Hamm Institute for American Energy
OKLAHOMA STATE UNIVERSITY

NEXT-GEN POWER: GEOTHERMAL FOR THE AI AND INDUSTRIAL ERA

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Executive Summary:
In decades past, the shale revolution catapulted the United States into global energy leadership, transformed geopolitics, and contributed to a level of prosperity and security doubters thought impossible. Today, with continued innovation and the right policy support, the moment is at hand for the exponential growth of next generation geothermal – a reliable, secure and clean American energy solution that blends legacy with possibility.

Under recent political paradigms, climate imperatives crowded out most other considerations. The drive to build intermittent renewable capacity overshadowed the reliability of the grid, affordable and stable energy prices. However, in Washington today, affordability and baseload generation are paramount – especially as the race for artificial intelligence and policies meant to reshore domestic manufacturing accelerate demand for around-the-clock electricity supplies. Financial incentives and preferential permitting and regulatory treatments are moving away from renewables – particularly wind – and in favor of baseload assets like natural gas, nuclear, and coal.

Where does that leave geothermal? It can be zero-emission and aligns with purchasing preferences of the technology firms driving incremental demand. Yet its significant technological advances are inherited directly from the shale revolution, and geothermal's baseload generation capacity and heartland economic development benefits conform to newly established Administration priorities. America has a significant competitive advantage with the resources, supply chains, expertise and entrepreneurs in place. Next-generation geothermal is uniquely positioned to be embraced by all, which should be a catalyst for a true "all-of-the-above" energy approach.

However, geothermal tends to be overlooked in the great energy debate and lacks powerful champions. For geothermal energy to flourish, policymakers must be educated about the latest technology innovations, the expanded map of reliable generation availability, what regulatory and tax policies are inhibiting increased private investment, and the tremendous upside: grid-scale, zero-emission, and 24/7 baseload generation. All we have to do is literally tap into the energy beneath our feet through the power of free enterprise, as geothermal trailblazers like Fervo Energy take inspiration from shale gamechangers like Continental Resources and Devon Energy.

Traditional, grid-scale geothermal energy has historically been regionally concentrated – primarily in geologically active, predominantly Western states. But breakthroughs in technology and new methods of subsurface development – driven largely by American entrepreneurs with

ties to the legacy shale industry – are meaningfully unlocking available footprint for lower cost, and scale of geothermal electricity production. The sector has a messaging challenge to break the old way of thinking and appeal to new stakeholders across the country.

In this paper we will briefly describe geothermal's history in the United States, new technological developments, policies that support or hinder its expansion, recommendations for policymakers to expand geothermal deployment, and how the policy and economic moment should expand utilization of this energy resource.

Geothermal Then and Now

The United States is the once-and-future king of geothermal energy development. Today, we are the world leader in installed capacity and production, with 3.9 GW of geothermal electric power online.[1] Despite this, geothermal is less than one percent of domestic electricity production.[2] Iceland is the world leader, as a nation of volcanoes and hot springs, on that score with one-quarter of its generation coming from geothermal (most of the rest is hydro, making Iceland's grid one of the, if not the, world's cleanest).[3] With the advent of new technologies we will describe a bit later, the Department of Energy projects that the United States could add 90 GW of geothermal production by 2050, supplying 12 percent of anticipated electricity demand.[4][5]

For the purposes of this discussion, we will be focused on grid-scale electricity generation from geothermal power plants, rather than heat pumps and other systems that serve individual properties. Geothermal plants require access to geologically heated water between 300 and 700 degrees Fahrenheit (°F) in order to operate.[6]

The first geothermal power plant was developed in Italy, coming online in 1904. Prince Piero Ginori Conti of Trevignano – yes, geothermal has royal origins – designed the Larderello Geothermal Energy plant in Tuscany. From a humble initial generation capacity of 10kW – enough to power five light bulbs – the plant has been gradually upgraded over the decades. The

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[1] https://www.thinkgeoenergy.com/thinkgeoenergys-top-10-geothermal-countries-2023-power-generation-capacity/#:~:text=United%20States*%20%E2%80%93%203%2C900%20MW%20(updated%20our%20numbers%20as%20per%20the%20notes%20below).

[2] https://www.eia.gov/tools/faqs/faq.php?id=427&t=3#:~:text=Geothermal,0.4%25.

[3] https://www.mfat.govt.nz/en/trade/mfat-market-reports/iceland-green-transition-and-renewable-energy-september-2024#:~:text=Iceland%E2%80%99s%20geothermal%20technology,cent%20from%20hydropower.

[4] https://www.congress.gov/crs-product/R48090.

[5] https://www.canarymedia.com/articles/geothermal/this-texas-geothermal-startup-is-storing-energy-in-the-ground#:~:text=The%20novel%20technologies%2C%20if%20successful%2C%20could%20help%20boost%20the%20nation%E2%80%99s%20geothermal%20capacity%20to%2090%C2%A0gigawatts%20of%20electricity%20by%202050%20%E2%80%94%20a%C2%A0nearly%2025%2Dfold%20increase%20from%20today%E2%80%99s%203.7%C2%A0gigawatts%2C%20according%20to%20a%C2%A0Department%20of%20Energy%20analysis%20released%20in%20January.

[6] https://www.eia.gov/energyexplained/geothermal/geothermal-power-plants.php.

site now has 34 generation units totaling 800 megawatts (MW), and Italy remains the sixth-largest producer of geothermal energy in the world.[7]

The next major plant would not come online for 54 years and would be constructed on the opposite side of the world – in Wairakei, New Zealand.[8]

Then entered the United States. As ever, Americans went big.

The United States installed its first-ever geothermal power plant – the Geysers – in Northern California in 1960, initially generating 11 MW.[9] Today, after subsequent development, it is the largest single geothermal steam electrical generation plant in the world, with baseplate generation of more than 1.5 gigawatts (GW), capable of powering between 1 million and 1.5 million American homes.[10]

After the Geysers began operation, US policymakers took notice.

In 1970, the Geothermal Steam Act was enacted into law, providing the Secretary of Interior with regulatory authority to lease federal lands for the purposes of geothermal exploration and development in similar fashion to conventional oil and gas leases.[11] In 1973 the National Science Foundation (NSF) was granted authority to serve as the lead agency on federal geothermal research and development efforts, and the next year Congress enacted the Geothermal Energy Research, Development, and Demonstration Act, which created the Geothermal Loan Guaranty program.[12] This provided a surety for federal agencies and private producers to invest in geothermal energy projects.

With the creation of the Department of Energy in 1977, most federal research and development and funding activities supporting advanced energy production were centralized within a single, Cabinet-level entity. In 1978, Congress expanded funding for geothermal as part of an energy strategy meant to reduce dependence on Middle Eastern oil imports after the embargoes and trade disruptions earlier in the decade.[13]

The first binary geothermal power plant began operations in 1982 in the Imperial Valley of California. The deployment of a binary plant represented a technology turning point. Previous geothermal plants operated by using below-ground reservoirs of steam to directly spin a turbine

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[7] https://www.power-technology.com/features/oldest-geothermal-plant-larderello/.
[8] https://www.sciencedirect.com/science/article/abs/pii/S0375650508000886#.
[9] https://www.thedriller.com/articles/87494-a-history-of-geothermal-energy-in-the-united-states; note there was a limited, but ultimately abandoned, power project sited at the Geysers in 1922.
[10] https://geysers.com/geothermal.
[11] 30 U.S.C. §§ 1001-1028.
[12] P.L. 93-410, https://www.govinfo.gov/app/details/STATUTE-88/STATUTE-88-Pg1079.
[13] https://www.osti.gov/servlets/purl/1209222.

or, using “hot rock” or “dry steam”, where water is introduced into underground heat reservoirs and converted into steam to generate energyF (many plants of these designs still operate in the Imperial Valley Geothermal Project). These technologies yield emissions to the atmosphere that must be controlled, due to acidic materials and sulfides that may come out of the ground.[14] Corrosion is also a significant challenge as equipment and turbines are directly exposed to these caustic materials. Since 2000, nearly all new geothermal plants have adopted a binary system design.[15]

Binary geothermal power plants are built upon a contained liquid loop. Using heat exchangers, hot water or rock in underground reservoirs transfer heat to the closed loop. The water in the loop flashes to steam, spins a turbine to generate electricity, then is condensed and cycled back through the system anew. This generally requires the construction of two facilities for the same power plant, located before and after the generation cycle – hence “binary.” This preserves the power generation equipment by avoiding direct exposure to byproducts from subterranean minerals while eliminating emissions of pollutants to the atmosphere.[16]

The Public Utility Regulatory Policies Act (PURPA) was enacted to facilitate the deployment of new energy sources, including geothermal projects that can be used for cogeneration or smaller power generation applications.[17] PURPA market signals, expanded federal grants and research through the National Labs, and the introduction of binary plants spurred geothermal development through the 1980s in California, as well as expansion into Nevada and Utah. American geothermal capacity expanded from 500 MW in 1975 to 3 GW by 1990 thanks to these policy and market tailwinds.[18][19]

Even with the advent of binary geothermal plants, the reach of potential development remained limited. These “conventional” geothermal plants require three natural elements be present in the local geology: heat, fluid, and permeability. In other words, the rocks need to be hot, there needs to be water present, and water must be able to flow through the rock reliably and with minimal encumbrance to support energy development. The US Geological Survey (USGS) has estimated these natural hydrothermal resources, primarily in the West, can only support approximately 9 GW of geothermal capacity in the entire United States.[20]

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[14] https://www.ucs.org/resources/environmental-impacts-geothermal-energy#:~:text=reservoir%20%5B4%5D.-,Air%20emissions,-The%20distinction%20between.
[15] https://www.eia.gov/todayinenergy/detail.php?id=44576.
[16] https://www.sciencedirect.com/topics/engineering/binary-cycle#:~:text=Binary%20cycle%20plants%20can%20achieve%20higher%20efficiencies%20than%20flash%20power%20systems%2C%20and%20they%20allow%20the%20utilization%20of%20lower%20temperature%20reservoirs.%20Other%20issues%2C%20such%20as%20corrosion%20and%20environmental%20concerns%2C%20are%20also%20eliminated.
[17] 16 U.S.C. 46 § 2601 et seq., available at https://www.law.cornell.edu/uscode/text/16/chapter-46.
[18] https://geothermaleducation.org/GEOpresentation/sld066.htm#.
[19] https://www.nrel.gov/docs/fy21osti/78291.pdf.
[20] https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf, p. 1-2.

Expansion of the sector slowed in the 1990s and 2000s, though additional states added geothermal assets, including Alaska, Hawaii, Idaho, New Mexico, and Oregon.[21] Without a transformative breakthrough, geothermal energy was doomed to be a bit player in the national energy mix.

Around 2005, the wide adoption of hydraulic fracturing and horizontal drilling technologies in the oil and gas sector spurred renewed interest in geothermal energy production. Another energy crisis, with oil cresting above $100 in nominal dollars led to the Energy Policy Act (EPA) of 2005 and the Energy Independence and Security Act (EISA) authorizing new programs related to renewable and conventional energy sourcesF of geothermal capacity across the United States by 2050, a 26-fold increase, with greater reach beyond geothermal's traditional western state markets.[22][23]

EGS is currently in the deployment stage. The Frontier Observatory for Research in Geothermal Energy (FORGE) is a $220 million, Department of Energy-funded research site serving as the testbed for EGS technologies.[24] It has demonstrated the viability of operating and sustaining fluid circulation and heat extraction. What's more, this site has birthed the world's largest EGS facility, Fervo Energy's Cape Station, backed by investors including Devon Energy advised by J.P. Morgan.

Further afield, the Geothermal Technologies Office's EGS Collab Project at the Sanford Underground Research Facility in South Dakota has created small-scale pilot fields to examine the physics of reservoir development and operational management.[25]

The success of private-sector projects like the Ormat Desert Peak project in Nevada have made clear the opportunity afforded by EGS techniques. At Desert Peak, an existing natural geothermal well was stimulated through drilling and fracturing techniques to increase productivity by 38 percent.[26]

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[21] https://www.sciencedirect.com/science/article/abs/pii/S0960148122007959#:~:text=The%20U.S.%20has%20experienced%20a%20stagnation%20in%20geothermal%20power%20capacity%20and%20decrease%20in%20geothermal%20power%20generation%20from%201990%20to%202018.
[22] https://www.energy.gov/sites/prod/files/2019/05/f63/0-GeoVision-ExecSummary-v2.pdf, p.6.
[23] https://shalemag.com/major-plans-for-geothermal-energy-development-across-u-s/#:~:text=Massive%20Advances%20Being%20Seen%20in%20Enhanced%20Geothermal%20Systems&text=During%20this%20test%2C%20it%20produced,10%25%20of%20the%20country's%20electricity.
[24] https://www.energy.gov/eere/geothermal/forge.
[25] https://sanfordlab.org/experiments/egs-collab.
[26] https://www.greentechmedia.com/articles/read/Making-Enhanced-Geothermal-Energy-Real#:~:text=The%20breakthrough%20at%20Ormat%27s%20Desert%20Peak%202,production%20increase%20from%20a%20sub%2Dcommercial%20conventional%20well.

Challenges and Opportunities
Even with these developments and increased market interest, barriers remain to EGS expanding geothermal's role in energy generation. Most challenges are similar to other energy sources – like nuclear – that have significant up-front capital costs that must be amortized over years of operation while their payback relies upon fickle, policy-distorted competitive electric markets.[27] This issue is not unique to the United States.[28]

By contrast, natural gas plants can be throttled up or down based on short-term or spot electricity prices, moving them earlier in the dispatch curve.[29][30] When weather conditions are right, wind and solar projects can generate sufficient volumes of electricity – and with tax incentives and state-level renewable energy requirements at play – can bid into markets with near-zero or even negative prices, jumping to the front of the dispatch queue.[31] At the same time, renewables are often compensated for capacity that they cannot provide when the grid is stressed due to high demand (e.g., an extreme heat or cold weather event) or supply issues (e.g., ice making natural gas units inoperable). Operators may ultimately be liable to repay these capacity payments, but that does not offset the market distortion.[32] Combined, market failures in the spot and capacity markets make large, capital-intensive, baseload generation capacity less economically viable.

Geothermal also resembles oil and gas in that there are exploration risks. Companies will need to conduct geological surveys of land and acquire it if viable, but there is no guarantee the reservoir underneath will yield the proverbial "gusher" of energy.[33] Under current requirements for National Environmental Policy Act (NEPA) reviews, any geothermal projects on public lands – where 90 percent of known geothermal resources reside – must go through the federal environmental review process for each exploratory well in addition to the production wells that would actually support the facility – not including the permitting of the facility itself and associated transmission infrastructure.[34] This expansion of an already burdensome federal permitting process poses challenges unique to geothermal development. For all of this, geothermal is not immune to not-in-my-backyard (NIMBY) sentiments from locals or opposition from environmental groups.[35]

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[27] https://www.rff.org/publications/explainers/geothermal-energy-101/#:~:text=Cost%3A%20Finally,long%20run.
[28] https://world-nuclear.org/information-library/energy-and-the-environment/renewable-energy-and-electricity.
[29] https://www.eia.gov/todayinenergy/detail.php?id=47556.
[30] The live dashboard of PJM, the largest regional transmission organization (RTO) by both generation and population served, allows one to watch these dispatch curves and the overall trends in the fuel mix across timescales: https://www.pjm.com/markets-and-operations.aspx.
[31] https://www.sciencedirect.com/science/article/pii/S2666792421000652?via%3Dihub.
[32] See now Federal Energy Regulatory Commission now-Chairman Mark Christie's comments on this capacity market issue here: https://www.ferc.gov/news-events/news/commissioner-clements-dissent-regarding-pjm-interconnection-llc-docket-no-er23.
[33] https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2020/Nielson.pdf.
[34] https://gdr.openei.org/files/1258/Geothermal%20Permitting%20and%20NEPA%20Timeline%20Analysis%20-%20FINAL.pdf#. "7-10-Year Project Development Time Frame" graphic below sourced from p. 894.
[35] https://www.sciencedirect.com/science/article/pii/S0301421522001471#:~:text=We%20identified%2053%20utility%2Dscale%20wind%2C%20solar%2C%20and%20geothermal%20energy%20projects%20that%20were%20delay

The high upfront capital costs and regulatory uncertainty lead to an estimated levelized cost of energy (LCOE) for EGS, without federal tax subsidies, of between $61 and $102 per MW-hour (MWh). That is still competitive with other generation sources. However, federal subsidies drive down the cost of utility-scale solar production from a range of $24 to $96 per MWh to between $0 and $77 per MWh. The limited incentives available to geothermal reduce the LCOE to only $37 to $87 per MWh.[36] Despite geothermal baseload capacity benefits, it cannot compete with zero production costs in a market where baseload capacity is not recognized adequately.

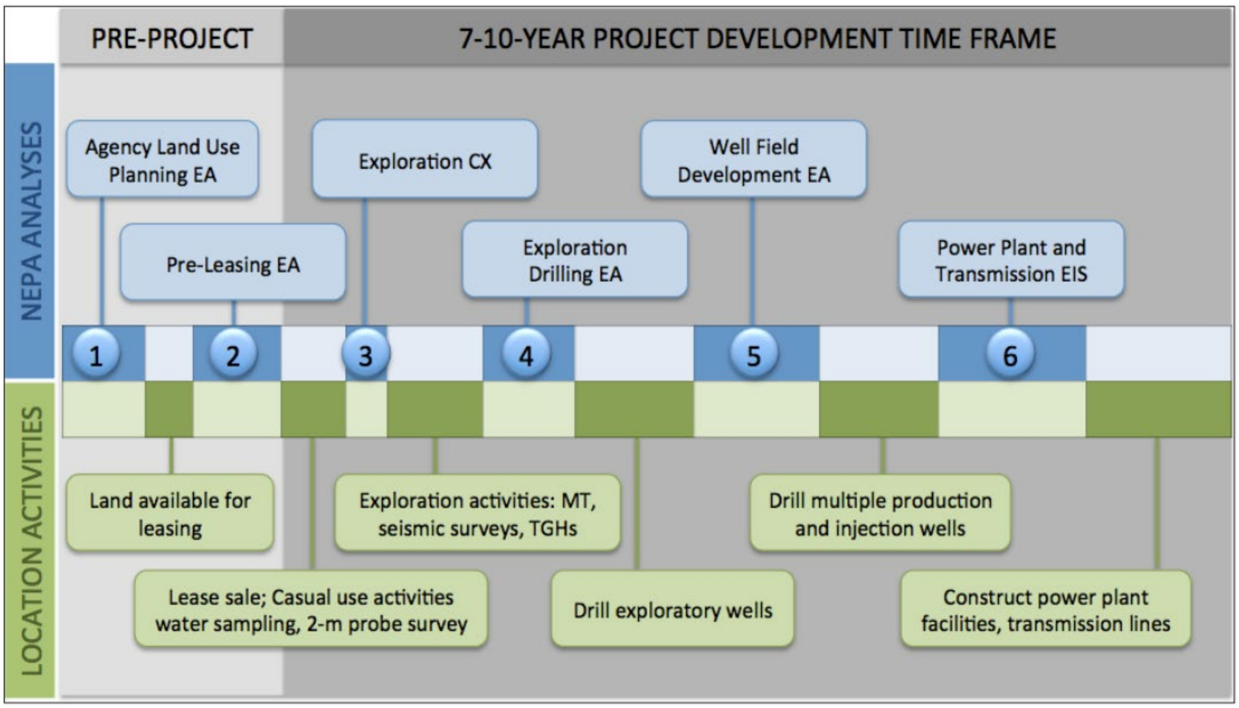

Figure 1. Example timeline of a geothermal location on federal lands illustrating that a single location could conceivably trigger NEPA analysis six separate times. Often data from each activity will provide the required information for the next permit application (e.g., exploration activities will help to target exploration well locations).

Meanwhile, the National Renewable Energy Laboratory estimates that permitting timelines for geothermal projects, not including emerging EGS plants with their additional drilling and reservoir maintenance requirements, average between five and seven years, compared to one to two years for natural gas plants.[37] The unique permitting delays leave geothermal at a disadvantage to conventional baseload resources.

ed%20or%20blocked%20between%202008%20and%202021%20in%2028%20U.S.%20states.%20Using%20multi%2Dlevel%20qualitative%20analysis%2C%20we%20have%20identified%20seven%20key%20sources%20of%20opposition.
[36] See p. 3: https://www.lazard.com/media/2ozoovyg/lazards-lcoeplus-april-2023.pdf.
[37] https://research-hub.nrel.gov/en/publications/efforts-to-streamline-permitting-of-geothermal-projects-in-the-un.

Finally, geothermal energy has not had the backing of federal investments in nearly the same breadth or significance as other renewable energy sources. Federal investments in geothermal energy and development for Fiscal Year 2024 (FY24) were flat at $118 million, compared to more than $1 billion for solar energy across research programs and earmarks for solar projects.[38]

So why should policymakers shift their focus to geothermal?

To meet the moment of rapidly increasing energy demand – particularly reliable baseload capacity – other renewables (with the exception of hydropower, which is only "renewable" depending on who you ask[39]) are ill-suited to the task. The capacity factor of other renewables lags rivals – when the wind is not blowing or the sun is not shining, these assets are not available.

Geothermal, by contrast, has a capacity factor that can be more than 90 percent – levels comparable to nuclear energy.[40] As long as the reservoir is maintained, facility maintenance is the only cause of downtime. Even more conservative estimates of a 70-percent capacity factor places geothermal ahead of all competitors except nuclear.[41] With broader geothermal fields and multiple plants operating, maintenance downtime can be managed to ensure a baseline of generation.[42] According to the Energy Information Administration (EIA), solar has a capacity factor of only 20 to 30 percent and wind only 35 to 45 percent, and that is highly variable based on location.[43] Determining when the asset is available is less up to the operators than divine intervention through weather patterns.

Despite this significantly better uptime, the lifecycle emissions of geothermal (including the production of equipment and construction and operation of the associated plants is an estimated 38 grams of carbon dioxide equivalent per kilowatt-hour (38gCO^2eq/kWh), according to the United Nations.[44] This is comparable to nuclear and wind generation. Emissions from criteria pollutants are similarly low to nonexistent, facilitating geothermal assets being deployed in already industrialized regions or behind-the-meter without burdening the local airshed with additional emissions.[45]

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[38] See p. 27 for geothermal, solar throughout: https://docs.house.gov/billsthisweek/20240304/FY24%20EW%20Conference%20JES%20scan.pdf.
[39] https://www.internationalrivers.org/news/10-reasons-why-hydropower-dams-are-a-false-climate-solution/.
[40] https://www.energy.gov/eere/geothermal/geothermal-faqs#:~:text=Geothermal%20energy%20is,renewable%20energy%20mix..
[41] https://www.statista.com/statistics/183680/us-average-capacity-factors-by-selected-energy-source-since-1998/.
[42] https://www.powermag.com/fighting-scale-and-corrosion-on-balance-of-geothermal-plant-equipment/.
[43] https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b.
[44] See p. 1335: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf#page=7.
[45] https://sites.lafayette.edu/egrs352-sp14-geothermal/contexts-and-consequences/environmental-pollutants/#:~:text=As%20far%20as,flash%20power%20plants.

Compared to renewable energy fields, the construction and operation of geothermal plants supports employment more akin to traditional fossil energy plants. In the exploration and development stages, particularly of EGS, skillsets and even equipment from oil and gas production can be utilized.[46] The plants themselves require engineers, pipefitters, electricians, and other trades to operate. Industry groups state that geothermal therefore supports 1.17 permanent jobs per megawatt of generation, more than any other electricity generation source. That figure rises to 2.13 jobs when indirect employment is included (e.g., administrative jobs, sales).[47] The National Renewable Energy Laboratory estimates that the addition of 60 GW of geothermal generation capacity by 2050 would create more than 100,000 permanent American jobs.[48] Geothermal technology does not require exotic minerals or other imported inputs like polysilicon or fissile material, like its solar and nuclear rivals. The supply chain lends itself to being wholly domestic.[49]

Land use is also minimal compared to other sources of renewable energy. Over 30 years of operation, geothermal requires approximately 400 square meters per GWh of generation. Wind requires four times that figure, solar eight times more.[50] This smaller footprint for geothermal minimizes the impact on ecosystems, public lands, and competing land uses like agriculture and ranching. Cogeneration means geothermal can support other local industries, such as utilization of heating for greenhouses, passive cooling for data centers, and extraction of minerals such as lithium and boron from brines generated as a byproduct of EGS.[51] Analysis by the Lawrence Berkeley National Laboratory estimated that lithium extraction from geothermal brines under the Salton Sea – adjacent the Imperial Valley Geothermal Project – could be the largest and most economic source of lithium brines in the world, making it a national security and economic asset for the United States.[52][53]

Finally, there is an added environmental benefit unique to broadened EGS. As mentioned earlier, geological features associated with other minerals often harbor geothermal potential. This extends to oil and gas fields. As oil and gas fields reach their end of life, geothermal energy may remain. In the case of marginal or orphaned wells, which have the potential to emit methane into

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[46] https://www.thirdway.org/blog/oil-markets-are-stabilizing-but-its-still-an-industry-in-decline#:~:text=Geothermal.%20The%20skillsets,fossil%20fuel%20workers.

[47] https://www.thinkgeoenergy.com/economic-values-of-of-geothermal-power-development-and-operation-a-2015-brief-by-gea/#:~:text=Geothermal%20power%20plants%20employ%20about,for%20about%20a%20100%20people.

[48] https://www.energy.gov/eere/geothermal/geovision#:~:text=This%20would%20increase%20geothermal%20electricity%20generation%20capacity,alone%20can%20double%20geothermal%20capacity%20by%202050.

[49] https://cresforum.org/publications/the-conservative-case-for-next-generation-geothermal-energy/#:~:text=Secure%3A%20Uses%20Existing,%5B22%5D.

[50] See p. 51: https://www.ourenergypolicy.org/wp-content/uploads/2016/02/Environmental-Guide.pdf.

[51] https://www.umass.edu/agriculture-food-environment/greenhouse-floriculture/fact-sheets/geothermal-heat-for-greenhouses.

[52] https://escholarship.org/content/qt4x8868mf/qt4x8868mf.pdf.

[53] https://www.energy.ca.gov/programs-and-topics/programs/lithium-valley-vision#.

the atmosphere and have minimal or negative economic value (negative because they are generally unfunded liability for state and local governments to contend with).[54] Geothermal projects could save costs and employ the same area's oil and gas workers to utilize these wells to develop geothermal capacity.[55] This will be a boon to rural economies where oil and gas depletion has impacted the local economy.

Current Federal Policies Regarding Geothermal Development

Since the enactment of the Geothermal Steam Act in 1970, the Bureau of Land Management (BLM) within the Department of Interior has been the lead agency for geothermal permitting on federal lands, which is where the majority of power plant-scale geothermal generation occurs.[56] As subsequent environmental statutes imposed additional regulatory requirements, this process requires several steps, including: the periodic identification of lands available for leasing; the holding of competitive lease auctions; NEPA reviews both for exploration as well as development; the approval of permits – again both for exploration and operation – for compliance with environmental statutes such as the Endangered Species Act, the Clean Air Act, and the Clean Water Act (CWA; excavation associated with drilling invariably leads to "burden" or "fill" material that must be relocated, triggering a Section 404 permitting requirement; projects must also demonstrate that fresh groundwater resources are not impacted); and finally commercial use permits and agreement on royalty payments to the federal government.[57][58]

The breadth and uncertainty of this regulatory process contributes a Department of Energy estimated seven-to-ten-year review *after* land resource nomination all the way to commercial operation, assuming that the resource even proves economical.[59] That is significantly longer than comparable permitting processes for oil and gas exploration – including hydraulic fracturing, which is similar to the reservoir construction processes of EGS – as well as renewable energy projects, the average for which is three years.[60] Development on private lands is less complex, but requires large parcels to access the reservoir and, in some jurisdictions, surface ownership is separate and apart ("severed") from mineral rights.[61][62] Additionally, geothermal development on private and state public lands may be affected by state laws defining who owns

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54 https://www.psu.edu/news/research/story/fossil-fuel-past-green-future-abandoned-wells-may-offer-geothermal-power.
55 https://www.energy.gov/eere/geothermal/wells-opportunity.
56 P.L. 91-581. https://www.congress.gov/91/statute/STATUTE-84/STATUTE-84-Pg1566.pdf.
57 https://drillingcontractor.org/geothermal-energy-holds-great-potential-but-technical-regulatory-challenges-must-be-overcome-58226#:~:text=The%20long%20regulatory%20timeline%20is,be%20completed%20prior%20to%20lease.
58 https://www.hunton.com/the-nickel-report/army-corps-finalizes-nationwide-permit-renewal-for-expedited-clean-water-act-permitting#:~:text=For%20example%2C%20NWP,the%20United%20States.
59 https://www.energy.gov/eere/geothermal/permitting-geothermal-power-development-projects.
60 https://www.thecgo.org/research/nepa-timelines-for-clean-energy-projects-understanding-delays-in-clean-energy-development.
61 https://www.landgate.com/news/what-is-geothermal-energy-how-can-landowners-monetize-it.
62 https://www.npr.org/2018/03/15/592890524/millions-own-gas-and-oil-under-their-land-heres-why-only-some-strike-it-rich.

geothermal resources. Ownership might be tied to water rights, mineral rights, or both depending upon the resource temperature.[63] Simply put, both public and private lands have their own obstacles. However, with 90 percent of geothermal resources on public lands, the NEPA process is the dominant legal and regulatory challenge.

As mentioned earlier, geothermal also lacks the scale of federal investment of other energy sources, both in terms of discretionary spending as well as tax incentives. Beyond direct research and development funding described earlier, various Office of Energy Efficiency and Renewable Energy (EERE) programs support intermittent renewable energy deployment, such as transmission and grid-level battery storage, or direct payments for uptake of the technologies. So, for approximately every $1 of direct spend for geothermal research and development, the taxpayer is spending $7 on wind and solar research development, despite the former being a nascent but high-potential technology while the latter is a multi-decade incumbent that has overtaken coal in the nation's energy mix.[64] The Department of Energy has estimated that simply matching the level of federal funding for other renewable energy technologies would reduce the costs of EGS by up to 50 percent by 2030.[65]

If the disparity in federal grantmaking seems stark, the situation in the Internal Revenue Code is even worse. Current tax policies targeting geothermal include a production tax credit (PTC) of 2.8 cents/kWh for ten years of operation; an investment tax credit (ITC) for 30 percent of qualified capital expenditures; and an accelerated depreciation schedule of capital investments over five years.[66][67] Like oil and gas, geothermal exploration and production benefits from the deduction of intangible drilling costs.[68]

Federal Policy Recommendations to Accelerate Geothermal Development

Investments in data centers and artificial intelligence clusters are driving significant increases in demand forecasts. Revisions to even recent demand growth forecasts have increased by nearly a factor of five. By 2029, the demand for electricity in the US may increase by a staggering 15.8

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[63] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5176318

[64] https://docs.house.gov/billsthisweek/20240304/FY24%20EW%20Conference%20JES%20scan.pdf..

[65] https://www.nrel.gov/docs/fy23osti/84822.pdf#:~:text=On%20September%208%2C%202022%2C%20the%20Enhanced%20Geothermal,assumptions%20used%20in%20the%20Enhanced%20Geothermal%20Shot.

[66] https://www.hklaw.com/en/insights/publications/2023/06/irs-releases-2023-section-45-production-tax-credit-amounts.

[67] https://www.bakerbotts.com/thought-leadership/publications/2024/december/final-regulations-issued-regarding-section-48-investment-tax-credit#:~:text=Section%2048%20provides%20an%20ITC%20in%20an%20amount%20generally%20equal%20to%2030%25%20of%20a%20taxpayer%E2%80%99s%20basis%20in%20%E2%80%9Cenergy%20property%E2%80%9D%20placed%20in%20service%20during%20the%20taxable%20year.%20%C2%A0Section%2048%20was%20originally%20enacted%20in%201962%20and%20has%20been%20subject%20to%20a%20series%20of%20amendments%20over%20the%20years%2C%20including%20most%20recently%20by%20the%20IRA.

[68] 26 CFR § 1.612-5. https://www.law.cornell.edu/cfr/text/26/1.612-5.

percent after decades of near zero. Globally, Goldman Sachs estimates that data center demand will grow by as much as 165 percent by the same year.[69]

The US is home to the largest data center clusters and is making immense private sector investments in the development of artificial intelligence. Demand growth from artificial intelligence clusters is estimated to amount to "only" about a quarter of the total electricity demand of data centers.[70] That means that even if the artificial intelligence sector turns out to be a bubble, the US will still see significant growth driven by data centers for data storage, cloud computing, and operating as the backbone of the internet.

Given the rapid changes in the outlook for electricity demand, shifting the 45Y and 48E emissions-based paradigm to one focused on supporting resources with the highest capacity factors would serve to rebalance markets like PJM that are not adequately compensating baseload generation. Geothermal would stand to benefit in particular, as would nuclear and large-scale natural gas plants that face headwinds from high initial capital costs and markets distorted by previous intermittent renewable energy tax credits and state-level regulatory mandates.

Beyond tax incentives or increasing federal funding geothermal research and development, Congress should look at shortening the incredibly long timelines for geothermal development. If New Zealand can permit geothermal generation within two years, there is no reason it should take seven to ten in the United States. Seismicity is a factor worth considering, but it should not be viewed as a reason to slow down progress. Injecting water into the subsurface can potentially trigger seismic activity. However, responsible operators are well aware of this risk and proactively apply well-established best practices from the oil and gas industry to manage and mitigate it effectively.

Permitting reform priorities for Congress should include:

- **Categorical exclusions**: Statutorily broadening and requiring agency sharing of categorical exclusions (CEs) under NEPA to reduce the scope and number of development steps subject to NEPA review. The concept, notionally, has broad support from industry stakeholders as well as climate activists who believe zero-emission energy development is an essential policy prerogative.[71] Statutory language could explicitly address CEs for exploration activities that have minimal surface impacts; development in brownfield sites or existing energy corridors and federally approved rights of way; projects using existing marginal or orphaned wells given the benefits of methane

[69] https://www.utilitydive.com/news/shocking-forecast-us-electricity-load-could-grow-128-gw-over-next-5-years-Grid-Strategies/734820/
[70] https://www.goldmansachs.com/insights/articles/ai-to-drive-165-increase-in-data-center-power-demand-by-2030
[71] https://bipartisanpolicy.org/report/categorical-exclusions/.

emissions reductions and limiting potential water pollution; and small-scale demonstration projects.

- **Scale back NEPA for test wells**: Waiving outright the full NEPA review requirements for drilling test wells and conducting other exploration activities, such as the use of ground-penetrating radar to identify geothermal resources. This would put geothermal energy on par with oil and gas in terms of regulatory treatment. Bipartisan legislation led by Senate Energy and Natural Resources (ENR) Ranking Member Martin Heinrich (D-NM) and now-Chairman Mike Lee (R-UT) would have created a categorical exclusion for this purpose. The Geothermal Energy Optimization (GEO) Act was introduced last Congress and was incorporated into broader leasing, transmission, and permitting reform legislation that cleared the Committee but failed to be enacted.[72] The leadership of ENR should reintroduce this commonsense legislation and move it on its own if a larger permitting package appears likely to bog down.

- **Tiered environmental protections**: Directing BLM, in partnership with other regulatory agencies, to devise a tiering of standardized environmental protections. The requirements would tighten over the stages of development. Exploration would have the fewest strictures or benefit from the CE provided by the GEO Act. Development wells would have another level of analysis. Finally, construction and operation of the facility would be subject to a NEPA analysis led by BLM. Such guidelines would provide certainty to geothermal developers and facilitate quicker regulatory reviews while demonstrating to the public a concise and defined list of environmental standards that must be met.
- **Entice private capital:** Finally, Congress could establish a geothermal exploration risk insurance program to serve as a signal to private markets that the federal government supports expanded geothermal development. In exchange for premiums and geological and business analyses, developers would benefit from insurance to support exploration activities, particularly for EGS. This will support additional private sector investment by defraying some of the early capital risks of EGS deployment and could be phased out over time as confidence in the technology grows and the upfront capital costs decline due to the development of economies of scale.[73] Policymakers skeptical of the Department of Energy Loan Program Office's private sector investments in specific companies could repurpose the office to provide risk insurance to geothermal and other capital-intensive baseload generation sources like nuclear.

Conclusion

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[72] https://www.congress.gov/bill/118th-congress/senate-bill/3954.
[73] https://www.thirdway.org/memo/geothermal-policies-to-help-america-lead#:~:text=De%2Drisk%20financing,Program%20(UCDP%2C%201980).

Perhaps more than any other energy source, geothermal energy should withstand political turmoil as control of Washington shifts, as it answers the stated policy priorities of both parties.

Geothermal energy provides the baseload capacity the country desperately needs. It does not require significant land use, nor does it meaningfully reduce the availability of land above geothermal reservoirs from utilization for other industries like agriculture. It is a zero-emission resource that can help contribute to a cleaner environment. If utilized at existing or orphaned wells, it can transform environmental liabilities into energy assets.

All Americans can cheer geothermal's wholly domestic supply chains and job-creating potential. Skilled trades in the oil and gas and power sectors, and even their equipment, can readily transition and expand to address the potentially rapid growth of EGS.

To date, there has been a lack of political will to support geothermal, despite the US being the world leader in geothermal generation and uniquely positioned to lead the pack in its future growth. Policymakers would be wise to provide favorable tax policy, certainty, expedited permitting policies, and research and development support to exponentially ramp up this energy resource. Our ability to meet the demand growth anticipated in coming decades – securely, reliably, and cleanly - may depend on it.

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