance is designed. In order to design insurance for next-generation technologies, more commercial-scale projects will first need to be built to collect the data necessary to assess the underproduction risk of different approaches.

France has administered a successful Geothermal Public Risk Insurance Fund for conventional hydrothermal projects since 1982. The insurance originally consisted of two parts: a Short-Term Fund to cover the risk of underproduction and a Long-Term Fund to cover uncertain long-term behavior over the operating lifetime of the geothermal plant. The Short-Term Fund asked project owners to pay a premium of 1.5% of the maximum guaranteed amount. In return, the Short-Term Fund provided a 20% subsidy for the cost of drilling the first well and, in the case of reduced output or a dry hole, a compensation between 20% and 90% of the maximum guaranteed amount (inclusive of the subsidy that has already been paid). The exact compensation is determined based on a formula for the amount necessary to restore the project's profitability with its reduced output. The Short-Term Fund relied on a high success rate, especially in the Paris Basin where there is known to be good hydrothermal resources, to fund the costs of failures. Geothermal developers that chose to get coverage from the Short-Term Fund were required to also get coverage from the Long-Term Fund, which was designed to hedge against the possibility of unexpected geological or geothermal changes within the wells, such as if their output declined faster than expected or severe corrosion or scaling occurred, over the geothermal plant's operating lifetime. The Long-Term Fund ended in 2015, but a new iteration of the Short-Term Fund was approved in 2023.

The Netherlands has successfully run a similar program to the Short-Term Fund since the 2000s. Private-sector attempts at setting up geothermal risk insurance packages in Europe and around the world have mostly failed, though. The premiums were often too high, costing up to 25–30% of the cost of drilling, and were established in developing markets where not enough projects were being developed to mutualize the risk.

To implement such a program at the DOE, projects seeking coverage would first submit an application consisting of the technical plan, timeline, expected costs, and expected output. The DOE would then conduct rigorous due diligence to ensure that the project's proposal is reasonable. Once accepted, projects would pay a small premium upfront; the DOE should keep in mind the failed attempts at private-sector insurance packages and ensure that the premium is affordable. In the case that either the installed capacity is much lower than expected or the output capacity declines significantly over the course of the first year of operations, the Fund would compensate the project based on the level of underproduction and the amount necessary to restore the project's profitability with a reduced output. The French Short-Term Fund calculated compensation based on characteristics of the hydrothermal wells; the DOE would need to develop its own formulas reflective of the costs and characteristics of different next-generation geothermal technologies once commercial data actually exists.

Before setting up a geothermal insurance fund, the DOE should investigate whether there are enough geothermal projects being developed across the country to ensure the mutualization of risk and whether there is enough commercial data to properly evaluate the risk. Another concern for next-generation geothermal is that a high failure rate could cause the fund to run out. To mitigate this, the DOE will need to analyze future commercial data for different next-generation technologies to assess whether each technology is mature enough for a sustainable insurance program. Last, poor state capacity could impede the feasibility of implementing such a program. The DOE will need personnel on staff that are sufficiently knowledgeable about the range of emerging technologies in order to properly evaluate technical plans, understand their risks, and design an appropriate insurance package.

Production Subsidy

While the green premium for next-generation geothermal has not been an issue in California, it may be slowing down project development in other states with lower electricity prices. The Inflation Reduction Act introduced a new clean energy Production Tax Credit that included geothermal energy for the first time. However, due to the higher development costs of next-generation geothermal projects compared to other renewable energy projects, that subsidy is insufficient to fully bridge the green premium. DOE could use OTA to introduce a production subsidy for next-generation geothermal energy with varied rates depending on the state that the electricity is sold to and its average baseload electricity price (e.g., the production subsidy likely would not apply to California). This would help address variations in the green premium across different states and expand the number of states in which it is financially viable to develop next-generation geothermal projects.

Conclusion

The United States is well-positioned to lead the next-generation geothermal industry, with its abundance of geothermal resources and opportunities to leverage the knowledge and workforce of the domestic oil and gas industry. The responsibility is on Congress to ensure that DOE has the necessary funding to support the full range of innovative technologies being pursued by this young industry. With more funding, DOE can take advantage of the flexibility offered by OTA to create agreements tailored to the unique challenges that the geothermal industry faces as it begins to scale. Successful commercialization would pave the way to unlocking access to 24/7 clean energy almost anywhere in the country and help future-proof the transition to a fully decarbonized power grid. be.

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