FERVO ENERGY

Written Testimony
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Chairman Murkowski, Ranking Member Manchin, and members of the Committee, thank you for the opportunity to join this important discussion on advanced geothermal energy development in the United States.

This discussion happens at a critical juncture for geothermal energy. **The Department of Energy recently released an important report, the GeoVision study, outlining the opportunity to power up to 16% of the United States electric grid and heat up to 45 million homes from geothermal energy by 2050.** Because of geothermal's unique attributes as an energy source, firm, low carbon, with 24/7 reliability, this is a major prize worth pursuing from the private and public sector alike. Additionally, many forces are coming together to make this the right time to develop more geothermal energy. First, increasing attention for climate change has led many states to target ambitious clean energy standards that go well beyond historic targets. Next, the Department of Energy Field Observatory for Research in Geothermal Energy (FORGE) is underway, the largest and most sophisticated advanced geothermal test bed ever created. Finally, oil and gas technology has advanced at a lightning pace this decade, and oil and gas operators are increasingly looking at new energy options as climate change puts pressure on their traditional businesses, so the time for technology transfer from the oil and gas industry has never been better.

However, geothermal energy today constitutes just 0.4% of current US electricity, and in recent years, growth has lagged significantly behind other renewable resources like wind and solar. My testimony today will focus on challenges and opportunities to geothermal energy development, drawing on my experience as the Co-Founder and CEO of Fervo Energy, where our mission is to leverage innovation in geoscience to advance the clean energy future.

If you would have found me five years ago, I was in my old job, as a wellsite supervisor in the heart of the oil boom in the Permian Basin in West Texas. In this role, I witnessed first-hand the revolution in oil and gas production from unconventional resources, catalyzed in large part from technologies supported by the Department of Energy such as horizontal drilling and distributed fiber optic sensing. While I found this job dynamic and interesting, like many people my age, with an increasing understanding of the urgency of climate change, I felt drawn to the burgeoning clean energy economy. As a drilling engineer, geothermal energy seemed like a perfect fit, and the more I learned about the huge untapped potential of geothermal, the more excited I became about applying my skills in this field. I left my oil job to study energy and the environment at Stanford University, where I met my co-founder and launched Fervo Energy in 2017.

Fervo Energy was founded to leverage recent subsurface technology advancements, such as horizontal drilling and distributed fiber optic sensing, to lower the development cost and increase the resource base of geothermal energy. To date, Fervo Energy has benefited tremendously from

the early stage public-private innovation ecosystem this Committee has been instrumental in creating. We are supported through grant awards from both the Geothermal Technology Office and ARPA-E. We are currently embedded with world class geoscience researchers at the Lawrence Berkeley National Lab through the DOE-supported Cyclotron Road entrepreneurial fellowship program. From the private sector, we are backed through venture capital investments including Breakthrough Energy Ventures, a billion-dollar clean energy fund dedicated to supporting breakthrough technology companies tackling climate change. This support has been critical to our success so far, but the greatest difficulty in scaling geothermal technology comes at the valley-of-death between the lab-scale and field-scale. I'd like to offer a few thoughts on how to accelerate this scale up for both Fervo and any other technology-enabled geothermal company.

Geothermal energy has many unique and valuable benefits

The recent GeoVision Study highlighted the immense potential and significant positive environmental, economic, and security impact of geothermal energy development in the United States. Geothermal energy:

- Is a clean, renewable, and fuel-secure resource. Increased development would lead to significant reductions in CO_2, SO_2, and NO_x emissions in the United States.
- Is a firm, always-on resource. Recent research has shown the benefit of including firm, low carbon resources in the electricity mix, reducing costs to decarbonizing by 10-62%.[1]
- Is a versatile energy resource, with the ability to provide everything from large-scale utility generation to residential heating and cooling options throughout the US.
- Leverages unique US expertise in subsurface development and geoscience. Both US public and private sector entities have been active in projects around the world, such as in Kenya, where geothermal provides 47% of electricity generation[2], and Indonesia, which holds up to 40% of the world's geothermal resources.
- Has enormous untapped potential, with NREL estimating the United States contains over 5,157 GW_e of electricity generation resource potential. The GeoVision study shows in certain scenarios generation could reach 120 GW_e by 2050, capable of providing 16% of US generation.
- Is often found on public lands, which means federal policy could have an outsized impact on accelerating development. The GeoVision study found that improving regulatory timelines alone through use of standardization and tools such as categorical exclusions could increase geothermal development 5-fold by 2050[3].

[1] Sepulveda et al., The Role of Firm Low-Carbon Resources in Deep Decarbonization of Power Generation, Joule (2018), https://doi.org/10.1016/j.joule.2018.08.006

[2] Annual Report, Kenya Power and Lighting Company, 2018.

[3] GeoVision: Harnessing the Heat Beneath Our Feet. Department of Energy. 2019.

Despite all these benefits, geothermal must overcome significant technical and non-technical barriers to become a major energy resource. Subsurface exploration is an inherently risky activity and new technology and business models must be developed to tackle this risk. Projects can have extended development timelines, challenging economics. Importantly, the jump between lab-scale innovation and field-scale deployment is significant, with many promising new technologies never successfully crossing this challenging valley. Many of the important research and development questions in geothermal energy can only be answered at the field scale, so it is imperative that a robust innovation ecosystem addresses this critical gap.

Supporting technology scale up

Restoration of the Investment Tax Credit to achieve parity with other clean energy resources would catalyze new geothermal development. Subsurface industries demonstrate a strong learning effect, growing far more efficient over time[4], but must be supported in early days in order to start the virtuous cycle of cost reduction. As an analogue, we can look to the pace of innovation in shale oil and gas boom. It should be noted that there are many differences between oil and gas, which is focused on extraction of hydrocarbons, and geothermal, which is principally focused on circulation of water through closed loop reservoirs to mine heat, but it can still serve as a useful analog.

Horizontal drilling first became commercially deployed in the late 1990s to develop shale resources. Early commercialization was supported directly through DOE-funded research into technologies such as horizontal drilling and advanced drill bit technology. In the last decade alone, productivity across the major shale basins in the United States has increased by a factor of 10X (see Figure 1). This has led to an unprecedented resurgence of oil and gas production. The US in 2018 recorded the highest oil and gas output in a single year for any country in history[5]. This multi-decade increase in productivity and output could never have occurred had the industry not had support in early days to develop the first-of-a-kind commercial projects. New technology deployments in subsurface industries always show a strong learning effect, but because of the capital intensity of new projects, initial deployment of a new technology before it reaches the learning phase is challenging.

[4] "Use of the Experience Curve to Understand Economics for At-Scale EGS Projects". Proceedings, 42nd Workshop on Geothermal Reservoir Engineering, Stanford University. Latimer and Meier. 2017.

[5] "U.S Oil and Gas Output Surges the Most Ever for a Single Country", Bloomberg, 2019. https://www.bloomberg.com/news/articles/2019-06-11/u-s-oil-gas-output-surges-the-most-ever-for-a-single-country

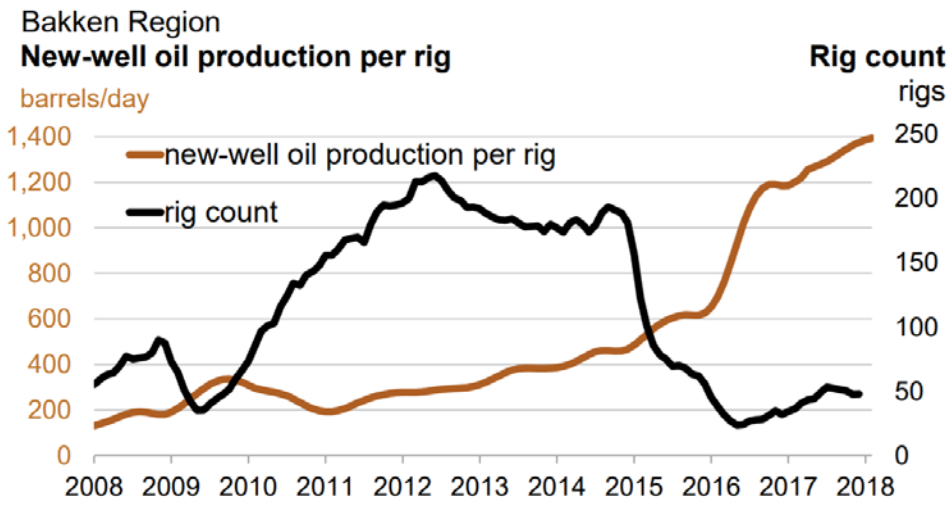

Figure 1: US Energy Information Agency Drilling Productivity Report. 2018.

Geothermal energy has the potential to have similar large-scale efficiency and productivity improvements, but needs similar early-stage support to deploy the earliest, higher cost initial projects. Because of rapid innovation in the oil and gas sector, technology transfer opportunities could lead geothermal to have an even faster commercialization cycle. While geothermal is quite different from oil and gas, targeting harder, hotter rocks, and focusing on closed loop circulation, there are still areas where recent innovation from oil and gas can be applied, such as seismic mapping or advanced directional drilling techniques. However, despite the fact the United States has now drilled over 300,000 horizontal wells for oil and gas production, horizontal drilling had never been systemically developed for geothermal energy. This is due in part to very unfortunate timing. In recent years, just when advanced drilling technology was reaching a maturity level that could make it very attractive, geothermal energy has had access to only a 10% Investment Tax Credit, while other resources such as solar energy receive a 30% Investment Tax Credit. In a hyper-competitive market like power generation, with low project margins, starting this deeply behind other resource classes makes even traditional project development challenging, and presents an incredible barrier to project development with any new technology approach. In order to send a clear enough signal to the market and investors, it is important that the ITC be installed for a meaningful and clear period-of-time to align with geothermal development cycles, such as a 5-year target.

The GeoVision study highlights numerous benefits for geothermal development, including generating 16% of US electricity, catalyzing over $200 billion in new investment, and significant reductions in emissions of CO_2, SO_2, and NO_x. A near-term restoration of the ITC to be comparable to the ITC received by other energy resources would be key to unlocking $200+ billion of new private sector investment over the next decades.

Supporting technology innovation

Increased funding to promising initiatives currently run by the Geothermal Technology Office (GTO) and the Advanced Research Projects Agency-Energy (ARPA-E) could dramatically accelerate early-stage technology innovation and adoption. The most challenging area for geothermal technology development is through the "valley of death" from the lab-scale to the field-scale. To address this point, the Department of Energy launched the FORGE program, beginning with a competitive site selection process in 2014, to establish a field test bed for the deployment of new technologies. FORGE has now completed the site selection phase and is moving forward with a multi-year R&D program at a site in Milford, Utah operated by a team for the University of Utah. This project is unprecedented and will enable the subsurface research community to develop, test, and improve new technologies in a well characterized and instrumented site. Similarly, ARPA-E recently initiated a program focused on unlocking the potential of geothermal through a funding announcement on "Innovating Through Unconventional Ideas"[6]. ARPA-E awarded projects focused on geothermal tools, including one to Fervo Energy, and announced that "topics explored under this opportunity are not part of existing ARPA-E programs, but if successful could establish new program areas for ARPA-E to explore." It is an exciting time for geothermal R&D with innovative projects underway from both the GTO and ARPA-E.

However, because of the high cost of testing new technology at the field scale, even these innovative programs will have limited opportunities for new technology deployment. Currently, due to drilling costs, only a limited number of wells will be developed for new technology evaluation at FORGE. Increased funding to the GTO could enable multiple more technologies and wells to be developed at the FORGE site and create opportunities for continued technology development beyond FORGE. With ARPA-E's unique focus on commercialization of breakthrough technology, additional funding for novel downhole tools, electronics, and sensors would help to unlock the prize for geothermal. Additionally, there are opportunities for innovative public-private partnerships for technology scale up at existing or new geothermal sites throughout the US that would greatly accelerate deployment. These collaborations could identify "Wells of Opportunity" or promising, but sub-commercial, geothermal reservoirs as low-cost, low-risk areas for geothermal technology deployment. These currently sub-commercial reservoirs, referred to as "In-Field" and "Near-Field" in the GeoVision study, would be ideal candidates for public-private partnership for new geothermal technology deployment and an important intermediate step for unlocking the full potential for geothermal energy (see Figure 2).

[6] ARPA-E: Innovating Through Unconventional Ideas. https://arpa-e.energy.gov/?q=news-item/arpa-e-innovating-through-unconventional-ideas

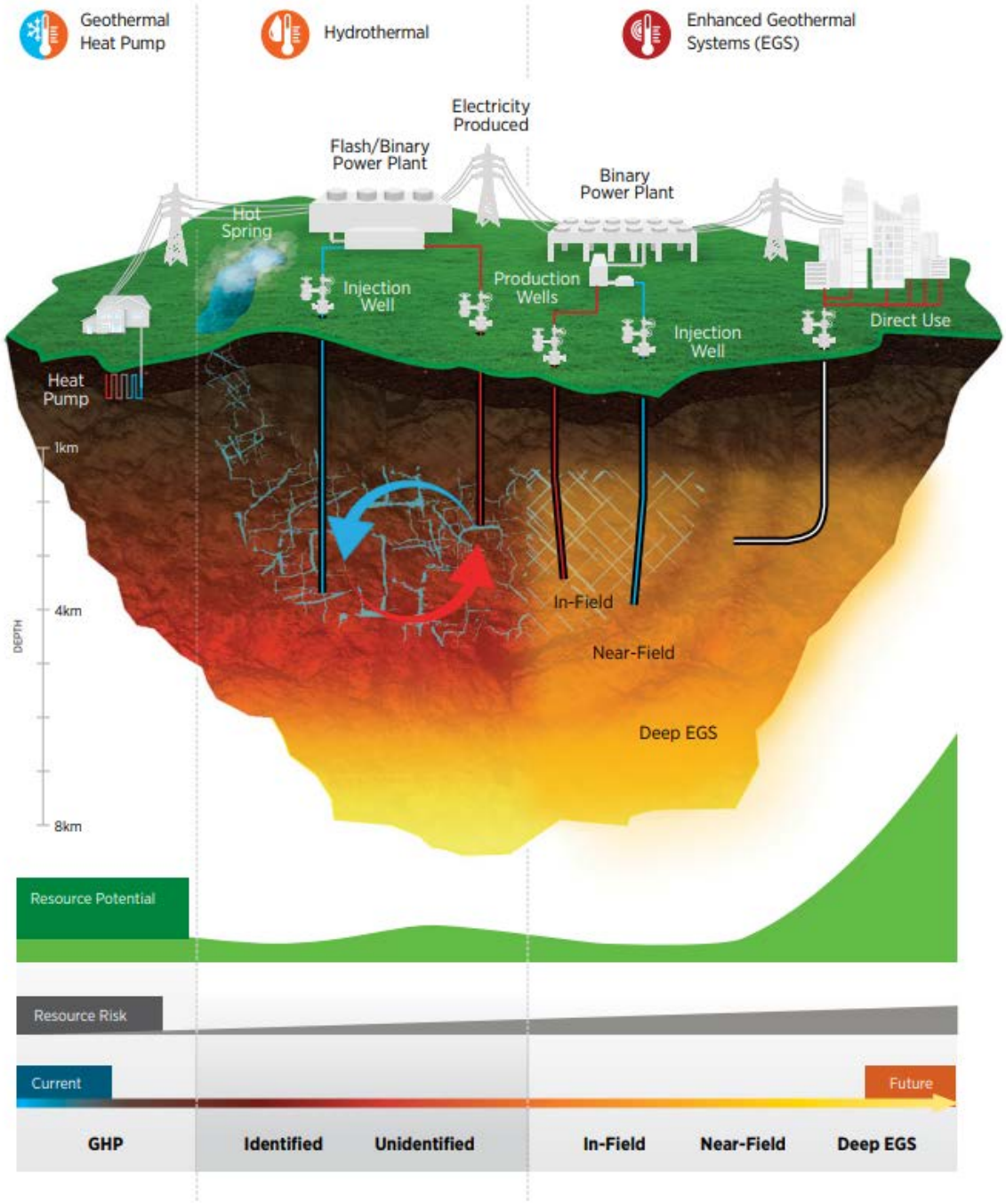

Figure 2: in-Field and Near-Field Candidates. GeoVision Study. 2019.

Funding for the Geothermal Technology Office has followed a good trend in recent years but still lags behind other energy R&D efforts. Funding in 2018 for the GTO was $80,906,000 from $38,094,000 in 2013. This compares to $241,600,000 and $290,719,000 for Solar Energy in the same years, respectively, or $726,817,000 and $536,969,000 for Fossil Energy Research and

Development in the same years, respectively[7][8]. Continued or increased growth of the Geothermal Technology Office Budget would enable more innovation opportunities.

To put these numbers into context, despite its great promise, geothermal typically receives <1% of renewable electricity federal subsidies and support (see Figure 3). Increasing funding could accelerate the progress of already ongoing promising R&D efforts and lead to a step-change in our likelihood of unlocking the potential $200 billion investment opportunity for geothermal in the United States. The right combination of early-stage R&D support and investment tax credits led to tremendous success in cost reduction and deployment for wind and solar and lessons from their success can drive similar progress for geothermal energy.

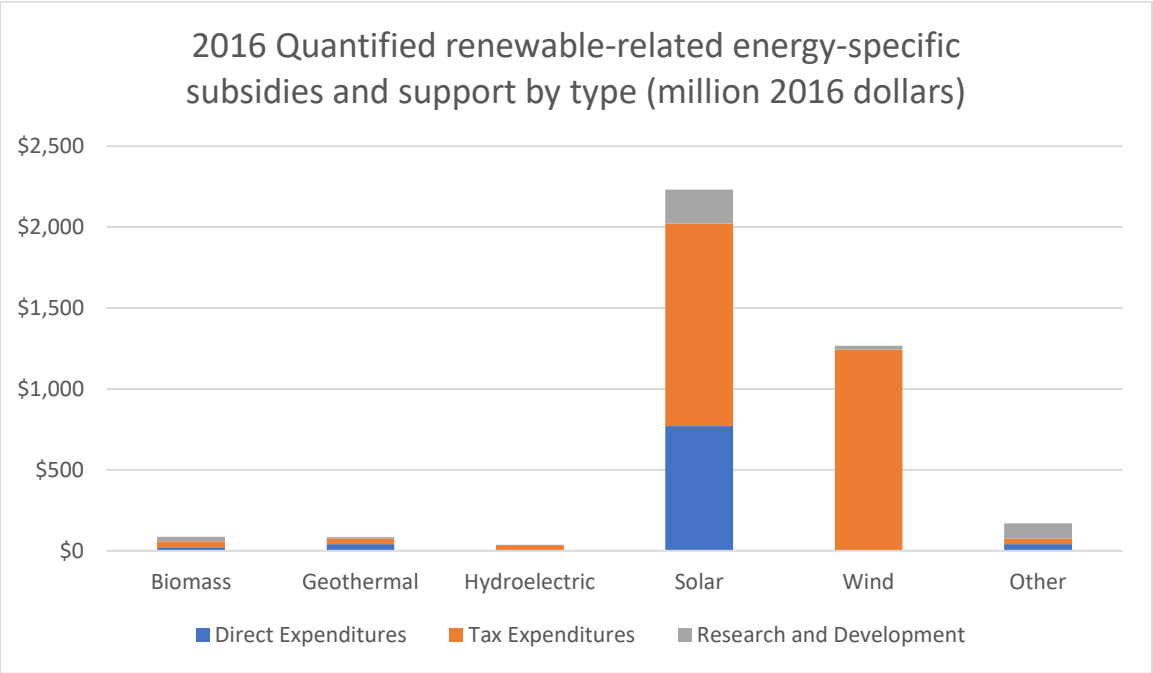

Figure 3: US Energy Information Agency Financial Interventions and Subsidies. Table 4. 2018.

Forces are aligning for geothermal energy and the time to act is now

Private sector, market, and technology forces are intersecting to create a unique opportunity in geothermal energy development. The GeoVision study outlines the $200 billion opportunity that would enable 16% of US electricity to come from clean, always-on geothermal electricity. Ambitious state level Renewable Portfolio Standards are driving renewed interest in geothermal energy. Private sector investors, like Breakthrough Energy Ventures, have identified geothermal

[7] Department of Energy FY2014 Budget Highlights. https://www.energy.gov/sites/prod/files/2013/04/f0/Highlights.pdf

[8] Department of Energy FY2019 Budget in Brief. https://www.energy.gov/sites/prod/files/2019/03/f60/doe-fy2020-budget-in-brief_0.pdf

as one of the most promising areas to help us achieve deep decarbonization to address climate change. Oil and gas technology has advanced at a rapid pace, and high interest in alternative sources of energy from the oil and gas operators make this a compelling time to focus on technology transfer. With the right policy and funding support, the geothermal industry can achieve the ambitious goals outlined in the GeoVision study and unlock a huge, valuable domestic clean energy resource.