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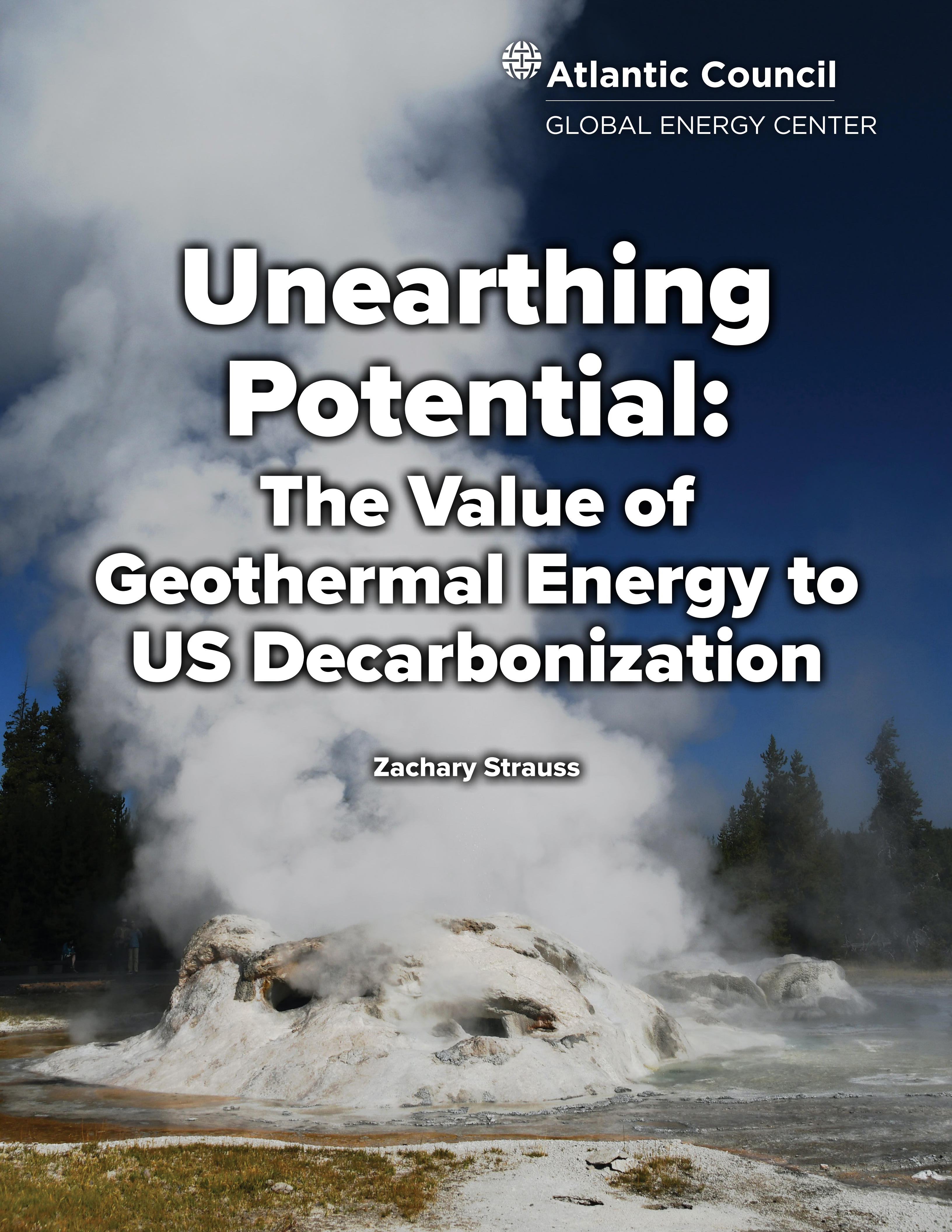

Unearthing Potential: The Value of Geothermal Energy to US Decarbonization

Zachary Strauss

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Cover photo: A geyser erupts in Yellowstone National Park. *Unsplash, Siegfried Poepperl (@siggi81p)*

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Contents

Executive Summary

Achieving US climate goals requires the development and widespread deployment of all available clean energy solutions. Geothermal energy, while currently only a marginal component of the US energy economy, will be indispensable in the fight against climate change. Geothermal capacity can support deep decarbonization in a way that most other clean energy solutions cannot by providing: clean, baseload power; a highly efficient means to heat and cool buildings, campuses, and cities; a host of agricultural and industrial applications; and the potential for sustainable lithium production.

Geothermal power plants consume only modest quantities of water and boast average availabilities of more than 90 percent, the highest of all power sources except nuclear.[1] With some seasonal variation, they are able to operate twenty-four hours a day and can produce two to four times as much power as solar or wind farms of equivalent capacity.[2] Binary power plants, which represent all geothermal capacity additions in the United States since 2000, produce essentially zero carbon emissions or pollutants, and have one of the smallest land footprints of any generation technology.[3] According to the US Department of Energy (DOE), widespread demonstration and deployment of enhanced geothermal systems (EGS)—in addition to regulatory and drilling improvements—could unlock 60 gigawatts (GW) of clean baseload power by 2050.[4] If this 60-GW estimate is realized, geothermal could generate nearly 10 percent of all US electricity and provide a strong base of clean, reliable energy upon which grids and communities can depend.[5]

Geothermal electricity plants can be colocated with solar photovoltaic arrays, produce green hydrogen, and support thermal tourism sites like Iceland's Blue Lagoon. Most lucratively, in specific areas like California's Salton Sea, geothermal plants can complement lithium extraction to produce renewable energy and sustainable minerals simultaneously.[6]

The geothermal power sector creates stable, long-term jobs, generates indirect employment across a number of supply chains, and supports rural communities local to geothermal plants. The industry employs people across a host of different occupations, from geologists to drill operators, with high levels of skill transferability for fossil fuel workers.[7]

At the same time, a number of obstacles are impeding the geothermal power sector, particularly long leasing and permitting timelines, waves of expiration and extension of federal tax credits, and funding deficits for research, development, and deployment. DOE estimates that regulatory reform and streamlining could cut the geothermal permitting timeline in half and increase installed capacity to 13 gigawatts electric (GWe) by 2050, doubling capacity in comparison to benchmark scenarios.[8] Raising tax credits to parity with solar projects and extending incentives for at least five years would boost investor confidence and raise geothermal's value. Furthermore, increasing federal funding would facilitate advancements in innovative geothermal technologies.

Looking beyond baseload power production, geothermal can play a major role in cutting residential and commercial building emissions across the country, predominantly through deployment of electric geothermal heat pumps (GHPs) for heating and cooling. GHPs draw upon the near-constant temperature of the shallow subsurface to provide clean and energy-efficient heating and cooling, reduce electricity demand during peak hours, and enhance grid and household resilience. They consume between 25 and 50 percent less electricity compared to standard heating, ventilating, and air-conditioning (HVAC) equipment

1 "Geothermal FAQs," US Department of Energy (DOE), Office of Energy Efficiency & Renewable Energy (website), accessed December 23, 2021, https://www.energy.gov/eere/geothermal/geothermal-faqs; and "What is Generation Capacity?," DOE Office of Nuclear Energy, May 1 2020, https://www.energy.gov/ne/articles/what-generation-capacity.

2 *GeoVision: Harnessing the Heat Beneath Our Feet*, Chapter 2, "What Is Geothermal Energy?," DOE/EE–1306, May 2019, 10-47, https://www.energy.gov/sites/prod/files/2019/05/f63/2-GeoVision-Chap2.pdf.

3 "Geothermal Basics," DOE, Energy Efficiency & Renewable Energy (website), accessed December 23, 2021, https://www.energy.gov/eere/geothermal/geothermal-basics.

4 "GeoVision," DOE Office of Energy Efficiency & Renewable Energy (website), accessed December 23, 2021, https://www.energy.gov/eere/geothermal/geovision.

5 *GeoVision*, 2019.

6 Jody C. Robins et al., *2021 U.S. Geothermal Power Production and District Heating Market Report*, National Renewable Energy Laboratory, July 2021, https://www.nrel.gov/docs/fy21osti/78291.pdf.

7 Dev Millstein et al., *GeoVision Analysis Supporting Task Force Report: Impacts*, National Renewable Energy Laboratory, May 2019, https://www.nrel.gov/docs/fy19osti/71933.pdf.

8 DOE Geothermal Technologies Office, "2020 United States Country Report," International Energy Agency (IEA) Geothermal Technical Collaboration Program, April 2021, https://drive.google.com/file/d/18TGm6O2N0uQ87omkqUC8XH6kanWQR1pg/view.

An aerial view of the Salton Sea, the center of California's geothermal power sector. *Reuters, Aude Guerrucci*

and generate up to 75 percent less emissions.[9] GHPs can lower utility bills up to 60 percent, consume modest quantities of water, and generate zero noise pollution.[10]

However, the GHP industry remains stymied by high capital and customer costs, and faces competition from cheaper alternatives and legacy fuels. Tax credits are crucial to driving customer adoption; waves of extension and expiration of federal incentives have hindered sector growth over the past decade. Raising GHP tax credits to parity with solar and extending the incentives for a least five years beyond their expiration in 2024 would bolster sector growth, as would the inclusion of GHPs in state renewable portfolio standards and the implementation of robust government heat-pump subsidy programs, particularly for low-income people.

While GHPs effectively serve singular buildings, direct-use geothermal, through district heating systems, can heat entire complexes, communities, and cities. There are twenty-three geothermal district heating (GDH) systems in the western United States, providing sustainably sourced heat to downtown areas, schools, hospitals, prisons, and universities.[11] However, the distance between subsurface resources and population centers along with high capital expenditure, competition from lower-cost alternatives, and weak public funding have thus far stymied the growth of GDH systems in the United States.

In addition to heating and cooling, direct-use geothermal heat has a number of productive and profitable ancillary applications: greenhouse agriculture, snow melting, aquaculture, pulp processing, pool and spa heating, and food drying.

9 "Choosing and Installing Geothermal Heat Pumps," DOE (website), accessed December 27, 2021, https://www.energy.gov/energysaver/choosing-and-installing-geothermal-heat-pumps.

10 Alison Gregor, "Geothermal Designs Arise as a Stormproof Resource," *New York Times*, November 6, 2012, https://www.nytimes.com/2012/11/07/business/geothermal-energy-advocates-hope-systems-get-a-second-look.html.

11 Robins et al., *2021 U.S. Geothermal*.

Employing subsurface heat instead of fossil fuels in agriculture and industry saves money, cuts emissions, and reduces energy consumption across a host of economic sectors.[12]

With proper financial and political support, geothermal energy could play a central role in decarbonizing the entire US economy. Deep decarbonization requires scaling proven solutions to difficult climate issues like sustainable lithium development, building-sector electrification, and grid reliability. As a nearly inexhaustible renewable resource with immense potential, the US geothermal energy sector is ready to take on the challenge; policymakers now must give it the opportunity.

With that in mind, this report offers the following policy recommendations:

1) **Increase geothermal power procurement and compensation:** To meet goals outlined in President Biden's executive order, Catalyzing Clean Energy Industries and Jobs through Federal Sustainability,[13] the federal government should procure a minimum percentage of geothermal energy as part of public operations and develop geothermal power on land adjacent to federal facilities. To that end, geothermal developers and regulators should move away from a levelized cost of energy (LCOE) when setting geothermal electricity rates and instead ascribe it a greater monetary value as clean, reliable energy.

2) **Augment federal funding for technology and innovation:** In line with the fiscal year 2022 and fiscal year 2023 budget solicitations, more funding should be allocated to research and development for hybrid opportunities for geothermal power; enhanced geothermal systems; and the creation of an advanced geothermal demonstration program.

3) **Streamline the permitting and leasing process:** Congress and the Department of the Interior should work to streamline the geothermal leasing and permitting process by: allocating greater resources to the Bureau of Land Management; developing a digital application tracking system; authorizing categorical exclusions that would streamline the permitting process for some drilling components in geothermal; creating a centralized, geothermal-specific Renewable Energy Coordination Office; and enacting H.R. 5350, the Enhancing Geothermal Production on Federal Lands Act, to authorize such categorical exclusions.

4) **Increase federal tax credits for geothermal energy:** Current GHP and geothermal power tax credits should be raised to parity with solar credits and extended for a duration of at least five years, especially as the production tax credit (PTC) expired at the end of 2021. Congress should pass the Groundsource Exchange Tax Parity Act, H.R. 3920, to raise the GHP commercial investment tax credit (ITC) to parity with solar. Congress should develop a new tax-credit regime for renewable energy technologies based on total market penetration through enactment of the Energy Sector Innovation Credit Act, S. 2475, and allow for monetization of credits through a direct pay mechanism.

5) **Expand heat pump subsidies and incentives:** Through the proposed High-Efficiency Electric Home Rebate Program, state and federal government should provide robust GHP subsidies to catalyze heat pump adoption. Specific heat pump subsidies should be designed to support low-income families and those dependent on fuel oil. While this program is part of the proposed Build Back Better legislation, should the bill fail, this initiative could be pulled out, introduced, and passed on its own. In line with its December 2021 executive order on federal sustainability, the Biden-Harris administration should work to retrofit old and outfit new public buildings with geothermal heat pumps.

12 "U.S. Renewable Energy Consumption by Source and Sector, 2020," US Energy Information Administration, accessed December 23, 2021, https://www.eia.gov/totalenergy/data/monthly/pdf/flow/renewable_energy_2020.pdf.

13 Exec. Order No. 14057, 86 Fed. Reg. 70935 (Dec. 13, 2021).

Introduction

To achieve net-zero emissions in the United States by 2050, substantial emissions reductions must be realized across the economy in the power, transportation, buildings, industrial, and agricultural sectors. To meet this challenge, all available clean energy solutions must be pursued, and investment, both political and financial, must be made in proven and innovative technologies. Geothermal energy has applications across all economic sectors and immense potential for growth in the United States.

While currently playing only a marginal role in the US economy and mindset, geothermal is well-suited to become a principal decarbonizing force in the energy transition. To achieve clean energy goals and combat climate change, policymakers, corporates leaders, and the public must recognize the holistic value US geothermal energy offers.

Geothermal power provides renewable, baseload, and reliable electricity that supports grid integrity and resilience. Geothermal plants have very small land footprints, produce zero to low emissions, and—with the proper technological innovation—could be deployed across the United States. Geothermal power developers also can provide substantial quantities of lithium from brines, in tandem with electricity generation, and yield a vital supply of minerals critical to transport electrification. At the same time, several barriers have stymied geothermal power-sector growth and potential. This report explores the obstacles facing the geothermal power sector, with a focus on permitting and leasing policy, tax credits, and research and demonstration funding.

From an economic-impact perspective, the geothermal power industry creates more long-term jobs than wind, solar, and natural gas per thousand homes powered; supports local communities with royalties and indirect employment; and provides a key opportunity for oil and gas workers as part of a just energy transition.

Looking beyond electricity, geothermal heat pumps are the most energy-efficient and environmentally friendly option for heating and cooling buildings. As such, they save property owners money, increase household resilience, and lower energy demand on the grid. Furthermore, direct-use geothermal district systems can heat and cool entire building complexes and cities. However, high up-front capital costs, uncertain congressional support, and weak federal funding have hampered the heat pump and district heating sectors.

Also applicable to agricultural and industrial decarbonization, direct-use geothermal heat can be employed across a number of economic sectors, such as aquaculture, greenhouse agriculture, pulp processing, and more.

In addition to showcasing the economy-wide benefits geothermal offers, this paper will explore the barriers facing geothermal development across applications and provide a number of policy solutions to these challenges. The US geothermal industry is here and ready to play its part, and political leaders must work to craft and put in place policy that stimulates sector growth through increased funding and dedicated technology development; advantageous tax and subsidy regimes; permitting reform; and other critical vectors of support.

The Role of Geothermal Energy in US Power Sector Decarbonization

As the energy transition accelerates, power demand is expected to grow dramatically as vehicles, buildings, and industry electrify across the economy. In fact, a 2018 National Renewable Energy Laboratory (NREL) report found that widespread electrification in the United States could result in as much as a 38 percent increase in electricity demand by 2050 relative to baseline scenarios.[14] Even as intermittent renewables continue to grow in their share of the electricity mix, the need for reliable, clean energy will continue to pose a major challenge to power-sector decarbonization. As a high-efficiency, baseload, renewable energy resource, geothermal power offers a clear, proven, and scalable solution. To meet the climate challenge, political and corporate leaders should employ policies that recognize geothermal power's numerous benefits for grid decarbonization and integrity.

Geothermal electricity has been produced in the United States since 1960, when the first power plant was brought online in Northern California at The Geysers, the largest geothermal resource in the world.[15] There are now ninety-four operating geothermal power plants in the United States generating a total 3.69 GW of electricity, representing 26 percent of the world's total installed geothermal capacity and 0.4 percent of total US utility-scale electricity generation.[16] All geothermal capacity additions since 2000 have been binary power plants, now considered the gold standard for conventional resource production due to their flexibility and environmental benefits.[17] At a binary plant, hot water from the earth is piped to the surface through a production well, where it then passes through a heat exchanger and warms a secondary working fluid with a lower boiling point than water. The secondary liquid flashes to vapor, rotating a turbine and generating electricity. The original subsurface water is pumped back into the ground through an injection well, replenishing the reservoir.

Binary plants produce essentially zero carbon emissions or pollutants and have one of the smallest land footprints of any generation technology, requiring eight times less land than solar and three times less space than wind per gigawatt-hour electric (GWe).[18] Binary plants also consume only modest quantities of water in comparison to thermoelectric plants.[19] They have a life expectancy of more than thirty years, while the subsurface heat reservoirs remain production-capable for much longer if appropriately managed.[20]

Geothermal plants boast average availabilities of more than 90 percent, the highest of all power sources except nuclear.[21] With some seasonal variation, they are able to operate twenty-four hours a day and can produce two to four times as much power as solar or wind farms of equivalent installed capacity.[22] Access to the geothermal resource is baked into the up-front capital cost of well drilling, and once a plant is operational, it can draw upon a nearly inexhaustible energy source for decades to produce clean, renewable electricity.[23] Geothermal power generation contributes to resource diversification, supports resource adequacy, and provides high levels of reliability.

Enhanced Geothermal Systems and DOE's *GeoVision*

Conventional geothermal power production requires three key elements: abundant heat at depth, permeability of rock, and sufficient fluid to carry heat to the surface. Currently, the reservoirs where geothermal resources can be readily exploited are found almost exclusively in the western contiguous United States, in addition to Hawaii

14 Trieu Mai et al., "Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States," National Renewable Energy Laboratory, 2018, https://www.nrel.gov/docs/fy18osti/71500.pdf.

15 "About Geothermal Energy: The Geysers," Calpine Corp. (website), accessed December 24, 2021, https://geysers.com/geothermal.

16 "Now Available: IEA 2020 U.S. Geothermal Report," US Department of Energy (DOE), Office of Energy Efficiency & Renewable Energy, June 8, 2021, https://www.energy.gov/eere/geothermal/articles/now-available-iea-2020-us-geothermal-report; and "Homepage," Geothermal Rising, accessed December 23, 2021, https://geothermal.org.

17 Robins et al., *2021 U.S. Geothermal.*

18 "Geothermal Basics"; and Bruce D. Green and R. Gerald Nix, "Geothermal—The Energy Under Our Feet," National Renewable Energy Laboratory, November 2006, https://www.nrel.gov/docs/fy07osti/40665.pdf.

19 "Water Efficient Energy Production for Geothermal Resources," DOE Office of Energy Efficiency & Renewable Energy, June 2015, https://www.energy.gov/sites/default/files/2015/12/f27/Water%20Efficient%20Energy%20Production%20for%20Geothermal%20Resources.PDF.

20 Robins et al., *2021 U.S. Geothermal*; and "Geothermal FAQs."

21 "Geothermal FAQs"; and "What Is Generation Capacity?"

22 *GeoVision*, Chapter Two.

23 *GeoVision*, Chapter Two.

Mammoth Hotsprings, Yellowstone National Park. *Unsplash, Nico Bistolfi (@nicobistolfi)*

and Alaska. Due to its unique geological and geographical characteristics, on top of a number of technical, regulatory, and economic barriers, geothermal power has remained a relatively small piece of the US energy system, making up just 0.4 percent of the total electricity mix.[24] However, more research and investment in advanced geothermal exploration and drilling technologies, particularly those that facilitate exploitation of unconventional, deeper resources beyond the western United States, would allow the geothermal power sector to grow substantially.

Innovative technologies for unconventional resource utilization are currently under development. NREL has mapped the available deep heat resources across the country in states like Texas, Louisiana, West Virginia, Pennsylvania, and beyond.[25] These deep, unconventional resources lack the rock permeability and water necessary for conventional geothermal production, but a novel approach called enhanced geothermal systems (EGS) could enable their successful exploitation and create nationwide geothermal opportunity.[26] In broad terms, EGS are enhanced man-made reservoirs that can extract an abundant heat resource found deep in the earth where rock permeability is insufficient for traditional development. Hot water from EGS wells can be used to generate renewable electricity and offer opportunities for a constellation of direct-use applications such as district heating or fish farming.[27] According to DOE, successful demonstration and deployment of EGS technologies, in addition to regulatory and drilling improvements, could unlock 60 GW of renewable baseload power by 2050, a twenty-sixfold increase on business-as-usual scenarios. If this 60-GW DOE analysis

24 "Electricity Explained," US Energy Information Administration, last updated March 18, 2021, https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php.

25 "Geothermal Resources of the United States: Identified Hydrothermal Sites and Favorability of Deep Enhanced Geothermal Systems," National Renewable Energy Laboratory, February 22, 2018, https://www.nrel.gov/gis/assets/images/geothermal-identified-hydrothermal-and-egs.jpg.

26 "Geothermal Anywhere," National Renewable Energy Laboratory, accessed December 23, 2021, https://www.nrel.gov/geothermal/anywhere.html.

27 "What Is an Enhanced Geothermal System (EGS)?," DOE Office of Energy Efficiency & Renewable Energy, accessed December 23, 2021, https://www1.eere.energy.gov/geothermal/pdfs/egs_basics.pdf.

titled *GeoVision* is realized, geothermal production could generate nearly 10 percent of all US power and provide a strong base of clean, reliable energy upon which grids and communities can depend.[28]

Despite its great promise, EGS development is challenging both technically and economically; developers must drill deep into the earth and sustain high flow rates of hot water over long periods of time in a way that is profitable.[29] While feasible, more funding for research, development, and demonstration (RD&D) is required to realize widespread EGS deployment across the United States.

Since 2014, the DOE has been working to develop a field laboratory for enhanced geothermal demonstration known as the Frontier Observatory for Research in Geothermal Energy (FORGE), located in Milford, Utah, and led by the University of Utah. FORGE Utah is currently the only government-sponsored EGS RD&D program in the United States, with a project timeline out to 2024. The FORGE demonstration entered phase three (implementation) in July 2019, with the first of two production/injection wells successfully completed in half the time expected.[30] Fracture system enhancement, reservoir stimulation, and testing activities are to follow. Robust technology development and demonstration programs like FORGE are crucial to EGS commercialization. While the bipartisan infrastructure bill allocates $84 million to EGS demonstration, additional funds should be appropriated in future solicitations to help bring these technologies to market at scale.[31]

Hybrid Value Streams with Power Production

Geothermal power generation can also be coupled with a number of other productive and often lucrative activities, like mineral extraction, creating hybrid value streams. For example, geothermal electricity plants can be combined with a solar photovoltaic array as part of a dual-energy system.[32] Power plants can also support major tourist industries. For example, Iceland's Blue Lagoon—the Nordic country's biggest attraction—is the product of an adjacent power-producing facility, with geothermal energy creating local revenue and jobs.[33]

As thermal hot water is often produced during oil and gas development, geothermal power generation can also be colocated with fossil-fuel extraction, while abandoned or declining oil and gas reservoirs can be converted for exclusive geothermal use.[34] The Energy Act of 2020 created a new program that intersects the Offices of Fossil Fuels and Geothermal Energy to assist in knowledge and technology transfer, and authorizes noncompetitive leasing for geothermal energy on federal lands if coproduced from an existing oil or gas well.[35]

Jobs and Economic Impacts

The geothermal power sector creates stable, long-term jobs, generates indirect employment across a number of supply chains, and supports rural communities local to geothermal plants. The industry employs people across a host of different occupations, from geologists to drill operators, with high levels of skill transferability for fossil fuel workers.[36] Based on data from California, geothermal plants create the second-most short-term construction jobs and support the highest number of long-term operations and management jobs per thousand homes powered, as compared to wind, solar, and natural gas.[37] Most of these long-term roles are filled by local workers and wages are mostly spent in the surrounding community, creating indirect employment through purchases at community establishments.[38]

Over the course of thirty to fifty years, an average 20-MW geothermal power plant will pay up to $11 million in property taxes and $22 million in annual royalties, with 75

28 *GeoVision*.

29 *GeoVision*, Chapter Two.

30 DOE Geothermal Technologies Office, "2020 United States Country Report," IEA Geothermal.

31 "Senate Passes Manchin's Bipartisan Infrastructure Bill," Senate Committee on Energy & Natural Resources, August 10, 2021, https://www.energy.senate.gov/2021/8/senate-passes-manchin-s-bipartisan-infrastructure-bill.

32 D. S. Wendt et al., "GeoVision Analysis Supporting Task Force Report: Geothermal Hybrid Systems," DOE Office of Scientific and Technical Information, June 1, 2018, https://www.osti.gov/servlets/purl/1460735.

33 "Unearthing Potential: The Future of US Geothermal Energy," Atlantic Council (event and recap), December 1, 2020, https://www.atlanticcouncil.org/event/unearthing-potential/.

34 Robins et al., *2021 U.S. Geothermal*. A 2020 study of North Dakota's Bakken oil field demonstrated that the hotter carbonate rocks underlying the area could be used to generate several megawatts of geothermal energy.

35 Energy Act of 2020, Senate Committee on Energy & Natural Resources (website), accessed December 23, 2021, https://www.energy.senate.gov/services/files/32B4E9F4-F13A-44F6-A0CA-E10B3392D47A; and Robins et al., *2021 U.S. Geothermal*. The Energy Act passed as part of the FY 2021 omnibus appropriations bill signed into law in late 2020.

36 "Careers in Geothermal Energy," US Bureau of Labor Statistics (website), accessed December 23, 2021, https://www.bls.gov/green/geothermal_energy/geothermal_energy.htm.

37 Dev Millstein et al., "GeoVision Analysis Supporting Task Force Report."

38 *GeoVision,* Chapter Four, "Analysis: Results, Opportunities, and Impacts," 66-85, accessed December 23, 2021.

Lithium Production from Geothermal Brines

To decarbonize the transportation sector—currently the greatest source of greenhouse gas emissions in the United States—the world needs a far greater supply of lithium than is currently being produced.[1] In certain instances, geothermal brines contain high quantities of lithium, meaning geothermal power production can be coupled with lithium extraction to defray project development costs and help shore up the lithium supply deficit in a sustainable manner.[2]

Most battery-grade lithium produced today is extracted from hard-rock mines or evaporation pools through environmentally damaging processes.[3] As a more sustainable complement to traditional mining, geothermal lithium production has a much smaller environmental footprint and emits far less greenhouse gas emissions. Moreover, as the US government works to ensure sufficient supplies of critical minerals are brought to bear in the energy transition, a domestic geothermal lithium industry provides a valuable opportunity for the United States to develop a foothold in the upstream lithium market.[4]

The Salton Sea, located in California's Imperial Valley and home to twelve geothermal power plants, could supply 40 percent of global lithium demand, according to the California Energy Commission.[5] With an estimated annual production capacity of 600,000 tons of lithium carbonate a year, and at a commodity price of $12,000 per ton (as of May 2021), lithium extraction from the Salton Sea could generate $7 billion in annual revenue.[6] Energy company Controlled Thermal Resources (CTR), in partnership with innovative lithium-extraction developer Lilac Solutions, is currently building the Hell's Kitchen combined geothermal-power and lithium-extraction plant on the Salton Sea, recently signing a twenty-five-year power purchase agreement (PPA) and securing a multimillion-dollar investment from General Motors.[7]

According to CTR's chief executive, Hell's Kitchen will generate fifteen times fewer emissions than a standard Australian lithium mine and potentially produce up to 60,000 tons of the mineral by 2024, which would make the project the largest lithium producer in the United States.[8] CTR estimates it will make fifteen times more money from lithium production than energy generation, with some of the revenue likely to be injected back into the local rural community.[9] Notably, CTR is not the only firm taking action on the Salton Sea: Berkshire Hathaway has secured funding from the California Energy Commission for a demonstration project, and San Diego-based Energy Source intends to produce 16,500 tons of lithium at its 60 megawatt (MW) Featherstone power plant by 2023.[10] US geothermal energy provides an immense opportunity to extract substantial quantities of domestic, sustainably sourced lithium supplies, supporting both local communities and transport electrification in the process.

1 "Sources of Greenhouse Gas Emissions," US Environmental Protection Agency, last updated July 27, 2021, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

2 *GeoVision*, Chapter 2.

3 Catherine Early, "Qué es el litio geotérmico y por qué puede revolucionar las energías limpias," BBC Mundo, December 10, 2020, https://www.bbc.com/mundo/vert-fut-55223891; and Sammy Roth, "Lithium Start-up Backed by Bill Gates Seeks a Breakthrough at the Salton Sea," *Los Angeles Times*, March 16, 2020, https://www.latimes.com/environment/story/2020-03-16/lithium-startup-lilac-solutions-bill-gates-salton-sea.

4 *Critical Minerals and Materials: U.S. Department of Energy's Strategy to Support Domestic Critical Mineral and Material Supply Chains (FY 2021-FY 2031)*, US DOE, January 20, 2021, https://www.energy.gov/sites/prod/files/2021/01/f82/DOE%20Critical%20Minerals%20and%20Materials%20Strategy_0.pdf.

5 Susanna Ventura et al, *Selective Recovery of Lithium from Geothermal Brines*, California Energy Commission, March 2020, https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-020.pdf.

6 Pratima Desai and Mai Nguyen, "Shortages Flagged for EV Materials Lithium and Cobalt," Reuters, July 1, 2021, https://www.reuters.com/business/energy/shortages-flagged-ev-materials-lithium-cobalt-2021-07-01/; and Ventura et al., *Selective Recovery of Lithium*.

7 Kevin Howard, "Geothermal Power Purchase Agreements on the Rise," Geothermal Rising, June 1, 2020, https://www.geothermal.org/node/152; and Ernest Scheyder, "GM Shakes Up Lithium Industry with California Geothermal Project," Reuters, July 2, 2021, https://www.reuters.com/business/autos-transportation/gm-shakes-up-lithium-industry-with-california-geothermal-project-2021-07-02/.

8 Scheyder, "GM Shakes Up Lithium Industry."

9 Robins et al., *2021 U.S. Geothermal*.

10 Robins et al., *2021 U.S. Geothermal*.

An aerial view of the brine pools of SQM lithium mine in the Atacama Desert of Chile. *Reuters, Ivan Alvarado*

percent of those royalties sent directly to state and county treasuries.[39] In certain jurisdictions home to operating geothermal plants, like California's Sonoma and Lake Counties, geothermal operators are the largest taxpayers, indirectly supporting essential public services.[40] As part of the construction process, geothermal plant developers also invest in roads and other transportation infrastructure that benefit both the local community and the plant.

39 "Geothermal Basics," Geothermal Rising, accessed December 23, 2021, https://geothermal.org/resources/geothermal-basics.

40 *Opportunities and Challenges for Advancement of Geothermal Energy in the United States*, *Hearing Before the Senate Comm. on Energy and Natural Resources*, 116th Cong. (June 20, 2019) (statement of Tim Spisak, state director for New Mexico, Oklahoma, Texas, and Kansas, Bureau of Land Management, US Department of the Interior), https://www.doi.gov/ocl/geothermal-energy-development.

Barriers to Geothermal Power Sector Growth

While geothermal power offers numerous advantages and benefits to the US electricity sector, many regulatory, financial, and policy barriers are holding the industry back. This next section explores the obstacles facing the geothermal power sector, with a focus on permitting and leasing policy, tax credits, and research and demonstration funding deficits.

Permitting and Leasing

According to the Department of the Interior, more than 40 percent of total US geothermal energy capacity is located on leases administered by the Bureau of Land Management (BLM).[41] Therefore, federal government permitting and leasing policy has and will continue to have a strong impact on the ability of resource developers to secure permits and leases in a timely fashion.

All geothermal projects managed by BLM must undergo a series of public reviews under the National Environmental Protection Act (NEPA). Data from NREL shows that one project could be subjected to as many as six different environmental reviews by various agencies throughout its development, resulting in timelines between five to seven years from lease application to energy generation, several years longer than solar projects.[42] Additionally, according to 2019 data, review for a geothermal drilling permit could take up to 200 percent longer than its equivalent in the oil and gas sector, despite pertaining to similar subsurface operations.[43] Depending on project location, geothermal lease and permit applications may also be required by the US Forestry Service, as well as both state and local government, with several disconnected layers of bureaucracy conducting similar, duplicative assessments.[44] These long permitting timelines and inefficient regulatory barriers deter investors, reduce the value of tax incentives, and raise total project costs.

Opportunities for Permitting Reform

The US Department of Energy estimates that just regulatory reform and streamlining could cut the geothermal permitting timeline in half and increase installed capacity to 13 GWe by 2050, doubling capacity in comparison to benchmark scenarios.[45] As a step forward, the US Congress, under the Energy Act of 2020, directed BLM to improve interagency cooperation for geothermal permitting on federal land. In addition, the act directs the Department of the Interior to generate 25 GW of renewable energy, geothermal included, on public lands by 2025.[46] With important permitting reform, geothermal energy could play a stronger role in meeting this goal.

Unlike in oil and gas development, geothermal exploratory wells that touch the subsurface reservoir do not enjoy categorical exclusions under NEPA, and developers are required to apply for a drilling permit for each exploratory area, spending limited resources on administrative fees.[47] Categorical exclusions for geothermal exploration that allow for resource confirmation would reduce administrative costs, shorten project timelines, and encourage bidding for new leases.[48] In recent years, several bills have been introduced in Congress to authorize such categorical exclusions, such as the Enhancing Geothermal Production on Federal Lands Act (2021), but none have been voted on to date.[49]

In addition, the BLM lacks the necessary funds and personnel to adequately process geothermal permits and lease applications in a timely fashion, resulting in costly project delays.[50] A permit is expected to be reviewed by BLM officials within sixty days of receipt, but responses often take much longer and the process remains opaque. Without a transparent, digitized application tracking system, many developers are left in the dark as their projects stall. The development of such an application monitoring system as

41 *Opportunities and Challenges for Advancement of Geothermal Energy in the United States, Hearing* (Spisak).

42 Aaron L. Levine and Katherine R. Young, *Efforts to Streamline Permitting of Geothermal Projects in the United States*, DOE Office of Energy Efficiency & Renewable Energy, Geothermal Technologies Office, January 1, 2018, https://www.osti.gov/pages/servlets/purl/1467102.

43 “Oil and Gas Permitting Actions Needed to Improve BLM’s Review Process and Data System,” US Government Accountability Office, March 2020, https://www.gao.gov/assets/gao-20-329.pdf.

44 Levine and Young, *Efforts to Streamline Permitting*.

45 DOE Geothermal Technologies Office, “2020 United States Country Report.”

46 Energy Act of 2020.

47 Levine and Young, *Efforts to Streamline Permitting*.

48 *Opportunities and Challenges for Advancement of Geothermal Energy in the United States, Hearing* (Spisak).

49 *Opportunities and Challenges for Advancement of Geothermal Energy in the United States, Hearing* (Spisak).

50 Levine and Young, *Efforts to Streamline Permitting*.

US Senator Joe Manchin (D-WV) trailed by reporters on Capitol Hill in the midst of ongoing negotiations over the Build Back Better bill, which aims to bolster the social safety net and fight climate change, on December 14, 2021. Manchin later publicly stated that he could not support the bill. *Reuters, Jonathan Ernst*

well as increased funding for BLM would streamline the review process.

Furthermore, while geothermal permitting applications are sent to Washington, reviews are conducted at local BLM offices, where employees may not have the necessary geothermal expertise.[51] To rectify this issue, BLM should create a centralized, geothermal-specific Renewable Energy Coordination Office, similar to those for solar and wind. Doing so would increase efficiency by committing full-time, geothermal-focused staff to the review process. Particularly in light of the Biden-Harris administration's moratorium on new oil and gas leasing on public lands, the establishment of specific geothermal offices and personnel is vital to ensuring that geothermal lease and permit requests are not mixed in with fossil fuels applications and are processed appropriately.[52]

Tax Credits for Power Production

Tax credits have allowed the geothermal power sector to attract investment, secure PPAs, and deploy more installed capacity. Geothermal power plants constructed before January 1, 2022, enjoy the full-value 2.5 cents per kilowatt-hour (KWh) production tax credit (PTC), which expired at the end of 2021.[53] In lieu of the PTC, geothermal plant operators can also opt for the 10 percent investment tax credit (ITC), which provides tax deductions based on

51 Levine and Young, *Efforts to Streamline Permitting*.

52 Jordan Blum, "Biden Issues Broad Moratorium on Oil and Gas Leases on Federal Lands and Waters," S&P Global Platts, January 27, 2021, https://www.spglobal.com/platts/en/market-insights/latest-news/oil/012721-biden-issues-broad-moratorium-on-oil-and-gas-leases-on-federal-lands-and-waters.

53 Molly F. Sherlock, "The Renewable Electricity Production Tax Credit: In Brief," Congressional Research Service, R43453, last updated April 29, 2020, https://sgp.fas.org/crs/misc/R43453.pdf.

total capital expenditure and does not expire.[54] However, the geothermal investment tax credit is significantly lower than those currently offered to solar and small-scale wind projects, which both benefit from a 26 percent ITC.[55] As proposed in President Biden's Build Back Better (BBB) agenda, the geothermal investment tax credit should be raised to parity with solar at 30 percent. Even if the BBB bill does not pass in its current form, Congress can enact stand-alone clean energy tax-credit legislation to accomplish these goals, and likely with bipartisan support.

Additionally, the geothermal production tax credit has been subject to frequent waves of expiration and extension. Unpredictable levels of congressional support make project planning difficult, harm development prospects, and chill investor interest and confidence. For example, the production tax credit inexplicably expired in 2017, depressing the geothermal power-production market for several years, with only two PPAs signed between 2016 and 2020. In total, Congress has allowed the geothermal PTC to lapse five times since its inception, and has reauthorized it only for one- or two-year extensions.[56] However, after Congress reinstated the PTC in 2019 and granted a one-year extension in 2020, thirteen new PPAs were secured over the next fifteen months.[57] Given that geothermal power plants are capital-intensive projects with long development timelines, these waves of expiration and extension have dramatic impacts on sector growth and investment.

In looking toward solutions, the geothermal production tax credit should support the longer plant development cycle and be extended for at least five years. This is an immediate and urgent priority, and Congress should act quickly to avoid an additional PTC lapse, regardless of BBB bill developments.

Beyond the standard ITC/PTC tax-credit regime, other innovative financing mechanisms can support geothermal development. For example, instead of offering tax credits based on kilowatt-hour produced or dollar invested, credits should be allocated to clean energy technologies based on total market penetration. According to the bipartisan Energy Sector Innovation Credit (ESIC) Act proposed by Senators Mike Crapo (R-ID) and Sheldon Whitehouse (D-RI), as any given technology grows in market share, the credits it receives incrementally decline on a sliding scale until they are no longer necessary to buoy development.[58] ESIC tax credits would be technology-neutral and serve as a permanent fixture of the tax code, thereby insulating them from congressional battles over expiration and extension. Given geothermal's relatively low level of total market penetration, such an approach would bolster sector development.

Avoiding tax equity financing altogether, a direct pay mechanism would mitigate issues posed by shrinking tax liability and maximize investment for geothermal technologies. Direct pay mechanisms allow developers to treat ITC/PTC credits as overpayment on their taxes and monetize them as direct compensation from the US Treasury when filing their returns.[59] Direct pay serves as perhaps the most efficient financing vector for geothermal projects, as it allows developers to receive the full value of their tax credits with no investment premiums or third-party lenders. Furthermore, to implement a direct pay mechanism, Congress would not have to appropriate any new funds, but simply change the way existing credits are monetized under law, making it a more politically feasible option.[60]

Funding Needs for Technology Development

Geothermal is the only clean energy sector to have seen a decrease in federal funding between FY 2020 and FY 2021, with the DOE Geothermal Technologies Office losing $4 million on a year-to-year basis to end up with a total budget of $106 million.[61] While the Biden-Harris administration did increase proposed spending for the geothermal industry to $164 million in its most recent annual budget request, proposed funding levels still lag the nuclear ($1.85 billion), solar ($387 million), wind ($205 million), and hydro ($197 million) industries.[62] Luckily, however, the bipartisan infrastructure package set aside $84 million for EGS demonstration projects and another $21.5 billion for clean energy demonstrations more broadly, a portion of which

54 "The Energy Credit or Energy Investment Tax Credit (ITC)," Congressional Research Service, IF10479, last updated April 23, 2021, https://crsreports.congress.gov/product/pdf/IF/IF10479.

55 "The Energy Credit or Energy Investment Tax Credit (ITC)."

56 Sherlock, "The Renewable Electricity Production Tax Credit: In Brief;" Robins et al., *2021 U.S. Geothermal*.

57 Howard, "Geothermal Power Purchase Agreements on the Rise."

58 "Crapo, Whitehouse Release Energy Innovation Tax Credit Proposal," United States Senate Committee on Finance (Newsroom website), April 26, 2021, https://www.finance.senate.gov/ranking-members-news/crapo-whitehouse-release-energy-innovation-tax-credit-proposal .

59 John Milko, "Direct Pay: Tackling Clean Energy's Tax Equity Troubles," Third Way, February 8, 2021, https://www.thirdway.org/memo/direct-pay-tackling-clean-energys-tax-equity-troubles.

60 Milko, "Direct Pay."

61 "DOE Office of Energy Efficiency and Renewable Energy: FY2021 Appropriations," Congressional Research Service, IF11840, May 27, 2021, https://www.everycrsreport.com/files/2021-05-27_IF11840_d7a367acb56dd066f8d6b7a75fbaf3fb741e23a3.pdf.

62 "Department of Energy FY 2022 Congressional Budget Request," DOE (website), Office of Chief Financial Officer, May 2021, https://www.energy.gov/sites/default/files/2021-05/doe-fy2022-budget-in-brief.pdf.

could be allocated to geothermal activities.[63] Despite this boost, more federal and state support for advanced geothermal development and demonstrations will be crucial to bringing down high costs and facilitating broad technology deployment.

The nuclear sector offers a key example of an effective advanced technology demonstration program that could be replicated in the geothermal industry. As part of developing the next generation of nuclear technologies, the US government established the Advanced Reactor Demonstration Program (ARDP) to demonstrate advanced reactors before bringing them to market at scale. Likewise, the development of an advanced geothermal demonstration program could spark innovative geothermal research, development, and deployment.

63 "DOE Fact Sheet: The Bipartisan Infrastructure Deal Will Deliver for American Workers, Families and Usher in the Clean Energy Future," DOE, November 8, 2021, https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families-and-0; "Senate Passes Manchin's Bipartisan Infrastructure Bill."

Geothermal Heat Pumps and Building Sector Decarbonization

Looking beyond power production, geothermal can play a major role in cutting residential and commercial building emissions across the country, predominantly through deployment of electric ground-source heat pumps for heating and cooling.

Benefits and Advantages of Geothermal Heat Pumps

To achieve deep decarbonization, building sector emissions, particularly those generated from space heating and cooling, must see significant reductions. Residential and commercial buildings currently generate 13 percent of total US greenhouse gas emissions, and space heating and cooling account for 50 percent of total energy use in American homes.[64] A vast majority of US households relies on natural gas or fossil-fuel generated electricity to heat and cool their spaces, and in the Northeast, people often depend on fuel oil, a more dangerous and costly option.[65] To meet President Biden's goal for a 50 percent reduction in emissions by 2030, buildings old and new must switch from furnaces, boilers, and fuel oil to electric heat pumps. GHPs in particular provide clean, energy-efficient heating and cooling, reduce electricity demand during peak hours, and enhance grid and household resilience.

Geothermal heat pumps rely on the near-constant average temperature of the shallow subsurface to efficiently heat and cool spaces. In the winter, this type of pump draws heat from the relatively warmer earth and channels it into the building, while in the summer, the device pulls heat from the interior and injects it into the earth. If fitted with a device called a desuperheater, a geothermal heat pump can also efficiently heat water, particularly in the summer months. Given that GHPs use shallow subsurface heat at low, near-constant temperatures, they can be installed and effectively used across all fifty states.

According to the US Environmental Protection Agency, geothermal heat pumps are the most energy-efficient, environmentally friendly, and cost-effective systems for heating and cooling buildings.[66] They consume between 25 and 50 percent less electricity than traditional HVAC systems, and reduce total energy consumption, as well as associated emissions, by almost 75 percent in comparison to electric resistance heating with standard air conditioning.[67] By drawing upon subsurface heat, GHPs can perform well regardless of the outdoor temperature.

Additionally, in reducing overall fuel and electricity use, geothermal heat pumps can cut building utility bills between 30 and 60 percent depending on the original energy source.[68] If GHPs are coupled with rooftop solar panels on a large community scale, as is the case at the Whisper Valley residential development in central Texas, household utility bills could essentially drop to $1.[69] A GHP subsurface pipe system carries a warranty of up to fifty years, and the heat pumps themselves enjoy life expectancies of twenty-five years—double that of certain standard heating and cooling equipment—cutting down maintenance and replacement costs.[70] Moreover, GHPs are insulated from inclement weather, consume almost zero water, and generate no noise pollution.[71]

Given their high level of efficiency and low electricity consumption, geothermal heat pumps endow property owners with a valuable resilience premium during load-shedding events, something particularly important during dangerous heat waves and deep freezes like those experienced recently in California and Texas. GHPs reduce overall

64 "Sources of Greenhouse Gas Emissions"; and "Use of Energy Explained: Energy in Homes," US Energy Information Administration (website), last updated June 23, 2021, https://www.eia.gov/energyexplained/use-of-energy/homes.php.

65 David Roberts, "Most American Homes Are Still Heated With Fossil Fuels. It's Time to Electrify," *Vox*, July 2, 2018, https://www.vox.com/energy-and-environment/2018/6/20/17474124/electrification-natural-gas-furnace-heat-pump.

66 "Geothermal Explained: Geothermal Heat Pumps," US Energy Information Administration, Last Reviewed November 19, 2020, https://www.eia.gov/energyexplained/geothermal/geothermal-heat-pumps.php.

67 "Choosing and Installing Geothermal Heat Pumps," DOE (website), accessed October 14, 2021, https://www.energy.gov/energysaver/choosing-and-installing-geothermal-heat-pumps.

68 Alison Gregor, "Geothermal Design Arise as a Stormproof Resource," *New York Times*, November 6, 2012, https://www.nytimes.com/2012/11/07/business/geothermal-energy-advocates-hope-systems-get-a-second-look.html.

69 Ross Trethewey, "Net Zero Neighborhood," *Ask This Old House*, YouTube video, June 4, 2018, https://www.youtube.com/watch?v=Uy0SEG36bEM.

70 *2015 AHSRAE® Handbook: Heating, Ventilating, and Air-Conditioning Applications*, ASHRAE, 2015, https://daycompany.ir/wp-content/uploads/2020/07/2015-Ashrae-Handbook-Hvac-Applications-2015.pdf.

71 Jay Egg, "How Can We Save 2-Trillion Gallons of Water," Geothermal Rising (website), July 29, 2021, https://geothermal.org/index.php/our-impact/blog/how-can-we-save-2-trillion-gallons-water; and Gregor, "Geothermal Designs Arise as a Stormproof Resource."

electricity demand on the grid, helping operators balance load, particularly during peak hours. As power demand rises with increasing electrification, and as extreme weather pushes the electricity grid to its limits, greater adoption of geothermal heat pumps would help mitigate grid failures, raise property values, and provide strong resilience benefits.

Fuel Oil Replacement in the US Northeast

In the northeastern United States, where about 20 percent of households rely on fuel oil for space heating, geothermal heat pumps could play an outsized role in reducing energy costs and lowering health risks.[72] In the states most dependent on fuel oil for space heating, such as New York and Massachusetts, residents pay disproportionately high heating bills, as much as $1,600 on average per winter.[73] Furthermore, reliance on fuel oil can be risky; major blizzards can paralyze fuel deliveries and leave inaccessible or rural areas without heat when they need it most. Fuel oil combustion also emits high levels of pollutants and increases risk for carbon-monoxide poisoning.[74]

New York is the state most dependent on fuel oil for space heating in the country, especially in upstate regions like the Hudson Valley.[75] In December 2021, the New York City government issued a moratorium on future gas hookups and fuel oil use in new city buildings, while Consolidated Edison halted new gas hookups for customers in Westchester County in 2019. In the outer boroughs and suburbs, geothermal heat pumps would be a worthwhile investment in the absence of gas, and as replacements for fuel oil.[76]

New York serves as a GHP market-development laboratory, with the state government investing $450 million in utility incentives and $200 million in market enabling.[77] While the up-front cost of a geothermal heat pump can be steep, after federal tax credits and generous state incentives are factored in, a homeowner in Queens would pay a significantly lower price.[78] Those in Westchester County—who could receive an additional 30-percent cost reduction due to the gas moratorium—may pay next to nothing. In looking to New York as a model, federal and state government should invest in robust GHP subsidy and cost-share programs that stimulate customer adoption.

In scaling the industry, government and corporate leaders must also strive to improve GHP accessibility for low-income individuals, many of whom do not own their own homes, are unable to take advantage of income tax credits, or do not have access to financing. Incentive regimes and specific deployment programs that prioritize low-income earners are crucial to ensuring all people can benefit from household geothermal energy. As part of the Build Back Better bill, the High-Efficiency Electric Home Rebate Program would create a heat pump rebate program that includes additional funds for low- and middle-income earners. While BBB may not pass the Senate, it is possible the heat-pump rebate program, or one like it, could be introduced and implemented as a stand-alone initiative given broader bipartisan support for both the geothermal source and energy efficiency.

Challenges to Heat Pump Adoption

Despite progress in New York, the GHP industry remains stymied by high capital and customer costs, most of which stem from onsite drilling. Access to cheap natural gas and alternative HVAC equipment is a disincentive for people to invest in new, labor-intensive technology, and not all homes are suitable for geothermal heat pumps, excluding some potential adopters.[79]

Advancements in GHP drilling technology and system installation would help lower overall sticker cost, and state and federal leaders should appropriate specific funding to support the development of such improvements.

72 *2020-2021 Winter Fuels Outlook*, US Energy Information Administration, October 2020, https://www.eia.gov/outlooks/steo/special/winter/2020_Winter_Fuels.pdf.

73 *2020-2021 Winter Fuels Outlook*; and "Heating Oil Explained," US Energy Information Administration, Last Updated February 9, 2021, https://www.eia.gov/energyexplained/heating-oil/use-of-heating-oil.php. During the winter of 2018-19, northeastern residences paid $780 on average for gas and almost $1,600 for heating oil.

74 Catherine Clifford, "This Google X Spin-off Backed by Bill Gates Is Offering a Pathway to Heat and Cool Your Home with Clean Energy," CNBC, March 17, 2021, https://www.cnbc.com/2021/03/17/dandelion-energy-offers-pathway-to-heat-cool-home-with-clean-energy.html.

75 "Heating Oil Explained."

76 Emma Newburger, "New York City Is Banning Natural Gas Hookups for New Buildings to Fight Climate Change," CNBC, December 15, 2021, https://www.cnbc.com/2021/12/15/new-york-city-is-banning-natural-gas-hookups-for-new-buildings.html.

77 Steven Nadel, "Programs to Electrify Space Heating in Homes and Buildings," American Council for an Energy-Efficient Economy, June 2020, https://www.aceee.org/sites/default/files/pdfs/programs_to_electrify_space_heating_brief_final_6-23-20.pdf.

78 "Understanding the Federal and State Incentives for Geothermal Heat Pumps," Dandelion Energy, accessed October 14, 2021, https://dandelionenergy.com/geothermal-state-federal-tax-incentives; and "Save Thousands with Geothermal," Consolidated Edison Co., accessed October 14, 2021, https://www.coned.com/en/save-money/rebates-incentives-tax-credits/rebates-incentives-tax-credits-for-residential-customers/electric-heating-and-cooling-technology-for-renters-homeowners/save-thousands-on-a-geothermal-system.

79 Robins et al., *2021 U.S. Geothermal*.

Furthermore, integrating more electricity savings and energy-efficiency requirements into building codes would also incentivize GHP adoption across building types and expand market penetration. Beyond building codes, the federal government should serve as an active adopter of GHPs and work to retrofit its portfolio of 300,000 buildings and hundreds of military installations.[80]

Heat pump tax incentives are vital to mitigating high capital costs and facilitating customer adoption. Currently, residential GHPs enjoy a 26-percent income tax credit, while commercial projects benefit from a 10-percent investment tax credit; both incentives are set to expire in 2024.[81] Much like the geothermal PTC, heat pump tax credits have experienced waves of expiration and extension, with unpredictable cycles of support creating uncertainty for both developers and property owners.[82] The 2017 expiration of both the residential and commercial credits, for example, depressed GHP sales by almost half for several years.[83]

To provide developers and customers with certainty, the GHP tax credits should be extended for a duration of at least five years beyond 2024, at a level equal to residential solar (now 26 percent), and with a backstop 10-percent credit to exist in perpetuity. Several legislative proposals would advance these goals, such as Representative Thomas Suozzi's (D-NY3) proposed Groundsource Exchange Tax Parity Act, which would peg the GHP commercial ITC at parity with solar.[84] Given GHPs' relatively low market penetration rate, the proposed Crapo-Whitehouse ESIC Act would also support sector growth.[85]

In addition, GHP technology would greatly benefit from inclusion in state renewable portfolio standards (RPS) and associated renewable energy-credit (REC) regimes. In 2012, Maryland became the first state to make GHPs eligible to receive RECs under a state RPS. Going further, New Hampshire will require that 2 percent of its energy comes from thermal resources starting in 2023, which includes heat produced from GHPs.[86] In total, only eleven states provide RECs to homeowners for energy avoided or heat produced with geothermal heat pumps.[87]

To provide monetizable value for subsurface heat or energy avoided, state governments should include geothermal heat pumps as a Tier 1 technology in their RPS, and like Maryland, mandate a certain percentage of their state RPS specifically be met with GHPs.[88] Thermal RECs for geothermal heat pumps, regardless of how they are characterized or quantified, would lower customer costs, increase project bankability, and expand the GHP market.

District Heating and Cooling

Beyond singular residential and commercial buildings, direct-use geothermal energy, through district heating systems, can heat entire complexes, communities, and cities. For example, the city of Boise, Idaho, installed a geothermal district heating system in the 1890s, the first in the country, which continues to provide heat to more than ninety buildings in the capital's downtown.[89] There are now currently twenty-three geothermal district heating (GDH) systems across the western United States, providing sustainably sourced heat to cities, schools, hospitals, prisons, and universities.[90] GDH systems rely on higher-temperature resources colocated with population centers; as most of these heat reservoirs are found in rural areas away from demand centers, the industry has been slow to develop.[91]

80 Office of the White House, "Fact Sheet: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability," December 8, 2021, https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/; and David Vine, "Where in the World is the U.S. Military," *Politico Magazine*, August 2015, https://www.politico.com/magazine/story/2015/06/us-military-bases-around-the-world-119321/.

81 "Tax Incentives for Energy-Efficiency Upgrades in Commercial Buildings," DOE (website), accessed October 14, 2021, https://www.energy.gov/eere/buildings/tax-incentives-energy-efficiency-upgrades-commercial-buildings; and Ted Craig, "Geothermal Industry Wins Tax Credit Extension in Stimulus Bill," *Air Conditioning | Heating | Refrigeration News*, December 31, 2020, https://www.achrnews.com/articles/144264-geothermal-industry-wins-tax-credit-extension-in-stimulus-bill.

82 "The 2021 Federal Geothermal Tax Credit: Your Questions Answered," Dandelion Energy, December 3, 2019, https://dandelionenergy.com/federal-geothermal-tax-credit.

83 Geothermal Exchange Organization officer, in a phone conversation with the author, September 1, 2020..

84 H.R. 3920, Groundsource Exchange Tax Parity Act, 117th Congress (2020-2021), https://www.congress.gov/bill/117th-congress/house-bill/3920?s=1&r=3.

85 "Crapo, Whitehouse Release Energy Innovation Tax Credit Proposal."

86 "Geothermal Heating and Cooling," Maryland Energy Administration, accessed October 14, 2021, https://energy.maryland.gov/Pages/Info/renewable/geothermal.aspx; and Samantha Donalds, *Renewable Thermal in State Renewable Portfolio Standards*, Clean Energy States Alliance, July 2018, https://www.cesa.org/wp-content/uploads/Renewable-Thermal-RPS.pdf.

87 Robins et al., *2021 U.S. Geothermal*, Table 9.

88 Elizabeth Shwe, "Maryland Eyes Expansion of Geothermal Industry," *Maryland Matters*, May 18, 2021, https://www.marylandmatters.org/2021/05/18/maryland-eyes-expansion-of-geothermal-industry/.

89 "Geothermal," City of Boise (website), accessed December 23, 2021, https://www.cityofboise.org/departments/public-works/geothermal/.

90 Robins et al., *2021 U.S. Geothermal*.

91 Kevin McCabe et al., "GeoVision Analysis Supporting Task Force Report: Thermal Applications," National Renewable Energy Laboratory, May 2019, https://www.nrel.gov/docs/fy19osti/71715.pdf; and Robins et al., *2021 U.S. Geothermal*.

A landscape of thermal pools and vents in Yellowstone National Park. *Unsplash, Dan Meyers (@dmey503)*

In addition, competition from lower-cost fuel alternatives, combined with high capital expenditure requirements and limited financial and government support, has thus far stymied GDH sector growth.[92]

Leading the way on climate action, universities serve as important laboratories for innovative district heating and cooling technologies. The DOE has funded several feasibility studies for lower-gradient, deep-direct-use district heating systems at universities that could catalyze sector development across the central and eastern United States. At Cornell University, for example, a DOE demonstration project is underway to identify if technology combining geothermal heat pumps and existing district infrastructure can provide campus-wide heating and cooling in a low subsurface-temperature environment.[93] Federal and state governments should create dedicated funding programs and develop incentive mechanisms for both conventional and innovative district heating projects like Cornell's.

Aquaculture, Greenhouses, and Industrial Processes

In addition to heating and cooling, direct-use geothermal heat has a number of productive and profitable ancillary applications: greenhouse agriculture, snow melting, aquaculture, pulp processing, pool and spa heating, and food drying. While agricultural and industrial activities only account for 2 percent of total US geothermal use, employing subsurface heat instead of fossil fuels saves money, cuts emissions, and reduces energy consumption.[94] As a primary example, an aquaculture farm in Klamath Falls, Oregon, relies on direct geothermal heat for the cultivation of eighty-five varieties of tropical fish, avoiding around 24

92 Robins et al., *2021 U.S. Geothermal*.

93 Robins et al., *2021 U.S. Geothermal*; and "About Earth Source Heat," Cornell University (website), accessed December 23, 2021, https://earthsourceheat.cornell.edu/about/.

94 "U.S. Renewable Energy Consumption by Source and Sector, 2020."

million KWh in electricity and generating annual savings of roughly $1.4 million.[95]

Many of these ancillary opportunities can also be coupled with heating and cooling systems, or with power production to generate hybrid revenue streams and improve project economics. Such is the case in Chena, Alaska, where waste heat from a geothermal microgrid is used in spas, district heating, greenhouses, and more.[96] As the country moves to decarbonize the entire economy, increased attention should be paid, and more funding should be appropriated, to agricultural and industrial geothermal project applications.

95 "'Gone Fishing' Aquaculture Project Klamath Falls, Oregon," Geo-Heat Center (website), June 1, 2003, http://digitallib.oit.edu/digital/collection/geoheat/id/10682/.

96 "400kW Geothermal Power Plant at Chena Hot Springs, Alaska," Final Project Report Prepared for the Alaska Energy Authority by Chena Power LLC, February 4, 2007, https://geothermalcommunities.eu/assets/elearning/7.13.FinalProjectReport_ChenaPowerGeothermalPlant.pdf; and "Geothermal Technologies Program–Alaska," DOE Office of Scientific and Technical Information (website), https://www.osti.gov/servlets/purl/1216140.

Conclusion

Achieving US climate goals requires the development and widespread deployment of all available clean energy solutions. Geothermal energy, while currently only a marginal component of the US energy economy and mindset, is indispensable to the fight against climate change. Geothermal energy can support deep decarbonization by providing: clean, baseload power; a highly efficient means to heat and cool buildings, campuses, and cities; a host of agricultural and industrial applications; and the potential for highly sustainable US lithium production. However, the holistic value of geothermal energy is not recognized in a way that allows it to reach its full potential. US public- and private-sector leaders should work to craft and implement policy that supports geothermal industries and addresses the current regulatory, technical, and economic barriers holding them back. With that in mind, this report offers the following policy recommendations:

1. **Increase geothermal power procurement and compensation:** Regulators, grid operators, and geothermal developers should move away from the levelized cost of energy when setting geothermal electricity rates and instead ascribe it greater monetary value as clean, reliable energy. Rate cases should reflect the holistic value that geothermal power offers. As expressed in Biden's executive order, Catalyzing Clean Energy Industries and Jobs through Federal Sustainability, the federal government has committed to achieving 100 percent carbon pollution-free electricity on a net annual basis by 2030, 50 percent of which must be 24/7 clean energy. To meet this ambitious goal, the federal government should require agencies to integrate a minimum percentage of geothermal energy into public operations, wherever applicable.

2. **Increase federal funding for technology and innovation:** While the funding allocation for geothermal energy increased from $106 million to $164 million (on a year-to-year basis) in the FY 2022 budget request, this sum still significantly lags appropriations to support nuclear, solar, and wind energy. Congress should appropriate additional funding for research and development for hybrid geothermal applications, enhanced geothermal systems, and the creation of an advanced geothermal demonstration program. To create nationwide opportunity for geothermal and unlock 60 GW of geothermal power by 2050, the federal government will need to invest more resources in RD&D for enhanced geothermal systems and effectively implement the $84 million earmarked for such purposes in the bipartisan infrastructure bill passed last year. Looking at the success of the Advanced Nuclear Demonstration Program, the US Department of Energy, with funding from Congress, should establish an advanced geothermal demonstration program to develop innovative geothermal technologies, like those that would improve resource identification and drilling efficiency, and deploy them across the country.

3. **Streamline the permitting and leasing process:** Long permitting timelines and inefficient regulatory barriers serve as primary obstacles to geothermal power-sector development. According to the Department of Energy, regulatory reform could cut the geothermal permitting timeline in half and increase installed capacity to 13 GWe by 2050, doubling capacity in comparison to benchmark scenarios. To accomplish this goal, Congress and the Department of the Interior should allocate greater resources to the Bureau of Land Management, which oversees leases hosting 40 percent of all US geothermal energy capacity. To provide developers with clearer project timelines and allow them to plan ahead, the Department of Interior should establish a digital lease/permit application tracking system. To allow geothermal developers to minimize lengthy regulatory hurdles for subsurface resource confirmation—a privilege afforded to the oil and gas sector—Congress should enable categorical exclusions for these geothermal activities and enact the proposed Enhancing Geothermal Production on Federal Lands Act. Lastly, BLM should create a centralized, geothermal-specific Renewable Energy Coordination Office akin to those established for solar and wind. This change would increase efficiency by committing full-time, geothermal-focused staff to the permit/lease review process and ensure geothermal requests are not mixed in with fossil-fuel applications.

4. **Increase federal tax credits for geothermal power:** Geothermal power tax credits have a strong impact on sector development and play an important role in securing PPAs. However, disparities between the geothermal ITC and those afforded to other renewables, as well as uncertain congressional support for the geothermal PTC, stymies industry growth and undermines investor confidence. As proposed in the BBB bill, the geothermal investment tax credit, currently at 10 percent without expiration, should be

raised to parity with solar at 30 percent. Additionally, as the PTC expired in 2021, Congress should work urgently to extend the geothermal production tax credit for at least five years at a rate of at least 2.5 cents/KWh. Regardless of how the larger BBB bill story unfolds, these legislative items can be introduced, passed, and implemented on their own as stand-alone policies.

5. **Increase heat pump subsidies and incentives:** To achieve net-zero emissions by 2050, old and new buildings across the country will need to be electrified. Geothermal heat pumps offer the most energy-efficient, environmentally friendly, and in many instances, cost-effective option for space heating and cooling. As seen in New York, robust public geothermal heat pump rebate and outreach programs can significantly lower up-front capital costs, expand the market, and positively contribute to building-sector electrification. Based on the proposed High-Efficiency Electric Home Rebate Program, currently a component of the BBB bill, state and federal government should create strong heat pump incentive programs to catalyze GHP adoption across the US building stock. Targeted heat pump subsidies should be earmarked for low-income households and those dependent on fuel oil. Even if the BBB bill fails in its current form, heat pump rebates or other building electrification legislation could be introduced and passed as a stand-alone policy given broader support for energy efficiency and geothermal energy on both sides of the aisle. To achieve its goal of a 50-percent reduction in federal building-sector emissions by 2032, outlined in its recent December executive order, the Biden-Harris administration should work to retrofit its portfolio of 300,000 federal buildings and hundreds of military installations with GHPs.

   Geothermal heat pumps bear high up-front capital costs, and both residential income tax credits and commercial investment tax credits are crucial to catalyzing GHP adoption across the US building stock. To grow GHP market share and provide developers and property owners with certainty, Congress should extend the GHP tax credits for a duration of at least five years beyond their 2024 expiration dates, at a level equal to residential solar (now 26 percent), and with a backstop 10-percent credit to exist in perpetuity. As an easy win toward these goals, Congress should enact the introduced Groundsource Exchange Tax Parity Act, which would raise the GHP commercial ITC to parity with solar.

With proper financial and political support, geothermal energy could play a central role in decarbonizing the entire US economy. The US geothermal energy sector is ready to take on the challenge. Policymakers now must give it the opportunity.

About the Author

Zachary Strauss is a policy analyst at Atlas Public Policy. He was previously an associate director for advanced energy with the Atlantic Council Global Energy Center where his work focused primarily on renewable energy, climate action, and national security. His interests included the confluence of energy and environment, electric mobility, hydro-kinetic energy, critical mineral politics, US geothermal, energy justice, and diversity in energy. He managed the Veterans Advanced Energy Project and founded Out in Energy, the first national organization representing LGBTQI+ energy and climate professionals.

Previously, Zachary interned at the Migration Policy Institute in Washington, DC where he conducted research and produced draft reports on trans-Mediterranean migration flows. He has over four years of professional and educational experience abroad, having worked and studied in France, Japan, Italy, and Spain. In 2017, he interned for the Permanent Chilean Mission to the Organization for Economic Cooperation and Development (OECD) in Paris, France, and from 2015 to 2016, taught English and International studies in Kumamoto, Japan within the public school system. He also served as an intern at US Consulate General Barcelona and helped stand up an English-teaching camp system in Romagna, Italy. Zachary received his master's degree in international security from Sciences Po, Paris and graduated *summa cum laude* with a bachelor's degree in European studies from Middlebury College. He is proficient in Spanish, French, Italian, Portuguese, and Japanese.

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