BEFORE THE PUBLIC SERVICE COMMISSION OF UTAH

PacifiCorp's 2021 Integrated Resource Plan	Docket No. 21-035-09

Questions Submitted by Fervo Energy Company in Advance of Technical Workshop

Introduction and Background

Pursuant to the Scheduling Order and Notice of Technical Conference issued on September 20, 2021, Fervo Energy Company ("Fervo") provides the following questions and comments regarding the Integrated Resource Plan filed by PacifiCorp d/b/a Rocky Mountain Power ("PacifiCorp") on September 1, 2021 ("2021 IRP"), as amended by the errata filed on September 15, 2021, in advance of the Technical Workshop scheduled for January 19, 2022.

PacifiCorp is a major potential buyer or developer of geothermal energy in a multi-state region with significant development potential. However, the 2021 IRP does not select new geothermal in any scenario and provides few further details on pathways for geothermal procurement.

The overarching purpose of Fervo's questions is to help clarify these pathways, including to examine sensitivities beyond assumed current commercial cost and regional development constraints. Each question is followed by comments with additional background details and references. Several of the questions reflect recent findings on geothermal in other regional resource plans as well as research and recommendations by the U.S. Department of Energy ("DOE"), National Renewable Energy Laboratory ("NREL"), and other entities.

The 2021 IRP does indicate PacifiCorp's interest in the category of clean, firm power,[1] in the form of advanced nuclear technology and non-emitting peaking resources, such as hydrogen-fueled peakers. Geothermal provides the same capabilities as these resources; hence, in addition to technical evaluation of specific geothermal projects, there should be consideration of a general category of clean, firm power which could be fulfilled by multiple eligible resources.[2]

Fervo realizes that geothermal proposals into PacifiCorp and other northwestern utility renewable procurements have been limited historically, but this has not been the case recently in some western

[1] There is not yet a standard terminology or description of requirements for "clean, firm power". Fervo's questions and comments below use the terms and definition in particular studies or procurements when referring to them.
[2] See, e.g., Long *et al*., Clean Firm Power is the Key to California's Carbon-Free Energy Future, *Issues in Science and Technology*, National Academies, March 24, 2021. See also California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Air Resources Board (CARB), "2021 SB 100 Joint Agency Report Achieving 100 Percent Clean Electricity in California: An Initial Assessment," March 2021, CEC-200-2021-001, available at https://www.energy.ca.gov/sb100#anchor_report.

states, including California, where geothermal procurement is expanding. Fervo and the geothermal sector look forward to working with PacifiCorp and the Public Service Commission of Utah ("Commission") to clarify the expansion opportunities for geothermal in the region. Geothermal can provide clean, firm and even operationally flexible power as well as local economic development opportunities.

The geothermal resource potential in Utah is massive, and because geothermal energy development requires the drilling and completion of a substantial number of wells, the construction workforce needed by the geothermal industry has a nearly identical skillset to that of oil and gas. The incredible resource potential, the demand for clean power, the existence of a robust oil and gas supply chain, and the ability of the geothermal industry to employ oil and gas workers make geothermal a great match for Utah's All-of-the-Above energy strategy.

Fervo Questions

Question 1. Fervo and other geothermal stakeholders and researchers have noted that in some cases, selection of geothermal resources in IRP modeling is highly sensitive to assumed geothermal costs.[3] What is the derivation of the assumed geothermal costs in the supply resource tables (see summary Table 1 below)? Have these costs been updated to reflect recent research cost estimates and data on public contracts?

Table 1 – Geothermal costs and attributes in Supply-Side Resource Tables (2021 IRP, pgs. 169-184)

	Design life/ contract life	Total Fixed Cost ($/kW-year)	Capacity Factor (%)	$/MWh Total Fixed Cost	$/MWh O&M Cost	$/MWh Total Resource Cost	ITC	Total Resource Cost with ITC
Blundell Dual Flash	40 yrs	$470.77	90	$59.71	$1.16	$60.87	-$16.12	$44.75
Greenfield Binary	40 yrs	$486.55	90	$61.71	$1.16	$62.88	-$16.12	$46.75
Generic Geothermal PPA	20 yrs	-	90	-	-	$77.34	-$16.12	$61.22

Fervo Comments on Question 1: The 2021 IRP (pgs. 194-195) mentions that these estimates of geothermal project costs were compiled from various technical assessments conducted for PacifiCorp as well as public sources, such as the Geothermal Research Council. Fervo requests that PacifiCorp identify the exact cost sources for its geothermal estimates and consider evaluating additional, more recent cost estimates for geothermal (see Question 5 below).

[3] See, e.g., Paul Thomsen, "Geothermal in Western U.S. Resource Planning: A Review of Recent Results," *GRC Transactions*, Vol. 45, 2021; Paul Thomsen, "Geothermal selection in California resource planning: Preliminary results from the CPUC's IRP tools and recommendations for future development and analysis," *GRC Transactions*, Vol. 42, 2018.

Question 2. Does the PacifiCorp IRP modeling assume cost declines in geothermal technologies over the planning period, and if not, how does this assumption compare to assumed cost declines in geothermal technology studies and cost declines assumed for other technologies? Can PacifiCorp examine how geothermal cost reductions might affect geothermal selection in the IRP modeling?

Fervo Comments on Question 2: While many resource plans we have reviewed do not model reductions in geothermal costs over the planning period, it is reasonable to consider such cost reductions if they are considered for other clean energy technologies in earlier phases of commercialization. For example, the NREL Annual Technology Baseline ("ATB") estimates cost reductions for several geothermal technologies from 2020 – 2050, although Fervo believes these cost reduction estimates are highly conservative considering the near-term deployment potential of geothermal energy.

Question 3. What is PacifiCorp's assumed geothermal resource potential in the region? How does PacifiCorp's assumed geothermal resource potential in the region compare to other regional estimates (see Table 2 below)?

Fervo Comments on Question 3: PacifiCorp's 2021 IRP appears to evaluate three specific geothermal projects and potential power purchase agreements, sized at 30 MW, 35 MW and 43 MW. It isn't clear whether there is any further scope for geothermal capacity expansion in the plan based on assumed technology costs. This approach can be contrasted to resource planning which uses the regional resource potential for geothermal (and other resources) as an input into capacity expansion modeling and allows the model to establish the least cost selection of each resource;[4] the ability to achieve these objectives is then determined through procurement processes (such as the CPUC's 2021 Mid-Term Reliability procurement process which allows for up to 1 GW of "firm resources with zero on-site emissions", including geothermal).

The sum of the project sizes reviewed by PacifiCorp is clearly well below the regional resource potential. As summarized in Table 2, there are several estimates of geothermal resource potential, which could be economic in the regions relevant to PacifiCorp procurement. In addition to the DOE assessments of technical geothermal resource potential, a few selected examples of assumed economic resource potential are as follows:

The Seventh Northwest Conservation and Electric Power Plan (2016, interim assessment in 2019) estimated that up to 475 MW of geothermal could be developed in the Pacific Northwest based on a geothermal "reference plant" cost and design.[5] The eighth such plan is currently underway.

[4] Examples of such "endogenous" selection within capacity expansion modeling of geothermal or firm clean power resources include the California Public Utilities Commission's ("CPUC's") IRP process; CEC, CPUC, and CARB, "2021 SB 100 Joint Agency Report," op cit.; Long *et al*., Clean Firm Power, 2021, op cit.

[5] Northwest Power and Conservation Council, Seventh Northwest Conservation and Electric Power Plan, Council Document No. 2016-2 (February 25, 2016).

For California's planning regarding renewable imports, which informed the CPUC's 2018 IRP decision, the CPUC assumed that up to 850 MW of Pacific Northwest geothermal could be developed for delivery to California load-serving entities but would potentially require transmission upgrades.[6]

Furthermore, the Utah FORGE project is in the process of demonstrating significant geothermal potential in Southwest Utah.[7]

Studies elsewhere in the Western region have also identified significant potential geothermal resources, some of which could serve PacifiCorp's load. These include several GW of resource potential in California and Nevada, where recent procurements have concomitantly increased.

Table 2 – Geothermal regional potential in recent planning studies

Study	**Estimated Resource Potential**		
	Pacific Northwest	*Nevada*	*California*
Seventh Northwest Conservation and Electric Power Plan	475 MW		
California Public Utilities Commission (CPUC) 2018 and 2020 IRPs for delivery to California	850 MW (2018 IRP)	320 MW	2.3 GW
NV Energy 2021 IRP		Up to 1,000 MW in some modeled scenarios	

Question 4. Can the process for the Plexos LT modeling be described further to explain whether geothermal was screened out prior to the modeling or included in the modeling but not selected by the tool?

Question 5. This question addresses sensitivity analysis on the resource scenarios analyzed in the 2021 IRP:

(a) Can PacifiCorp conduct sensitivity analysis on assumed geothermal costs to establish the costs at which the Plexos LT model selects geothermal? For example, these sensitivity cases could include $60/MWh, $65/MWh and $70/MWh to help capture the potential range of selected geothermal if geothermal costs were to be reduced due to technical innovation.

[6] CPUC Proceeding R.16-02-007, Order Instituting Rulemaking to Develop an Electricity Integrated Resource Planning Framework and to Coordinate and Refine Long-Term Procurement Planning Requirements, Inputs & Assumptions (Exhibit B to ALJ Ruling issued September 19, 2017).

[7] Utah FORGE is a dedicated underground field laboratory sponsored by the DOE with a stated purpose of accelerating breakthroughs in Enhanced Geothermal Systems.

(b) Further, can PacifiCorp conduct sensitivity analysis on assumed geothermal regional potential to determine how much geothermal is selected at different cost assumptions? We recommend evaluating no constraint on geothermal resource potential (or the potential for equivalent zero-carbon firm resources) at the stated costs. The selection of scenarios to model in this fashion should include the preferred portfolio scenarios as well as selected other portfolios.

Fervo Comments on Question 5: As reviewed in other recent resource planning results, and as demonstrated in other analysis,[8] geothermal selection (or that of equivalent zero-carbon firm resources) in capacity expansion models can be highly sensitive to assumed costs and regional resource potential (and, of course, many other factors as well, including the comparative costs of other clean energy resources and energy storage).

With respect to question 5(a), because technical innovation is affecting current and forecast geothermal costs,[9] resource planners need to consider that cost sensitivity analysis is required to fully evaluate potential geothermal procurement.

An example of a planning research study examining the impact of such cost reductions is the California joint agency SB100 study[10], where geothermal cost assumptions in the range of $77-$87/MWh (before financial incentives) resulted in a range of selection across multiple scenarios (from zero up to an assumed California and Nevada regional resource potential of 2.3 GW). However, the study also conducted sensitivity analysis on a $60/MWh zero-carbon firm or dispatchable resource with a 90% capacity factor, which resulted in very high selection of that resource of between 15-20 GW in different scenarios, depending on the scenario.

Other studies have also demonstrated the impact of cost sensitivity analysis on geothermal selection using a capacity expansion model.[11]

With respect to question 5(b) regarding the regional resource potential, California stakeholder analysis showed that relaxing the assumed regional resource limit did result in a capacity expansion with the model selecting additional geothermal.[12]

Another example of the impact of relaxing assumed regional resource limits on the desirability of resources such as geothermal is the California joint agency SB100 study noted above, where the zero-carbon, firm resource with no regional resource limits is selected well beyond the assumed regional geothermal resource potential (showing that the possible market could be greatly expanded in the event of innovation in geothermal exploration and development). Similarly, the comparison of several

[8] See, e.g., Thomsen, 2021, 2018, op cit.
[9] See, e.g., NREL ATB, 2021 geothermal costs, https://atb.nrel.gov/electricity/2021/geothermal
[10] CEC, CPUC, and CARB, "2021 SB 100 Joint Agency Report," op cit.
[11] Thomsen, 2021, 2018, op cit.
[12] Thomsen, 2018, op cit.

capacity expansion models based on California's carbon reduction goals showed that clean, firm power could substantially displace variable energy resources.[13]

These proposed cost and regional potential sensitivity analyses are intended primarily to clarify under what conditions PacifiCorp's IRP modeling does select geothermal resources (since the current IRP does not provide any such indication). This information would be a basis for further modeling analysis. These cost sensitivity recommendations are not intended to indicate specific cost offers.

Question 6. Why does the IRP modeling select small modular nuclear reactors at a higher cost and slightly lower capacity factor than geothermal, when the two resources otherwise have similar operating and emissions characteristics (See Table 3)?

Fervo Comments on Question 6: This question is intended to further clarify the factors which could lead to PacifiCorp's future demand for clean, firm power resources. As noted, Fervo's preference is for further evaluation of a generic category of clean, firm power across planning scenarios.

Table 3 – Comparison of geothermal and modular nuclear costs and attributes in 2021 IRP Supply-Side Resource Table

Resource name	$/MWh Total Resource Cost	Capacity factor	EFOR
Geothermal (see Table 1 above)	$44.71 - $61.22	90%	5%
Small modular reactor	$104.29 (conversion of fixed and O&M costs)	86%	5%

Question 7. Can PacifiCorp provide additional details on the potential cost and resource development impact of displacing wind, solar and storage with flexible but firm resources such as geothermal (or other firm or dispatchable non-emitting resources)? These benefits can include lower capital costs, land-use needs and transmission requirements.

Fervo Comments on Question 7: The PacifiCorp 2021 IRP provides some details on how selection of new renewables and non-emitting resources vary depending on the modeled scenarios (see, e.g., IRP Vol. 1, pgs. 256-257). However, these results are presented in aggregated format and the implications for geothermal development pathways are difficult to extract. A number of planning sensitivity studies as well as research studies have demonstrated that, particularly in higher renewable energy scenarios, each MW of geothermal or a similar zero-carbon resource displaces multiple MWs of variable energy resources and energy storage. For example, Thomsen (2021, 2018)[14] used the CPUC's capacity expansion model to find that an incremental MW of geothermal displaced 3-5 MW of solar and battery storage, depending on the scenario.

[13] Long *et al*., 2021, op cit.
[14] Thomsen 2021, 2018, op cit.

CEC, CPUC and CARB (2021) also demonstrated a very large displacement of solar and storage when evaluating zero-carbon firm or dispatchable resources in high renewable generation scenarios.[15] Long *et al*. (2021)[16] also show results for such displacement in a California case-study, and also measure reductions in land use and transmission needs.

These findings clarify that in the screening of resource types for evaluation, simple levelized cost of electricity ("LCOE") comparisons are inadequate, and comprehensive modeling is necessary to fully examine how to develop least-cost portfolios. In addition, the smaller land footprint of geothermal resources can further lower development costs, risks, and overall environmental impact.

Question 8. Has PacifiCorp considered geothermal projects that provide operational flexibility? Could PacifiCorp clarify what opportunities may exist for new geothermal projects to provide operational services?

Fervo Comments on Question 8: The 2021 IRP does not mention any further adaptation of geothermal operations to meet PacifiCorp's evolving operational needs. Warren, Porse and Winich (2021)[17] review the range of operational attributes (e.g., ancillary services, ramping support) that could be provided by geothermal plants, and that may facilitate the transition to clean energy in PacifiCorp's resource portfolio.

Concluding Comments

Fervo appreciates the opportunity to ask these questions and provide these comments on PacifiCorp's 2021 IRP. Many resource planners and researchers are currently re-evaluating the benefits which could be provided by geothermal in the United States. We see this as a collective effort between buyers of clean, firm power and the geothermal industry to clarify the potential scope of demand for geothermal resources, the scale of the economic benefits, and the associated infrastructure needs, such as transmission expansion, to support large-scale deployment. Fervo can also provide additional background on any of the questions and comments included here.

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Respectfully submitted

/s/
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[15] CEC, CPUC, and CARB, "2021 SB 100 Joint Agency Report," op cit.
[16] Long *et al*., 2021, op cit.
[17] Ian Warren, Sean Porse, Jeff Winick, Geothermal Representation in Power System Models, National Renewable Energy Laboratory and Department of Energy, *GRC Transactions*, Vol. 45, 2021