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On Preliminary Draft Utility-Scale Renewable Energy Generation Research Roadmap

Additional submitted attachment is included below.

NREL Transforming ENERGY

MEMO

Date: July 12, 2019

To: California Energy Commission

From: Katherine Young
Geothermal Laboratory Program Manager
National Renewable Energy Laboratory

Subject: Comments on the Preliminary Draft Utility-Scale Renewable Energy Generation Research Roadmap (docket number 19-ERDD-01)

This memo provides comments on the geothermal section of the draft roadmap.

Thank you for the time and effort that went into developing both the *Technical Assessment of Grid Connected Renewable Energy and Storage Technologies and Strategies* and the *Preliminary Draft Utility-Scale Renewable Energy Generation Research Roadmap*, and for providing the opportunity for public comment.

My name is Katherine Young, and I am the Laboratory Program Manager of Geothermal Research at the National Renewable Energy Laboratory (NREL) in Colorado. I am also a director of the Geothermal Resources Council. I have spent more than a decade at NREL focused on the advancement of geothermal technologies, so they can continue to provide a cost-effective, viable option for clean energy and job creation. As an engineer, I have led research projects on geothermal exploration, drilling, regulations, thermal applications, and resources engineering, most recently supporting the Department of Energy's (DOE) *GeoVision* study. Before joining NREL, I was a water rights engineer, a software developer, and a professional in hydrocarbon cementing and fracturing. My entire career has been about leveraging science in new ways to create practical, cost-effective solutions. This experience has given me a deep understanding of and profound appreciation for the role that scientific research can play in maintaining our nation's leadership in science and innovation, and also, how those accomplishments can drive competitiveness, autonomy, and security.

Benefits to California

In my view, the subject this roadmap is timely and especially important to the energy future of our country. Often when people discuss renewable energy, the environmental impact is at the forefront of the conversation. Geothermal meets these requirements with new plants that have little to no emissions, little water use, and a significantly lower land-use footprint than other energy technologies.

The economic benefits are equally impactful. Geothermal creates more local long-term, wage-earning jobs, includes more local spending during construction and operations than other power technologies, and provides more affordable, less volatile consumer energy prices. Geothermal technology's always-available characteristic provides much-needed reliability for both electricity and heating, and is accessible throughout California. Geothermal plants also offer grid reliability, resiliency, and security to California's changing grid challenges through traditional services, such as regulation reserve, frequency response, and contingency

reserves (spinning and non-spinning) to more nontraditional services, such as flexible capacity, voltage control, inertia, and black start capabilities. Additionally, geothermal brines carry valuable minerals such as lithium to the surface that could create a reliable domestic supply for our nation.

Despite these remarkable characteristics, there is still much more that remains to be done. Geothermal technology has great unmet potential. But to reach that potential, foundational scientific R&D and the breakthroughs it can produce are needed to accomplish the goals for a competitive, geothermal market.

Technology Roadmap

Of the research areas outlined in the Technical Assessment, we feel the most impactful areas for transforming geothermal development in California include:

- G.10 - Lowering Well Field Costs
- G.5 - Corrosion-Resistant, **Low-Cost** Geothermal Piping **and Well Casing**
- G.6 - Material Recovery from Geothermal Brines

These topics are discussed in more detail below.

Additional, lower-cost, but impactful research topics include:

- G.9 - Oil–Gas Well Reuse
- G.15 - Modeling for Flexible Generation
- O.G.5 - Flexible Geothermal Energy Generation

Lowering Costs Through Advanced Wells

The cost of geothermal development is about 50% on the surface (e.g., power plants, piping) and 50% below ground (e.g., drilling and well construction costs). Many of the below-ground costs are borne at the front end of the project development, which can make project financing challenging. And though drilling and well construction activities are present in many industries, time and costs are significantly higher for geothermal. Geothermal drilling averages about 150–200 feet per day, compared to oil and gas wells that that average more than 750 feet per day, and sometimes are as fast as a mile a day (a.k.a. "MAD" wells). The oil and gas industry has seen well drilling rates more than double in the last 10 years[1] while geothermal drilling rates have remained constant. This is in part because of the large volume of oil and gas wells drilled; however, it suggests that reducing geothermal drilling time and costs is feasible. Advancements in oil and gas development have made possible things that once seemed impossible—producing gas from shale and developing deep offshore resources—in a relatively short period of time. We believe these same types of dramatic improvements are possible for geothermal drilling, if, and only if, support is provided for needed research.

Drilling in geothermal rocks is slower for many reasons—wells are typically drilled in harder, hotter rocks, with more lost circulation, and the industry has been slower to adopt new technologies, sometimes because of cost. Drilling rates are important because drill rigs and equipment have expensive daily rental rates; each extra day spent on the rig significantly increases well costs. Target areas for research and industry adoption include increasing drilling efficiency, increasing drilling speed, and

[1] https://www.eia.gov/analysis/studies/drilling/pdf/upstream.pdf

reducing construction costs. These advances have uses for multiple industries, making R&D investment even more impactful.

Increase Drilling Efficiency

Improving drilling efficiency is a near-term research effort that can have a big impact on drilling rates; the oil and gas industry reports drilling as much as 50% faster through efficiency improvements alone. The oil and gas industry uses downhole tools to measure drilling mechanics data that help make real-time efficiency decisions. But these tools are not rated for high-temperature geothermal environments, and the risk of burning up a tool makes the use of these tools too costly for geothermal developers to gamble on. Research into low-cost, high-temperature power and sensing electronics for extreme environments would not only help the geothermal industry, it would also benefit other industries, including vehicle technology, aviation, and manufacturing (e.g., metal forging and chemical industries). Additional research that would benefit geothermal and all other well-drilling industries includes advanced data analytics, machine learning, and mitigation of lost circulation events.

Increase Drilling Rates

Some rocks are harder than others; the harder the rock, the more energy it takes to crush and the longer it takes to drill through. In general, the sedimentary rocks drilled to access oil and gas rocks are softer, making it easier and faster to drill. Advances in rotary bit drilling, such as the development of the polycrystalline diamond bit, have made some progress in increasing drilling rates in harder rocks, but challenges still exist. Early-stage energy drilling technologies such as electronic pulse drilling, laser drilling, and projectile drilling show promise in significantly advancing drilling rates and reducing downtime during drilling. Testing of these energy drilling technologies are reported to advance drilling rates by 10 times over traditional rotary rates—translating to a significant potential for cost savings. Research into these types of technologies to more quickly drill through harder rock will support not only the geothermal industry, but also support accessing the nation's mineral resources and harder-rock oil and gas plays.

Reduce Construction Costs

Well construction is a significantly high cost of developing a geothermal well field. Geothermal wells are larger, with a typical hole diameter more than twice the size of oil and gas wells, requiring more casing and cement to be used in construction. Additionally, because of the harsh environment, geothermal wells often need more expensive metal alloys containing significant concentrations of chromium, manganese, cobalt, and titanium to manage the high temperatures and thermal cycling that occur during operations. Research into low-cost materials for well construction can have significant benefits not only in geothermal, but also for other industries, such as chemical plants and vehicles. The use of computational materials design is a key U.S. opportunity in the development of new functional alloys using raw materials that are abundant in the United States.

Mineral Recovery from Geothermal Brines

Geothermal power plants produce a large volume of brine, which contains dissolved chemical components, including critical and strategic minerals (e.g., lithium, manganese, copper, silver, gold) in

various locales, at various concentrations[2]. Thus, significant quantities of valuable minerals could be recovered as a by-product of geothermal power plants.

For example, lithium extraction from geothermal brines offers the potential to provide the United States with a secure, strategic domestic supply of lithium for increasing energy storage and electric vehicle demands, and for other end-use applications. As of 2018, 35% of the lithium end-use was for lithium batteries and the automotive lithium-battery market is expected to grow, reaching a demand of 39 gigawatt-hours by 2020, with a market value of $14.3 billion[3]. The United States is expected to remain one of the largest markets for electric vehicle lithium batteries until at least 2020[4]. Lithium, as needed for the lithium-battery market alone, is a significant driver for investment in technologies to recover this mineral from geothermal brines and it is vital for the United States to position itself in this growing global market.

The large lithium resources available in geothermal brines in California, if recovered and processed economically, could position the California to be become a global supplier of recovered lithium. Active geothermal plants in the Salton Sea alone have reported potential to produce nearly 90,000 metric tons per year of lithium. Currently, there is a plethora of potential lithium recovery processes with little confirmation of their bankability, economics, and experience operating in realistic conditions. Research dollars are needed to advance the technologies beyond early-phase testing to large-scale demonstrations to prove and test the mined resource as well as garner investor and consumer interest in full-scale deployment.

In Conclusion

California has some of the best geothermal resources in the world, but they remain underutilized. To realize this potential, investment in new technologies to lower cost are required.

Today we sit at a critical juncture. If we seize the opportunities before us, capitalize on our prior work, and appropriately invest in new early-stage research and in-depth analysis, American businesses and consumers will benefit significantly from major advancements in geothermal technologies. There is still important research we must do to improve cost, performance, reliability, and integration of geothermal energy. I know that researchers at NREL and other institutions are prepared to tackle these challenges, allowing geothermal energy to meet its potential for our energy future.

NREL, along with our partner laboratories, and university and industry collaborators, will continue to help our country succeed in an increasingly competitive global economy. California would benefit by leveraging the progress science can deliver to remain leaders in this important growing industry.

Thank you for your interest in advancing geothermal research and technologies.

[2] Neupane, G. and D. Wendt. 2017. *Assessment of Mineral Resources in Geothermal Brines in the US*. Proceedings, 42nd Workshop on Geothermal Reservoir Engineering. Stanford University. https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2017/Neupane2.pdf
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