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Strategic Planning for Geothermal Expansion in the Western United States

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INTRODUCTION

Over the past five years, Western U.S. utility and regional planners have begun to evaluate scenarios where geothermal resources (and other firm clean resources) could contribute up to 10% of annual energy generation in the region. However, in these high geothermal scenarios, regional planners generally don't specify exact locations of potential geothermal resources, and the associated transmission requirements. Moreover, for most of the transmission planning in the region and the new inter-state transmission projects in advanced development, geothermal energy is very much a secondary consideration after wind and solar energy.

As we proposed in Dowty and Thomsen (2025), to address these shortcomings, a western regional plan for resource and transmission development to support a potentially significant geothermal expansion should aim to study several topics. First, reasonable long-term geothermal resource development objectives need to be delineated. Second, the current and planned transmission networks must be analyzed to determine how they can support geothermal development and contracting, identifying necessary upgrades. Third, conceptual transmission planning is needed to identify additional transmission needs for high geothermal scenarios.

This brief paper presents a methodology for policymakers, planners, and the geothermal industry to collaboratively develop a regional plan that integrates resource and transmission planning through 2045, supporting high geothermal scenarios. The plan should identify potential geothermal technologies, suitable locations, associated transmission needs, attributes of the expanded geothermal fleet, and the estimated value of geothermal purchase contracts necessary to justify transmission expansion. Additional details can be found in Dowty and Thomsen (2025).

1 RECENT "HIGH" GEOTHERMAL PLANNING SCENARIOS IN THE WESTERN U.S.

We base our geothermal planning scenarios for the region on existing regional resource plans, and then do some qualitative modifications based on our commercial experience. Table 1 is a summary of some of the resource planning studies which have notable expansions of geothermal. In the last column of the table, there is a measure of the percentage of geothermal either as capacity (MW) or annual energy (GWh). Percentage of capacity is not an ideal measure, given the high-capacity factor of geothermal, but in some studies, it was the easier metric to calculate. Dowty and Thomsen (2024) provides more details on these plans and others.

Table 1 – Geothermal Resource Additions (MW) in Selected Long-Term Forecasts for the Western U.S.

Year of Publication	Study and Target Year	Region	Capacity of Geothermal or Clean Baseload Selected	Percentage (%) of Total Capacity (MW) or Energy (GWh)
2024	WECC 2034 ADS – 2034 (WECC, 2024)	WECC	~5.7 GW of existing and planned geothermal	~1% of capacity
2024	CPUC 2022 IRP (CPUC 2024)	California and regional resources	Base case: 2.3 GW of new geothermal; High Gas Retirement Sensitivity case: up to 5.1 GW of geothermal or other firm clean resources by 2045	2% - 4.5% of capacity, depending on year and scenario

Table 1 – Geothermal Resource Additions (MW) in Selected Long-Term Forecasts for the Western U.S.

Year of Publication	Study and Target Year	Region	Capacity of Geothermal or Clean Baseload Selected	Percentage (%) of Total Capacity (MW) or Energy (GWh)
2024	Colorado (CEO, 2024)	Colorado	2 GW high geothermal scenario	10% annual energy in high geothermal scenario
2021	LADWP, LA 100% study (Cochran and Denholm, 2021)	LADWP, regional resources	Up to 1.6 GW new geothermal in sensitivity scenarios	6%-19% annual energy, depending on scenario and year (pg. 6-58)
2021	California SB100 study – 2040 (CEC, CPUC, CARB, 2021)	California, regional resources	15-20 GW of "zero carbon firm resources" in sensitivity cases	~20% of capacity

2 WEST-WIDE HIGH GEOTHERMAL RESOURCE SCENARIOS FOR FUTURE STUDY

While many scenarios could be developed, we suggest that an initial "high geothermal" scenario for the entire west should plan towards 15 GW of new geothermal by 2045, which would provide around 10% of the region's forecast energy needs (depending on the scenario) and also be used as a basis for transmission expansion. Dowty and Thomsen (2025) provide additional reasoning behind the distribution of geothermal in this scenario, and we would invite the geothermal industry to further refine this scenario or add others. Figure 1, on next page, provides a geographical representation of this scenario superimposed over a geothermal resource map of the region, based on the several resource planning surveys we and others have previously conducted. The location of the circles showing the total capacity of each subregion are not intended to be exact.

Reflecting current exploration and commercial interest, about 11 GW of the geothermal is assumed to be in Nevada and California, with the remaining 4 GW in other parts of the west. What we call primary destination markets indicate where most of the commercial interest is likely to be for geothermal developed in each state or region, based on our analysis. The secondary destination markets will also have commercial interest, if there is sufficient development and transmission availability (along with a competitive delivered price).

3 GEOTHERMAL IN TRANSMISSION PLANNING AND DEVELOPMENT

Because the geothermal in this planning scenario will not be distributed evenly across the west, the addition of up to 15 GW of geothermal in the locations identified will only partly be able to take advantage of existing transmission. This is in part because of prior allocated transmission uses along with the forecast needs of the very large capacities of wind and solar also projected for the future regional resource mix. Hence, new transmission will likely need to be developed specifically to accommodate geothermal, including expansion of existing transmission lines.

The high geothermal scenario we have outlined (and any others subsequently proposed by the industry) will require coordination in transmission planning from a wide variety of entities – including ISOs, utilities, and other regional transmission planning groups – and subsequent regulatory approvals. The geothermal industry needs to be active as a stakeholder in the major transmission planning forums, particularly if the objective is to drive a truly regional plan for geothermal development. Ideally, the geothermal industry can provide anticipatory scenarios which have sufficient lead time for utility transmission planning and integration into regional transmission planning.

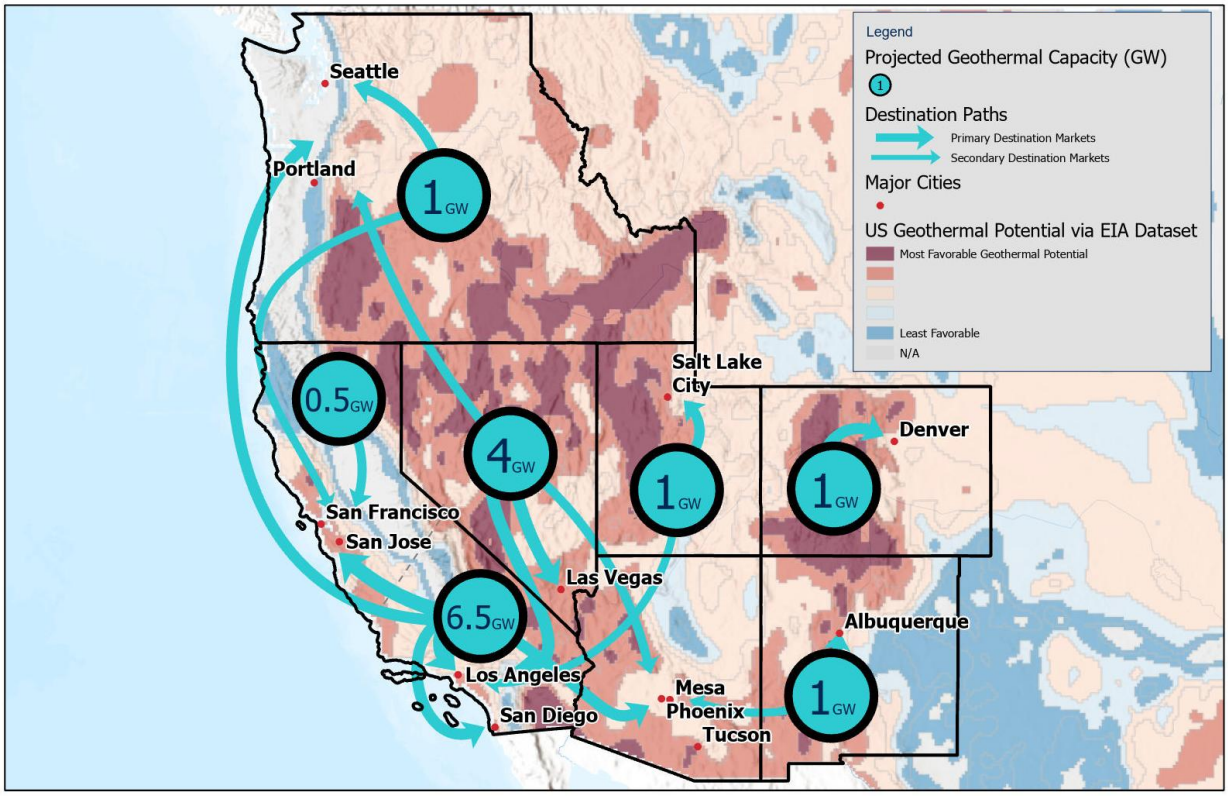


Figure 1. A Western High Geothermal Scenario

3.1 California

California planning merits the most initial attention from the geothermal sector, given that it presents the largest potential regional market. Due to CPUC clean energy requirements, CAISO currently incorporates about 2.3 GW of geothermal and 5 GW of firm clean energy (which could be conventional or enhanced geothermal systems) in its annual and long-term transmission planning processes (CAISO, 2022, 2024, 2025). The CPUC and CAISO anticipate that northern California will have minimal new geothermal resources, but will require about two-thirds of the firm clean resources. In contrast, the southern California grid and the transmission interfaces with Nevada are being planned to add just over 2 GW of new geothermal and about one-third of the non-specified firm clean resources.

There is a smaller but significant geothermal market among the publicly owned utilities in California, of which the largest are the Los Angeles Dept. of Water and Power (LADWP) and the Sacramento Municipal Utility District (SMUD). LADWP (2022, 2023) is currently considering only incremental increases in geothermal procurement. However, it has conducted more conceptual decarbonization planning with high geothermal scenarios which provide around 10% or more of the utility's energy (Cochran and Denholm, 2021). The analysis evaluated 34 potential geothermal zones, each with an estimated resource potential, and assumptions about the quantity, path and cost of transmission needed for interconnection.

Our initial scenario target of 7 GW of geothermal for California by 2045 is thus well within current planning expectations for the state, and could even eventually support export to Arizona and PNW utilities, requiring analysis of export capability (which is currently much less constrained than imports).

3.2 Nevada

NV Energy is the primary utility transmission planner for Nevada, and there are several merchant lines in development or expansion. There are also state-wide coordination efforts, such as the ongoing Regional Transmission Coordination Task Force. We believe that the state is well on its way to being able to support our target of 4 GW of geothermal by 2045, but much more work is needed. NV Energy's Greenlink West (GLW) and Greenlink North (GLN) 525 kV lines due for operations in the late 2020s are expected to improve access for geothermal projects. There are several new merchant transmission projects that could also facilitate geothermal delivery to the north of Nevada, including SWIP-N, a 525 kV extension of the existing Nevada One line (ON Line) into Idaho, and the Cross-Tie 500 kV line, being developed to provide an intertie between Nevada

and Utah. If geothermal development can access GLN and GLW, this could also facilitate transfers to the Pacific Northwest via SWIP and to Utah via Cross-Tie. Another potential expansion would entail upgrades to the existing 230 kV Dixie Valley-Oxbow line, to accommodate delivery of up to 300 MW of Nevada geothermal into California, delivered at the Bishop substation located just south of the Mammoth area. The Dixie Valley-Oxbow line could also be interconnected into both the future GLN and GLW lines.

3.3 Arizona and New Mexico

Arizona has a limited geothermal resource and is likely to be an importer rather than a developer/exporter of geothermal power in a regional high geothermal scenario. As noted above, this is already the case for the limited geothermal consumed in the state. Based on this initial review, we suggest that further analysis of Arizona transmission focus on the forecast availability of the interties with California, Nevada, and New Mexico, and any upgrades needed to deliver an additional 1 GW of geothermal power to Arizona from those states.

New Mexico has the potential for new geothermal to be used for local utility load and other commercial demand as well as export to Arizona and California. The state has significant new transmission in advanced planning and construction stages. These transmission projects promise to provide sizable capacity to export clean energy, which merits a greater commercial focus by the geothermal industry on the state.

3.4 Pacific Northwest, Utah and Colorado

For the Pacific Northwest, we have suggested planning for 1 GW of new geothermal development, and the next step would be to distinguish between demand for geothermal served by resource development in the region and imports, and the resulting implications for transmission upgrades. Geothermal selection in utility IRPs in the region has recently been limited by the slow pace of local geothermal development. An emphasis on future imports from Nevada, California and Utah, utilizing both existing and planned transmission, could thus help to bolster PNW commercial interest. The large Cape Station project in Utah is currently contracted to serve California load, but could also serve the local loads as it expands. We expect that a 1 GW geothermal expansion in Colorado would mostly serve the state's load, and hence rely on transmission upgrades within the state.

4 A PHASED APPROACH TO PLANNING FOR GEOTHERMAL EXPANSION

The implementation of this Western U.S. geothermal plan could unfold over several phases, as outlined below. The next few years would focus on immediate planning and transmission access needs of the geothermal industry, while continuing the conceptualization of the high geothermal scenarios. Subsequently, the process would be iterative to reflect new information. Since new transmission lines can take up to 10 years or more to develop and energize, the first phase should anticipate transmission needs into the mid- to late 2030s.

Phase 1 (2025-2030) would include the following key elements:

- Project development and operational plant re-powering, targeting 2 GW of new geothermal across the west;
- Queue reform proposals to address the needs of geothermal exploration and development, allowing prioritization of clean, firm resources that meet all requirements (i.e., site control, commercial development, etc.) at interconnection application stage;
- Analysis of CAISO and utility transmission capacities, focusing on allocated reservations that aren't being used and could feasibly be released and/or re-assigned to interconnecting generators with in-service dates that are 5-7 years out due to 'unavailable' transmission capacity;
- Open Access Transmission Tariff (OATT) reform proposals to put limits on the extent of time that unused interconnection capacity and transmission reservations can be held by interconnection customers and generators;
- Detailed review of all regional resource plans for further analysis of geothermal selection (building on Dowty and Thomsen, 2024, 2025);
- Initial western geothermal resource plan scenarios developed by the geothermal industry, expanding on the above proposal(s);
- Identification of needed transmission access and upgrades for each phase of the geothermal expansion; and

- Establish communication with all relevant planning entities.

We envision two more phases to this process, Phase 2 (2030-2035) and Phase 3 (2035 onwards). For Phase 2, the target would be an additional 5 GW of geothermal across the west, while Phase 3 would add another 8 GW. The processes established in Phase 1 would iterate and evolve over these subsequent phases.

5 CONCLUSIONS

Resource plans for the Western U.S. are showing the potential for scenarios in which geothermal power can comprise up to 10% of annual energy production, with the majority of this expansion taking place after 2030. Currently, these plans are not coordinated, and transmission planning to support such an expansion is also in the early stages. This paper recommends that further development of high geothermal scenarios take place, with ongoing input from the geothermal industry. An initial target of 15 GW of geothermal for the Western U.S. by 2045 seems reasonable given the current geothermal or firm clean energy scenarios being evaluated by different planning entities. Given the timelines for transmission expansion, a process for transmission assessment and planning to address these scenarios needs to take shape in the next few years.

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