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Fervo Energy Company Comments on Preliminary Draft Renewable Energy Generation Research Roadmap

Additional submitted attachment is included below.

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July 12, 2019

California Energy Commission
Dockets Office, MS-4
Docket No. 19-ERDD-01
1516 Ninth Street
Sacramento, CA 95814-5512

RE: Fervo Energy Company Comments on the June 28, 2019 Request for Public Comments on the Preliminary Draft Renewable Energy Generation Research Roadmap, Docket 19-ERDD-01

Fervo Energy Company appreciates this opportunity to comment on the California Energy Commission's (CEC) Request for Public Comments on the Preliminary Draft Renewable Energy Generation Research Roadmap following the webinar held on June 28, 2019.

Fervo Energy is pleased that the CEC has identified geothermal energy as a key non-variable renewable energy resource for the state. We are in strong agreement with the CEC Renewable Energy Generation Roadmap study results, which found that new investment into geothermal RD&D could lead to technology breakthroughs that would unlock a **technically accessible resource of up to 50 GW in California** – a generation capacity that could provide **50% to 100% of the state's firm, dispatchable electricity generation**[1]. These findings echo the recent GeoVision[2] study released by the US Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) on May 30, 2019, which found that geothermal energy deployment throughout California and other western states could achieve a 26-fold increase in generation capacity by 2050. Given the massive potential for geothermal energy to play a major role in meeting California's carbon emissions reduction standards set out in Senate Bill 100, this is clearly a prize worth pursuing.

As a technology-enabled startup focused on commercializing advanced geothermal electricity generation, Fervo Energy has a pulse on what innovations are likely to have the largest impact, where the key barriers to scale-up and commercialization exist, and how California's public dollars could be used to catalyze private-sector investment. To this end, we offer the following suggestions for directing future potential CEC investment:

1. Funding for enhanced geothermal systems, with a focus on funding innovations that support increased wellbore flow rates, cost reductions in drilling, and improved reliability in exploration drilling.
2. Funding for field-scale pilot demonstration projects for first-of-its-kind geothermal technologies.
3. Funding for flexible and dispatchable geothermal operations.

These topics address the most critical technical barriers facing geothermal energy – increased investment across these technology areas will facilitate large-scale deployment of geothermal energy in California, with the potential for massive carbon emission reductions, increased grid reliability, and thousands of new high-paying jobs.

[1] Rogers, J. (2019). Research Roadmap for Cost and Technology Breakthroughs for Renewable Energy Generation. Technical report, Energetics.
[2] GeoVision: Harnessing the Heat Beneath our Feet. (2019). Technical report, US Department of Energy.

Funding for Enhanced Geothermal Systems

If geothermal energy is to make a meaningful impact on climate change, then enhanced geothermal systems will likely make up the majority of installed geothermal capacity. Citing resource assessments performed by the US Geological Survey and NREL, the CEC Roadmap Study found that California's total geothermal resource capacity (including enhanced geothermal systems) is estimated to be as high as 50 GW. Most of the EGS resource consists of reservoirs within the temperature range of 150 °C to 225 °C, where binary power plants are most effective (binary plants enable entirely closed-loop geothermal systems with zero carbon emissions). Furthermore, geothermal operators have already demonstrated that binary plants can operate in flexible and dispatchable modes[3], a trait that will augment high levels of wind and solar penetration in California's future grid[4,5].

New RD&D funding for enhanced geothermal systems should be directed toward innovations that target the most critical barriers facing large-scale deployment: a) consistently achieving high production flow rates, b) lowering drilling costs, and c) improving reliability in exploration drilling. These technical challenges were identified in many of the R&D Opportunity Areas and Technologies listed in the CEC Roadmap Study (for example, O.G.3 – *Enhanced Geothermal Systems*, O.G.4 – *Exploration, Resource Characterization, and Resource Development*, O.G.7 – *Innovative Geothermal Systems*, and O.G.8 – *Increasing Cost-Effectiveness*), and are reflected in the specific Emerging and Breakthrough Technologies (for example, G.1 – *Improved Fluid Injection*, G.2 – *Characterizing and Modeling EGS Reservoirs*, G.4 – *Improved Well Connectivity in EGS*, G.10 – *Lower Drilling Costs*, G.11 – *Water Reinjection*, and G.14 – *Geophysical Methods*). Remarkable opportunities for innovation exist across each of these categories.

Funding for Field-Scale Pilot Demonstration Projects for First-of-its-Kind Geothermal Technologies

Many of the most important research questions in geothermal energy development, such as flow properties across thousands of feet of fractures, can only be answered definitively at the field scale. However, because of the investment barrier to developing a new project, there are limited opportunities to test technology at this most critical scale. As a result, many major advancements of crucial sub-components of successful geothermal energy projects end up in the awkward position of being all dressed up with nowhere to go after a promising lab phase.

There are very few opportunities to test geothermal technologies in field conditions in the United States and the problem is actually getting worse. Although the US is the largest producer of geothermal energy in the world, with over 3.7 GW of installed capacity, over 90% of that capacity was installed before 1990. As a result, there is a negligible amount of new drilling in the US today. Most geothermal assets are held by private equity or pension investors that do not have the risk appetite for new development, much less new technology, and as a result there is not an organic pathway for new technology adoption in the geothermal industry today.

The DOE Geothermal Technology Office has funded many impactful geothermal technologies over the years and is currently leading a $140m multi-year effort titled the Field Observatory for Research in Geothermal Energy (FORGE) to provide a test bed for new geothermal technology field deployment. This is the most exciting program in the history of geothermal energy, however, because of its basic science focus and the required budget for measurement and evaluation equipment, it will ultimately only provide 2 or 3 new wells for new technology

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[3] Ormat Technologies. (2013). A discussion of the benefits geothermal power provides to future U.S. power systems. Technical report, Ormat Technologies.

[4] Sepulveda, N.A., Jenkins, J.D., et al. (2018). The role of firm low-carbon electricity resources in deep decarbonization of power generation. *Joule*, **2**, 1-18. https://doi.org/10.1016/j.joule.2018.08.006.

[5] Shaner, M.R., Davis, S.J., Lewis, N.S., and Caldeira, K. (2018). Geophysical constraints on the reliability of solar and wind power in the United States. *Energy Environ. Sci.*, **11**, 914-925. https://doi.org/10.1039/c7ee03029k.

testing. With dozens of research groups and technologies vying for a spot in 2 to 3 wells, many technologies will not be able to take advantage of the FORGE test bed.

Fervo Energy recommends that funding for geothermal energy technologies have a focus on field-scale deployment and demonstration in order to accelerate commercialization timelines. This new funding would build upon the CEC's successful track record for investing in field-scale demonstration projects, such as the *Santa Rosa Geysers Recharge Project*[6], *Investigating Flexible Generation Capabilities at The Geysers*[7], *High-Resolution Imaging of Geothermal Flow Paths Using a Cost Effective Dense Seismic Network*[8], and *Well to Wheels Lithium Recovery*[9]. These are exactly the type of projects that the CEC should continue investing in.

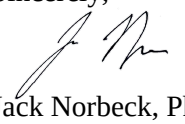
Funding for Flexible and Dispatchable Geothermal Operations

Geothermal energy has historically been classified as a "baseload" renewable energy resource. This sentiment needs to change if geothermal is to compete in emerging clean energy markets. Recent studies have found that most geothermal power contracts currently encourage constant generation, but that geothermal plants could operate flexibly or in load-following modes if the market appropriately incentivized the benefits that geothermal's unique load profiles can deliver[2,3]. Preliminary research funded by the CEC has shown tremendous promise for increasing grid reliability and cost-effectiveness through flexible geothermal operations[7,10]. Further R&D into the operational and reservoir challenges associated with flexible geothermal generation will ensure that future geothermal deployment will be optimized to support the high penetration levels of variable energy sources anticipated as California strives to achieve 100% clean electricity generation.

Background on Fervo Energy

Fervo Energy is a technology-enabled geothermal developer focused on developing innovative geoscience solutions to unlock the massive domestic geothermal resource. Fervo seeks to operate geothermal systems in a flexible, dispatchable mode to provide the foundation to variable clean energy resources (such as wind and solar) necessary to achieve 100% zero-carbon electricity generation. Fervo has received private-sector investment from Breakthrough Energy Ventures and other venture capital firms, support from the Cyclotron Road entrepreneurial fellowship program, and grant funding from the Department of Energy (DOE) Geothermal Technology Office, ARPA-E, and Stanford University.

Sincerely,



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[6] Brauner, E. et al. (2002). Santa Rosa Geysers Recharge Project: GEO-98-001 – Final Report. Technical report, California Energy Commission. https://ww2.energy.ca.gov/reports/2003-03-01_500-02-078V1.PDF.
[7] CEC. (2018). Electric Program Investment Charge 2017 Annual Report. Technical report, California Energy Commission.
[8] CEC. (2019). High-resolution imaging of geothermal flow paths using a cost effective dense seismic network. http://innovation.energy.ca.gov/.
[9] CEC. (2018). Senator Hueso Announces $2.5 Million Grant for New Geothermal Project. https://sd40.senate.ca.gov/news/20180504-senator-hueso-announces-25-million-grant-new-geothermal-project.
[10] Rutqvist, J., et al. (2018). Modeling of coupled flow, heat, and mechanical well integrity during flexible geothermal production. Paper presented at the 2018 Stanford Geothermal Workshop. https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2018/Rutqvist.pdf.